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Designation: C 5 – 03

Standard Specification for Quicklime for Structural Purposes[1]

This standard is issued under the fixed designation C 5; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

This standard has been approved for use by agencies of the Department of Defense.

1. Scope

1.1 This specification covers all classes of quicklime such as crushed lime, granular lime, ground lime, lump lime, pebble lime, and pulverized lime, used for structural purposes.

2. Referenced Documents

2.1 *ASTM Standards:*

C 25 Test Methods for Chemical Analysis of Limestone, Quicklime, and Hydrated Lime[2]

C 50 Practice for Sampling, Inspection, Packing, and Marking of Lime and Limestone Products[2]

C 51 Terminology Relating to Lime and Limestone (As Used by the Industry)[2]

C 110 Test Methods for Physical Testing of Quicklime, Hydrated Lime, and Limestone[2]

C 1489 Specification of Lime Putty for Structural Purposes[2]

E 11 Specification for Wire-Cloth Sieves for Testing Purposes[3]

3. Terminology

3.1 *Definitions*—Unless otherwise specified, for definitions of terms used in this standard, refer to Terminology C 51.

4. Chemical Composition

4.1 The quicklime shall conform to the following requirements as to chemical composition, calculated on a nonvolatile basis:

	Calcium Lime	Magnesium Lime
Calcium oxide, min, %	75	
Magnesium oxide, min, %		20
Calcium and magnesium oxide, min, %	95	95
Silica, alumina, and oxide of iron, max, %	5	5
Carbon dioxide, max, %:		
If sample is taken at place of manufacture	3	3
If sample is taken at any other place	10	10

5. Residue

5.1 The quicklime shall contain no more than 15 weight % of residue.

6. General Requirements

6.1 Quicklime shall be slaked and aged in accordance with the printed directions of the manufacturer. The resulting lime putty shall be stored until cool.

6.2 Lime putty prepared in accordance with Appendix X1.4.2 must conform to the requirements of Specification C 1489.

7. Sampling, Inspection, etc.

7.1 The sampling, inspection, rejection, retesting, packaging, and marking shall be conducted in accordance with Methods C 50.

8. Test Methods

8.1 Conformance to chemical requirements shall be determined in accordance with Test Methods C 25.

8.2 Conformance to plasticity and residue requirements shall be determined in accordance with Test Methods C 110.

9. Keywords

9.1 building (structural); calcium oxide; dolomitic lime; high calcium lime; lime putty; magnesium oxide; plasticity; quicklime; residue; slaking

[1] This specification is under the jurisdiction of ASTM Committee C07 on Lime and is the direct responsibility of Subcommittee C07.02 on Structural Lime.

Current edition approved May 10, 2003. Published July 2003. Originally approved in 1913. Last previous edition approved in 1997 as C 5 – 79 (1997).

[2] *Annual Book of ASTM Standards*, Vol 04.01.

[3] *Annual Book of ASTM Standards*, Vol 14.02.

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APPENDIX

(Nonmandatory Information)

X1. SLAKING AND PREPARATION OF LIME PUTTY

X1.1 *Introduction*

X1.1.1 Quicklime can never be used as such for structural purposes; it must always be slaked first. Since the method of slaking is an important factor in determining the quality of the finished product, the following directions for the preparation of lime putty are given, not as a part of the specification, but as information for the further protection of the purchaser.

X1.1.2 Different kinds of lime vary considerably in the way in which they behave with water. A little supervision over the operation of slaking will amply pay for itself by ensuring the production of the greatest possible quantity and the best possible quality of putty. To find out how to slake a new lot of lime, it is safest to try a little of it and see how it works. Since different lots of the same brand of lime vary somewhat, and since the weather conditions at the time have a decided influence, it is wise to try a sample from each lot used, whether familiar with the brand or not.

X1.2 Classification of Limes

X1.2.1 In a bucket, put two or three lumps of lime about the size of one's fist, or, in the case of granular lime, an equivalent amount. Add sufficient water to just barely cover the lime, and note how long it takes for slaking to begin. Slaking has begun when pieces split off from the lumps or when the lumps crumble. Water of the same temperature should be used for test and field practice.

X1.2.2 If slaking begins in less than 5 min, the lime is quick slaking; from 5 to 30 min, medium slaking; over 30 min, slow slaking.

X1.3 Directions for Slaking

X1.3.1 Slake quicklime in accordance with the printed directions of the manufacturer. When such directions are not provided, proceed as follows:

X1.3.2 For quick-slaking lime, always add the lime to the water, not the water to the lime. Have sufficient water at first to cover all the lime completely. Have a plentiful supply of water available for immediate use—a hose throwing a good stream, if possible. Watch the lime constantly. At the slightest appearance of escaping steam, hoe thoroughly and quickly, and add enough water to stop the steaming. Do not be afraid of using too much water with this kind of lime.

X1.3.3 For medium–slaking lime, add the water to the lime. Add enough water so that the lime is about half submerged. Hoe occasionally if steam starts to escape. Add a little water now and then if necessary to prevent the putty from becoming dry and crumbly. Be careful not to add any more water than required, and not too much at a time.

X1.3.4 For slow–slaking lime, add enough water to the lime to moisten it thoroughly. Let it stand until the reaction has started. Cautiously add more water, a little at a time, taking care that the mass is not cooled by the fresh water. Do not hoe until the slaking is practically complete. If the weather is very cold, it is preferable to use hot water, but if this is not available, the mortar box may be covered in some way to retain the heat.

X1.4 Preparation of Putty for Use

X1.4.1 After slaking, prepare putty for use as follows:

X1.4.2 *White Coat*—After slaking and aging finishing quicklime in accordance with the printed directions of the manufacturer, store the putty until cool. If no printed directions are provided by the manufacturer, prepare the putty for use as follows: After the action has ceased, run off the putty through a No. 10 (2.00-mm) sieve conforming to Specification E 11, and store for a minimum of 2 weeks.

X1.4.3 *Base Coats*—After the action has ceased, run off the putty through a No. 8 (2.36-mm) sieve conforming to Specification E 11. Add sand up to equal parts by weight, all of the hair or other fibers required, and store for a minimum of 2 weeks.

X1.4.4 *Masons' Mortar*—After the action has ceased, add part or all of the sand required, and store for a minimum of 24 h.

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Designation: C 10/C 10M – 09

Standard Specification for Natural Cement[1]

This standard is issued under the fixed designation C 10/C 10M; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope*

1.1 This specification covers natural cement.

NOTE 1—Examples of typical past uses of natural cement include unit masonry mortar, cement plaster, grout, whitewash, and concrete.

1.2 The values stated in either SI units or inch-pound units are to be regarded separately as standard. The values stated in each system may not be exact equivalents; therefore, each system shall be used independently of the other. Combining values from the two systems may result in non-conformance with the standard. Values in SI units [or inch-pound units] shall be obtained by measurement in SI units [or inch-pound units] or by appropriate conversion, using the Rules for Conversion and Rounding given in IEEE/ASTM SI 10, of measurements made in other units [or SI units]. Values are stated in only SI units when inch-pound units are not used in practice.

1.3 The text of this standard references notes and footnotes which provide explanatory material. These notes and footnotes (excluding those in tables and figures) shall not be considered as requirements of the standard.

2. Referenced Documents

2.1 *ASTM Standards:*[2]

C 109/C 109M Test Method for Compressive Strength of Hydraulic Cement Mortars (Using 2-in. or [50-mm] Cube Specimens)
C 114 Test Methods for Chemical Analysis of Hydraulic Cement
C 150 Specification for Portland Cement
C 151 Test Method for Autoclave Expansion of Hydraulic Cement
C 183 Practice for Sampling and the Amount of Testing of Hydraulic Cement
C 185 Test Method for Air Content of Hydraulic Cement Mortar
C 187 Test Method for Normal Consistency of Hydraulic Cement
C 188 Test Method for Density of Hydraulic Cement
C 191 Test Methods for Time of Setting of Hydraulic Cement by Vicat Needle
C 204 Test Methods for Fineness of Hydraulic Cement by Air-Permeability Apparatus
C 219 Terminology Relating to Hydraulic Cement
C 305 Practice for Mechanical Mixing of Hydraulic Cement Pastes and Mortars of Plastic Consistency
C 465 Specification for Processing Additions for Use in the Manufacture of Hydraulic Cements
C 778 Specification for Standard Sand
C 786 Test Method for Fineness of Hydraulic Cement and Raw Materials by the 300-μm (No. 50), 150-μm (No. 100), and 75-μm (No. 200) Sieves by Wet Methods
IEEE/ASTM SI 10 Standard for Use of the International System of Units (SI): The Modern Metric System

3. Terminology

3.1 For definitions of terms related to this specification, see Terminology C 219.

4. Ordering Information

4.1 Orders for material under this specification shall include the following:

4.1.1 This specification number and date, and

4.1.2 Optional physical requirements as given in 7.2.

5. Additions

5.1 The cement covered by this specification shall contain no addition except as follows:

5.1.1 Water, or calcium sulfate, or both.

5.1.2 Processing additions used in the manufacture of the cement shall have been shown to meet the requirements of Specification C 465 in the amounts used or greater.

6. Chemical Requirements

6.1 Natural cements shall conform to the standard chemical requirements in Table 1.

[1] This test method is under the jurisdiction of ASTM Committee C01 on Cement and is the direct responsibility of Subcommittee C01.10 on Hydraulic Cements for General Concrete Construction.

Current edition approved June 1, 2009. Published July 2009. Originally approved in 1904. Last previous edition approved in 2007 as C 10 – 07.

[2] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

***A Summary of Changes section appears at the end of this standard.**

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TABLE 1 Standard Requirements

	Applicable Test Methods	Requirements
Chemical Requirements		
Loss on ignition, max, %:	C 114	12
Insoluble residue, min, %:	C 114	2
Sulfur trioxide (SO_3), max, %:	C 114	3.0
Physical Requirements		
Autoclave length change, max, %:	C 151, as modified in 10.1.4	0.80
Fineness, m^2/kg or % retained:	C 204 or C 786	[A]
Time of setting, Vicat test[B]:	C 191	
Time in minutes, not less than		30
Air content of mortar[C], volume %:	C 185	
max		12
Compressive strength, min, MPa [psi]:	C 109/C 109M, as modified in 10.1.7	
7 days		3.5 [510]
28 days		7.0 [1020]

[A]The fineness shall be chosen at the option of the purchaser as per 7.2.
[B]The time of setting is that described as initial setting time in Test Method C 191.
[C]Compliance with the requirements of this specification does not necessarily ensure that the desired air content will be obtained in concrete.

7. Physical Requirements

7.1 Natural cements shall conform to the respective standard physical requirements prescribed in Table 1.

7.2 In order to match historic cements, at the option of the purchaser, the required values for % retention on the 300-µm (N0. 50), 150-µm (No. 100), and 75-µm (No. 200) sieves, or of air permeability fineness shall be agreed at time of placing the order.

NOTE 2—If no data on historic cement fineness are available, the purchaser may wish to consider that previous editions of this specification from 1904 to 1976 required minimum values as follows:

1954-1976: Minimum 550 m^2/kg fineness (air-permeability method)

1937-1954: Maximum 15% retained on a 75-µm (No. 200) sieve

1904-1937: Maximum 10% retained on a 150-µm (No. 100) sieve, maximum 30 % retained on a 75-µm (No. 200) sieve

8. Acceptance and Rejection

8.1 Natural cement meets the strength requirements of this standard if the 7-day strength exceeds the minimum in Table 1. The cement also meets the strength requirements of this standard if the cement fails the 7-day strength minimum, but exceeds the 28-day strength minimum in Table 1.

8.2 If the cement fails an initial test for autoclave expansion, it meets the requirements of this standard if it passes on a second and third series of test specimens.

8.3 The cement shall be rejected if it fails to meet any of the requirements of this specification, subject to the provisions of 8.1 and 8.2.

8.4 Re-test cement remaining in storage for a period longer than six months after initial test. Reject it if it fails to meet any of the requirements of this specification at that time.

8.5 Tentative or provisional acceptance of the cement shall not deprive the purchaser of the right of rejection in the event final tests or retests fail to meet applicable requirements.

8.6 At the option of the purchaser, packages more than 2 % below the mass marked thereon shall be rejected and if the average mass of packages in any shipment, as shown by determining the mass of 50 packages selected at random, is less than that marked on the packages, the entire shipment shall be rejected.

9. Packaging and Package Marking

9.1 When the cement is delivered in packages, the words "Natural Cement," the name and brand of the manufacturer, and the mass of the cement contained therein, shall be plainly indicated on each package. Similar information shall be provided in the shipping documents accompanying the shipment of packaged or bulk cement. All packages shall be in good condition at the time of inspection.

10. Test Methods

10.1 Sample the cement and determine the properties enumerated in this specification in accordance with the following ASTM methods:

10.1.1 *Sampling*—Practice C 183.

10.1.2 *Chemical Analysis*—Test Methods C 114.

10.1.3 *Fineness*—One of the following test methods shall be used:

10.1.3.1 Test Method C 204. In this fineness determination, the specific gravity of natural cement shall be considered to be 2.90. Tests shall be made at a porosity of 0.530 ± 0.005. In case of dispute, the true specific gravity used shall be as determined in accordance with Test Method C 188.

10.1.3.2 Test Method C 786.

10.1.4 *Autoclave Expansion*—Test Method C 151 with the following modification:

10.1.4.1 The cement used in preparing the test specimens shall be a blend of 75 weight percent of the natural cement to be tested with 25 weight percent of portland cement conforming to the requirements of Type II cement in Specification C 150.

10.1.4.2 The natural cement and the portland cement shall be dry mixed to a uniform blend before water is added.

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10.1.5 *Time of Setting*—Test Method C 191.

10.1.6 *Air Content of Mortar*—Test Method C 185. In this air content determination, the specific gravity of natural cement shall be considered to be 2.90. In case of dispute, the true specific gravity used shall be as determined in accordance with Test Method C 188.

10.1.7 *Compressive Strength*—The compressive strength shall be determined for mortar cubes prepared as follows:

10.1.7.1 The proportions shall be one part of cement to one part of standard sand by mass. The amount of mixing water is based on the amount of water required to produce a neat cement paste of normal consistency from the same sample of cement according to Test Method C 187. Calculate the percentage of water required as follows:

$$y = \frac{P}{3} + 6.5$$

where:

y = water required for the mortar as a percentage of the combined mass of cement and sand, and

P = water needed for normal consistency, percent by mass of cement.

10.1.7.2 The standard sand shall be 20-30 sand conforming to Specification C 778.

10.1.7.3 The mortar shall be mixed in accordance with Practice C 305. The quantities of materials to be mixed at one time in the batch of mortar for making six and nine test specimens shall be as follows:

	Number of Specimens	
	6	9
Cement, g	900	1335
Sand, g	900	1335
Water, mL	18y	26.7y

10.1.7.4 The 2-in. [50-mm] cube specimens shall be molded and tested in accordance with Test Method C 109/C 109M.

11. Keywords

11.1 hydraulic cement; natural cement; specification

SUMMARY OF CHANGES

Committee C01 has identified the location of selected changes to this specification since the last issue, C 10 – 07, that may impact the use of this specification. (Approved June 1, 2009)

(*1*) Revised the standard as a dual unit specification.

Committee C01 has identified the location of selected changes to this specification since the last issue, C 10 – 06, that may impact the use of this specification. (Approved December 1, 2007)

(*1*) Revised Note 1.

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Designation: C11 – 10

Standard Terminology Relating to Gypsum and Related Building Materials and Systems[1]

This standard is issued under the fixed designation C11; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope*

1.1 This standard covers terminology relating to gypsum and related building materials and systems. The terms are generically defined. More specific and expanded definitions may appear in appropriate standards.

2. Referenced Documents

2.1 *ASTM Standards:*[2]

C22/C22M Specification for Gypsum
C28/C28M Specification for Gypsum Plasters
C35 Specification for Inorganic Aggregates for Use in Gypsum Plaster
C36/C36M Specification for Gypsum Wallboard[3]
C37/C37M Specification for Gypsum Lath[3]
C52 Specification for Gypsum Partition Tile or Block[3]
C59/C59M Specification for Gypsum Casting Plaster and Gypsum Molding Plaster
C61/C61M Specification for Gypsum Keene's Cement
C317/C317M Specification for Gypsum Concrete
C318/C318M Specification for Gypsum Formboard
C472 Test Methods for Physical Testing of Gypsum, Gypsum Plasters and Gypsum Concrete
C473 Test Methods for Physical Testing of Gypsum Panel Products
C475/C475M Specification for Joint Compound and Joint Tape for Finishing Gypsum Board
C843 Specification for Application of Gypsum Veneer Plaster
C557 Specification for Adhesives for Fastening Gypsum Wallboard to Wood Framing
C587 Specification for Gypsum Veneer Plaster
C588/C588M Specification for Gypsum Base for Veneer Plasters[3]
C954 Specification for Steel Drill Screws for the Application of Gypsum Panel Products or Metal Plaster Bases to Steel Studs from 0.033 in. (0.84 mm) to 0.112 in. (2.84 mm) in Thickness
C1007 Specification for Installation of Load Bearing (Transverse and Axial) Steel Studs and Related Accessories
C1396/C1396M Specification for Gypsum Board
E84 Test Method for Surface Burning Characteristics of Building Materials
E96/E96M Test Methods for Water Vapor Transmission of Materials
E119 Test Methods for Fire Tests of Building Construction and Materials
E337 Test Method for Measuring Humidity with a Psychrometer (the Measurement of Wet- and Dry-Bulb Temperatures)

3. Terminology

accelerator, *n*—a material that reduces setting time.

accessories, *n*—products fabricated for the purpose of forming corners, edges, control joints, or decorative effects.

adhesive, *n*—a substance capable of holding materials together by surface attachment.

admixture, *n*—a material other than water, aggregates, hydraulic cementitious material, and fiber reinforcement that is used as an ingredient to modify properties and is added to the batch before or during its mixture.

aggregate, *n*—an inert granular material which may be added to gypsum plasters. **(C35)**

all purpose compound, *n*—a compound formulated and manufactured to serve as a taping or finishing compound, or both.

anhydrite, *n*—the mineral consisting primarily of anhydrous calcium sulfate, $CaSO_4$.

[1] This terminology is under the jurisdiction of ASTM Committee C11 on Gypsum and Related Building Materials and Systems and is the direct responsibility of Subcommittee C11.91 on Terminology and Editorial.

Current edition approved Jan. 1, 2010. Published February 2010. Originally approved in 1916. Last previous edition approved in 2008 as C11–08c. DOI: 10.1520/C0011-10.

[2] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For Annual Book of ASTM Standards volume information, refer to the standard's Document Summary page on the ASTM website.

[3] Withdrawn. The last approved version of this historical standard is referenced on www.astm.org.

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arris (of an arch), *n*—the outside corner or angle formed by the meeting of a wall surface with the curved surface of an arch (see Fig. 1).

base coat, *n*—any or all layers of plaster in place prior to application of finish coats.

DISCUSSION—The first application is normally called a scratch coat and the second application is referred to as a brown coat.

bedding coat, *n*—that coat of plaster to receive aggregate or other decorative material of any size, impinged or embedded into its surface, before it sets.

bond plaster, *n*—a calcined gypsum plaster specially formulated for application over rough monolithic concrete as a bonding coat for a subsequent gypsum plaster layer. **(C28/C28M)**

bridging, *n*—*in framing*, sections of wood or metal pieces used between framing members to stiffen, give lateral support, and minimize rotation.

brown coat, *n*—the second layer in three-coat plaster application.

building construction joint, *n*—a designed division of a building that allows movement of all component parts of the building, in any plane, which may be caused by thermal, seismic, wind loading, or any other force. The construction of the separation is accomplished by one of the following methods: (*1*) manufactured devices suitable for this application, or (*2*) by field fabrication of suitable materials.

calcined gypsum, *n*—a dry powder; primarily calcium sulfate hemihydrate, resulting from calcination of gypsum; cementitious base for production of most gypsum plasters: also called plaster of paris, sometimes called stucco.

calcium sulfate, *n*—the chemical compound $CaSO_4$.

cementitious material, *n*—a material that, when mixed with water, with or without aggregate, provides the plasticity and the cohesive and adhesive properties necessary for placement, and the formation of a rigid mass.

check cracking (in joint systems), *n*—short, narrow cracks randomly oriented in the surface of the dried joint compound.

coat, *n*—a layer of plaster applied in a single operation.

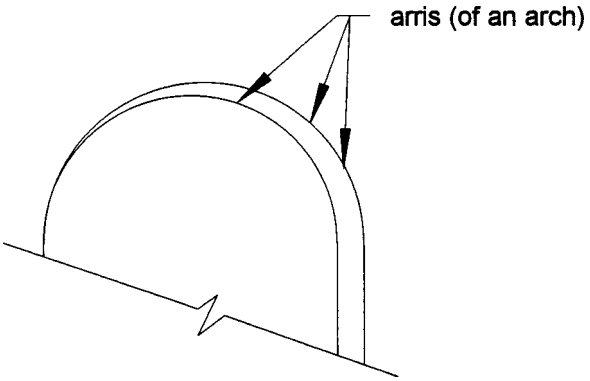

FIG. 1 Arris (of an Arch)

combined water, *n*—the water chemically held, as water of crystallization, by the calcium sulfate dihydrate or hemihydrate crystal.

compressive strength, *n*—the maximum load sustained by a standard specimen of a material when subjected to a crushing force.

consistency, *n*—a property of a material determined by the complete flow force relation. **(C557)**

consistency (normal), *n*—the number of millilitres of water per 100 g of gypsum plaster or gypsum concrete required to produce a mortar or a slurry of specified fluidity. **(C472)**

control (expansion-contraction) joint, *n*—a designed separation in the system materials that allows for movement caused by expansion or contraction of the system. The construction of the separation is accomplished by one of the following methods: *(1)* manufactured devices suitable for this application, or *(2)* by field fabrication of suitable materials.

core (of gypsum board), *n*—the hardened material filling the space between the face and back papers consisting substantially of rehydrated gypsum with additives.

cored tile or block, *n*—see **gypsum tile or block**. **(C52)**

cornerbead, *n*—an accessory for outside corners.

corner reinforcement, exterior, *n*—a preformed section of wire or expanded sheet steel, for the reinforcement of exterior stucco external corners (arrises).

cure (portland cement plaster or stucco), *v*—(*1*) to provide conditions conducive to the hydration process of portland cement plaster or stucco, or (*2*) to maintain proper temperature and a sufficient quantity of water within the plaster to ensure cement hydration.

density, *n*—the weight per unit volume of a material. **(C472)**

dried sample, *n*—a sample devoid of free water.

edge (of glass mat gypsum panels), *n*—the bound edge as manufactured.

edge (of gypsum board), *n*—the paper-bound edge as manufactured.

edge trim, *n*—an accessory to cover exposed ends or edges of gypsum board.

embedding compound—see **taping compound.**

end (of glass mat gypsum panels), *n*—the end perpendicular to the bound edge. The gypsum core is always exposed.

end (of gypsum board), *n*—the end perpendicular to the paper-bound edge. The gypsum core is always exposed.

expansion joint, *n*—see **control (expansion-contraction) joint**.

face, *n*—the surface designed to be left exposed to view or to receive decoration or additional finishes.

featured edge, *n*—an edge configuration of the paper bound edge of gypsum board that provides special design or performance.

fineness modulus, *n*—an empirical factor obtained by adding total percentages of a sample of aggregate retained on each of a specified series of sieves and dividing by 100. The sieve sizes used are: No. 100 (150 μm), No. 50 (300 μm), No. 30

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(600 µm), No. 16 (1.18 mm), No. 8 (2.36 mm), No. 4 (4.75 mm), ⅜ in. (9.5 mm), ¾ in. (19.0 mm), 1½ in. (38.1 mm) and larger, increasing in the ratio of 2 to 1.

finish coat, *n*—the final layer of plaster applied over a basecoat or other substrate.

finishing compound, *n*—(*sometimes called topping compound*) a compound specifically formulated and manufactured for use over taping or all purpose compounds to provide a smooth and level surface for the application of decoration.

fire-resistance classification, *n*—a standard rating of fire-resistance and protective characteristics of a building construction or assembly. **(E119)**

flame spread classification, *n*—a standard rating of relative surface burning characteristics of a building material as compared to a standard material. **(E84)**

flexural strength, *n*—the maximum load sustained by a standard specimen of a sheet material when subjected to a bending force.

floating, *v*—the act of spreading, compacting, or consolidating to achieve a specified uniform appearance.

framing member, *n*—stud, plate, track, joist, furring, and other support to which a gypsum panel product, or metal plaster base is attached.

free water, *n*—all water contained by gypsum board or plaster in excess of that chemically held as water of crystallization.

gauging plaster, *n*—a calcined gypsum plaster designed to be mixed with lime putty. **(C28/C28M)**

glass mat, *n*—a woven or non-woven fabric of glass fibers with or without a binder.

grout, *n*—gypsum or portland cement plaster used to fill crevices or to fill hollow metal frames.

gypsum, *n*—the mineral consisting primarily of fully hydrated calcium sulfate, $CaSO_4 \cdot 2H_2O$ or calcium sulfate dihydrate. **(C22/C22M)**

gypsum backing board, *n*—a ¼ in. to ⅝ in. gypsum board for use as a backing for gypsum wallboard, acoustical tile, or other dry cladding.

water resistant gypsum backing board—a gypsum board designed for use on walls primarily as a base for the application of ceramic, or plastic tile.

gypsum base for veneer plasters, *n*—a gypsum board used as the base for application of a gypsum veneer plaster. **(C588/C588M)**

gypsum board, *n*—the generic name for a family of sheet products consisting of a noncombustible core primarily of gypsum with paper surfacing.

gypsum casting plaster, *n*—a calcined gypsum plaster used primarily to form objects, such as lamp bases, art ware, and novelties, etc. **(C59/C59M)**

gypsum concrete, *n*—a calcined gypsum mixed with wood chips or aggregate, or both. **(C317/C317M)**

gypsum core board, *n*—a ¾ in. (19.0 mm) to 1 in. (25.4 mm) gypsum board consisting of a single board or factory laminated multiple boards, used as a gypsum stud or core in semisolid or solid gypsum board partitions.

gypsum formboard, *n*—a gypsum panel product used as the permanent form for poured gypsum roof decks. **(C318/C318M)**

gypsum lath, *n*—a gypsum board used as the base for application of gypsum plaster. **(C37/C37M)**

perforated gypsum lath—a gypsum lath having perforations to provide mechanical keying of the basecoat plaster.

foil-backed gypsum lath—the same as plain gypsum lath except that in addition, the back surface shall be covered with a continuous sheet of pure bright finished aluminum foil.

type X lath—a gypsum lath specially manufactured to provide specific fire-resistant characteristics.

gypsum molding plaster, *n*—a calcined gypsum plaster used primarily for plaster casts or molds, sometimes used as a gauging plaster. **(C59/C59M, C28/C28M)**

gypsum neat plaster, *n*—a calcined gypsum mixed at the mill with ingredients to control working quality and setting time. **(C28/C28M)**

DISCUSSION—Neat plaster is either fibered or unfibered. The addition of aggregate is required on the job.

gypsum panel products, *n*—the general name for a family of sheet products consisting essentially of gypsum.

gypsum plaster, *n*—the generic name for a family of powdered cementitious products consisting primarily of calcined gypsum with additives to modify physical characteristics, and having the ability, when mixed with water, to produce a plastic mortar or slurry which can be formed to the desired shape by various methods and will subsequently set to a hard, rigid mass. **(C28/C28M)**

gypsum sheathing, *n*—a gypsum board used as a backing for exterior surface materials, manufactured with water-repellant paper and may be manufactured with a water-resistant core. **(C1396/C1396M)**

gypsum tile or block, *n*—a cast gypsum building unit. **(C52)**

gypsum veneer plaster systems, *n*—veneer plaster applied in accordance with Specification C843 to gypsum base for veneer plasters.

gypsum wallboard, *n*—a gypsum board used primarily as an interior surfacing for building structures. **(C36/C36M)**

foil-backed gypsum wallboard—a gypsum wallboard with the back surface covered with a continuous sheet of pure bright finished aluminum foil. **(C36/C36M)**

type X gypsum wallboard—a gypsum wallboard specially manufactured to provide specific fire-resistant characteristics **(C36/C36M).**

gypsum wood-fibered plaster, *n*—a calcined gypsum plaster containing shredded or ground wood fiber added during manufacture.

hemihydrate, *n*—the dry powder, calcium sulfate hemihydrate, resulting from calcination of $CaSO_4 \cdot 2H_2O$, calcium sulfate dihydrate. See **calcined gypsum**.

joining, *n*—the juncture of two separate plaster applications of the same coat, usually within a single surface plane.

joint compound, *n*—a compound used for taping or finishing gypsum board, or both.

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joint tape, *n*—a type of paper, metal, fabric, glass mesh, or other material, commonly used with a cementitious compound, to reinforce the joints between adjacent gypsum boards. **(C475/C475M)**

joint tape, self-adhering, *n*—a joint tape manufactured to adhere directly to the substrate.

DISCUSSION—Tapes having this quality do not require mechanical or embedment means of attachment to the substrate.

Keene's cement, *n*—an anhydrous gypsum plaster characterized by a low mixing water requirement and special setting properties, primarily used with lime to produce hard, dense finish coats. **(C61/C61M)**

key, *n*—the grip or mechanical bond of one coat of plaster to another coat, or to a substrate.

DISCUSSION—It may be accomplished physically by the penetration of wet mortar or crystals into paper fibers, perforations, scoring irregularities, or by the embedment of the lath.

lath—see **gypsum lath**.

load-bearing partition, *n*—a partition designed to support a portion of the building structure.

machine direction, *n*—the direction parallel to the paper-bound edge of the gypsum board.

manufactured sand, *n*—the fine material resulting from the crushing and classification by screening, or otherwise, of rock, gravel, or blast furnace slag. **(C35)**

masonry cement, *n*—a hydraulic cement for use in mortars for masonry construction, containing one or more of the following materials: portland cement, portland blast furnace slag cement, portland-pozzolan cement, natural cement, slag cement, or hydraulic lime; and in addition usually containing one or more materials such as hydrated lime, limestone, chalk, calcareous shell, talc, slag, or clay as prepared for this purpose.

mechanical bonds, *n*—the attachment created when plaster penetrates, into or through, the substrate, or envelops irregularities in the surface of the substrate.

members (in application of gypsum panel products), *n*—framing to which gypsum panel products are attached.

mill-mixed plaster (ready-mixed plaster), *n*—material formulated and dry-blended by the manufacturer, requiring only the addition of and mixing with water.

mortar, *n*—a mixture of gypsum plaster with aggregate or hydrate lime, or both, and water to produce a trowelable fluidity.

natural sand, *n*—the fine granular material resulting from the natural disintegration of rock or from the crushing of friable sandstone. **(C35)**

neat gypsum plaster—see **gypsum neat plaster**.

nominal thickness (of gypsum panel products), *n*—the manufacturer-stated thickness of the gypsum panel product.

paper joint tape, *n*—a strip of paper reinforcing material designed to be embedded in the joint compound and to reinforce the joint between two gypsum boards.

perlite aggregate, *n*—a siliceous volcanic glass expanded by heat. **(C35)**

perm, *n*—a unit of measurement of water vapor permeance; a metric perm, or 1 g/24 h·m^2·mm Hg. U.S. unit, 1 grain/h·ft^2·in. Hg. **(E96/E96M)**

permeability, *n*—the property of a porous material that permits a fluid (or gas) to pass through it; in construction, commonly refers to water vapor permeability of a sheet material or assembly and is defined as water vapor permeance per unit thickness. Metric unit of measurement, metric perms per centimetre of thickness. See **water vapor transmission, perm, permeance**. **(E96/E96M)**

permeance (water vapor), *n*—the ratio of the rate of water vapor transmission (WVT) through a material or assembly between its two parallel surfaces to the vapor pressure differential between the surfaces. Metric unit of measurement is the metric perm, 1 g/24 h·m^2·mm Hg; U.S. unit, 1 grain/h·ft^2·in. Hg. See **water vapor transmission**, **permeability**, **perm**. **(E96/E96M)**

plaster—see **gypsum plaster, gypsum neat plaster**.

plaster bond, *n*—the adhesion between plaster coats or between plaster and substrate.

plastic cement, *n*—a hydraulic cement to which one or more plasticizing agents (but not more than 12 % by volume) have been added during intergrinding or blending to increase the workability and molding qualities of the resultant cement paste, mortar, or plaster.

plasticity, *n*—the property of freshly mixed cement paste, mortar, or plaster which determines its workability and molding qualities.

portland cement, *n*—a hydraulic cement produced by pulverizing clinker consisting essentially of hydraulic calcium silicates, and usually containing one or more forms of calcium sulfate as an interground addition.

portland cement plaster, *n*—a plaster mix in which portland cement or combinations of portland and masonry cements or portland cement and lime are the principal cementitious materials mixed with aggregate.

purity, *n*—the percentage of $CaSO_4 \cdot ½\ H_2O$ in the calcined gypsum portion of a gypsum plaster or gypsum concrete, as defined by Specification C28/C28M, for Gypsum Plasters. The percentage of $CaSO_4 \cdot 2H_2O$ in the gypsum or the gypsum portion of fully hydrated, dry, set gypsum plaster. **(C472, C28/C28M)**

ready-mixed plaster, *n*—a calcined gypsum plaster with aggregate added during manufacture. **(C28/C28M)**

recessed edge, *n*—see **tapered edge**

relative humidity, *n*—the ratio of actual water vapor pressure to the saturation water vapor pressure at the same temperature, expressed as a percentage. **(E337)**

retarder, *n*—a material that extends setting time.

round edge, *n*—a rounded, paper-bound edge formation on gypsum board, commonly used for gypsum lath. **(C37/C37M, C473)**

saddle-tie, *for furring*, *n*—a single or double strand of wire used to attach furring members to framing members of wall or ceiling assemblies. See Fig. 2.

saddle-tie, *for furring*, *v*—to attach furring members to framing members of wall or ceiling assemblies using a single or double strand of wire. See Fig. 2.

saddle-tie, *for wire hangers*, *v*—to attach wire hangers to main runners. See Fig. 3.

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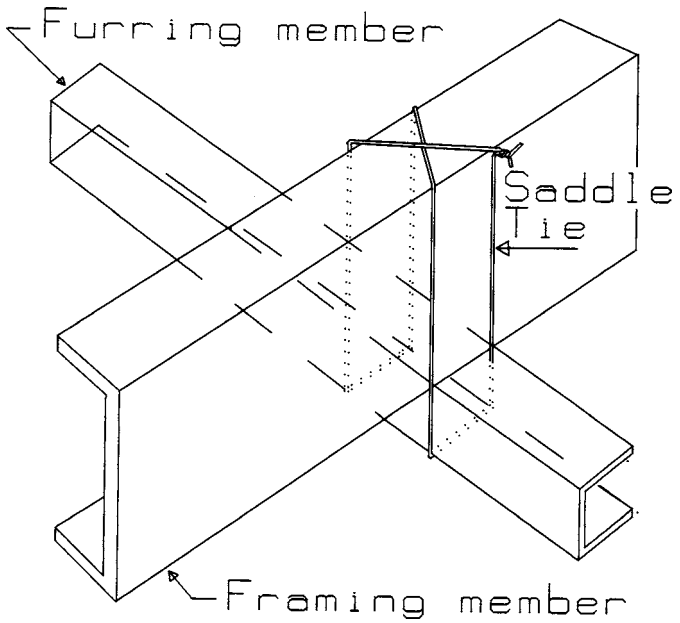

FIG. 2 Saddle-Tie

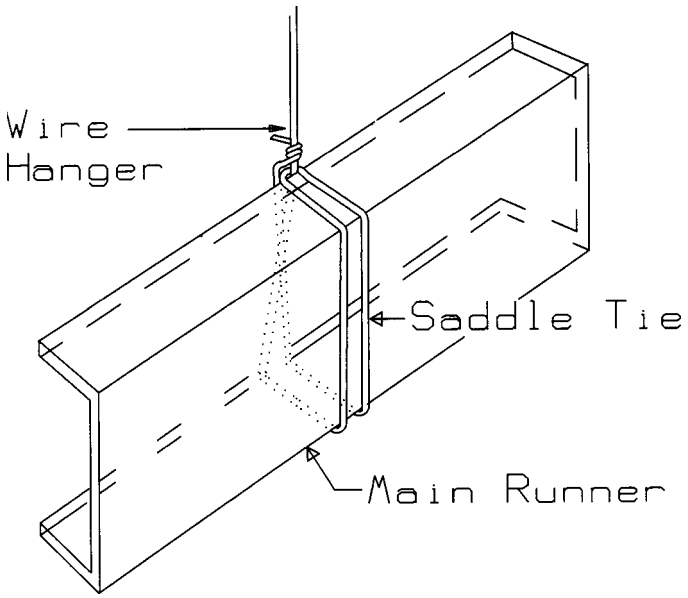

FIG. 3 Saddle-Tie

sample as received, *n*—a representative portion of product or material in the state received by the testing laboratory.

scratch coat, *n*—the first layer of plaster applied over lath or other substrate.

set, *n*—the chemical and physical change in plaster as it goes from a plastic, workable state to a rigid state. See **setting time**. **(C472)**

setting time, *n*—the elapsed time required for a gypsum plaster to attain a specified hardness and strength after mixing with water. **(C472)**

shipment (of gypsum panel products), *n*—the quantity of gypsum panel products shipped by a manufacturer and included on a single invoice.

smooth-trowel finish, *n*—a uniform finish free of grainy or coarse areas, trowel marks, or other avoidable imperfections.

steel drill screw, *n*—self-drilling screw with the ability to drill its own hole and form or cut mating threads without deforming its threads or breaking. **(C954, C1007)**

stucco, *n*—a portland cement-aggregate plaster mix designed for use on exterior surfaces. See **portland cement plaster**.

synthetic gypsum, *n*—a chemical product, consisting primarily of calcium sulfate dihydrate ($CaSO_4 \cdot 2H_2O$) resulting primarily from an industrial process.

tapered edge, *n*—an edge formation of gypsum board which provides a shallow depression at the paper-bound edge to receive joint reinforcement. Also known as a **recessed edge**. **(C473, C36/C36M)**

taping compound, *n*—(*sometimes called embedding compound*) a compound specifically formulated and manufactured for use in embedding of joint reinforcing tape at gypsum board joints.

temper, *v*—to mix or restore to a workable consistency.

texture finish, *n*—any applied decorative finish other than smooth.

three-coat work, *n*—plaster applied in three successive coats with time between coats for setting or drying, or both.

topping compound—see **finishing compound**.

veneer plaster, *n*—a calcined gypsum plaster formulated to be applied in thin coats. **(C587)**

vermiculite aggregate, *n*—a micaceous mineral that expands with heat. **(C35)**

wallboard—see **gypsum wallboard**. **(C36/C36M)**

water absorption, *n*—the amount of water absorbed by a material under specified test conditions commonly expressed as weight percent of the test specimen.

water-repellent paper, *n*—gypsum board paper surfacing which has been formulated or treated to resist water penetration.

water-resistant core, *n*—a gypsum board specially formulated to resist water penetration.

water vapor transmission (WVT), *n*—the rate of water vapor flow, under steady specified conditions, through a unit area of a material, between its two parallel surfaces and normal to the surfaces. Metric unit of measurement is 1 g/24 h·m^2. See **permeability**,**permeance**, **perm**. **(E96/E96M)**

wood-fibered plaster, *n*—a calcined gypsum plaster containing shredded or ground wood fiber added during manufacture. **(C28/C28M)**

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SUMMARY OF CHANGES

Committee C11 has identified the location of selected changes to this terminology since the last issue, C11–08c, that may impact the use of this terminology. (Approved January 1, 2010)

(*1*) Revised the definition of **nominal thickness (of gypsum panel products)**.

Committee C11 has identified the location of selected changes to this terminology since the last issue, C11–08b, that may impact the use of this terminology. (Approved August 1, 2008)

(*1*) Added the new term **steel drill screw**.

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Designation: C 22/C 22M – 00 (Reapproved 2005)ε1

Standard Specification for Gypsum[1]

This standard is issued under the fixed designation C 22/C 22M; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

ε[1] NOTE—Paragraph 1.3 was added editorially October 2005.

1. Scope

1.1 This specification covers gypsum, calcium sulfate combined with two molecules of water in crystalline form and having the approximate chemical formula $CaSO_4 \cdot 2H_2O$.

1.2 The values stated in either inch-pound units or SI (metric) are to be regarded separately as the standard. Within the text, the SI units are shown in brackets. The values stated in each system shall be used independently of the other. Values from the two systems shall not be combined.

1.3 The text of this specification references notes and footnotes which provide explanatory material. These notes and footnotes (excluding those in tables and figures) shall not be considered as requirements of the specification.

2. Referenced Documents

2.1 *ASTM Standards:* [2]

C 11 Terminology Relating to Gypsum and Related Building Materials and Systems

C 471M Test Methods for Chemical Analysis of Gypsum and Gypsum Products [Metric]

C 472 Test Methods for Physical Testing of Gypsum, Gypsum Plasters and Gypsum Concrete

3. Terminology

3.1 *Definitions*—Definitions shall be in accordance with Terminology C 11.

4. Chemical Composition

4.1 Gypsum shall contain not less than 70.0 weight percent $CaSO_4 \cdot 2H_2O$.

4.2 The chemical composition, within the limits prescribed by 4.1, shall be specified in the purchase order or contract.

5. Physical Properties

5.1 *Size*—If necessary, gypsum shall be crushed or ground, or both, to the size specified in the purchase order.

6. Sampling

6.1 *Bulk*—When gypsum is shipped in bulk, samples of approximately 5 lb [2 kg] each shall be taken at regular intervals during the complete loading or unloading of the carrier, in such a way as to accumulate not less than 200 lb [90 kg] of material and to represent correctly the percentages of both the coarse particles and the fines in the shipment. This material shall be broken to pass a 1-in. [25.0-mm] sieve, thoroughly mixed, and reduced by quartering to provide not less than a 1-lb [0.5-kg] sample for the laboratory.

6.2 *Packages*—When gypsum is shipped in packages, not less than 1 % of the packages shall be sampled. Samples shall be taken from both the surface and the center of the packages. These samples shall then be broken, mixed, and quartered in accordance with 6.1.

6.3 *Laboratory Samples*—Each laboratory sample shall be placed immediately in an airtight container and shipped to the laboratory for testing.

7. Test Methods

7.1 The chemical composition of gypsum shall be determined in accordance with Test Methods C 471M.

7.2 The physical properties of gypsum shall be determined in accordance with Test Methods C 472.

8. Inspection

8.1 Inspection of the gypsum shall be agreed upon between the purchaser and the supplier as part of the purchase agreement.

9. Rejection

9.1 Rejection of gypsum that fails to conform to the requirements of this specification shall be reported to the producer or supplier promptly and in writing. The notice of rejection shall contain a statement documenting how the gypsum has failed to conform to the requirements of this specification.

[1] This specification is under the jurisdiction of ASTM Committee C11 on Gypsum and Related Building Materials and Systems and is the direct responsibility of Subcommittee C11.01 on Specifications and Test Methods for Gypsum Products.

Current edition approved October 1, 2005. Published November 2005. Originally approved in 1919. Last previous edition approved in 2000 as C 22/C 22M – 00.

[2] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

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10. Certification

10.1 When specified in the purchase agreement, a manufacturer's or supplier's report shall be furnished at the time of shipment certifying that the product is in compliance with this specification.

11. Packaging and Package Marking

11.1 Gypsum shall be shipped either in packages or in bulk.

11.2 When shipped in packages for resale, the following information (See Note 1) shall be legibly marked on each package or on a tag of suitable size attached thereto:

11.2.1 Name of manufacturer,

11.2.2 Description of material, and

11.2.3 Net or gross weights, or both, of the package.

11.3 When shipped in bulk, a card containing the required information in accordance with 11.2 shall be conspicuously placed in the carrier.

NOTE 1—State law may require additional information.

12. Keywords

12.1 calcium sulfate; gypsum

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Designation: C 25 – 06

Standard Test Methods for Chemical Analysis of Limestone, Quicklime, and Hydrated Lime[1]

This standard is issued under the fixed designation C 25; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

This standard has been approved for use by agencies of the Department of Defense.

1. Scope

1.1 These test methods cover the chemical analysis of high-calcium and dolomitic limestone, quicklime, and hydrated lime. These test methods are classified as either standard (preferred) or alternative (optional).

1.2 The standard test methods are those that employ classical gravimetric or volumetric analytical procedures and are typically those required for referee analyses where chemical specification requirements are an essential part of contractual agreement between buyer and seller.

1.3 Alternative or optional test methods are provided for those who wish to use procedures shorter or more convenient than the standard methods for the routine determinations of certain constituents. Optional test methods may sometimes be preferred to the standard test methods, but frequently the use of modern and expensive instrumentation is indicated which may not be accessible to everyone. Therefore, the use of these test methods must be left to the discretion of each laboratory.

1.4 The analytical procedures appear in the following order:

	Section
Aluminum Oxide	15
Available Lime Index	28
Calcium and Magnesium Oxide:	
Alternative EDTA Titration Method	31
Calcium Carbonate Equivalent	33
Calcium Oxide:	
Gravimetric Method	16
Volumetric Method	17
Carbon Dioxide by Standard Method	22
Combined Oxides of Iron and Aluminum	12
Ferrous Iron	Appendix X5
Free Calcium Oxide	Appendix X6
Free Moisture in Hydrated Lime	21
Free Moisture in Limestone	20
Free Silica	29
Insoluble Matter Including Silicon Dioxide:	
Standard Method	8
Optional Perchloric Acid Method	9
Insoluble Matter Other Than Silicon Dioxide	11
Loss on Ignition	19
Magnesium Oxide	18
Manganese:	
Bismuthate Method	Appendix X4
Periodate (Photometric) Method	27
pH Determination of Alkaline Earth Solutions	34
Phosphorus:	
Titrimetric Method	Appendix X3
Molybdovanadate Method	26
Silicon Dioxide	10
Strontium Oxide	Appendix X2
Sulfur Trioxide	23
Total Carbon:	
Direct Combustion-Thermal Conductivity Cell Method	32
Total Carbon and Sulfur:	
Combustion/Infrared Detection Method	35
Total Iron:	
Standard Method, Potassium Dichromate Titration	13
Potassium Permanganate Titration Method	Appendix X1
Ortho-Phenanthroline, Photometric Method	14
Total Sulfur:	
Sodium Carbonate Fusion	24
Combustion-Iodate Titration Method	25
Unhydrated Oxides	30

1.5 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.* For specific precautionary statements, see 9.3, 10.2.1, 18.4.3, 31.6.4.2, X2.3.1, and X5.4.1.1.

2. Referenced Documents

2.1 *ASTM Standards:* [2]

C 50 Practice for Sampling, Sample Preparation, Packaging, and Marking of Lime and Limestone Products

C 51 Terminology Relating to Lime and Limestone (as used by the Industry)

C 911 Specification for Quicklime, Hydrated Lime, and Limestone for Chemical and Industrial Uses

[1] These test methods are under the jurisdiction of ASTM Committee C07 on Lime and are the direct responsibility of Subcommittee C07.05 on Chemical Tests.

Current edition approved Feb. 15, 2006. Published March 2006. Originally approved in 1919. Last previous edition approved in 1999 as C 25–99.

[2] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

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D 1193 Specification for Reagent Water
E 29 Practice for Using Significant Digits in Test Data to Determine Conformance with Specifications
E 50 Practices for Apparatus, Reagents, and Safety Considerations for Chemical Analysis of Metals, Ores, and Related Materials
E 70 Test Method for pH of Aqueous Solutions With the Glass Electrode
E 173 Practice for Conducting Interlaboratory Studies of Methods for Chemical Analysis of Metals [3]
E 200 Practice for Preparation, Standardization, and Storage of Standard and Reagent Solutions for Chemical Analysis
E 691 Practice for Conducting an Interlaboratory Study to Determine the Precision of a Test Method
E 832 Specification for Laboratory Filter Papers

3. Terminology

3.1 Definitions—Unless otherwise specified, for definitions of terms used in these test methods refer to Terminology C 51.

4. Significance and Use

4.1 These test methods provide accurate and reliable analytical procedures to determine the chemical constituents of limestone, quicklime, and hydrated lime (See Note 1). The percentages of specific constituents which determine a material's quality or fitness for use are of significance depending upon the purpose or end use of the material. Results obtained may be used in relation to specification requirements.

4.2 Because quicklime and hydrated lime quickly absorb water and carbon dioxide from the air, precision and bias are extremely dependent upon precautions taken during sample preparation and analysis to minimize excessive exposure to ambient conditions.

NOTE 1—These test methods can be applied to other calcareous materials if provisions are made to compensate for known interferences.

5. General Apparatus and Materials and Reagents

5.1 *General Apparatus and Materials*:

5.1.1 *Balance*—The balance shall be of an analytical type with a capacity not to exceed 200 g. It may be of conventional design or it may be a constant-load, direct-reading type. It shall be capable of reproducing weighings within 0.0002 g with an accuracy of ± 0.0002 g. Rapid weighing devices that may be provided such as a chain, damper, or heavy riders shall not increase the basic inaccuracy by more than 0.0001 g at any reading and with any load within the rated capacity of the balance.

5.1.2 *Weights*—Weights used for analysis shall conform to Class S-1 requirements of the National Institute of Standards and Technology as described in NIST Circular 547.[4] They shall be checked at least once a year or when questioned, and adjusted to within allowable tolerances for Class S-1 weights. All new sets of weights purchased shall have the weights of 1 g and larger made of stainless steel or other corrosion-resistant alloy not requiring protective coating and shall meet the density requirements for Class S.

5.1.3 *Glassware and Laboratory Containers*—Standard volumetric flasks, burets, pipets, dispensers, etc., shall be carefully selected precision grade or better and shall be calibrated, if necessary, to meet the requirements of each operation. Standard-type interchangeable ground glass or TFE-fluorocarbon joints are recommended for all volumetric glassware. Polyethylene containers are recommended for all aqueous solutions of alkalies and for standard solutions where the presence of dissolved silica or alkali from the glass would be objectionable.

5.1.4 *Desiccators*—Desiccators shall be provided with a good desiccant such as anhydrous magnesium perchlorate, activated alumina, sulfuric acid, or phosphoric anhydride. Anhydrous calcium sulfate may also be used provided it has been treated with a color-changing indicator to show when the desiccant has lost its effectiveness. Calcium chloride and silica gel are not satisfactory desiccants for this type of analysis.

5.1.5 *Filter Paper*—Filter paper shall conform to the requirements of Specification E 832, Type II (quantitative). Class E shall be used for coarse and gelatinous precipitates. When medium-textured paper is required, Class F filter paper shall be used. When a retentive paper is needed, Class G shall be used.

Recommendations: Class	Filter Pore Size (microns)	Filter Speed
E	20 to 25	fast speed
F	8	medium speed
G	2.5	slow speed

5.1.6 *Crucibles*—Platinum crucibles and tight fitting lids should preferably be made of pure unalloyed platinum and be of 25 to 35-mL capacity. Where alloyed platinum is used for greater stiffness or to obviate sticking of fused material to crucible or lid, the alloyed platinum should not decrease in weight by more than 0.2 mg when heated at 1200 °C for 1 h.

5.1.7 *Muffle Furnace*—The electric muffle furnace should be capable of continuous operation up to 1000 °C and be capable of intermittent operation at higher temperatures if required. It should have an indicating pyrometer accurate to ± 25 °C.

5.2 *Reagents*:

5.2.1 *Purity of Reagents*—Reagent grade chemicals shall be used in all tests. Unless otherwise indicated, it is intended that all reagents shall conform to the specifications of the Committee on Analytical Reagents of the American Chemical Society[5] where such specifications are available. Other grades may be used provided it is first ascertained that the reagent is of sufficiently high purity to permit its use without lessening the accuracy of the determination. In addition to this, it is desirable in many cases for the analyst to ensure the accuracy of his results by running blanks or checking against a comparable sample of known composition.

[3] Withdrawn.

[4] Available from National Institute of Standards and Technology (NIST), 100 Bureau Dr., Stop 3460, Gaithersburg, MD 20899-3460.

[5] *Reagent Chemicals, American Chemical Society Specifications,* American Chemical Society, Washington, DC. For suggestions on the testing of reagents not listed by the American Chemical Society, see *Analar Standards for Laboratory Chemicals,* BDH Ltd., Poole, Dorset, U.K., and the *United States Pharmacopeia and National Formulary,* U.S. Pharmacopeia Convention, Inc. (USPC), Rockville, MD.

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5.2.2 *Purity of Water*—Unless otherwise indicated, references to water are understood to mean distilled water or other water of equivalent purity. Water conforming to Specification D 1193 meets these requirements.

5.2.3 *Concentration of Reagents*:

5.2.3.1 *Concentrated Acids and Ammonium Hydroxide*—When acids and ammonium hydroxide are specified by name or chemical formula only, it shall be understood that concentrated reagents approximating the following specific gravities or concentrations are intended:

Acetic acid ($HC_2H_3O_2$)	99.5 %
Hydrochloric acid (HCl)	sp gr 1.19
Hydrofluoric acid (HF)	48 %
Nitric acid (HNO_3)	sp gr 1.42
Perchloric acid ($HClO_4$)	70 %
Phosphoric acid (H_3PO_4)	85 %
Sulfuric acid (H_2SO_4)	sp gr 1.84
Ammonium hydroxide (NH_4OH)	sp gr 0.90

5.2.3.2 *Dilute Reagents*—The concentration of dilute acids and NH_4OH except when standardized, are specified as a ratio stating the number of measured volumes of the concentrated reagent to be diluted with a given number of measured volumes of water. In conformance with international practice, new and revised methods will use the "plus" designation instead of the ratio (:) symbol as the specified designation of dilution; for example, $H_2SO_4(5 + 95)$ means 5 volumes of concentrated H_2SO_4(sp gr 1.84) diluted with 95 volumes of water.

5.2.3.3 *Standard Solutions*—Concentrations of standard solutions shall be expressed as normalities (*N*) or as equivalents in grams per millilitre of the component to be determined, for example: 0.1 *N* $K_2Cr_2O_7$ solution (1 mL = 0.004 g Fe_2O_3). The average of at least three determinations shall be used for all standardizations. The standardization used to determine the strength of the standard solutions is described in the text under each of the appropriate procedures.

6. General Procedures

6.1 *Sampling*—Samples of lime and limestone for chemical analysis shall be taken and prepared in accordance with the requirements of Practice C 50 applicable to the material to be tested.

6.2 *Tared or Weighed Crucibles*—The tare weight of crucibles shall be determined by preheating the empty crucible to constant weight at the same temperature and under the same conditions as shall be used for the final ignition of a residue and cooling in a desiccator for the same period of time used for the crucible containing the residue.

6.3 *Constancy of Weight of Ignited Residue*—To definitely establish the constancy of weight of the ignited residue, the residue and container shall be ignited at the specified temperature and time, cooled to room temperature in a desiccator, and weighed. The residue and container shall then be reheated for at least 30 min at the same temperature, cooled in a desiccator for the same period of time, and reweighed. Additional ignition periods may be required until two consecutive weights do not differ by more than 0.2 mg, at which time it shall be considered that constant weight has been attained. For ignition loss, each reheating period shall be 5 min.

6.4 *Calculation*:

6.4.1 The calculations included in the individual procedures sometimes assume that the exact weight specified has been used. Accurately weighed samples which are approximately but not exactly equal to the weight specified may be used provided appropriate corrections are made in the calculation. Unless otherwise stated, weights of all samples and residues should be recorded to the nearest 0.0001 g.

6.4.2 In all mathematical operations on a set of observed values, the equivalent of two more places of figures than in the single observed values shall be retained. For example, if observed values are read or determined to the nearest 0.1 mg, carry numbers to the nearest 0.001 mg in calculation.

6.5 *Rounding Figures*—Rounding figures to the nearest significant place required in the report should be done after the calculations are completed, in order to keep the final results free from calculation errors. The rounding procedure should follow the principle outlined in Practice E 29.

7. Performance Requirements for Test Methods

7.1 *Referee Analyses*—The reference test methods that appear in Sections 8 through 32, or any other test methods qualified in accordance with 7.3, are required for referee analysis in those cases where conformance to the requirements of a chemical specification are questioned. In these cases a limestone, quicklime, or hydrated lime shall not be rejected for failure to conform to chemical requirements unless all sample preparation and analysis of any one constituent is made entirely by reference test methods prescribed in the appropriate sections of this test method or by other qualified test methods. Exception can be made when specific test methods are prescribed in the standard specification for the limestone, quicklime, or hydrated lime in question. The test methods actually used for the analysis shall be designated.

7.1.1 When there is a question regarding acceptance, referee analyses shall be made in duplicate. If the two results do not agree within the permissible variation given in Table 1, the determination including sample preparation shall be repeated

TABLE 1 Maximum Permissible Variations in Results[A]

(Column 1) Constituent	(Column 2) Maximum Difference Between Duplicates	(Column 3) Maximum Difference of the Average of Duplicates from SRM Certificate Values[B]
Al as Al_2O_3	0.20	± 0.30
Ca as CaO	0.20	± 0.30
Mg as MgO	0.20	± 0.30
C (lime and hydrated lime)	0.20	± 0.30
C (limestone)	0.60	± 0.60
Fe as Fe_2O_3	0.10	± 0.15
Si as SiO_2	0.15	± 0.30
Mn	0.05	± 0.10
P	0.02	± 0.05
Sr as SrO	0.05	[C]
S	0.03	± 0.05

[A] For demonstrating the performance of rapid test methods the SRM closest in overall composition to the limestone shall be used (See Table 2). In the case of quicklime or hydrated lime, the SRM closest in overall composition, after heating at 1000 °C for 1 h, to the product composition shall be used, except for C and S determinations (See Note 3).

[B] Interelement corrections may be used for any standardization provided improved accuracy can be demonstrated.

[C] No SRM currently available.

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in duplicate until the results agree within the permissible variation. When the results agree within the permissible variation, their average shall be accepted as the correct value. For the purpose of comparing results, the percentages shall be calculated to one more significant figure than reported as indicated in the test methods. When a blank determination is specified, one shall be made with each individual analysis or with each group of two or more samples analyzed on the same day for a given constituent.

7.1.2 Test results from Referee methods intended for use as a basis for product acceptance or rejection, or for manufacturer's certification, can be used only after demonstration of precise and accurate analyses by meeting the requirements of 7.1.3, or except when demonstrated under 7.3.2.1. Such demonstrations may be made concurrently with analysis of the limestone, quicklime, or hydrated lime product being tested. The demonstration is required only for those constituents being used as a basis for acceptance, rejection, or certification of a limestone, quicklime, or hydrated lime, but may be made for any constituent of limestone, quicklime, or hydrated lime product for which a standard exists. Such demonstrations must be made annually.

7.1.3 Demonstrations shall be made by analysis of each constituent of concern in a SRM limestone, quicklime, or hydrated lime (See Notes 2 and 3). Duplicate samples shall be run on different days. The same test methods to be used for analysis of the limestone, quicklime, or hydrated lime being tested shall be used for analysis of the SRM. If the duplicate results do not agree within the permissible variation given in Table 1, the determinations shall be repeated, following identification and correction of problems or errors, until a set of duplicate results do agree within the permissible variation.

NOTE 2—The term SRM refers to approved Standard Reference Materials listed in Table 2.

NOTE 3—There are no SRMs that are quicklime or hydrated lime as supplied. When analyzing a quicklime or hydrated lime the SRM in carbonate form needs to be converted to closely resemble the matrix of the product being tested. To accomplish this conversion, heat the chosen SRM for 1 h at 1000 °C, immediately prior to analysis and protect it from hydration or carbonation with sealed containers and desiccation during cooling. Carbon and sulfur may be driven off during heating, rendering the converted SRM unsuitable as a standard for carbon and sulfur determinations. For carbon and sulfur determinations use the appropriate SRM in its normal matrix.

7.1.4 The average of the results of acceptable duplicate determinations for each constituent may differ from the SRM certificate value by no more than the value shown in Column 3 of Table 1. When no SRM certificate value is given, a generally accepted accuracy standard for that constituent has not been identified. In such cases, only the differences between duplicate values as specified in 7.1.3 shall apply and notification of this exception shall be reported.

7.1.5 In questions concerning the acceptance or rejection of a limestone, quicklime, or hydrated lime product, upon request data shall be made available to all parties involved demonstrating that precise and accurate results were obtained with SRM samples by the same analyst making the acceptance determination.

7.2 *Optional Analyses*—The alternative test methods, as opposed to reference methods, provide procedures that are, in some cases, shorter or more convenient to use for routine determination of some constituents (See Note 4). In some instances longer, more complex procedures have been retained as alternative test methods to permit comparison of results by different procedures or for use when unusual materials are being examined, or when unusual preparation for analysis is required. Results from alternative test methods may be used as a basis for acceptance or rejection.

NOTE 4—It is not intended that the use of reference test methods be confined to referee analysis. A reference test method may be used in preference to an alternative test method when so desired. A reference test method must be used where an alternative test method is not provided.

7.2.1 Duplicate analyses and blank determinations are left to the discretion of the analyst when using the alternative test methods. The final results should include the number of determinations performed and whether or not they were corrected for blank values.

TABLE 2 Approved SRM List

(SRM)	Al as % Al2O3	Ca as % CaO	Mg as % MgO	Fe as % Fe2O3	Si as % SiO2	% Mn	% P	Sr as % SrO	% S	Ti as % TiO2	K as % K2O	Na as % Na_2O	% L.O.I.
ECRM-752-1[A]	0.12	55.4	0.15	0.045	0.70	0.008	NC[B]	0.019	0.007	0.009	0.02	NC	43.4
IPT 35	0.24	53.8	0.70	0.14	1.98	0.009	0.003	0.04	NC	0.013	0.10	0.004	43.0
IPT 44	0.33	50.5	2.93	0.30	2.69	0.012	0.006	0.04	NC	0.019	0.12	0.002	42.9
IRSID DO 1-1[C]	0.55	52.69	0.60	1.04	1.99	0.022	0.022	NC	0.040	0.030	NC	NC	NC
NIST 1C	1.30	50.3	0.42	0.55	6.84	0.019	0.017	0.030	NC	0.07	0.28	0.020	39.9
NIST 88B	0.34	29.95	21.0	0.277	1.13	0.012	0.002	0.0076	NC	(0.016)[D]	0.103	0.029	(46.98)
BCS 368	0.17	30.8	20.9	0.23	0.92	0.05	NC	0.0089	NC	<0.01	NC	(<0.01)	46.7
IRSID 702-1	0.40	30.05	20.51	0.629	2.22	0.098	0.024	NC	0.027	0.022	NC	NC	NC
GBW 07214	0.017	54.95	0.67	0.071	0.38	0.007	0.0011	NC	0.020	NC	NC	NC	43.57
GBW 07215	0.50	51.56	2.67	0.292	1.17	0.014	0.0013	NC	0.196	NC	NC	NC	43.22
GBW 07216	0.027	36.55	16.59	0.226	0.092	0.022	0.0018	NC	0.014	NC	NC	NC	46.23
GBW 07217	0.295	30.60	20.73	0.376	0.96	0.048	0.0012	NC	0.174	NC	NC	NC	46.30
GBW 03106	0.64	50.38	2.28	0.29	4.38	0.0055	0.006	NC	0.006	0.034	0.14	0.070	41.58
GBW 03108	0.88	47.49	3.63	1.97	3.84	0.15	0.017	NC	0.036	0.14	0.23	0.024	41.52
IPT 48	0.17	31.0	21.2	0.17	0.45	0.011	0.0096	0.009	NC	0.006	0.026	0.013	46.9

[A] This SRM is still available, but its name has been changed from BCS 393 to ECRM 752-1.
[B] NC = not certified.
[C] This SRM has been found to be unavailable commercially. The use of private stock, though, is still allowed.
[D] ( ) = not certified, data for information only.

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7.3 *Performance Requirements for Alternative Test Methods*:

7.3.1 *Definition and Scope*—When analytical data obtained in accordance with this section is required, any test method may be used that meets the requirements of 7.3.2. A test method is considered to consist of the specific procedures, reagents, supplies, equipment, instrument, etc. selected and used in a consistent manner by a specific laboratory.

7.3.1.1 If more than one instrument is used for the same analysis, use of each instrument shall constitute a separate test method and each must be qualified separately.

7.3.2 *Qualification of a Test Method*—Prior to use each test method (See 7.3.1) must be qualified for each material that will be tested. Qualification data or, if applicable, requalification data shall be made available.

7.3.2.1 Using the test method chosen, make single determinations for each constituent under consideration on the SRM which in overall composition most closely resembles the limestone, quicklime, or hydrated lime to be tested (See Note 2). Complete two rounds of tests on nonconsecutive days repeating all steps of sample preparations. Calculate the differences between values and the averages of values from the two rounds of tests. Blank determinations are not required, if it has been determined that blank values do not affect the validity of the data. Blank or interference-corrected data must be so designated.

7.3.2.2 The differences between duplicates obtained for any single constituent shall not exceed the limits shown in Column 2 of Table 1.

7.3.2.3 For each constituent the average of the duplicates obtained shall be compared to the SRM Certificate value and shall not differ from the certified value by more than the value in Column 3 of Table 1. The qualification testing shall be conducted with newly prepared specimens.

7.3.2.4 The standardization, if applicable, used for qualification and analysis of each constituent shall be determined by valid curve-fitting procedures (See Note 5). Restandardization shall be performed as frequently as required to ensure that the accuracy and precision in Table 1 are maintained.

NOTE 5—An actual drawing of a curve is not required, if such a curve is not needed for the method in use. A point-to-point, saw-tooth curve that is artificially made to fit a set of data points does not constitute a valid curve-fitting procedure.

7.3.3 *Partial Results*—Test methods that provide acceptable results for some constituents, but not for others, may be used only for those components for which acceptable results are obtained.

7.3.4 *Report of Results*—Chemical analyses obtained by qualified alternative test methods shall be indicated as having been obtained by alternative methods and the type of test method used shall be designated.

7.3.5 *Rejection of Material*—See 7.1 and 7.2.

7.3.6 *Requalification of a Test Method*:

7.3.6.1 Requalification of a test method, as defined in 7.3.2, shall be required annually.

7.3.6.2 Requalification also shall be required upon receipt of substantial evidence that the test method may not be providing data in accordance with Table 1. Such requalification may be limited to those constituents indicated to be in error and shall be carried out prior to further use of the method for analysis of those constituents.

7.3.6.3 Substantial evidence that a test method may not be providing data in accordance with Table 1 shall be considered to have been received when a laboratory is informed that analysis of the same material by Reference Test Methods run in accordance with 7.1.1, a certified value of an approved SRM, or an accepted value of a known secondary standard differs from the value obtained by the test method in question by more than twice the value of Column 2 of Table 1 for one or more constituents. When indirect test methods are involved, as when a value is obtained by difference, corrections shall be made for minor constituents in order to put the analyses on a comparable basis prior to determining the differences (See Note 6). For any constituents affected, a test method also shall be requalified after any substantial repair or replacement of one or more critical components of an instrument essential to the test method.

NOTE 6—Instrumental analyses can usually detect only the element sought. Therefore, to avoid controversy, the actual procedure used for the elemental analysis should be noted when differences with reference procedures exist. For example, Combined Oxides of Iron and Aluminum by Wet Test should be compared to the sum of Fe_2O_3 and Al_2O_3 obtained instrumentally.

7.3.6.4 If an instrument or piece of equipment is replaced even by one of identical make and model, or is significantly modified, a previously qualified test method using such new or modified instrument or equipment shall be considered a new method and must be qualified in accordance with 7.3.2.

7.4 *Precision and Bias*—Different analytical test methods are subject to individual limits of precision and bias. It is the responsibility of the user to demonstrate that the test methods used at least meet the requirements shown in Table 1.

8. Insoluble Matter Including Silicon Dioxide (Standard Method)

8.1 *Scope*—This test method is based on a double evaporation to dryness of the hydrochloric acid solution of the limestone or lime sample to convert silicon dioxide (SiO_2) to the insoluble form. The acid-insoluble residue of a typical limestone consists of free silica and a mixture of minerals such as clay, mica, feldspar, tourmaline, barytes, garnet, zircon, rutile, etc.

8.2 *Summary of Test Method*—After dissolution in hydrochloric acid, the silica is dehydrated by a double evaporation to dryness. After each dehydration, the dry salts are redissolved with dilute hydrochloric acid, the solution is filtered, and the siliceous residue and other insoluble matter separated. The two papers containing the residues are combined, ignited, and weighed.

8.3 *Procedure*:

8.3.1 Weigh 0.5 g of quicklime or hydrated lime, or 1.0 g of limestone ground to pass a No. 50 (250-μm) sieve (See Note 7). If the sample is a limestone or hydrated lime, ignite in a covered platinum crucible in an electric muffle (See Note 8) at 950 °C for 15 min or longer to effect complete decomposition. Transfer to an evaporating dish, preferably of platinum (See Note 9), containing about 10 mL of water, mix to a thin slurry,

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add 5 to 10 mL of HCl, and digest with the aid of gentle heat and agitation until solution is complete (See Note 10).

NOTE 7—Due to the rapidity with which quicklime and hydrated lime absorb water and carbon dioxide from the air, samples must be protected in tightly stoppered containers at all times. Samples for analysis are to be weighed quickly and the sample container re-stoppered immediately after the sample has been removed.

NOTE 8—Ignition of the sample in an electric muffle is far superior to flame ignition. However, if an electric muffle is not available, flame ignition and the blast lamp may be used.

NOTE 9—If a platinum dish is not available, porcelain may be used. A glass container positively must *not* be used.

NOTE 10—Alternatively, the loss on ignition (LOI) can be determined first, using 0.5 g of sample. The insoluble matter including silicon dioxide can then be assayed using the ignited product that remains in the LOI crucible.

8.3.2 Evaporate the solution to dryness on a steam bath. When dry or nearly so, cover the dish and place it in an air bath or drying oven or on a metal triangle resting on a hot plate. Heat for 1 h at 100 °C, remove the dish from the heat, and allow the dish and contents to cool slightly.

8.3.3 Drench the cooled mass with 20 mL (1 + 1) HCl and place on the water bath for 10 min. Filter the mixture containing the insoluble residue through a retentive filter of suitable size. Wash filter thoroughly with warm, diluted (5 + 95) HCl and then twice with hot water. Reserve the paper and residue.

8.3.4 Evaporate the filtrate to dryness, dehydrate and extract the residue with HCl as before, but this time heat the acidified solution for 1 to 2 min. Filter through a second and smaller piece of retentive filter paper and wash as before. Retain the filtrate for iron, aluminum, calcium, and magnesium determinations; combine the two wet papers containing the separated residues and transfer to a weighed platinum crucible.

8.3.5 Char carefully without allowing the paper to inflame, and then ignite at 1000 °C for 30 min in an electric muffle furnace (See Note 8). Cool in a desiccator and weigh. The increase in weight represents the insoluble matter including SiO_2.

8.4 *Calculation*—Calculate the percentage of insoluble matter including silicon dioxide to the nearest 0.01 % as follows:

$$\text{Insoluble matter including } SiO_2 = (A/B) \times 100 \quad (1)$$

where:

A = mass of ignited residue, g, and
B = original mass of sample, g.

8.5 *Precision and Bias*—This test method was originally approved for publication before the inclusion of precision and bias statements within standards was mandated. The user is cautioned to verify by the use of reference materials, if available, that the precision and bias of this test method are adequate for the contemplated use.

9. Insoluble Matter Including Silicon Dioxide (Optional Perchloric Acid Method)

9.1 *Scope*—In this test method the insoluble matter including silicon dioxide is determined gravimetrically as in the standard method except that perchloric acid is used to dehydrate the silica. The procedure is more rapid than in the standard method because only a single dehydration is necessary. Fuming perchloric acid is a very powerful dehydrating agent, and silicic acid can usually be completely converted to the insoluble silicon dioxide in less than 20 min. This test method has been determined by other agencies such as the Association of Official Agricultural Chemists (AOAC) to be comparable to the standard hydrochloric acid method.

9.2 *Summary of Test Method*—The sample is decomposed without prior ignition by a mixture of nitric (HNO_3) and perchloric ($HClO_4$) acids and evaporated to fumes of $HClO_4$. The fuming perchloric acid is refluxed at this temperature for a short period of time to completely dehydrate the silica. The residue of silica and insoluble matter is filtered and washed free of acids and salts. The filter paper containing the residue is burned off, the resultant ash is ignited at high temperature until the ash is white, and then is weighed.

9.3 *Procedure*:

Warning—Perchloric acid ($HClO_4$) is an extremely reactive liquid. When using $HClO_4$, there are precautions to be followed which, if unheeded, may lead to serious explosions. Contact of the hot concentrated acid with organic matter must be absolutely avoided. Any organic matter in the sample must first be destroyed by the addition of nitric acid (HNO_3) to the sample prior to fuming with $HClO_4$. All evaporations involving $HClO_4$ must be done in a well-ventilated hood made of nonporous and inorganic material, preferably Type 316L stainless steel. Facilities should be provided for washdown procedures that should be performed regularly and thoroughly. These precautions on perchloric acid use are fully discussed in Practices E 50.

9.3.1 Weigh 0.5 g of quicklime or hydrated lime, or 1 g of limestone ground to pass a No. 50 (250-µm) sieve. Transfer the sample to a 250-mL beaker, wet carefully with a few millilitres of water, and dissolve cautiously with 10 mL of concentrated nitric acid. Add 20 mL of perchloric acid and boil until dense white fumes appear. If the solution darkens at this point, add several millilitres of HNO_3 until the solution clears. Heat again to fumes.

9.3.2 With the beaker covered, boil gently for 15 min to completely dehydrate the silica. Never allow contents to become solid or go to dryness, otherwise the separation of silica will be incomplete. If this happens, add more $HClO_4$ and repeat the dehydration.

9.3.3 Cool, add 50 mL of water, heat to boiling, and filter immediately using medium textured paper. Wash paper and residue thoroughly (at least 15 times) with hot water. Test with pH paper until washings are free of acid (See Note 11). Reserve the filtrate for iron, aluminum, calcium, and magnesium determinations.

NOTE 11—The filter paper and silica residue must be washed free of perchlorate salts to prevent small explosions from occurring in the crucible when the filter paper is charred and ignited.

9.3.4 Place the filter paper and contents in a weighed platinum or porcelain crucible and heat gently with a low flame until paper chars without inflaming, or alternatively char in an electric muffle at 300 to 400 °C. Slowly raise the temperature until the carbon has been burned and the ash is white. Finally, ignite at 1000 °C for 30 min. Cool in a desiccator and weigh as insoluble matter including SiO_2.

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9.4 *Calculation*—Calculate the percentage of insoluble matter including silicon dioxide to the nearest 0.01 % as follows:

$$\text{Insoluble matter including } SiO_2,\ \% = (A/B) \times 100 \quad (2)$$

where:

A = mass of ignited residue, g, and
B = original mass of sample, g.

9.5 *Precision and Bias*:

9.5.1 Four laboratories cooperated in testing on four limestone samples and three laboratories cooperated in testing on an additional eight limestone samples thereby obtaining the precision data summarized in Table 3.

9.5.2 The user is cautioned to verify by the use of reference materials, if available, that the bias of this test method is adequate for the contemplated use.

10. Silicon Dioxide

10.1 *Scope*—For control purposes or routine determinations, a separate analysis of SiO_2 may not be necessary. However, for certain applications in process industries, the amount of silica derived from the lime or limestone could be important. To satisfy situations such as this, silicon dioxide may be determined by volatilizing the SiO_2 from the insoluble residue with hydrofluoric acid and the percent SiO_2 determined by the difference in mass obtained.

10.2 *Procedure*:

10.2.1 To the ignited residue in the platinum crucible (See 8.3.5 or 9.3.4), add 5 mL of water, 5 mL of hydrofluoric acid (HF), and 1 or 2 drops of H_2SO_4.

Warning—All acids should be handled with care, but extra precaution is required with hydrofluoric acid. This is a very dangerous acid, harmful to eyes and skin; rubber gloves and goggles should be worn when using this acid. It does its work silently and leaves a festering sore that is slow to heal. Any acid that touches the skin should be immediately washed off with copious quantities of water. A physician should be notified immediately if any acid is sprayed into the eyes or if prolonged contact with the skin occurs.

10.2.2 Evaporate to dryness on a hot plate and heat in an electric muffle at 1000 °C (See Note 8) for 2 or 3 min. Cool in a desiccator and weigh. The difference between this mass and the mass of insoluble matter including silicon dioxide is the mass of SiO_2.

10.3 *Calculation*—Calculate the percent of silicon dioxide to the nearest 0.01 % as follows:

$$SiO_2,\ \% = ([A-B]/C) \times 100 \quad (3)$$

where:

A = mass of ignited residue, g (insoluble matter including SiO_2),
B = mass of ignited residue less SiO_2, g, and
C = original mass of sample, g.

10.4 *Precision and Bias*:

10.4.1 Three laboratories cooperated in testing on four limestone samples and two laboratories cooperated in testing on an additional eight limestone samples thereby obtaining the precision data summarized in Table 3.

10.4.2 The user is cautioned to verify by the use of reference materials, if available, that the bias of this test method is adequate for the contemplated use.

11. Insoluble Matter

11.1 *Scope*—The difference between the mass of insoluble matter (including silicon dioxide) and silicon dioxide represents the mass of insoluble matter other than silicon dioxide. The insoluble matter contains the remnants of any clay, siliceous minerals, or other refractory material present in limestone. The elemental components are mainly iron and aluminum which should be removed and added to the main filtrate from the SiO_2 separation. If the insoluble matter including silica is reported as such and no hydrofluoric acid treatment is indicated, then there is no need to make a recovery of the metals and the insoluble residue may be discarded.

11.2 *Procedure*—The insoluble matter left in the crucible after the silica is volatilized with HF may be dissolved by fusing the residue with 2 to 3 g of sodium carbonate (Na_2CO_3) (See Note 12). Cool the melt and dissolve it in diluted HCl. Add the solution to the filtrate from the dehydration and separation of insoluble matter including silicon dioxide (See 8.3.4 or 9.3.3).

NOTE 12—Fusion with pyrosulfate is to be avoided because this will introduce undesirable sulfates into the solution.

11.3 An alternative fusion can also be made using either lithium metaborate or lithium tetraborate as opposed to using sodium carbonate.

TABLE 3 Precision Summary of Classical Test Methods

Section	Test Method	Average,[A] % Found	Range,[A] % Found	Repeatability (R_1, E 173)	Reproducibility (R_2, E 173)
8	Insol + SiO_2 (Standard)	. . .	. . .	. . .	. . .
9	Insol + SiO_2 (Optional)	1.405	0.09–6.40	0.184	0.351
10	SiO_2	1.177	0.03–5.36	0.128	0.146
11	Insoluble Matter	0.242	0.02–0.93	0.169	0.204
12	Combined Oxides	0.459	0.22–1.21	0.181	0.282
13	Fe_2O_3	0.180	0.05–0.36	0.064	0.183
15	Al_2O_3	0.268	0.10–0.88	0.165	0.223
16	CaO (Gravimetric)	54.46	53.4–55.1	0.558	1.020
17	CaO (Volumetric)	30.57	30.4–30.7	0.371	1.132
17	CaO (Volumetric)	53.82	49.6–55.3	0.187	0.298
18	MgO (Gravimetric)	0.817	0.19–2.28	0.158	0.210
18	MgO (Gravimetric)	21.34	21.1–21.5	0.652	1.716
19	Loss on Ignition	43.73	43.6–43.9	0.158	0.463

[A] Average and range of the limestones tested.

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11.4 *Calculation*—Calculate the percentage of insoluble matter other than silicon dioxide to the nearest 0.01 % as follows:

$$\text{Insoluble matter other than } SiO_2,\ \% = A - B \quad (4)$$

where:
A = insoluble matter including SiO_2, %, and
B = SiO_2, %.

11.5 *Precision and Bias*:

11.5.1 Three laboratories cooperated in testing on four limestone samples and two laboratories cooperated in testing on an additional eight limestone samples thereby obtaining the precision data summarized in Table 3.

11.5.2 The user is cautioned to verify by the use of reference materials, if available, that the bias of this test method is adequate for the contemplated use.

12. Combined Oxides (Iron, Aluminum, Phosphorus, Titanium, Manganese)

12.1 *Scope*—The combined oxides describe a group of metals that form precipitates with ammonium hydroxide which may then be ignited to their respective oxides. Historically, it has been the practice to report the combined oxides present in limestone samples as a group because it was not always easy or desirable to determine each metal oxide separately. The group of metal oxides consists primarily of the oxides of iron and aluminum, with minor amounts of titanium dioxide (TiO_2), phosphorus pentoxide (P_2O_5), and manganese oxide (Mn_3O_4) also present. Where separate determinations are preferred, the combined oxides are usually weighed first, iron oxide is then assayed separately, and aluminum oxide is finally determined by calculating the difference between the percent combined oxides and the percent Fe_2O_3. The other metal oxides are generally assumed to be present in trace amounts and are often disregarded. When necessary, these metals may be analyzed separately and appropriate corrections made in the Al_2O_3 analysis.

12.2 *Summary of Test Method*—In this test method, aluminum, iron, titanium, and phosphorus are precipitated from the filtrate after SiO_2 removal, by means of ammonium hydroxide. With care, little if any manganese will be precipitated. The precipitate is ignited and weighed as the combined metal oxides.

12.3 *Special Solution*:

12.3.1 *Methyl Red Solution (0.2 %)*—Dissolve 2 g of methyl red indicator with 1 L of 95 % ethyl alcohol.

12.4 *Procedure*:

12.4.1 To the acid solution from the determination of SiO_2(See 8.3.4 or 9.3.3), add hydrochloric acid (HCl) if necessary to ensure a total of 10 to 15 mL of HCl.

NOTE 13—Sufficient hydrochloric acid must be present before the solution is rendered ammoniacal to prevent the precipitation of magnesium.

12.4.2 If a platinum evaporating dish has been used for the dehydration of SiO_2, or a fusion made in the platinum crucible containing the HF-insoluble residue, iron may have been partially reduced. The iron must then be oxidized by adding 1 mL of saturated bromine water to the filtrate. Boil the filtrate to eliminate the excess bromine completely before adding methyl red indicator.

12.4.3 Dilute with water to a volume of 200 to 250 mL, add a few drops of methyl red solution, and heat just to boiling. Add NH_4OH (1 + 1) (See Note 14) until the color of the solution becomes distinctly yellow, then add 1 drop in excess (See Note 15). Heat the solution containing the precipitate to boiling and boil for 50 to 60 s. Remove from heat and allow the precipitate to settle (not more than 5 min). Filter using medium-textured paper and wash the precipitate two or three times without delay with a hot, 2 % solution of ammonium chloride (NH_4Cl) (See Note 16).

NOTE 14—The NH_4OH used to precipitate the hydroxides must be free of any dissolved carbon dioxide (CO_2).

NOTE 15—At the neutral point, it usually takes 1 drop of NH_4OH (1 + 1) to change the color of the solution from red to orange and another drop to change the color from orange to yellow. If the color fades during the precipitation or while heating, add more of the indicator. The boiling should not be prolonged as the precipitate may peptize and be difficult to retain on the filter. The solution should be distinctly yellow when it is ready to filter. If it is not, restore the yellow color with more NH_4OH (1 + 1).

NOTE 16—Two drops of methyl red indicator solution should be added to the NH_4Cl solution in the wash bottle followed by NH_4OH (1 + 1) added dropwise until the color just changes to yellow. If the color reverts to red at any time due to heating, it should be brought back to yellow by the addition of a drop of NH_4OH (1 + 1).

12.4.4 Set aside the filtrate and dissolve any precipitate from the paper with 40 mL hot (1 + 3) HCl, pouring the hot acid through the paper into the beaker in which the precipitation was made. Wash the filter paper thoroughly with hot HCl (1 + 19) followed by hot water and reserve the paper. Boil the solution and precipitate the hydroxides with NH_4OH as before. The precipitate is filtered through a fresh piece of medium textured filter paper and washed four or five times (See Note 17) with a hot 2 % solution of NH_4Cl. Combine filtrates for Ca and calcium magnesium analysis.

NOTE 17—If perchloric acid has been used, the final precipitate should be washed at least eight times to remove all traces of perchlorate salts (See 9.3).

12.4.5 Place the moist precipitate and the two filter papers in a weighed platinum crucible (See Note 9), heat slowly until the papers are charred, and finally ignite to constant weight at 1050 to 1100 °C. Cool in a desiccator and weigh.

12.5 *Calculation*—Calculate the percentage of ammonium hydroxide group (combined oxides) to the nearest 0.01 % as follows:

$$\text{Combined oxides},\ \% = (A/C) \times 100 \quad (5)$$

where:
A = mass of the combined oxides, g, and
C = original mass of sample, g.

12.6 *Precision and Bias*:

12.6.1 Four laboratories cooperated in testing on four limestone samples and three laboratories cooperated in testing on an additional seven limestone samples thereby obtaining the precision data summarized in Table 3.

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12.6.2 The user is cautioned to verify by the use of test reference materials, if available, that the bias of this test method is adequate for the contemplated use.

13. Total Iron, Standard Method

13.1 *Scope*—Iron in limestone is usually present as pyrite (FeS_2) with occasional occurrences of other discrete iron minerals. The amount present varies according to the location and geological history of the deposit. During lime calcination, most if not all of the iron minerals present in the limestone ore will be converted to iron oxide or sulfate.

13.2 *Summary of Test Method*—In this test method, the total Fe_2O_3 content of the sample is determined from the ignited combined oxides by fusing the oxides with potassium pyrosulfate and leaching the melt with sulfuric acid. The iron is reduced to the ferrous state with stannous chloride and titrated with a standard solution of potassium dichromate ($K_2Cr_2O_7$).

13.3 *Special Solutions*:

13.3.1 *Stannous Chloride Solution* (50 g/L)—Dissolve 5 g of $SnCl_2 \cdot 2H_2O$ in 10 mL of HCl and dilute to 100 mL with water. Add several pieces of mossy tin metal to the bottle to preserve the $SnCl_2$ solution.

13.3.2 *Sodium Diphenylamine Sulfonic Acid Indicator* (2 g/L)—Dissolve 0.20 g sodium diphenylamine sulfonate in 100 mL of water. Store in a dark-colored bottle.

13.3.3 *Mercuric Chloride Solution* (5 %)—Dissolve 5 g of $HgCl_2$ in 100 mL of water.

13.3.4 *Potassium Dichromate, Standard Solution* (0.05 *N*)—Dry pure crystals of $K_2Cr_2O_7$ at 110 °C, then pulverize and dry at 180 °C to constant weight. Dissolve 2.4518 g of pulverized $K_2Cr_2O_7$ in water and dilute to 1 L. This is a primary standard, 1 mL = 0.0040 g Fe_2O_3.

13.4 *Procedure*:

13.4.1 To the combined oxides of iron and aluminum (See Note 18) in the platinum crucible, add 3 to 4 g of potassium pyrosulfate ($K_2S_2O_7$). Fuse at low heat until the oxides form a clear melt in the crucible. Cool, break up the button by gently tapping the crucible on the bench, and wash fragments into a small beaker with hot H_2SO_4(5 + 95). Add 5 mL of H_2SO_4(sp gr 1.82) to the contents in the beaker, and heat to dissolve the fused mass. Evaporate the solution to fumes of sulfuric acid and fume strongly for about 10 min. Cool, add 20 mL of water, and warm to dissolve the salts. There may be traces of silica appearing at this point, which for most routine work can be ignored. If the analyst prefers to determine it, however, the precipitate can be filtered, washed, and ignited. The recovered SiO_2 can then be added to the mass of SiO_2 previously found and its mass deducted from the gross mass of iron and aluminum reported (See Note 18).

NOTE 18—When the iron is present in small quantities, it is not always desirable to determine it in the ignited oxides from the 0.5-g sample. Under these conditions, the alternative procedure should be used with a larger sample weight.

NOTE 19—The recovered SiO_2 is usually small, but could be as much as 1 to 2 mg, even after two evaporations.

13.4.2 To the sulfuric acid solution, add 10 mL HCl (1 + 1) and heat to near boiling. Add dropwise stannous chloride solution (See Note 20) until the yellow color of the ferric iron just disappears. Add 2 or 3 drops of $SnCl_2$ in excess.

NOTE 20—If the stannous chloride has little effect and more than 5 to 10 mL are required, it has probably become oxidized to stannic chloride and a fresh supply should be obtained.

13.4.3 Cool the mixture and add approximately 100 mL of cold water. Add 10 mL of mercuric chloride solution, stir, and allow to stand for 3 to 5 min.

NOTE 21—A slight, white, silky precipitate should form. If the precipitate appears gray or black, it indicates too much $SnCl_2$ was added and the analysis must be repeated.

13.4.4 Add 5 mL of H_3PO_4 and 3 drops of sodium diphenylamine sulfonate indicator.

13.4.5 Titrate with standard 0.05 *N* $K_2Cr_2O_7$ solution adding the solution slowly while stirring constantly. The end point is indicated by a change in color from green to deep blue-violet.

13.5 *Calculation*:

$$Fe_2O_3, \% = (A/C) \times B \times 100 \quad (6)$$

where:

A = $K_2Cr_2O_7$ used in titration, mL,
B = 0.004 (Fe_2O_3 equivalent of $K_2Cr_2O_7$), and
C = sample, g.

13.6 *Precision and Bias*:

13.6.1 Four laboratories cooperated in testing on four limestone samples and three laboratories cooperated in testing on an additional seven limestone samples thereby obtaining the precision data summarized in Table 3.

13.6.2 The user is cautioned to verify by the use of reference materials, if available, that the bias of this test method is adequate for the contemplated use.

14. Total Iron by Ortho-Phenanthroline Photometric Method

14.1 *Scope*—When the iron oxide content is very low, less than 0.1 %, and an accurate analysis at this low level is required, it is preferable to determine iron using procedures that have better sensitivity than the titrimetric methods. For an accurate determination of minute amounts of iron, the ortho phenanthroline method has proved invaluable.[6] In general, the method consists of reducing the iron to the ferrous state and then adding a slight excess of 1, 10 phenanthroline, which forms a complex with ferrous iron, giving an orange-pink color. The color intensity is proportional to the iron content of the solution.

14.2 *Summary of Test Method*—The bulk of the iron in the sample is dissolved with HCl, the silica dehydrated and separated by filtration, and the insoluble matter including SiO_2, ignited in a platinum crucible and treated with HF and H_2SO_4 to expel the SiO_2 and recover the small amount of iron that may not have dissolved with HCl. The acidified solution is transferred to a volumetric flask and diluted to volume. The iron is reduced with hydroxylamine hydrochloride and the

[6] Sandel, E. B., *Colorimetric Determination of Traces of Metals,* 3rd Ed., Interscience Publications, 1959.

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color of the ferrous complex is developed with 1,10 phenanthroline and compared against a set of iron standards similarly treated.

14.3 *Special Solutions*:

14.3.1 *Hydroxylamine Hydrochloride* (10 g/100)—Dissolve 10 g of hydroxylamine hydrochloride in 100 mL of water. Prepare fresh every week.

14.3.2 *Ammonium Acetate* (20 g/100)—Dissolve 200 g in 1 L of water.

14.3.3 *1,10 (Ortho) Phenanthroline* (0.1 g/100)—Dissolve 1.0 g in 1 L of hot water.

14.3.4 *Iron Standard Solution* (1 mL = 1.0 mg Fe_2O_3)—Dissolve 0.7000 g of pure iron wire by heating gently in 20 mL of HCl (1 + 1) and dilute to 1 L in a volumetric flask.

14.3.4.1 *Iron Work Standard Solution* (1 mL = 0.01 mg Fe_2O_3)—Transfer 10 mL of the iron standard solution to a 1 L volumetric flask and dilute to volume with water.

14.3.5 *Preparation of Calibration Curve*—To each of six 50 mL volumetric flasks, add, respectively, 1, 2, 4, 6, 8, and 10 mL of working iron standard solution. When diluted to volume, each mL of the prepared standard solutions will contain, respectively 0.2, 0.4, 0.8, 1.2, 1.6, and 2.0 micrograms Fe_2O_3.

14.3.5.1 Add to each flask in the following sequence, mixing after each addition, 1 mL of hydroxylamine hydrochloride solution, 5 mL of ammonium acetate, and 5 mL of 1,10 phenanthroline. Roll a small piece of congo red paper into a ball and insert it into the volumetric flask. Add NH_4OH (1 + 1) until the congo red indicator turns bright red, then add 1 drop of NH_4OH (1 + 1) in excess. Dilute to 50 mL, mix, and let stand for 15 to 20 min. Determine the absorbance of the solution in a spectrophotometer at a wavelength setting of 510 nm using water in the reference cell. Prepare a calibration curve by plotting the absorbance versus the concentration of Fe_2O_3 in µg/mL of solution.

14.4 *Procedure*:

14.4.1 Weigh 1 g of the properly prepared sample in 10 mL HCl (1 + 1) and evaporate rapidly to dryness. Add 50 mL of HCl (1 + 4) and heat to dissolve the salts. Filter the insoluble matter including SiO_2 through a retentive paper and wash several times with hot water. Reserve the residue. Heat the filtrate to boiling.

14.4.2 Place the paper containing the insoluble matter from the evaporated HCl solution in a platinum crucible. Char the paper at low heat without inflaming, then ignite at higher heat until the carbon has been completely burned off. Cool, add 1 mL H_2SO_4 and 10 to 15 mL HF and evaporate to fumes of sulfuric acid. Cool, dilute the contents of the crucible with water, and warm to dissolve salts. Transfer the acidified solution to the main solution containing the bulk of the iron.

14.4.3 Transfer the combined solutions to a 100 mL volumetric flask and dilute to volume. Pipet the aliquot containing 0.02 to 0.10 mg Fe_2O_3 into a 50 mL volumetric flask. Dilute to about 25 mL and add in the following sequence, mixing well after each addition: 1 mL hydroxylamine hydrochloride, 5 mL ammonium acetate, and 5 mL of 1,10 phenanthroline. Roll a small piece of congo red paper into a ball and insert into the volumetric flask. Add NH_4OH (1 + 1) until the congo red indicator turns a bright red, then add one drop of NH_4OH (1 + 1) in excess. Dilute to 50 mL, mix and let stand for 15 to 20 min. Determine the absorbance of the solution in a spectrophotometer at a wavelength setting of 510 nm using water in the reference cell. Compare against a set of standards similarly treated.

14.5 *Calculation*:

14.5.1 Calculate the % Fe_2O_3 as follows:

$$\% Fe_2O_3 = \frac{C \times D}{W \times 10^4} \quad (7)$$

where:

C = concentration of Fe_2O_3 in sample solution, µg/mL (determined from calibration curve),
D = dilution factor, and
W = sample mass, g.

14.6 *Precision and Bias*:

14.6.1 The number of laboratories, materials, and determinations in this study does not meet the minimum requirements for determining precision prescribed in Practice E 691:

	Test Methods C 25	Practice E 691 Minimum
Laboratories	2	6
Materials	5	4
Determinations	4	2

14.6.2 The following precision statements are provisional. Within five years, additional data will be obtained and processed which does meet the requirements of Practice E 691.

14.6.2.1 Precision, characterized by repeatability, *Sr* and *r*, and reproducibility, *SR* and *R*, has been determined for the following test method and materials to be:

Precision Statement for Test Method:	% Fe_2O_3			Color	
Material	Average	*Sr*	*SR*	*r*	*R*
S-1143	0.0358	0.0058	0.0201	0.0163	0.0564
S-1145	0.0480	0.0053	0.0214	0.0148	0.0599
S-1141	0.1688	0.0466	0.0640	0.1306	0.1792
S-1142	0.2025	0.0141	0.0631	0.0396	0.1767
S-1144	0.9252	0.0562	0.2096	0.1574	0.5870

15. Aluminum Oxide

15.1 *Scope*—Aluminum oxide, for the purpose of this test method, is considered to be the difference between the combined oxides and Fe_2O_3. When phosphorus or titanium are determined, their oxides must also be deducted.

15.2 *Procedure*—Subtract the percent Fe_2O_3 obtained in accordance with Sections 5.1.1 and 5.1.2 from the percent combined oxides (See Section 5.1). Report the remainder as percent Al_2O_3. In special cases where P_2O_5 and TiO_2 need to be reported, a correction for these oxides must be made.

15.3 *Calculation*—Calculate the percent Al_2O_3 as follows:

$$Al_2O_3, \% = A - B \quad (8)$$

where:

A = combined oxides ($Al_2O_3 + Fe_2O_3$), %, and
B = Fe_2O_3, %.

15.4 *Precision and Bias*:

15.4.1 Four laboratories cooperated in testing on four limestone samples and three laboratories cooperated in testing on an additional seven limestone samples thereby obtaining the precision data summarized in Table 3.

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15.4.2 The user is cautioned to verify by the use of reference materials, if available, that the bias of this test method is adequate for the contemplated use.

16. Calcium Oxide by Gravimetric Method

16.1 *Scope*—Calcium is separated from magnesium by means of a double precipitation as the oxalate after the determination of the ammonium hydroxide group. The precipitate is converted to CaO by ignition and weighed. The gravimetric method should be used when a recovery of aluminum is indicated or when a determination of strontium by gravimetric analysis is required.

16.2 *Summary of Test Method*—Calcium is precipitated with ammonium oxalate $(NH_4)_2C_2O_4$, filtered, ignited to the oxide, and redissolved with HCl. Any of the NH_4OH group of metals that escaped precipitation before may be recovered at this point by the addition of a small amount of NH_4OH and boiling. Any precipitate that separates out is assumed to be $Al(OH)_3$ and after ignition to Al_2O_3 this amount is added to the mass of Al_2O_3 calculated in 16.2. Calcium is precipitated a second time as the oxalate, filtered, washed, ignited, and weighed as CaO.

16.3 *Special Solutions*:

16.3.1 *Ammonium Oxalate Solution* (saturated)—Dissolve 45 g of ammonium oxalate $(NH_4C_2O_4)$ in 1 L of hot water. When cooled to room temperature the supersaturated solution will partially crystallize out and the supernatant solution will then be saturated with ammonium oxalate.

16.3.2 *Ammonium Oxalate Wash Solution* (1 g/L)—Dissolve 1 g of $(NH_4)_2C_2O_4$ in 1 L of water.

16.4 *Procedure*:

16.4.1 Add 30 mL of HCl (1 + 1) and 20 mL of 10 % oxalic acid to the combined filtrates from the iron and aluminum hydroxide precipitation and heat the solution to boiling. To the boiling solution, add ammonium hydroxide (1 + 3) slowly until a precipitate begins to form. At this point, add the ammonium hydroxide still more slowly (dropwise, with a pipet) while stirring continuously until the methyl red just turns yellow. Add 25 mL of hot saturated ammonium oxalate solution while stirring. Remove from the heat and let stand until the precipitate has settled and the supernatant liquid is clear. Allow to cool for a minimum of 1 h, and filter using a retentive paper. Wash the paper and precipitate with five 10-mL portions of cold, neutral 0.1 % solution of $(NH_4)_2C_2O_4$(See Note 22). Reserve filtrate for the magnesium determination.

NOTE 22—Hot solutions should be avoided when washing the CaC_2O_4 precipitate. One litre of hot water will dissolve 5 mg of CaO. One litre of cold 0.1 % $(NH_4)_2C_2O_4$ solution will dissolve only 0.1 mg of CaO.

16.4.2 Place the wet filter and precipitate in a platinum crucible, and char the paper without inflaming at low heat. Increase the heat to burn off all the carbon and ignite at 1000 °C for about 10 min. Cool, dissolve the ignited oxide in 50 mL of dilute HCl (1 + 4), and dilute to about 100 mL with water. Add a few drops of methyl red indicator and neutralize with NH_4OH till the color of indicator changes to yellow. Heat just to boiling. If a small amount of $Al(OH)_3$ separates, filter it, wash with a hot 2 % solution of NH_4Cl, ignite, weigh, and add this to the mass of Al_2O_3 determined in 15.2.

16.4.3 Heat the filtrate to boiling and add slowly, while stirring, 35 mL of saturated $(NH_4)_2C_2O_4$ solution. Digest, filter, and wash as in 16.4.1. Combine the filtrate and washing with the ones reserved from the first precipitation, and retain for the determination of MgO. Place the filter in a tared platinum crucible with cover and carefully char the paper without inflaming. Increase the heat to burn off the carbon and ignite the calcium oxide in the covered platinum crucible at 1000 °C. Cool in a desiccator and weigh as CaO. Repeat the ignition to constant weight avoiding any hydration or carbonation of the lime.

16.5 *Calculation*—Calculate the percent calcium oxide (CaO) as follows:

$$\text{CaO, \%} = (M/W) \times 100 \quad (9)$$

where:

M = mass of CaO, g, and
W = mass of sample, g.

16.6 *Precision and Bias*:

16.6.1 Two laboratories cooperated in testing on four limestone samples and obtained the precision data summarized in Table 3.

16.6.2 The user is cautioned to verify by the use of reference materials, if available, that the bias of this test method is adequate for the contemplated use.

17. Calcium Oxide by Volumetric Method

17.1 *Scope*—This volumetric test method is used mostly for ordinary control work in the plant laboratory, but it is capable of giving exact results, especially with those products that are free of interfering elements. Traces of strontium, barium, magnesium, or oxalate that may be present will also be titrated and calculated as calcium on an equivalence, not weight, basis.

17.2 *Summary of Test Method*—In this test method, the calcium oxalate precipitate is dissolved with dilute sulfuric acid and the liberated oxalic acid is titrated with standard potassium permanganate. The calcium equivalent of the oxalic acid is determined and the grams of CaO calculated.

17.3 *Special Solutions*:

17.3.1 *Potassium Permanganate, Standard Solution* (0.175 *N*):

17.3.1.1 Dissolve 5.64 g of potassium permanganate $(KMnO_4)$ in 1 L of water and boil gently for 20 to 30 min. Dilute again to 1 L, cover and allow to age for several days. Filter through purified asbestos or a wad of glass wool, and standardize against the National Institute of Standards and Technology's standard sample 40C of sodium oxalate $(Na_2C_2O_4)$ or equivalent as follows:

17.3.1.2 Transfer 0.5 g of the standard sodium oxalate dried at 105 °C to a 400-mL beaker. Add 250 mL of diluted H_2SO_4(5 + 95) freshly boiled for 10 to 15 min and cooled to 27 ± 3 °C. Stir until the oxalate has dissolved. Add 40 to 42 mL of the standard $KMnO_4$ solution at the rate of 25 to 35 mL/min, while stirring slowly. Let stand until the pink color disappears (about 60 s) (See Note X1.2).

17.3.1.3 Heat the contents of the beaker to 60 °C and complete the titration at this temperature by adding $KMnO_4$ solution until a slight pink color persists for 30 s. Add the last

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0.5 to 1 mL dropwise, allowing each drop to become decolorized before the next one is added.

17.3.1.4 Determine the exact normality of the $KMnO_4$ solution from the following:

$$N = W/V \times 0.06701 \quad (10)$$

where:

N	=	normality of $KMnO_4$ solution,
W	=	mass of standard sodium oxalate,
V	=	$KMnO_4$ used to titrate sodium oxalate, mL, and
0.06701	=	sodium oxalate equivalent to 1 mL of 1 *N* $KMnO_4$ solution, g.

17.3.1.5 Determine the CaO equivalent of the $KMnO_4$ solution as follows:

$$F = N \times 0.02804 \quad (11)$$

where:

F	=	CaO equivalent of the $KMnO_4$ solution in grams CaO/mL,
N	=	normality of $KMnO_4$ solution, and
0.02804	=	CaO equivalent to 1 mL of 1 *N* $KMnO_4$ solution, g.

17.4 *Procedure*:

17.4.1 Add 30 mL of HCl (1 + 1) and 20 mL of 10 % oxalic acid to the combined filtrates from the iron and aluminum hydroxide precipitation and heat the solution to boiling. To the boiling solution, add ammonium hydroxide (1 + 3) slowly until a precipitate begins to form. At this point, add the ammonium hydroxide still more slowly (dropwise, with a pipet) while stirring continuously until the methyl red just turns yellow. Add 25 mL of hot saturated ammonium oxalate while stirring. Remove from the heat and let stand until the precipitate has settled and the supernatant liquid is clear. Allow to cool and filter at the end of 1 h. Wash the paper with cold water, limiting the total washings to 125 mL (See Note 23). Retain the filtrate for magnesium.

NOTE 23—A Gooch crucible may be used instead of filter paper to filter the CaC_2O_4 precipitate.

17.4.2 With a jet of hot water, wash the precipitate from the paper into the beaker in which the precipitation was made. Fold the paper and leave it adhering to the upper portion of the beaker. Add to the contents of the beaker 250 mL of hot, diluted H_2SO_4(1 + 19) and heat to 80 to 90 °C.

17.4.3 Titrate with 0.175 *N* $KMnO_4$ solution until the pink end point is obtained. Drop the folded filter paper that contained the original precipitate into the liquid and macerate it with a stirring rod; the pink color of the solution will be discharged (See Note 24). Finish the titration by adding the $KMnO_4$ standard solution dropwise until the end point is again obtained.

NOTE 24—There will always be some fine particles of precipitate imbedded in the pores of the filter paper which are dissolved by the acid in solution. The filter paper is not introduced at the beginning of the titration to avoid introduction of traces of organic matter due to the action of the hot sulfuric acid on the paper; these would consume $KMnO_4$ and give high results for CaO.

17.5 *Calculation*—Calculate the percentage of CaO in the sample using the CaO equivalent from 17.3.1.5 as follows:

$$\text{CaO, \%} = (V \times F)/W \times 100 \quad (12)$$

where:

V	=	$KMnO_4$ solution used in titration, mL,
F	=	CaO equivalent of $KMnO_4$, and
W	=	original mass of sample, g.

17.6 *Precision and Bias*:

17.6.1 Two laboratories cooperated in testing on twelve limestone samples and obtained the precision data summarized in Table 3.

17.6.2 The user is cautioned to verify by the use of reference materials, if available, that the bias of this test method is adequate for the contemplated use.

18. Magnesium Oxide

18.1 *Scope*—Magnesium oxide in lime and limestone may vary from a few tenths to 2 % for high-calcium limestone to as much as 22 % for dolomitic limestone. The pyrophosphate gravimetric method has been used successfully throughout the industry to determine magnesium within this wide range.

18.2 *Summary of Test Method*—In this test method, magnesium is doubly precipitated as magnesium ammonium phosphate from the filtrate after removal of calcium. The precipitate is ignited and weighed as magnesium pyrophosphate ($Mg_2P_2O_7$). The MgO equivalent is then calculated.

18.3 *Special Solutions*:

18.3.1 *Ammonium Phosphate, Dibasic Solution* (250 g/L)—Dissolve 250 g of dibasic ammonium phosphate ($(NH_4)_2HPO_4$) in 1 L of water.

18.3.2 *Ammonium Hydroxide Wash Solution* (5 + 95)—Dilute 50 mL of NH_4OH with 950 mL of water and add 1 or 2 mL of HNO_3.

18.4 *Procedure*:

18.4.1 Add 2 drops of methyl red indicator to the combined filtrates from the determination of calcium, acidify with HCl, and concentrate to about 250 mL. Add to this solution about 10 mL of the $(NH_4)_2HPO_4$ solution, 250 g/L, and cool the solution to room temperature. Add NH_4OH slowly while stirring constantly until the solution is alkaline or the crystalline magnesium ammonium phosphate begins to form; then add about 15 to 20 mL of NH_4OH in excess and continue stirring for several more minutes. Allow the beaker and precipitate to stand in a cool place overnight. Filter and wash with cold dilute ammonium hydroxide wash solution (5 + 95).

18.4.2 Dissolve the precipitate with hot diluted HCl (1 + 9) and wash the filter paper well with hot diluted HCl (1 + 99). Dilute the solution to 100 mL, cool to room temperature, and add 1 mL of the 20 % solution of $(NH_4)_2HPO_4$. Precipitate the magnesium ammonium phosphate as before and allow to stand for about 2 h in a cool place.

18.4.3 Filter the precipitate on paper or in a tared Gooch crucible, washing with diluted NH_4OH (5 + 95). If filtered through a Gooch, place directly in a muffle at 400 °C and raise heat to 1100 °C. If filtration was through paper, place paper and precipitate in a weighed platinum or porcelain crucible. Slowly char the paper without inflaming and carefully burn off the

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resulting carbon (**Warning**—Extreme caution should be exercised during this ignition. Reduction of the phosphate precipitate can result if carbon is in contact with it at high temperatures. There is also a danger of occluding carbon in the precipitate if ignition is too rapid.). Ignite at 1100 °C for ½ h, cool in desiccator, and weigh as $Mg_2P_2O_7$ (See Note 25).

NOTE 25—For research purposes or in the most exacting types of work, the manganese content of the pyrophosphate residue should be determined and deducted as $Mn_2P_2O_7$.

18.5 *Calculation*—Calculate the percentage of MgO to the nearest 0.01 % as follows:

$$\text{MgO, \%} = A \times 36.2/B \quad (13)$$

where:

A = $Mg_2P_2O_7$, g,
B = sample, g, and
36.2 = molecular ratio of 2MgO to $Mg_2P_2O_7 \times 100$.

18.6 *Precision and Bias*:

18.6.1 Four laboratories cooperated in testing on three limestone samples and three laboratories cooperated in testing on an additional nine limestone samples thereby obtaining the precision data summarized in Table 3.

18.6.2 The user is cautioned to verify by the use of reference materials, if available, that the bias of this test method is adequate for the contemplated use.

19. Loss on Ignition

19.1 *Scope*—Loss on ignition (LOI) is the loss in weight expressed as percent of the initial "as received" sample weight obtained after ignition of the sample at 1000 °C to constant weight. The loss in weight is due to a release of free moisture, chemically combined "lattice" or "hydroxy" water, CO_2, SO_2, and volatile pyrolytic products of any organic material that may be present.

19.2 *Summary of Test Method*—The tared crucible containing the weighed sample is ignited to constant weight. The loss in weight is the LOI of the sample.

19.3 *Procedure*—Transfer approximately 1 g of the sample prepared to pass a 100-mesh (149-µm) U.S. standard sieve to a tare-weighed porcelain or platinum crucible. Cover with a lid and weigh accurately to within 0.1 mg. When testing quicklime, the crucible cover is not required. Also, quicklime may be placed directly into a muffle at 1000 °C avoiding preignition. Pre-ignite in a muffle furnace at approximately 400 °C for 30 min. Then increase muffle temperature to 1000 °C ± 20 °C, and maintain at this temperature for a minimum of 20 min or until constant mass is obtained. The difference between the original mass of the sample and the final mass represents the loss on ignition.

19.4 *Calculation*—Calculate LOI as follows:

$$\text{LOI, \%} = (A - B)/C \times 100 \quad (14)$$

where:

A = mass of crucible + sample, g,
B = mass of crucible plus sample after ignition, g, and
C = mass of sample, g.

19.5 *Precision and Bias*:

19.5.1 Fifteen laboratories cooperated in testing on three samples of high calcium limestone to obtain the precision data for percent LOI given in 19.5.2 and 19.5.3.

19.5.2 The repeatability (Practice E 691 [r]) was found to be 0.158 % LOI.

19.5.3 The reproducibility (Practice E 691 [R]) was found to be 0.463 % LOI.

19.5.4 The user is cautioned to verify by the use of reference materials, if available, that the bias of this test method is adequate for the contemplated use.

20. Free Moisture in Limestone

20.1 *Scope*—For the purpose of this test method, the conventional definition of "hygroscopic moisture" or "free water" (also known as "free-moisture") is accepted; that is, the amount of water and any other volatile matter than can be expelled from a sample of the material by drying to constant weight at a temperature slightly above the boiling point of water.

20.2 *Summary of Test Method*—The sample in a container is heated in a drying oven at 115 to 120 °C constant weight. The loss in weight represents the free moisture.

20.3 *Special Apparatus*:

20.3.1 *Bottle,* weighing, low-form, glass-stoppered, or wide-form, large porcelain crucible.

20.4 *Procedure*—Weigh 1 g of the prepared sample in the stoppered weighing bottle. Remove the stopper and heat in a drying oven at 115 to 120 °C for 2 h. Quickly stopper, cool in a desiccator, and weigh, lifting the stopper momentarily just before weighing. The use of a similar weighing bottle as a counterpoise carried through all the operations is a desirable procedure unless a single pan balance is used. The loss in weight represents "free moisture" loss at 120 °C.

20.5 *Calculation*—Calculate the percent "free moisture" as follows:

$$\text{Free-moisture, \%} = (A - B)/C \times 100 \quad (15)$$

where:

A = mass of crucible and sample before heating, g,
B = mass of crucible and sample after heating at 120 °C, g, and
C = original mass of sample, g.

20.6 *Precision and Bias*—The precision and bias of this test method have not been determined.

21. Free Moisture in Hydrated Lime

21.1 *Scope*—The free moisture in hydrated lime is that water that is released from the sample at a temperature of 115 to 120 °C. This distinguishes it from the hydroxyl water that is chemically bound to the lime and which cannot be liberated except at higher temperatures.

21.2 *Summary of Test Method*—Free moisture in hydrated lime is determined by aspirating a slow stream of CO_2-free air over the sample in a container placed inside a 115 to 120 °C oven. The loss in weight of the sample is equal to the free moisture of the hydrated lime.

21.3 *Special Apparatus*:

21.3.1 *Sample Flask E,* illustrated in Fig. 1, consists of a 50-mL flat-bottom, glass-stoppered flask, supplied with a ground glass joint and solid ground glass stopper.

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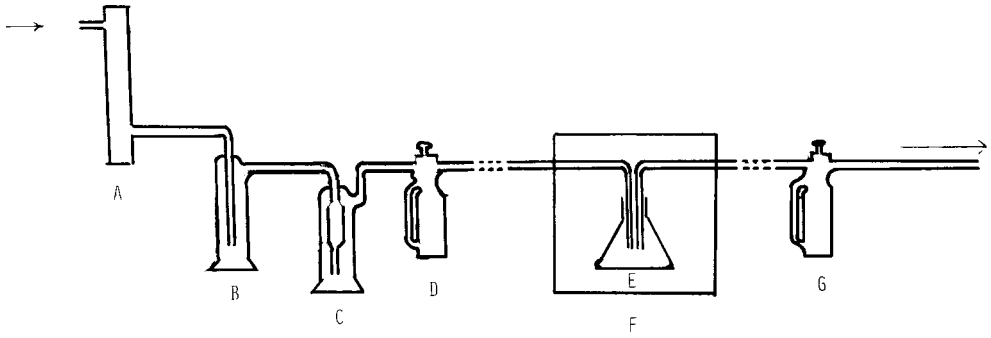

A Soda-Lime Tower at inlet to remove CO_2.
B Bottle containing lime water to show when soda lime tower is exhausted.
C Fleming jar containing sulfuric acid to remove water from air.
D Absorption bulb filled with Anhydrone (Magnesium Perchlorate) to complete drying of air.
E 50-mL sample flask.
F Drying oven operating at 110 °C.
G Absorption bulb filled with Anhydrone to prevent moisture backup into sample.

FIG. 1 Apparatus for Free Moisture in Hydrated Lime

21.3.1.1 The flask shall be fitted with an interchangeable hollow ground-glass stopper, equipped with two glass entry tubes for conducting the dry air over the sample.

21.3.2 *Purifying Train* (See Fig. 1), located outside the oven *F* for conducting the dry air over the samples, shall consist of a series of scrubbers and absorption bulbs to remove CO_2 and moisture from the air. The apparatus are arranged in the following order starting from the air source:

21.3.2.1 *Soda-Lime Tower A,* at the air inlet to remove CO_2 from the air.

21.3.2.2 *Bottle B,* containing lime water to show when the soda lime is exhausted.

21.3.2.3 *Fleming Jar C,* containing sulfuric acid to remove water from the air.

21.3.2.4 *Absorption Bulb D,* filled with Anhydrone (magnesium perchlorate) to complete the drying of the air.

21.3.2.5 *Sample Flask E.*

21.3.2.6 *Drying Oven F.*

21.3.2.7 *Absorption Bulb G,* also filled with Anhydrone and located on the exit side of the sample bulb as a protective barrier against atmospheric moisture.

21.4 *Procedure*—Weigh 2.5 to 3 g of the prepared sample, and using glazed paper folded in the shape of a funnel, transfer it rapidly into the previously weighed bottle and immediately restopper it. Insert the bottle into the 120 °C oven and quickly exchange stoppers. Connect the sample bottle to the purifying train by means of flexible tubing and pass a slow current of dry CO_2-free air through the apparatus for 2 h. Disconnect the sample bottle from the train, remove it from the oven with another quick exchange of stoppers, and place it in a desiccator to cool. When cool, remove it to the balance case for several minutes before weighing it, and just before weighing, lift the stopper slightly for an instant to relieve any vacuum that may exist in the bottle. The loss in weight of the sample represents "free moisture" loss as 120 °C. Use a bottle similar to the one containing the sample as a counterpoise in all weighings unless a single-pan balance is used.

21.5 *Calculation*—Calculate the percent "free moisture" in the sample as follows:

$$\text{Free moisture, } \% = (A - B)/C \times 100 \quad (16)$$

where:

A = mass of sample flask + sample, g,
B = mass of sample flask after drying, g, and
C = mass of sample, g.

21.6 *Precision and Bias*—The precision and bias of this test method have not been determined.

22. Carbon Dioxide by Standard Method

22.1 *Scope*—Carbon dioxide in limestone is sometimes determined to verify the presence of carbonates other than calcium or magnesium. These may include carbonates of iron, manganese, and occasionally traces of other substances. Samples of lime and hydrated lime are analyzed for CO_2 to check for the presence of carbonates, most of which are there as uncalcined limestone.

22.2 *Summary of Test Method*—The sample is decomposed with HCl and the liberated CO_2 is passed through a series of scrubbers to remove water and sulfides. The CO_2 is absorbed with Ascarite, a special sodium hydroxide absorbent, and the gain in weight of the absorbtion tube is determined and calculated as percent CO_2.

22.3 *Special Apparatus*:

22.3.1 The apparatus illustrated in Fig. 2 consists of the following:

22.3.1.1 *Purifying Jar A,* Fleming, containing sulfuric acid.

22.3.1.2 *Drying Tube B,* U-shaped with side arms and glass stoppers. Side arms are shaped to hold rubber tubing. Contains Anhydrone on left side and Ascarite on right side.

22.3.1.3 *Erlenmeyer Flask C,* 250-mL, 24/40 ground-glass joint.

22.3.1.4 *Separatory Funnel D,* with ground-glass stopper and interchangeable hollow ground-glass joint. A delivery tube bent at the end extends into the sample flask about ½ in. from the bottom. Used to introduce acid into flask.

22.3.1.5 *Condenser E.*

22.3.1.6 *Gas-Washing Bottle F,* 250-mL, with fritted disk containing distilled water to retain most of the acid volatilized from the alkalimeter.

22.3.1.7 *U-Tube G,* containing mossy zinc to remove the last traces of HCl.

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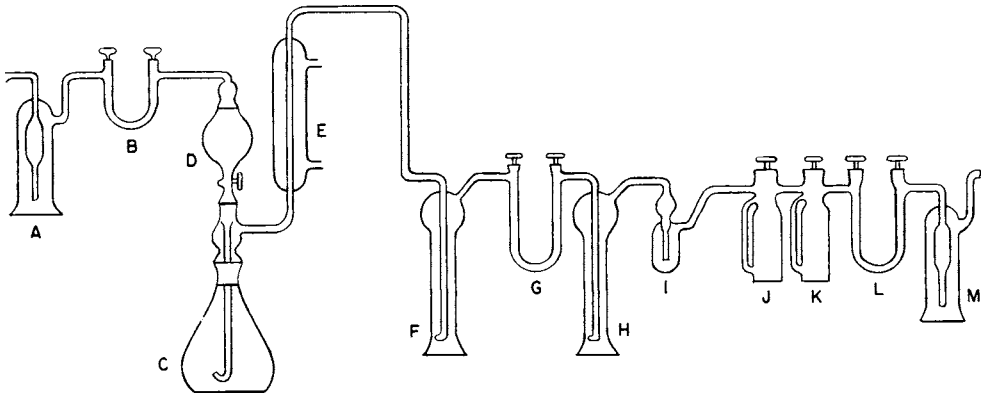

A Purifying jar, Fleming, containing concentrated H_2SO_4.
B Drying tube, U-shaped, Ascarite in right side, Anhydrone in left side.
C Erlenmeyer flask, 250-mL, 24/40 glass joint.
D Separatory funnel.
E Condenser.
F Gas-washing bottle, 250-mL with fritted disk, containing water to retain most of the acid volatilized from the alkalimeter.
G U-tube containing mossy zinc to remove the last traces of HCl.
H Gas-washing bottle, 250-mL with fritted disk, containing concentrated H_2SO_4.
I Trap.
J Absorption bulb containing Anydrone.
K CO_2 absorption bulb containing Ascarite.
L U-guard tube with Anhydrone in left side and Ascarite in right side.
M Purifying jar, Fleming, containing concentrated H_2SO_4.

FIG. 2 Apparatus for Carbon Dioxide by Standard Method

22.3.1.8 *Gas-Washing Bottle H,* 250-mL, with fritted disk, containing concentrated H_2SO_4 and trap *I,* to remove any SO_3 mist that may have been carried over.

22.3.1.9 *Absorption Bulb J,* containing Anhydrone to remove last traces of water vapor.

22.3.1.10 *CO_2 Absorption Bulb,* containing Ascarite filled as follows: On the bottom of the bulb, place a layer of glass wool extending above the bottom outlet and on top of this a layer of Anhydrone about ⅜ in. thick; immediately above this is placed another layer of glass wool, and Ascarite is then added to almost fill the bulb. A top layer of Anhydrone about ⅜ in. thick is placed on top of the Ascarite and topped off with a covering of glass wool.

22.3.1.11 *U-Guard Tube L,* filled with Anhydrone in left side and Ascarite in right side.

22.3.1.12 *Purifying Jar M,* Fleming, containing H_2SO_4.

22.4 *Procedure*:

22.4.1 Weigh an indicated amount of prepared sample, 0.5 g for limestone and 5 g for lime or hydrated lime, and transfer to the 250-mL Erlenmeyer flask. Connect the sample flask to apparatus as shown in the diagram (See Fig. 2). Purge the system free of carbon dioxide by passing a current of CO_2-free air through the apparatus for 10 to 15 min.

22.4.2 Weigh the absorption bulb and attach it to the train. Remove the glass stopper from separatory funnel, place 50 mL of dilute HCl (1 + 1) in the separatory funnel (*D*) and replace the stopper with the interchangeable hollow ground-glass joint through which passes a tube for admitting purified air. Open the stopcock of the separatory funnel and admit air through the top of the funnel to force the hydrochloric acid into the Erlenmeyer flask (*C*).

22.4.3 Start cold water circulating through the condenser (*E*) and, with CO_2-free air passing at a moderate rate through the absorption train, place a small hot plate or gas burner under the sample flask and boil for about 2 min. Remove the hot plate and continue the flow of purified air at about three bubbles per second for 30 min to sweep the apparatus free of CO_2. Close the absorption bulb, disconnect it from the train and weigh, opening the stopper momentarily to equalize the pressure. Use a second absorption bulb as counterpoise in all weighings unless a single pan balance is used.

22.5 *Calculation*—Calculate the percent CO_2 as follows:

$$CO_2, \% = (A - B)/C \times 100 \quad (17)$$

where:
A = mass of absorption bulb + CO_2, g,
B = mass of absorption bulb before the run, g, and
C = mass of sample, g.

22.6 *Precision and Bias*—The precision and bias of this test method have not been determined.

23. Sulfur Trioxide

23.1 *Scope*—This test method will determine sulfur compounds, mostly present as sulfates in lime and limestone, that are soluble in dilute HCl. Iron pyrites and other sulfides will not be included because they will either be volatilized as H_2S or not react at all with the acid.

23.2 *Summary of Test Method*—In this test method, sulfate is precipitated from an acid solution of the lime or limestone with barium chloride ($BaCl_2$) and the SO_3 equivalent is calculated.

23.3 *Special Solution*:

23.3.1 *Barium Chloride Solution* (100 g/L)—Dissolve 100 g of barium chloride ($BaCl_2 \cdot 2H_2O$) in 1 L of water.

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23.4 *Procedure*—Select and weigh the prepared sample into a 250-mL beaker containing 50 mL of cold water in accordance with the following:

Expected SO_3 Range, %	Sample Weight, g
0.001 to 0.500	10.00
0.500 to 2.50	5.00
2.50 to 12.5	2.00

Stir until all lumps are broken and the lighter particles are in suspension. Add 50 mL of diluted HCl (1 + 1) and heat until the reaction has stopped and decomposition is complete. Digest for several minutes at a temperature just below boiling. Add a few drops of methyl red indicator and render the solution alkaline (yellow color) with NH_4OH (1 + 1). Heat the solution to boiling. Filter through a medium-textured paper and wash the residue thoroughly with hot water. Dilute the filtrate to 250 mL, add 5 mL of HCl (1 + 1), heat to boiling, and add slowly 10 mL of hot $BaCl_2$ solution. Continue the boiling until the precipitate is well formed, stir well, and allow to stand overnight at room temperature. Take care to keep the volume of solution between 225 and 250 mL, and add water for this purpose if necessary. Filter through a retentive paper and wash the precipitate with hot water. Place the paper and contents in a weighed platinum crucible, and slowly char the paper without flaming. Burn off all the carbon, ignite in a muffle at 1000 °C, cool in a desiccator, and weigh.

23.5 *Calculation*—Calculate the percentage of SO_3 to the nearest 0.001 as follows:

$$SO_3, \% = A \times 0.343/W \times 100 \quad (18)$$

where:

A = mass of $BaSO_4$, g,
W = mass of sample, g, and
0.343 = molecular ratio of SO_3 to $BaSO_4$.

23.6 *Precision and Bias*:

23.6.1 Six laboratories cooperated in testing on four samples of limestone and lime materials covering the range from 0.04 to 5.15 % SO_3 to obtain the precision data given in 23.6.2 and 23.6.3.

23.6.2 The repeatability (Practice E 173 R_1) was found to be (0.135 % SO_3 per weight in grams of sample analyzed).

23.6.3 The reproducibility (Practice E 173 R_2) was found to be (0.271 % SO_3 per weight in grams of sample analyzed).

23.6.4 The user is cautioned to verify by the use of reference materials, if available, that the bias of this test method is adequate for the contemplated use.

24. Total Sulfur by Sodium Carbonate Fusion

24.1 *Scope*—Sulfur in limestone is chiefly, if not wholly, present as sulfide, usually as pyrite. If the total sulfur obtained in the following test method is in excess of that present as soluble sulfate, the difference can be assumed to be present as iron disulfide.

24.2 *Summary of Test Method*—The sample is fused with sodium carbonate and the ignited mass is leached in water and dissolved with HCl. The solution is made ammoniacal and the hydroxide precipitate is filtered. The sulfur in the filtrate is precipitated with a 10 % solution of barium chloride. The precipitate is ignited and weighed as barium sulfate ($BaSO_4$) and the SO_3 equivalent is calculated.

24.3 *Procedure*:

24.3.1 Select and weigh the prepared sample into a porcelain crucible in accordance with the following:

Expected S Range, %	Sample Weight, g	Na_2CO_3 Weight, g
0.001 to 0.20	10.00	5.00
0.200 to 1.00	5.00	2.50
1.00 to 5.00	2.00	1.00

Add the indicated amount of Na_2CO_3 and mix well. Heat in a muffle at 600 °C for 15 min. Increase the heat 50 °C every 15 min until 1000 °C is reached and maintain at this temperature for 15 min. (See Note 26). Cool, place the crucible and cover in a 400-mL beaker, and cover with hot water. Add 10 mL bromine water (See Note 27) and then add sufficient HCl (1 + 1) to make the solution slightly acid to methyl red. Boil until solution is complete and all bromine has been expelled. Remove the crucible and wash with hot water.

NOTE 26—Since not enough flux is used to produce more than a sintering, the air entering the crucible after the bulk of the carbon dioxide has been released effects very speedy oxidation in the porous mass.

NOTE 27—It has been found that 10 mL of 30 % hydrogen peroxide (H_2O_2) may be substituted for the bromine water to accomplish oxidation without affecting the analytical result.

24.3.2 Add a few drops of methyl red indicator and render the solution alkaline with NH_4OH (1 + 1). Heat the solution to boiling, filter using a retentive paper and wash with hot water. To the filtrate add 5 mL of HCl (1 + 1), adjust the volume to about 250 mL, and bring the solution to boiling. To the boiling solution, add 10 mL of hot $BaCl_2$ solution, slowly and with stirring. Allow to stand overnight. Filter through a retentive paper and wash the precipitate with hot water. Place paper and contents in a weighed platinum crucible and slowly char the paper without flaming. Burn off the carbon and ignite in a muffle at 1000 °C for 1 h. Cool in a desiccator and weigh as $BaSO_4$.

24.4 *Calculation*—Calculate the percentage of sulfur to the nearest 0.001 as follows:

$$S, \% = A \times 13.73/W \quad (19)$$

where:

A = mass of $BaSO_4$, g,
W = sample, g, and
13.73 = mass of molecular ratio of S to $BaSO_4 \times 100$.

24.5 *Precision and Bias*:

24.5.1 Six laboratories cooperated in testing on four samples of limestone and lime materials covering the range from 0.021 to 2.15 % sulfur to obtain the precision data given in 24.5.2 and 24.5.3.

24.5.2 The repeatability (Practice E 173 R_1) was found to be (0.065 % S per weight in grams of sample analyzed).

24.5.3 The reproducibility (Practice E 173 R_2) was found to be (0.094 % S per weight in grams of sample analyzed).

24.5.4 The user is cautioned to verify by the use of reference materials, if available, that the bias of this test method is adequate for the contemplated use.

25. Total Sulfur by the Combustion-Iodate Titration Method

25.1 *Scope*—This test method covers the determination of sulfur in concentration from 0.005 to 1 %. At the combustion

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temperature of approximately 1650 °C, complete combustion of the sulfur in the sample will take place regardless of sulfur form or sample matrix.

25.2 *Summary of Test Method*—A major portion of the sulfur in various types of lime and limestone samples is converted to oxides of sulfur, primarily sulfur dioxide (SO_2), by combustion in a stream of oxygen at the elevated temperature of a high-frequency induction furnace. During the combustion, the SO_2 is absorbed in an acidified starch-iodine solution and titrated with potassium iodate. The latter is standardized against limestone standard samples of known sulfur content to compensate for characteristics of a given apparatus and for day-to-day variation in the percentage of sulfur recovered as SO_2. Compensation is also made for the blank due to accelerators and crucibles.

25.3 *Apparatus:*

25.3.1 *Induction Furnace*—The induction furnace shall be supplied with a rheostat used to control the power input to the reduction coil that will avoid heating some types of samples too rapidly during the early stages of combustion. The train of the induction furnace shall include an oxygen purifier, described in 25.3.3.

25.3.2 *Automatic Titrator*—This apparatus shall consist of an absorption and titration vessel of appropriate volume and contain an inlet bubbler tube for the sulfur gases with a float valve to prevent backflow of liquid when the sample is starting to consume oxygen. The vessel must be shaped to effect complete absorption of SO_2 in a small volume of solution. The titrator comes equipped with a buret that should be approximately 10 mL in capacity marked with 200 divisions. The automatic titrator utilizes a photoelectric cell to activate a titrator inlet valve that allows the titration to proceed without the presence of an operator.

25.3.3 *Oxygen Purifiers*—Reagent-grade oxygen from a commercial tank is passed through a suitable two-stage reduction valve to provide an even and adequate flow of oxygen through a purifying train consisting of a sulfuric acid tower, an absorption bulb containing 20 to 30-mesh inert base impregnated with NaOH, and another absorption bulb containing anhydrous magnesium perchlorate Mg (ClO_4). A flowmeter precedes the induction furnace assembly.

25.3.4 *Combustion Crucibles*—The crucibles for use with the induction furnace must be of adequate thickness to retain the molten slag and have a sulfur blank as low and consistent as possible. The crucibles for use in the induction furnace must have adequate capacity and may be provided with suitable covers.

25.3.5 *Glass Accelerator Scoop.*

25.3.6 *Starch Dispenser*—A plastic bottle with a device for dispensing a few millilitres of starch solution at a time.

25.3.7 *Timer,* having a 0 to 15-min range in ¼-min intervals. Turns off the furnace at end of preset time and automatically resets.

25.3.8 *Loading Funnel*—Three-legged funnel that fits over the crucible and simplifies addition of sample.

25.4 *Reagents:*

25.4.1 *Copper (Low-Sulfur) Ring Accelerator.*

25.4.2 *Iron (Low-Sulfur) Accelerator*—Iron chips. (For samples containing very low percentages of sulfur, the use of iron powder is recommended because of its low blank.)

25.4.3 *Tin Metal (Low-Sulfur) Accelerator,* granular.

25.4.4 *Potassium Iodate* (KIO_3) *Crystal.*

25.4.5 *Potassium Iodide* (KI) *Crystal.*

25.4.6 *Starch,* soluble.

25.5 *Special Solutions*:

25.5.1 *Potassium Iodate,* standard solutions.

25.5.1.1 KIO_3*Standard Solution A*—Dissolve 0.2227 g KIO_3 in 900 mL of water containing 1 g sodium hydroxide (NaOH) and dilute to 1 L. For a 0.500-g sample, the buret reads directly in percent sulfur.

25.5.1.2 *Starch-Iodide Solution*—Transfer 2 g of soluble starch (for example, Arrowroot) to a 50-mL beaker, add a few millilitres of water, and stir into a smooth paste. Slowly add starch to 500 mL of distilled water while stirring. Add 4 g of NaOH and continue stirring the solution until the appearance changes from cloudy to translucent. Add 6 g of potassium iodide (KI), stir until the KI is dissolved, and dilute to 1 L.

NOTE 28—Discard any starch solution that imparts a red tinge to the blue color when titrating.

25.6 *Calibration*—This test method and instrument should be standardized by using a limestone sample of known sulfur content as determined by the Total Sulfur Method by Sodium Carbonate Fusion, Section 24. The Leco instrument, in addition, may be standardized daily by running limestone reference materials whose sulfur content, as determined by the Total Sulfur Method, ranges from 0.02 to 0.05 %. The limestone standards are run to determine the day-to-day variations in the test method and to verify that the electronics in the Leco are working properly.

25.6.1 It has been found through round robin studies that the practice of pre-igniting samples at 1000 °C causes erratic recovery of sulfur. This practice should not be used.

25.7 *Procedure*:

25.7.1 Allow 15 min for the electronics in the furnace assembly and titrator to warm up.

25.7.2 Set the grid-current tap switch to low, medium, or high position. Determine the position on a test run, with the sample and accelerators that will give a complete combustion at approximately 400 mA as indicated on the plate current ammeter.

25.7.3 Set the automatic timer to the estimated time required to evolve the sulfur in the sample completely, as follows:

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Sample	Time, Min
Quicklime	8
Hydrated Lime	10
Limestone	12

25.7.4 Weigh the sample and brush carefully into the combustion crucible using the loading funnel. The correct sample weight is determined by the estimated sulfur content of the sample as follows:

Sulfur %	Sample Weight (g)
0.001	0.500

25.7.5 The choice of accelerators is left to the discretion of the user, as each furnace will burn differently in accordance with type and amount used. Generally, the more accelerator used, the greater the furnace temperature. Tin metal, iron chip, iron powder, and copper ring have been found to be suitable materials. Porous covers should be used to prevent splattering of the hot flux and damage to the combustion tube. Do not re-use crucibles or covers.

25.7.6 Run a blank determination before each series (of sulfur determinations) using a crucible that contains all the accelerators but no sample.

25.7.7 Place the crucible and sample on the pedestal and lift into position in the combustion tube.

25.7.8 With the oxygen flow at 1 L/min, close stopcock on bottom of titration vessel, and add the HCl to the middle of the bell-shaped portion of the titration vessel. Always fill to the same level.

25.7.8.1 Add one measure of starch solution to the titration vessel. Fill the iodate buret.

25.7.9 Turn the double throw switch on the titrator to the end-point position (down). Slowly rotate the end-point control in a clockwise direction until it has added KIO_3 in the amount to give a solid medium blue color. After the indicator light (for solenoid valve) has stopped blinking, place the switch in the neutral position and fill the KIO_3 buret again. Turn the switch to the titrate position.

25.7.10 Turn on the power of the high-frequency furnace. The temperature will rise in the crucible as indicated by the plate current ammeter on the induction furnace that must indicate a reading of at least 400 mA before complete combustion of sulfur can take place.

25.7.11 As sulfur dioxide is given off, the unit will begin titrating automatically. The titration is finished when the indicator light stops blinking for a period of time, or the iodate in the buret stops falling over a period of time.

25.7.12 Inspect the crucible for a proper burn. A rough, bumpy surface or appearance of non-combustion indicates that the furnace temperature was too low. Sticking of the porous cover to the crucible indicates that the furnace temperature may have been too hot. Both conditions indicate poor sulfur recovery and may be helped by a slight change in accelerator amounts.

25.8 *Calculation*:

25.8.1 Calculation of Furnace Factor *(F)*

$$F=\frac{R}{(A-B)/(W\times 2)} \tag{20}$$

where:

A = buret reading as % Sulfur (S),
B = buret reading for Blank determination,
R = % Sulfur (by Sodium Carbonate Fusion Method) of the reference material, and
W = weight of sample, g.

25.8.2 Calculate the percentage of sulfur in the sample by using furnace factor *F*.

$$\%\ S=F\times\frac{A-B}{W\times 2} \tag{21}$$

where:

A = buret reading as % Sulfur (S),
B = buret reading for Blank determination,
F = furnace factor, and
W = weight of sample, g.

25.9 *Precision and Bias*:

25.9.1 Nine laboratories cooperated in testing on three samples of high-calcium limestone to obtain the precision data for % sulfur given in 25.9.2 and 25.9.3.

25.9.2 The repeatability (Practice E 691 [r]) was found to be 0.0070 % sulfur.

25.9.3 The reproducibility (Practice E 691 [R]) was found to be 0.0120 % sulfur.

25.9.4 The user is cautioned to verify by the use of reference materials, if available, that the bias of this test method is adequate for the contemplated use.

26. Phosphorus by Molybdovanadate Method

26.1 *Scope*—This method is suitable for the determination of small amounts of phosphorous in lime and limestone samples. The procedure is based on the fact that phosphorous in its ortho form will combine with ammonium molybdovanadate to yield a yellow color that can be measured spectrophotometrically. Total phosphate is determined after a strong oxidation decomposition with perchloric acid.

26.2 *Summary of Test Method*—The sample is decomposed with perchloric acid, the solution filtered, SiO_2 expelled, and the insoluble residue fused with Na_2CO_3. Ammonium molybdovanadate which is then added reacts with the phosphorous in solution to form the heteropoly phosphomolybdovanadate complex. The absorbance of the solution is measured with a photometer at 430 nm and compared against standards similarly treated.

26.3 *Special Solutions*:

26.3.1 *Phosphorous Standard Stock Solution* (0.5 mg P/mL)—Weigh 1.0983 g of potassium dihyrogen phosphate, KH_2PO_4, into a 250-mL beaker and dampen with about 5 to 10 mL of water. Add 10 mL HNO_3 and 25 mL $HClO_4$(See Note 29), heat on a hot plate, and evaporate to heavy fumes of $HClO_4$. Cover and boil until the solution is colorless or slightly yellow (10 to 15 min). Cool the solution, transfer to a 500-mL volumetric flask, dilute to volume, and mix. Store in a borosilicate or plastic bottle with a screw cap.

26.3.2 *Phosphorous Working Standard* (0.05 mg P/mL)—Dilute 50 mL of stock solution 26.3.1 to 500 mL with distilled water. Store in a Pyrex or plastic bottle with screw cap.

26.3.3 *Ammonium Molybdovanadate Solution*:

26.3.3.1 Dissolve 1.25 g of ammonium metavanadate in 400 mL of 1 + 1 nitric acid in a 1 L volumetric flask.

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26.3.3.2 Dissolve 50 g of ammonium molybdate in 400 mL of distilled water.

26.3.3.3 Pour solution from 26.3.4.2 into solution 26.3.4.1, mix, and dilute to volume with distilled water.

26.4 *Preparation of Standard Curve*:

26.4.1 To each of seven individual 50 mL volumetric flasks, add with a buret 0, 1, 2, 4, 6, 10, and 14 mL of phosphorous working standard solution corresponding to 0, 0.05, 0.10, 0.20, 0.30, 0.50, and 0.70 mg of phosphorous, respectively.

26.4.2 Add 1 mL of perchloric acid and dilute to about 20 mL with water. Add 10 mL of the molybdovanadate solution, swirling the contents of the flask during the addition. Dilute to volume with distilled water, mix well, and allow to stand for 10 min. The prepared standard solutions will contain 0 (blank), 1.0, 2.0, 4.0, 6.0, 10.0, and 14.0 micrograms (µg) P/mL.

26.4.3 Determine the absorbance of each standard solution in the spectrophotometer at a wavelength of 430 nm using the blank standard as the reference solution. Prepare a calibration curve by plotting absorbance versus concentration of phosphorous in µg/mL.

26.5 *Procedure*:

26.5.1 Weigh 5.0 g of prepared sample into a 250-mL beaker and dampen with about 5 to 10 mL of water. Add 10 mL HNO_3 and 25 mL $HClO_4$(See Note 29), heat on hot plate, and evaporate to heavy fumes of $HClO_4$. Cover and boil until solution is colorless or slightly yellow (10 to 15 min). Cool slightly and add 50 mL H_2O. Filter through retentive filter paper and wash thoroughly with hot H_2O (See Note 30). Reserve filtrate.

NOTE 29—If a special perchloric acid hood is not available, the use of perchloric may be omitted. Instead, add 10 mL HNO_3 and evaporate to dryness. Take up salts with 5 mL HCl, break up residue, and again evaporate to dryness. Boil up with 1 mL of HNO_3 and 20 mL of water, and filter, etc.

NOTE 30—The filter paper and silica residue must be washed free of perchlorate salts to prevent small explosions from occurring in the crucible when the filter paper is charred and ignited.

26.5.2 Place paper and contents in a platinum crucible and heat gently with a low flame until paper chars. Ignite at a higher temperature until ash is white. Cool, add 2 drops of H_2SO_4(1 + 1) and 10 to 15 mL HF. Evaporate cautiously to dryness and heat in a muffle at 1000 °C for 2 min (See Note 31). Fuse residue with 0.5 g of Na_2CO_3, cool, add 5 mL H_2O and 1 mL $HClO_4$ and warm to dissolve. Combine the filtrates and transfer to a 100 mL volumetric flask. Dilute to volume and mix.

NOTE 31—The treatment of the residue with HF and H_2SO_4 may be omitted if the SiO_2 in the sample is low, <3 %.

26.5.3 Pipet 25 mL of solution into a 50 mL-volumetric flask and add 10 mL ammonium molydovanadate solution, dilute to volume and mix well. Allow to stand 30 min and measure the absorbance at 430 nm using the blank standard solution in the reference cell. Compare against a set of standards similarly treated.

26.6 *Calculation*:

26.6.1 Calculate % P_2O_5 as follows:

$$\%\ P_2O_5 = \frac{C \times D \times 2.2913}{W \times 10^4} \qquad (22)$$

where:

C = concentration of P in sample solution, µg/mL determined from calibration curve,
D = dilution factor, and
W = g of sample.

26.7 *Precision and Bias*:

26.7.1 The number of laboratories, materials, and determinations in this study does not meet the minimum requirements for determining precision prescribed in Practice E 691:

	Test Methods C 25	Practice E 691 Minimum
Laboratories	3	6
Materials	5	4
Determinations	4	2

26.7.2 The following precision statements are provisional. Within five years, additional data will be obtained and processed which does meet the requirements of Practice E 691.

26.7.2.1 Precision, characterized by repeatability, *Sr* and *r*, and reproducibility, *SR* and *R*, has been determined for the following test method and materials to be:

Precision Statement for Test Method:	% P_2O_5			Color	
Material	Average	*Sr*	*SR*	*r*	*R*
S-1145	0.0031	0.0010	0.0017	0.0029	0.0046
S-1142	0.0091	0.0019	0.0031	0.0053	0.0087
S-1141	0.0221	0.0014	0.0043	0.0040	0.0122
S-1144	0.0657	0.0063	0.0144	0.0175	0.0404
S-1143	0.1353	0.0077	0.0147	0.0215	0.0413

27. Manganese by the Periodate (Photometric) Method

27.1 *Scope*—In this method, periodate is the oxidizing agent used to convert manganous into permanganate ion whose color can then be read in a photometer at a wavelength of 545 nm. This method is capable of determining small amounts of Mn as low as 10 ppm.

27.2 *Summary of Test Method*—The same sample solution prepared in the determinations of phosphorous by molybdovanadate (See 26.5.1 to 26.5.2) can be used for the determination of manganese by periodate. The acid solution is oxidized to permanganate by potassium periodate. Photometric measurement is made at 545 nm.

27.3 *Special Solutions*:

27.3.1 *Manganese Standard Solution* (1 mL to 50 µg Mn)—Dissolve 0.0500 g pure manganese (Mn) metal in 20 mL H_2SO_4(1 + 9) and dilute to 1 L with water.

27.3.2 *Nitric-Phosphoric Acid Mixture*—Add 800 mL HNO_3 and 200 mL H_3PO_4 to 400 mL of H_2O and dilute to 2 L.

27.4 *Preparation of Calibration Curve*:

27.4.1 Transfer 0, 1, 2, 3, 5 and 10 mL of manganese standard solution to six 150 mL beakers, respectively. Add 25 mL of acid mixture to each and heat but do not boil. While heating, add potassium periodate (KIO_3) crystals, a few milligrams at a time (about 0.3 g total), until the permanganic color is fully developed. Keep solution near boiling for 10 min after color develops; the total heating period should last about 30 min.

27.4.2 Allow to cool, transfer to a 50-mL volumetric flask, dilute to volume and mix. Read absorbance at 545 nm using the "0" standard (blank) in the reference cell and construct a calibration curve by plotting absorbance versus concentration of Mn in µg/mL.

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27.5 *Procedure*:

27.5.1 Weigh 2.0 g of prepared sample into a 250-mL beaker and dampen with about 5 to 10 mL of water. Add 10 mL HNO_3 and 20 mL $HClO_4$(See Note 32), heat on hot plate, and evaporate to heavy fumes of $HClO_4$. Cover and boil until solution is colorless or slightly yellow (10 to 15 min). Cool slightly and add 50 mL H_2O. Filter through retentive filter paper and wash thoroughly with hot H_2O (See Note 30). Reserve filtrate.

NOTE 32—If a special perchloric hood is not available, omit the use of $HClO_4$. Instead, evaporate to dryness twice with nitric acid and finally boil with 10 mL HNO_3 and 50 mL H_2O.

27.5.2 Transfer paper and contents to a platinum crucible and heat until paper chars. Ignite at a higher temperature until ash is white. Cool, expel SiO_2 with HF and H_2SO_4, evaporate to dryness (See Note 31) and fuse residue with Na_2CO_3. Cool, add 10 mL H_2O and 2 mL HNO_3 and warm to dissolve. Combine solution with filtrate reserved in 27.5.1 and transfer to a 100 mL volumetric flask. Dilute to volume and mix.

27.5.3 Transfer an aliquot containing <500 µg Mn to a 150 mL beaker. Add 25 mL of acid mixture, heat to near boiling and develop the permanganate color by small additions of KIO_3 as directed in 27.4.1. Cool the solution, transfer to a 50 mL volumetric flask, dilute to volume and mix.

27.5.4 Record the absorbance at 545 nm using the blank standard solution in reference cell as in preparation of standard curve, and compare against a set of standards similarly treated.

27.6 *Calculation*:

27.6.1 Calculate the percent Mn as follows:

$$\% \text{ Mn} = \frac{C \times D}{W \times 10^4} \quad (23)$$

where:

C = concentration of Mn in sample solution µg/mL determined from calibration curve,
D = dilution factor, and
W = g of sample.

27.7 *Precision and Bias*:

27.7.1 The number of laboratories, materials, and determinations in this study does not meet the minimum requirements for determining precision prescribed in Practice E 691:

	Test Methods C 25	Practice E 691 Minimum
Laboratories	4	6
Materials	5	4
Determinations	4	2

27.7.2 The following precision statements are provisional. Within five years, additional data will be obtained and processed which does meet the requirements of Practice E 691.

27.7.2.1 Precision, characterized by repeatability, *Sr* and *r,* and reproducibility, *SR* and *R,* has been determined for the following test method and materials to be:

Precision Statement for Test Method:		% Mn		Color	
Material	Average	*Sr*	*SR*	*r*	*R*
S-1145	0.0011	0.0004	0.0005	0.0011	0.0014
S-1143	0.0025	0.0005	0.0007	0.0014	0.0020
S-1142	0.0147	0.0010	0.0010	0.0028	0.0028
S-1141	0.0271	0.0012	0.0024	0.0034	0.0066
S-1144	0.1096	0.0072	0.0108	0.0200	0.0304

28. Available Lime Index

28.1 *Scope*—The available lime index of high-calcium quicklime and hydrated lime designates those constituents that enter into the reaction under the conditions of this specified test method, otherwise known as the "rapid sugar test method." The interpretation of results obtained by this test method shall be restricted by this definition.

28.2 *Summary of Test Method*—The sample is slaked and dispersed with water. The lime is solubilized by reaction with sugar to form calcium sucrate which is then determined by titration against standard acid using phenolphthalein as the indicator.

28.3 *Special Solutions*:

28.3.1 *Hydrochloric Acid, Standard* (1.000 *N*)—Prepare a solution by diluting 83 mL of HCl to 1 L with CO_2-free water. Standardization of sock solution should be performed on a regular basis at a minimum of once per month. For precision and bias information on standardization with Na_2CO_3 or Tris-(Hydroxymethyl) Amino-Methane see Practice E 200.

28.3.2 *Standardization of HCl with Na_2CO_3*:

28.3.2.1 Transfer approximately 20 g of primary standard anhydrous sodium carbonate (Na_2CO_3) to a platinum dish or crucible, and dry at 250 °C for 4 h. Cool in a desiccator.

28.3.2.2 Weigh accurately 4.4 g to the nearest 0.1 mg of the dried Na_2CO_3 and transfer to a 500-mL flask. Add 50 mL of CO_2-free water, swirl to dissolve the carbonate, and add two drops of a 0.1 % solution of methyl red in alcohol. Titrate with the HCl solution to the first appearance of a red color, and boil the solution carefully, until the color is discharged (See Note 29). Cool to room temperature, and continue the titration, alternating the addition of HCl solution and the boiling and cooling to the first appearance of a faint red color that is not discharged on further heating.

28.3.2.3 *Calculation*—Calculate normality as follows:

$$A = (B \times 18.87)/C \quad (24)$$

where:

A = normality of the HCl solution,
B = Na_2CO_3 used, g, and
C = HCl solution consumed, mL.

NOTE 33—This titration can also be performed potentiometrically with the aid of a glass electrode and a calomel electrode.

28.3.3 *Standardization of HCl with TRIS (THAM)—[Tris-(Hydroxymethyl) Amino-Methane]*:

28.3.3.1 Transfer an appropriate amount of primary standard tris-(hydroxymethyl) amino-methane to suitable dish or crucible and dry in a vacuum at 70 °C for 24 h (refer to Practice E 200). As an alternative, Tris can also be dried at 105 °C (± 5 °C) for 2 h in a regular laboratory drying oven. Cool in a desiccator to room temperature.

28.3.3.2 *Preparation of Mixed Indicator*—Mix 100 mg of Bromocresol Green with 2 mL 0.1 *N* NaOH and dilute with CO_2-free water to 100 mL. Dissolve 100 mg of Alizarin Red S in 100 mL CO_2-free H_2O. Mix equal portions of Bromocresol Green and Alizarin Red S solutions to form mixed indicator.

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28.3.3.3 Weigh approximately 8 g of TRIS to the nearest 0.1 mg and dissolve in 50 mL of CO_2-free water. Add 6 drops of mixed indicator (See Note 30) and titrate to a bright yellow end-point with acid.

NOTE 34—This titration can also be performed potentiometrically using a suitable pH meter to a pH of 4.70.

28.3.3.4 *Calculation*—Calculate normality as follows:

$$A = B/(0.121136 \times C) \quad (25)$$

where:

A = normality of the HCl solution,
B = Tris-(Hydroxymethyl) Amino-Methane used, g,
C = HCl solution consumed, mL.

28.3.4 *Phenolphthalein Indicator (4 %)*—Dissolve 4 g of dry phenolphthalein in 100 mL of 95 % alcohol.

28.3.5 *Sucrose Solution*—(40 g of pure cane sugar in solid form may be used per sample in place of a sugar solution.) Prepare a 40 % solution (w/v) using pure cane sugar and CO_2-free water in a large beaker and stir until dissolved. Add several drops of phenolphthalein indicator solution. Add 0.1 *N* NaOH solution dropwise with stirring until a faint pink color persists. Stock solution of sugar may be made for convenience; however, it should not be stored for more than two days. As an alternative the acidity of each lot of sugar can be determined, and a correction applied to the titration.

28.4 *Procedure*:

28.4.1 *Procedure for Quicklime*:

28.4.1.1 The sample as received at the laboratory shall be thoroughly mixed and a representative sample with minimum weight of 100 g shall be taken and pulverized to pass a No. 50 sieve for analysis. Weigh rapidly 2.804 g of the finely pulverized sample, brush carefully into a 500-mL Erlenmeyer flask containing about 40 mL of CO_2-free water (See Note 35), and immediately stopper the flask.

NOTE 35—Water should not be added to the sample because, especially with quicklime, there is a tendency for the material to cake and form lumps difficult to completely dissolve in the sugar solution later. On the other hand, if the lime is added to a little water, a better dispersion of the fine particles occurs, leading to a more rapid dissolution of the sample. It is possible that in the case of quicklime, some slaking action occurs to facilitate the dispersion and solution.

28.4.1.2 Remove the stopper. Place the flask on a hot plate and immediately add 50 mL of boiling CO_2-free water to the flask. Swirl the flask and boil actively 1 min for complete slaking. Remove from the hot plate, stopper the flask loosely, and place in a cold-water bath to cool to room temperature.

28.4.1.3 Add 100 mL of the neutralized sugar solution (or approximately 40 g of pure cane sugar). Stopper the flask, swirl, and let stand for 15 min to react. (Reaction time should not be less than 10 min nor more than 20 min.) Swirl at 5-min intervals during reaction. Remove stopper, add 4 to 5 drops of 4 % phenolphthalein indicator solution and wash down the stopper and sides of the flask with CO_2-free water.

28.4.1.4 When titrating (See Note 36), first add about 90 % of the acid requirement from a 100-mL buret. Finish the titration, more carefully at approximately one drop per second, to the first disappearance of the pink color, which persists for 3 s. Note the endpoint and ignore any further return of color.

NOTE 36—A mechanical stirrer may be used during the titration if desired. Put a clean magnetic stirrer bar into the flask and place the flask on the magnetic stirrer. Adjust to stir as rapidly as possible without incurring any loss by spattering. Unless the operator is familiar with previous analyses of the lime under test, and in cases where the available lime content varies to extremes, it is good practice to run a preliminary test by slow titration to determine the proper amount of acid required to neutralize the sample.

28.4.2 *Procedure for Hydrated Lime*—The procedure for determining $Ca(OH)_2$ is the same as for CaO with the exception that cold CO_2-free water is used and the boiling and cooling steps are omitted.

28.5 *Calculation*:

28.5.1 Calculate for CaO as follows:

$$\text{Available lime (CaO), } \% = N \times V \times 2.804/W \quad (26)$$

where:

N = normality of acid solution,
V = standard HCl used (1.000 *N*), mL,
W = weight of sample, g, and
2.804 = CaO, g, equivalent to 1 mL of standard acid × 100, or 1 mL of standard HCl = 1 % CaO if exactly 2.804 g of sample is used.

28.5.2 Calculate for $Ca(OH)_2$ as follows:

$$\text{Available lime } [Ca(OH)_2], \% = N \times V \times 3.704/W \quad (27)$$

where:

N = normality of acid solution,
V = standard HCl (1.000 *N*), mL,
W = weight of sample, g, and
,mdit> 3.704 = $Ca(OH)_2$, g, equivalent to 1 mL of standard acid × 100 or 1 mL of standard HCl = 1.32 % $Ca(OH)_2$ when exactly 2.804 g of sample is used.

28.6 *Precision and Bias*:

28.6.1 Twenty-four laboratories cooperated in the testing of three high calcium quicklimes and one high calcium hydrated lime thereby obtaining the repeatability (*r*) and reproducibility (*R*) (Practice E 691) data contained in Table 4.

28.6.2 The user is cautioned that the repeatability and reproducibility are considered adequate for the purposes of the test method. However, higher levels of MgO and nonreactive CaO increase the value of the repeatability (within lab) slightly and the reproducibility value (between labs) noticeably.

28.6.3 Due to the lack of a recognized industry standard, the bias of this test method has not been determined.

29. Free Silica

29.1 *Scope*—Free silica is usually present in the acid-insoluble residue of lime and limestone samples. This method is applicable to the determination of free silica when it exceeds 0.05 %.

TABLE 4 Precision Data (Results in % Available CaO)

Material	Average	*r*	*R*
Hydrated lime	71.967	0.367	0.963
Magnesian quicklime	88.495	0.479	1.784
Shaft kiln quicklime	94.393	0.398	1.405
Rotary kiln quicklime	94.438	0.337	1.092

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29.2 *Summary of Test Method*—After dissolution of a large sample of lime or limestone, the insoluble matter including SiO_2 is separated, ashed, and the oxides fused with pyrosulfate. The silicic acid liberated from the clay minerals in the insoluble matter is dissolved in a hot solution of sodium hydroxide but the free silica is unaffected.

29.3 *Procedure*:

29.3.1 Weigh 5.0 g of the prepared sample in a 400-mL beaker, add 25 mL of HCl (1 + 1), and heat to a boil. Using a retentive paper, filter the insoluble matter including SiO_2 and wash several times with hot water. Discard the filtrate.

29.3.2 Place the paper containing the insoluble matter in a platinum crucible and char the paper without inflaming at low heat. Increase the heat to burn off the carbon, but do not exceed 600 ± 50 °C. Cool, add approximately 10 g of fused and powdered $KHSO_4$ or $K_2S_2O_7$ in the platinum crucible, and blend thoroughly with a small spatula. Fuse thoroughly over a gas burner, first by gradual heating to prevent loss of SO_3. When the fusion becomes quietly molten, finish the fusion at a dull red heat not over 800 °C.

NOTE 37—Do not continue heating to a point where salts begin to freeze on top of the melt and on the sides of the crucible because of the difficulty of subsequent solution.

29.3.3 Cool the crucible and its contents and dissolve the melt by heating with 150 to 200 mL of water in a 400-mL beaker. To the warm solution, cautiously add approximately 12 g of NaOH pellets a few at a time to dissolve the precipitated silicic acid (See Note 37). Digest on a hot plate for 30 min at 80 to 90 °C.

NOTE 38—Free silica is not transformed to silicic acid by the fusion and is not affected by the caustic treatment.

29.3.4 Filter quickly, using a retentive paper; thoroughly scrub and wash the beaker with hot water. Wash the filter paper and its contents ten times with hot water; five times with hot dilute HCl (1 + 1) to dissolve iron and other contaminants of the free silica, and finally five times with hot water or until free of acid. Transfer the paper and residue to a tared platinum crucible, ignite at 1000 °C to constant weight, cool in a dessicator, and weigh as free silica.

29.3.5 To the ignited and weighed residue add 2 drops of H_2SO_4(1 + 1) and approximately 10 mL of HF, evaporate to dryness, ignite and weigh (See Note 34). If the mass of the residue exceeds 0.001 g, the determination may have been improperly accomplished. Replicate determinations should then be made to verify the validity of the results, or the residue examined by X-ray diffraction to determine whether refractory or highly insoluble minerals are present.

NOTE 39—Occasionally the free silica is contaminated by compounds not decomposed during fusion or dissolved in the subsequent treatments. The residue then is treated with HF and sulfuric and SiO_2 expelled.

29.4 *Calculation*—Calculate the percent free silica as follows:

$$\text{Free silica, } \% = (A - B)/W \times 100 \quad (28)$$

where:

A = crucible + insoluble residue, g,
B = crucible minus SiO_2, g, and
W = sample, g.

29.5 *Precision and Bias*—The precision and bias of this test method have not been determined.

30. Unhydrated Oxides Calculated on As-Received Basis

30.1 *Scope*—From the analytical determinations made in accordance with the preceding sections, it is possible to calculate combined water, $CaCO_3$, and $CaSO_4$ in samples of lime and hydrated lime. Unhydrated oxides of MgO in hydrated lime can also be calculated.

30.2 *Summary of Test Method*—Determine the percent of free water, LOI, CO_2, SO_3, CaO, and MgO in accordance with the preceding sections. Calculate combined H_2O, calcium carbonate, calcium sulfate, and unhydrated magnesium oxide using the following procedures.

30.3 *Procedure*:

30.3.1 Calculate percentage of combined water in quicklime from the loss on ignition and CO_2 determinations, as follows:

$$\text{Combined } H_2O, \% = \% \text{ LOI} - \%(CO_2 + \text{FM}) \quad (29)$$

30.3.2 Calculate the percentage of combined water in hydrated lime from the LOI, CO_2, and free moisture (FM) determinations as follows:

$$\text{Combined } H_2O, \% = \% \text{ LOI} - \%(CO_2 + \text{FM}) \quad (30)$$

30.3.3 Calculate the percent unhydrated oxides on the as-received basis as follows (See Notes 40-42):

NOTE 40—The calculations involved in determining the percentage of unhydrated oxides on the as-received basis are illustrated in Table 5.

NOTE 41—This method for calculating the percentage of hydrated oxides is intended primarily for use with Type S hydrated lime.

NOTE 42—It is recognized that the results from this method of calculation may not be in strict accord with the actual composition of the material. Experience indicates, however, that these results provide an index to the performance of the material in practice. The value obtained by this calculation shall be reported to the nearest 0.5 %.

30.3.3.1 Calculate the CaO equivalents of the CO_2 and SO_3 as follows:

$$CO_2 \times 1.275 = \text{equivalent CaO } (A) \text{ as } CaCO_3 \quad (31)$$

$$SO_3 \times 0.700 = \text{equivalent CaO}(B) \text{ as } CaSO_4 \quad (32)$$

TABLE 5 Example of Calculation, Unhydrated Oxides

Compound	Values Determined From Chemical Analysis, %	Residual Values	Factors	Calculated Values, %
CO_2	0.40		× 1.275	= equivalent CaO = 0.51
SO_3	0.48		× 0.700	= equivalent CaO = 0.34
CaO	42.79 – (0.51 + 0.34 = 0.85)	= 41.94	× 0.3213	= equivalent H_2O = 13.48
H_2O	25.09 – 13.48	= 11.61	× 2.238	= equivalent MgO = 25.98
MgO	30.68 – 25.98			= unhydrated MgO = 4.70

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30.3.3.2 Subtract the sum of these CaO equivalents from the total CaO:

$$\text{Total CaO} - (A + B) = \text{hydrated CaO}(C) \quad (33)$$

30.3.3.3 Calculate the H_2O equivalent of the remaining CaO as follows:

$$\text{Hydrated CaO } (C) \times 0.3213 = \text{equivalent } H_2O \ (D) \text{ as } Ca(OH)_2 \quad (34)$$

30.3.3.4 Subtract this value for H_2O (D) from the combined water as calculated in 30.3.1 and 30.3.2.

$$\text{Combined water} - H_2O \ (D) = \text{equivalent } H_2O \ (E) \text{ as } Mg(OH)_2 \quad (35)$$

30.3.3.5 Calculate the MgO equivalent of the remaining water (E) as follows:

$$H_2O \ (E) \times 2.238 = \text{equivalent MgO } (F) \text{ as } Mg(OH)_2 \quad (36)$$

30.3.3.6 Subtract this MgO equivalent (F) from the total MgO as determined from preceding sections to obtain the percentage of unhydrated MgO on the as-received basis.

$$\text{Total MgO} - \text{MgO equivalent } (F) = \textit{unhydrated MgO} \quad (37)$$

31. Calcium and Magnesium Oxide (Alternative EDTA Titration Method)

31.1 *Scope*—This test method is a rapid EDTA complexometric method for determining calcium and magnesium in lime and limestone products. Ordinarily the EDTA procedure is designed to follow routine separations, that is, single dehydration of silica and a single precipitation with NH_4OH of the combined oxides of iron and aluminum. For expediency, the assays can be run directly without prior separation of the combined oxides of iron and aluminum by using the complexing action of EDTA at appropriate pH levels.

31.2 *Summary of Test Method*:

31.2.1 In this test method, calcium and magnesium are determined by EDTA titration after separation of silica and the NH_4OH group during a routine analysis of lime and limestone. The assays may also be made after a direct HCl decomposition followed by removal of the silica and insoluble.

31.2.2 If interfering elements are present in large enough quantities to cause problems, the interferences may be suppressed by the addition of complexing or masking agents such as triethanolamine or cyanide.

31.2.3 For the determination of calcium, the solution is adjusted to a pH of 12 to 12.5 with KOH solution and titrated with EDTA to a blue end point using hydroxy naphthol blue as the indicator. Both CaO and MgO are then titrated from a solution buffered to pH 10 with $NH_3 \cdot NH_4Cl$ using Calmagite as the indicator. MgO is calculated by subtracting the EDTA equivalent to CaO present from the EDTA equivalent to CaO + MgO.

31.3 *Reagents*:

31.3.1 *EDTA Solution* (0.4 %)—Dissolve 4 g of disodium dihydrogen ethylenediamine tetraacetic acid in water and dilute to 1 L.

31.3.2 *Potassium Hydroxide, Standard Solution* (1 *N*)—Dissolve 56 g of KOH in 1 L of distilled water.

31.3.3 *Ammonia Buffer* (pH 10.5)—Dissolve 67.5 g of NH_4Cl in 300 mL of distilled water, add 570 mL of NH_4OH, and dilute to 1 L.

31.3.4 *Hydroxy Naphthol Blue* (calcium indicator)—Disodium salt of 1-(2-naphthol azo-3,6 disulfonic acid)2 naphthol-4-sulfonic acid on suitable carrier.

31.3.5 *Calmagite* (magnesium + calcium indicator)—1-(hydroxyl-4-methyl-2 phenylazo)-2 naphthol-4 sulfonic acid on a suitable carrier.

NOTE 43—Both the hydroxy naphthol blue and Calmagite indicators are manufactured by Mallinckrodt Chemical Works, St. Louis, MO. Each indicator is a diluted mixture of dye plus an inert carrier.

31.3.6 *Hydrochloric Acid* (1 + 1).

31.3.7 *Hydrochloric Acid* (1 + 9).

31.3.8 *Triethanolamine* (1 + 2).

31.3.9 *Potassium Cyanide Solution* (20 g/L)—Dissolve 2 g of KCN in 100 mL of water.

31.3.10 *Calcium Standard Solution* (1.00 mg CaO/mL)—Weigh 1.785 g of $CaCO_3$, primary standard grade. Dissolve in HCl (1 + 9) and dilute to 1 L with distilled water.

31.3.11 *Magnesium Standard Solution* (1.00 mg MgO/mL)—Dissolve 0.603 g of magnesium metal turnings in HCl and dilute to 1 L with distilled water.

31.4 *Apparatus*:

31.4.1 *Magnetic Stirrer* with light.

31.4.2 *Stirring Bar,* TFE-fluorocarbon-covered.

31.5 *Standardization*:

31.5.1 *Calcium*—Pipet 10 mL of standard CaO solution into an Erlenmeyer flask and add 100 mL of distilled water. To prevent precipitation of calcium, add about 10 mL of EDTA titrating solution. Adjust to pH 12 to 12.5 with about 15 mL of 1 *N* KOH solution and stir. Add 0.2 to 0.3 g of hydroxy naphthol blue indicator (See Note 44) and complete titration to a clear blue end point (See Note 45). Titrate three or more aliquots and use the average to calculate the titer of the CaO solution.

$$\text{CaO titer, mg/mL} = 10 \text{ mg CaO standard/mL EDTA titration} \quad (38)$$

NOTE 44—The amount of indicator is usually a matter of individual preference, but if Mallinckrodt reagents are used, the recommended dosages are considered the proper amounts to add for easy end point detection.

NOTE 45—The use of a magnetic stirrer with light may be very helpful in detecting the color change. The end point is the first definite blue color that remains stable for at least 30 s.

31.5.2 *Magnesium*—Pipet 10 mL of the 1.00-mg/mL standard MgO solution into an Erlenmeyer flask and add 100 mL of distilled water. Adjust to pH 10 with 10 mL of the ammonium chloride-ammonium hydroxide buffer solution, and add 0.3 to 0.4 g of Calmagite indicator (See Note 44). Titrate with disodium EDTA, noting the color change from a red to deep blue end point (See Note 45). Titrate three or more aliquots and use the average to calculate the magnesium titer.

$$\text{MgO titer, mg/mL} = 10 \text{ mg MgO standard/mL EDTA titration} \quad (39)$$

31.6 *Procedure*:

31.6.1 If using limestone, dry the sample at 110 °C to constant weight and cool to room temperature.

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31.6.2 Weigh 0.5 g of the dry sample into a 250-mL beaker, add 10 mL of HCl (1 + 1), and carefully evaporate to dryness on hot plate. Dissolve residue in 25 mL of HCl (1 + 9), dilute to about 100 mL with water, and digest at low heat for 15 min. Cool, transfer to a 250-mL volumetric flask, dilute to volume, mix, and let settle or filter using a medium textured paper.

31.6.3 Alternatively, if the standard procedure has been used to determine the silica and insoluble and iron and aluminum, the filtrate remaining after the precipitation of the iron and aluminum with ammonia can be used for the Ca and Mg EDTA determination. Continue the analysis as follows: Acidify the filtrate with HCl, transfer to a 250-mL volumetric flask, dilute to volume with distilled water, and mix.

31.6.4 *Calcium Oxide*:

31.6.4.1 Pipet a 20-mL aliquot from the 250-mL volumetric flask and transfer to an Erlenmeyer flask. Dilute to 150 mL with water, adjust the pH to 12 with about 30 mL of 1 *N* KOH solution, and stir.

NOTE 46—Precipitation of calcium hydroxide can be prevented, if necessary, by adding one half to one third of the estimated volume of disodium EDTA solution before the addition of the potassium hydroxide. Presence of a large precipitate can cause loss of sharpness in the end point.

31.6.4.2 If the sample is known to contain significant quantities (>1 %) of iron, manganese, and heavy metals (See Note 47), add 2 to 3 drops of 2 % potassium cyanide solution, or 10 mL of triethanolamine.

NOTE 47—If silica and phosphate or excessive amounts (>5 %) of iron and aluminum are present, they should first be removed by a double ammonia precipitation as in the standard procedure.

Warning—Cyanides should be used with utmost care because they can be very toxic compounds. They should be kept basic and prescribed disposal procedures used. Waste cyanide solutions must not be poured down laboratory sinks. Such solutions can be rendered relatively harmless by making them strongly basic, pH 12 or higher, with sodium hydroxide, adding calcium hypochlorite, and letting the solution stand for 24 h.

31.6.4.3 Add 0.2 to 0.3 g of hydroxy naphthol blue indicator (See Note 39) and titrate as in 36.5.1 to a clear blue end point (See Note 45).

31.6.4.4 *Calculation*:

$$\text{CaO, \%} = \text{CaO titer} \times \text{mL EDTA} \times 1.25/\text{weight of sample, g} \quad (40)$$

31.6.5 *Magnesium Oxide*:

31.6.5.1 Pipet a 20-mL aliquot of the acid solution from the 250-mL volumetric flask and transfer to an Erlenmeyer flask. Dilute with 100 mL of water, add about 20 mL of ammonia buffer to pH 10, and stir.

31.6.5.2 Add 2 to 3 drops of 2 % potassium cyanide solution, or 10 mL of triethanolamine and 1 drop of triethanolamine (**Warning**—See 31.6.4.2) (See Note 47). Add EDTA standard solution equivalent to calcium titration; then add approximately 0.4 g of Calmagite indicator (See Note 39).

31.6.5.3 Titrate to a blue end point with the 0.4 % EDTA solution (See Note 45).

31.6.5.4 The titration determines both the calcium and magnesium present in solution. Subtraction of the EDTA titration obtained for calcium from the total titration gives the titration value for magnesium.

31.6.5.5 *Calculation*:

$$\text{mL EDTA solution equivalent to MgO} = (\text{mL EDTA solution used in CaO + MgO titration}) - \text{mL} - \text{mLEDTA solution used in CaO titration}) \quad (41)$$

$$\text{MgO, \%} = \text{mL EDTA equivalent to MgO} \times \text{MgO EDTA titer} \times 1.25/\text{weight of sample, g} \quad (42)$$

TABLE 6 Precision of Calcium Oxide

Sample Tested	CaO Found	Repeatability 1 sigma	Reproducibility 1 sigma
A-1a	53.48	0.31	0.27
A-2b	30.98	0.28	0.41
L-1	53.92	0.29	0.26
P-1a	53.88	0.31	0.28
Pooled	. . .	0.30	0.31

TABLE 7 Precision of Magnesium Oxide

Sample Tested	MgO Found	Repeatability Within Laboratories	Reproducibility Between Laboratories
A-1a	1.58	0.19	0.18
A-2b	21.58	0.24	0.41
L-1	0.58	0.21	0.22
P-1a	1.45	0.23	0.24
Pooled	. . .	0.22	0.28

31.7 *Precision and Bias:*[7]

31.7.1 The precision of this test method was tested by ten laboratories using three limestone and one dolomite reference samples. The results shown in Tables 6 and 7 are summarized as follows:

31.7.1.1 The overall precision (1 sigma) between laboratories (reproducibility) for CaO is ± 0.31 absolute units.

31.7.1.2 The overall precision (1 sigma) between laboratories for MgO is ± 0.28 absolute units.

31.7.1.3 The overall precision (1 sigma) within laboratories (repeatability) for CaO is ± 0.24 absolute units.

31.7.1.4 The overall precision (1 sigma) within laboratories for MgO is ± 0.22 absolute units.

32. Total Carbon by the Direct Combustion-Thermal Conductivity Cell Method

32.1 This test method covers the determination of carbon in lime and hydrated lime samples having a carbon concentration in the range from 0.005 to 5 %.

32.2 *Summary of Test Method*—All the carbon in the sample is converted to CO_2 by combustion in a stream of purified oxygen using an induction furnace. Under some conditions, CO is formed and a catalyst furnace is used to convert it to CO_2. The products of combustion are swept into the carbon analyzer where the CO_2 is selectively absorbed by a molecular sieve. The CO_2 is later released and swept by a fresh stream of oxygen past a thermal conductivity cell which senses the amount of CO_2 present. The signal from the sensor is amplified and electronically converted to % C which is displayed on a digital readout panel.

[7] Supporting data have been filed at ASTM International Headquarters and may be obtained by requesting Research Report RR: C07-1000.

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32.3 *Apparatus*:

32.3.1 *Combustion Furnace and Carbon Determinator*—This unit is commercially available.

32.3.2 *Crucibles*—Use crucibles recommended by the manufacturer of the instrument.

32.3.3 *Oxygen Cylinder with Two-Stage Regulator.*

32.3.4 *Purifying Train,* consisting of a sulfuric acid tower, an absorption bulb containing Ascarite and another absorption bulb containing Anhydrone. A flowmeter precedes the induction furnace assembly.

32.3.5 *Catalyst Furnace,* to convert CO to CO_2.

32.3.6 *Combustion Tube with Built-In Jet.*

32.4 *Reagents*:

32.4.1 *Iron Chip Accelerator,* low-carbon.

32.4.2 *Copper-Tin Accelerator.*

32.5 *Preparation of Apparatus*:

32.5.1 Assemble the apparatus. Start the flow of oxygen at 1500 mL/min and the carrier gas flow at the rate recommended by the manufacturer of the apparatus.

32.5.2 Test the furnace and the analyzer to ensure the absence of leaks and make the required electrical power connections. Prepare the induction furnace and analyzer for calibration and sample analysis according to the manufacturer's manual of instructions.

32.5.3 After the instrument has been prepared for calibration, check the CO_2 collection time which should have an 80 to 90-s time duration. The collection time can be checked by operating without a sample. If it is outside of this range, make the necessary adjustment of the collect relay as provided for in the manual of instructions.

32.6 *Calibration*:

32.6.1 Select NIST steel calibration standards containing approximately 0.02 to 1 % carbon (See Note 48).

NOTE 48—The accuracy of this test method is dependent to a large extent on the accuracy of the methods used to certify the carbon concentration in the calibration standards as well as upon their homogeneity. Tests made on NIST steel standards have shown that they are sufficiently homogeneous to permit the use of samples as small as 20 mg.

32.6.2 Condition the analyzer if more than 2 h have elapsed since the last sample was run and determine the blank reading as follows:

32.6.2.1 Load into a crucible 1.5 g of iron chip accelerator and 1 g of tin-coated copper.

32.6.2.2 Proceed as directed in 32.7.1 to 32.7.4.

32.6.2.3 Repeat 32.6.2.1 and 32.6.2.2 a sufficient number of times to establish that low and consistent blank readings are obtained.

32.6.2.4 The normal blank reading should be 0.007 to 0.009. If it is out of this range, determine the cause, correct it, and repeat the steps as directed in 32.6.2.1 through 32.6.2.2.

32.6.3 *Calibration Curve*:

32.6.3.1 The calibration of the analyzer should be done using carbon standards that bracket the percent carbon in the samples estimated from previous tests, using the following guidelines:

% Carbon in Sample	High-Carbon Standard, %	Low-Carbon Standard, %
0.5–1	1.0	0.4
0.2–0.5	0.6	0.2
0.1–0.2	0.2	0.1
0.02–0.1	0.1	0.01

32.6.3.2 Treat each standard as directed in 32.7.1 to 32.7.4.

32.6.3.3 Select two standards, one slightly higher and the other slightly lower than the carbon concentration of the sample.

32.6.3.4 Run the high standard first and observe the reading. The carbon reading should be within ± 1 % of the standard carbon value plus the blank (See Note 49). If it is within this range, proceed to 32.6.3.7.

NOTE 49—For example, with a blank reading of 0.009, a carbon standard which has a standardized value of 0.428 % should read 0.433 to 0.441.

32.6.3.5 If the reading is out of this range, run a duplicate sample.

32.6.3.6 If the second sample has approximately the same value as the first sample, adjust the slope control (See Note 50) to bring the reading to within the tolerance of the standard.

NOTE 50—Not all manufacturers may have this particular feature in their instrument, in which case the manual of instructions supplied with each instrument should be adhered to very closely and the instructions followed.

32.6.3.7 Run a carbon standard that has a carbon value lower than the sample as directed in 32.6.3.1 to 32.6.3.3.

32.6.3.8 The reading should be within +1 % of the carbon value plus the blank (See Note 50).

32.6.3.9 If the reading is within tolerance range, proceed to sample analysis, 32.7.1 to 32.7.4.

32.6.3.10 If the reading is out of the tolerance range, run a duplicate sample. If the second sample has the same out of tolerance value as the first sample, repeat 32.6.3.4 to 32.6.3.9, readjusting the slope control to bring the high standard within the tolerance of the standard.

32.6.3.11 If the standards are still out of line, refer to the manufacturer's manual for instruction, determine the cause, correct it, and repeat the standardization procedure, 32.6.3.2 to 32.6.3.8.

32.7 *Procedure*:

32.7.1 Stabilize the furnace and analyzer as directed in 32.5.1 to 32.5.3.

32.7.2 Weigh duplicate samples to the nearest 1 mg, using the following guidelines:

Carbon Content, %	Sample Weight, g
0 to 0.1	1.000
0.1 to 2	0.500
2 to 5	0.250

32.7.3 Transfer the sample to a combustion crucible, add 1.5 g of iron chip accelerator and 1 g of the tin-coated copper accelerator. Place the crucible on the furnace pedestal, raise the pedestal into position, and lock the system. Start the flow of oxygen at 1500 mL/min, and flush the system for 30 s.

32.7.4 Start the cycle timer which energizes the furnace and starts the programmer, after having set it to provide a combustion cycle of 1 min. Using the variable transformer, manually control the plate current within the range from 350 to 450 mA. When the cycle is complete, remove and discard the crucible. Record the reading.

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32.8 *Calculation*—Subtract the value found for the blank in 32.6.2.3 from the reading found in 32.7.4 and record the net reading. Calculate the percentage of carbon as follows:

$$\text{Carbon, } \% = A/B \quad (43)$$

where:
A = net carbon content, %, and
B = sample mass, g.

32.9 *Precision and Bias*—The precision and bias of this test method have not yet been determined.

33. Calcium Carbonate Equivalent

33.1 *Scope*—The calcium carbonate equivalence (CCE) test is used to determine the neutralizing capability of a calcareous material and to report this value in terms of percent calcium carbonate equivalents (% $CaCO_3$).

33.2 *Significance and Use*—Calcareous materials such as crushed limestone, hydrated lime and pulverized slags (from the production of steel) have been used extensively as soil modifiers or agricultural liming materials. A measure of their neutralizing capability can be determined through the use of this method of test. Not all neutralizing components of acalcareous material may be beneficial, therefore, the chemical analysis is suggested.

33.3 *Apparatus*:

33.3.1 *pH Metre,* conforming to Sections 4 and 5 of Test Method E 70.

33.3.2 *Mechanical Stirrer.*

33.3.3 *Sieve,* No. 60 (250-µm).

33.4 *Reagents*:

33.4.1 *Preparation of Mixed Indicator*—Mix 100 mg of Bromocresol Green with 2 mL of 0.1 *N* NaOH and dilute with CO_2-free water to 100 mL. Dissolve 100 mg of Alizarin Red S in 100 mL CO_2-free H_2O. Mix equal portions of Bromocresol Green and Alizarin Red S solutions to form mixed indicator.

33.4.2 *Hydrochloric Acid,* Standard (1.0 *N*)—Prepare a 1.0 *N* solution of hydrochloric acid (HCl) and standardize. Refer to available lime index test method for procedure on standardization of hydrochloric acid. For further information on preparation and standardization of solutions see Practice E 200.

33.4.3 *Phenolphthalein Indicator Solution* (1 g/100 mL)—Dissolve 1.0 g phenolphthalein in 100 mL of alcohol.

33.4.4 *Sodium Hydroxide Standard Solution* (0.5V AN)—Dissolve 20 g of sodium hydroxide (NaOH) in 150 mL of carbon dioxide—free water. Cool the solution to 25 °C and dilute to 1 L. Prepare free from carbonates and store in a polyethylene bottle provided with a siphon tube and with guard tubes containing soda-lime, or other suitable device, to prevent absorption of carbon dioxide (CO_2) from the air:

33.4.4.1 Standardize against 1.0 *N* hydrochloric acid with three 50 mL aliquots using phenolphthalein solution as indicator. Take the average of the three results as the normality of the Sodium Hydroxide Standard Solution.

$$\text{Normality (NaOH)} = \frac{V_2 N_2}{V_1} \quad (44)$$

where:
V_1 = volume of NaOH Standard Solution,
V_2 = volume of HCl used to neutralize NaOH, and
N_2 = normality of HCl Standard Solution.

33.5 *Preparation of Sample*:

33.5.1 Weigh and dry the limestone and slag samples to constant weight at a temperature of 110 ± 5 °C. Record the as-received and dry weights in order to calculate moisture content. Use lime samples as received. Grind the sample to pass a No. 60 (250-µm) sieve, mix thoroughly, and store in airtight containers.

33.6 *Procedure*:

33.6.1 *Indicator Titration Method*—Using Table 8 as a guide (See Note 51), weigh the material, to the nearest 0.1 mg, and place into a 500-mL Erlenmeyer flask; add 100 mL of 1.0 *N* HCl and boil gently for 5 min. Cool, and titrate the excess acid with 0.5 *N* NaOH solution using phenolphthalein as indicator. Calculate CCE as described in 33.6.3.

33.6.2 *Potentiometric Titration Method* (applicable to agricultural liming materials containing large amounts of ferrous iron or coloring matter, but not to silicate materials)—Proceed as in 33.6.1 through "Cool. . .". Transfer to a 400-mL beaker and insert glass and calomel electrodes of a pH metre and a

TABLE 8 Recommended Sample Weight[A]

Sample Type	Formula	Purity, %	Theoretical C.C.E.	Sample Weight, g
Magnesium oxide	MgO	97	248.33	1.9
Dolomitic lime	CaO MgO	97	207.69	2.3
Calcium oxide	CaO	97	178.48	2.6
Dolomitic Type N hydrate	Ca(OH)2 MgO	98	175.01	2.6
Dolomitic Type S hydrate	Ca(OH)2 Mg(OH)2	98	151.21	3.0
Calcium hydroxide	Ca(OH)2	98	135.11	3.4
Dolomitic limestone	CaCO3 MgCO3	97	108.56	4.3
Calcium carbonate	CaCO3	97	100.00	4.6

[A] For those materials not listed in Table 8: To determine the amount of 1.0 *N* HCl required for neutralization, a preliminary titration using 2 g of sample (weighed to the nearest 0.1 mg) should be performed to a yellow end point using mixed indicator. Using the following formula, determine the sample weight need for testing and proceed to 33.6.1.

$$Wr, \text{ grams (g)} = \frac{Wu * 100}{Vu + 10}$$

where:
Wr = sample weight required for testing, g,
Wu = sample weight used in preliminary titration, g, and
Vu = volume of 1.0*N* HCl used in preliminary titration, mL.

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mechanical stirrer. Stir at a moderate speed to avoid splash. Deliver from a buret the 0.5 *N* NaOH solution rapidly to pH 5, then dropwise until the solution attains pH 7 and remains constant for 1 min while stirring. Report as $CaCO_3$ equivalent as described in 33.6.3.

33.6.3 Calculation of Percent Calcium Carbonate Equivalence:

33.6.3.1 *Dry Basis*:

$$\% \ CaCO_{3(dry)} = \frac{5.0045\ (V_1N_1 - V_2N_2}{W} \quad (45)$$

where:

V_1 = HCl solution used, mL,
N_1 = normality of HCl solution,
V_2 = NaOH solution required for titration of excess acid, mL,
N_2 = normality of NaOH solution, and
W = sample weight, g.

33.6.3.2 *As-received basis (limestone only)*:

$$\% \ CaCO_{3(as\ received)} = [1 - (A - B/A)] \times \% \ CaCO_{3(dry)} \quad (46)$$

where:

A = as received sample weight from 33.5.1, and
B = dry sample weight from 33.5.1.

34. pH of Alkaline Earth Solutions

34.1 *Scope*—This method covers the electrometric pH analysis of solutions made from a variety of lime, hydrate, and limestone-bearing materials.

34.2 *Summary of Test Method*—In this test method a sample of material is mixed with CO_2-free deionized water so that the pH of the solution is determined electrometrically. To ensure that an accurate measurement of pH is obtained for samples with a pH greater than 11.5, it is critical that all samples and buffer solutions be at 25.0 °C when measured.

34.3 *Special Apparatus*:

34.3.1 *pH Metre*—A commercially available pH metre capable of calibration with a minimum of two different buffers (See Note 51).

NOTE 51—It is necessary that the pH metre be equipped with a combination pH electrode as well as a temperature compensation probe. It is strongly recommended that a combination pH and temperature compensation probe be used.

34.3.2 *Constant Temperature Water Bath*—The water bath should be large enough to hold all samples and buffer solutions necessary to perform this method.

34.4 *Special Solutions*:

34.4.1 *Potassium Chloride Solution (0.2 M)*—Dry reagent grade KCl crystals at 110 °C for 1 h. Dissolve 14.91 g of the dry KCl in CO_2-free deionized water and dilute to 1 L.

34.4.2 *Sodium Hydroxide Solution (0.2 M)*—Dissolve 8.00 g of NaOH in CO_2-free deionized water and dilute to 1 L. Standardize this solution with potassium acid phthalate using phenolphthalein as the indicator.

34.4.3 *Hydroxide-Chloride Buffer Solution (pH 13.0 at 25.0 °C)*—Dilute 25.0 mL of the KCl solution and 66.0 mL of the NaOH solution to 100 mL with CO_2-free deionized water.

34.4.4 *Phenolphthalein Indicator*—Dissolve 4 g of dry phenolphthalein in 100 mL of 95 % alcohol.

34.4.5 Commercially available pH buffer solutions, pH 7 and pH 10.

34.5 *Standardization of Sodium Hydroxide Solution*:

34.5.1 *Initial Standardization*—Transfer 50.0 mL of the sodium hydroxide solution to be standardized to a well rinsed 50-mL Class A buret by means of a pipette. Accurately weigh out 8.0 ± 0.1 g of reagent grade potassium hydrogen phthalate which has been dried in an oven at 110 °C for 1 h. Record the weight to the nearest 0.1 mg, then quantitatively transfer the weighed material into a 400-mL beaker. Add 185 mL of CO_2-free deionized water which is at a temperature of 26.0 ± 2.0 °C. Stir this mixture gently until all of the crystals dissolve. Add five drops of the phenolphthalein indicator solution and proceed to titrate the prepared standard with the sodium hydroxide solution to be standardized. Titrate to an endpoint of light pink which will persist for at least 6 s.

34.5.2 *Calculation of Sodium Hydroxide Normality*—The normality of the sodium hydroxide solution can be calculated from the following equation:

$$\text{Normality of NaOH} = \frac{\text{Wt. of potassium hydrogen phthalate}}{\text{mL of NaOH} \times \text{factor of } 0.204228} \quad (47)$$

This preliminary standardization may reveal the necessity for either dilution with CO_2-free deionized water or the 0.2 molarity specified.

34.5.3 *Correction if Base is "too weak"*—If the molarity (normality) is determined to be too weak, it can be adjusted by the addition of additional sodium hydroxide. An example of this calculation follows. If 1.0 L of 0.1979 N solution needs to be strengthened to 0.2000 N, calculate how many grams of sodium hydroxide need to be added as follows:

$$\begin{aligned} &1.0\ L \times 0.1979\ M = 0.1979\ \text{mole} \\ &0.2\ M - 0.1979\ M = 0.0021\ M \\ &NaOH = 39.997\ \text{g/mole} \\ &39.997\ \text{g/mole} \times 0.0021\ \text{mole} = 0.0830\ \text{g needed} \end{aligned} \quad (48)$$

After the addition of additional sodium hydroxide is completed, recheck the standardization as specified in section 34.4.

34.5.4 *Correction if Base is "too strong"*—If the molarity (normality) is determined to be too strong, it can be adjusted by the addition of CO_2-free deionized water. An example of this calculation follows. If 1.0 L of 0.2019 N solution needs to be weakened to 0.2000 N, calculate how many millilitres of CO_2-free deionized water need to be added as follows:

$$\begin{aligned} &1.0\ L \times 0.2019\ M = 0.2019\ \text{mole} \\ &0.2019 - 0.200 = 0.0019\ L \text{ or } 1.9\ mL \text{ of } CO_2 - \\ &\text{free deionized water needed} \end{aligned} \quad (49)$$

After the addition of additional CO_2-free deionized water is completed, recheck the standardization as specified in section 34.5.

34.6 *Calibration of pH Metre*—Due to the wide variety of commercially available pH equipment, a detailed calibration procedure cannot be incorporated into this test method. Follow the manufacturer's instructions for calibration of your particular equipment.

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34.6.1 Using the appropriate combination of the commercially available pH 7 and pH 10.0 buffers, and the Hydroxide-Chloride buffer (pH 13.0), choose the pair of buffers which best brackets the pH of the sample being tested. Standardize your pH metre in accordance with the manufacturer's instructions. For samples with pH less than 11.5, the temperature of the samples and buffers should be kept at 25.0 ± 3.0 °C (See Note 53).

NOTE 52—For alkaline solutions in this pH range the temperature does not cause errors to the extent that it does with samples with a pH in excess of 11.5, therefore the temperature is not as critical.

For samples with a pH greater than 11.5, it is imperative that all solutions be at 25.0 ± 0.1 °C while they are being measured. If all buffers and test solutions are not within this range, due to the high pH being measured, large errors in the measured pH will occur. This can easily be accomplished by the use of a constant temperature water bath (See Note 54).

NOTE 53—In strongly alkaline solutions, especially above pH 12, the concentration of hydroxide ions is so high that the small amount of hydrogen ions produced by the ionization of water is sufficient to change the pH appreciably with temperature.

34.7 *Procedure—Materials with pH Less than 11.5*:

34.7.1 Weigh 10.0 g of the prepared sample and record the weight to the nearest 0.1 mg. Quantitatively transfer the weighed material into a 250-mL Erlenmeyer flask containing 200 mL of CO_2-free deionized water. Add a magnetic stir bar, immediately stopper the flask with a rubber stopper, and stir for 30 min.

34.7.2 Let the solution stand for at least 30 min to allow the suspended material to settle out from the suspension, as well as to allow the sample temperature to stabilize at 25.0 ± 3.0 °C. A constant temperature water bath may be necessary to obtain the desired temperature range.

34.7.3 Once the temperature of the sample is stabilized at 25.0 ± 3.0 °C, using a 50-mL transfer pipette, transfer 50 mL of the settle solution to a 100-mL beaker containing a magnetic stir bar.

34.7.4 Slowly stir the sample solution using a magnetic stirrer. Using a previously standardized pH metre, standardized in accordance with section 34.6, quickly measure the pH of the sample. Report the pH to four significant figures.

34.8 *Procedure—Materials with pH of 11.5 and greater*:

34.8.1 Weigh 10.0 g of the prepared sample and record the weight to the nearest 0.1 mg. Quantitatively transfer the weighed material into a 250-mL Erlenmeyer flask containing 200 mL of CO_2-free deionized water. Add a magnetic stir bar, immediately stopper the flask with a rubber stopper, and stir for 30 min.

34.8.2 Place the sample solution into a constant temperature water bath set at 25.0 °C. Let the solution stand for at least 30 min to allow the suspended material to settle out from the suspension as well as to allow the sample temperature to stabilize at 25.0 ± 0.1 °C.

34.8.3 Once the temperature of the sample is stabilized at 25.0 ± 0.1 °C, using a 50-mL transfer pipette, transfer 50 mL of the settled solution to a 100-mL beaker containing a magnetic stir bar.

34.8.4 Slowly stir the sample solution using a magnetic stirrer. Using a previously standardized pH metre, standardized in accordance with section 34.6, quickly measure the pH of the sample solution (See Note 53). It is imperative that the temperature of the test solution remain at 25.0 ± 0.1 °C during the pH measurement. If needed, the pH measurement should be carried out in a constant temperature water bath. Report the pH to four significant figures.

34.9 *Precision and Bias*:

34.9.1 The number of laboratories, materials, and determinations in this study does meet the minimum requirements for determinating precision prescribed in Practice E 691:

	Test Methods C 25	Practice E 691 Minimum
Laboratories	7	6
Materials	12	4
Determinations:	3	2

34.9.2 *Precision Statement for Test Method: pH*—Precision, characterized by repeatability, *Sr* and *r,* and reproducibility, *SR* and *R,* has been determined for the following materials to be:

Materials	Average	*Sr*	*SR*	*r*	*R*
Sample A kiln dust	12.3817	0.0069	0.2791	0.0194	0.7814
Sample B waste lime	12.2998	0.0297	0.4004	0.0831	1.1210
Sample C dolo hydrate	12.4073	0.0123	0.2408	0.0345	0.6741
Sample D dolo lime	12.3942	0.0177	0.2785	0.0495	0.7799
Sample E –325 stone	11.2199	0.0274	0.3355	0.0766	0.9393
Sample F cyclone dust	12.4090	0.0164	0.2336	0.0459	0.6541
Sample G bottom ash	12.1948	0.0120	0.4049	0.0336	1.1338
Sample H fly ash	9.6776	0.0557	0.3821	0.1559	1.0699
Sample I fly ash	11.3193	0.0143	0.2191	0.0402	0.6136
Sample J hydrate	12.4111	0.0244	0.2994	0.0684	0.8384
Sample K h. hyd. lime	12.5477	0.0069	0.1875	0.0193	0.5249
Sample L quicklime	12.4331	0.0260	0.1767	0.0728	0.4949

35. Total Carbon and Sulfur by the Combustion/Infrared Detection Method

35.1 *Scope*:

35.1.1 This test method is for the determination of carbon or sulfur, or both, in lime and limestone. This test method has also been adapted for use with kiln flue dusts. This test method covers the determination of carbon and sulfur in an acceptable concentration range from 0.01 to 13 % carbon and from 0.005 to 3 % sulfur.

35.1.2 Hydrated lime, hydroxides, and samples with high moisture cannot be suitably analyzed for sulfur using an induction furnace unit. Significant portions of SO_2 will be trapped in the dust filter which will be moist due to the water released or produced from the combustion. These samples must be analyzed on a resistance-furnace-type unit. Carbon results will not be similarly effected. Because of the high moisture content in the post-combustion gases, moisture filters must be checked often, and when needed, changed.

35.1.3 This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.

35.2 *Summary of Test Method*:

35.2.1 A sample of lime, limestone, or kiln flue dust is weighed into a ceramic crucible, accelerators are added, and the crucible is placed in the furnace. In a pure oxygen environment at the high temperatures generated by the furnace,

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the sample is fluxed and oxidized converting carbon into CO/CO_2 and sulfur into SO_2. The combustion gases are swept through a drying tube to remove the combustion moisture and then swept toward the analyzer. In the analyzer, the gas stream passes through the carbon and sulfur infrared detection cells where measurement occurs.

35.2.2 Both carbon and sulfur are calibrated against a reference material or standard with known carbon and sulfur concentrations. This is to compensate for characteristics of a given apparatus, and for the blank due to accelerators and crucibles.

35.3 *Apparatus*:

35.3.1 *Furnace*:

35.3.1.1 *Induction*—The induction furnace works by supplying power to an inductor coil, which interacts with the sample and accelerators in a ceramic crucible. The power can be controlled by the voltage to the coil and the accelerators used in combusting the sample. Some instruments are supplied with a rheostat used to control the power input to the induction coil. This is used to avoid heating some types of samples too rapidly during the early stages of combustion. Combustion takes place in an oxygen stream, which carries the combustion products through various dust and moisture traps to a detector.

35.3.1.2 *Resistance*—The resistance furnace is an open-ended combustion system that provides an oxygen environment in two separate areas. A purge flow of oxygen around the front of the combustion area provides an oxygen blanket to keep the atmosphere out while acting as a primary source for combustion. The second oxygen flow is delayed to start after the majority of the sample has been combusted and provides a direct lance flow of oxygen onto the sample to combust the remaining sample material.

35.3.2 *Detector*—The detector shall consist of one or more infrared solid-state absorption detectors for carbon or sulfur, or both. The detector may be packaged with the furnace unit as long as interference does not occur during analysis.

NOTE 54—Halogens can be a source of problems. If they are, or are suspected to be, present, it is suggested that a halogen trap be used.

35.3.3 *Combustion Crucibles*—The crucibles must be of adequate thickness and capacity to retain the molten slag and have a sulfur blank as low and consistent as possible.

Warning—There is an explosion hazard associated with the analysis of coal and coke in an induction furnace. Flammable gasses may collect in the IR cell within the closed system. These types of materials should be analyzed in a resistance furnace. See the manufacturer's instructions and cautions before analyzing any samples.

Warning—It is extremely dangerous to change the oscillator tube in the induction furnace electrical cabinet. This should only be done by trained personnel. Serious injury or death can result. See manufacturer's instructions and cautions before attempting to change the oscillator tube.

35.4 *Reagents*—Use reagents recommended by the instrument manufacturer or their equivalent.

35.5 *Calibration*:

35.5.1 *Calibration Standard*—This test method and instrument must be calibrated daily or as indicated by check standards by using a standard of known carbon and sulfur content.

35.5.2 *Check Standard*—The instrument calibration must be validated on a regular basis (See 35.6.3.6) using a check standard. The check standard is used to determine the shift-to-shift variations in the test method and to verify that the electronics are working properly. The check and calibration standard cannot be the same standard. The standards must have a known carbon or sulfur content, or both, either as determined by a reference method, such as the Total Gravimetric Sulfur Method (See Section 24), or certified upon purchase traceable to a nationally recognized standard.

35.6 *Procedure*:

35.6.1 *Instrumental Setup*—Clean and perform routine maintenance on furnace and detector units in accordance with recommended procedures in the manufacturer's operating manual. It is recommended that a minimum of three conditioning samples be analyzed before instrument calibration.

35.6.2 *Calibration Procedure*:

35.6.2.1 Prepare blanks, analyze, reset instrument blank values, and record results. Check with previous blank values and if necessary repeat. Prepare calibration samples, analyze, reset instrument values, and record results.

35.6.2.2 It is recommended that a check standard be prepared and analyzed on a routine basis (See 35.6.3.6). This is to verify that routine samples tested during a specific interval are accurate according to the last instrument calibration.

35.6.2.3 Run laboratory samples as specified in 35.6.3.

35.6.3 *Sample Procedure*:

35.6.3.1 Weigh samples to the nearest 0.1 mg in accordance with the manufacturer's instructions for a specific instrument.

NOTE 55—It has been found through round-robin studies that the practice of pre-igniting samples at 1000 °C causes erratic recovery of sulfur. This practice should not be used.

35.6.3.2 Place the sample in the instrument and perform the analysis.

35.6.3.3 Analysis time is generally 65 s. This can be determined by watching the integration time of materials, and finding out what is a normal time for the type of sample you are running. If analysis time for sulfur exceeds the normal expected time, then changing of the Anhydrone tube is recommended as moisture absorption/desorption of SO_2 may be occurring. Be cautious about the variability of instruments and materials. It is possible to have bimodal curves that indicate a late release of sulfur. When in doubt, check the instrument with a material of known concentration.

NOTE 56—An anhydrone tube that has collected moisture or particulates may "cake" and cause your analysis time to increase. When operating the instrument, you can also expect the analysis time to increase due to dust and moisture from combustion of the sample. The tube should be cleaned, or replaced, at regular intervals.

35.6.3.4 Inspect the crucible for a proper burn. A rough, bumpy surface or appearance of noncombustion indicates that the furnace temperature was too low.

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35.6.3.5 After each analysis, record results and continue. It is recommended that samples be saved until results can be verified by a check standard.

35.6.3.6 Analyze the check standard after a minimum of every 10 samples to verify instrument performance. If the analysis of the check standard is not within tolerance (See Note 57), then find the cause and recalibrate.

NOTE 57—For purposes of this procedure, tolerance can be defined as results which meet the published certified value of the standard within the published standard deviation of the standard's certified value. The use of NIST traceable standards or comparable is recommended.

35.7 *Precision and Bias*—The precision and bias of this test method have not yet been determined.

36. Keywords

36.1 alternative method; aluminum; available lime index; calcium; carbon; carbon dioxide; chemical analysis; free moisture, lime; free moisture, limestone; free silica; hydrated lime; instrumental analysis; iron; limestone; loss on ignition, (LOI); magnesium; manganese; methods, classical; methods, historical; oxides; oxides, unhydrated; phosphorus; quicklime; reference method; silicon dioxide; Standard Reference Material (SRM); strontium; sulfur

APPENDIXES

(Nonmandatory Information)

HISTORICAL ASTM METHODS

X1. TOTAL IRON BY THE POTASSIUM PERMANGANATE TITRATION METHOD

INTRODUCTION

The following test methods have been published as information only and are a collection of classical methods that had historically been widely used by the industry. Because they are presently of limited use, they have been deleted from the main body of reference test methods. Since some laboratories may still wish to perform these analyses, they have been placed in these appendixes. The precision and bias testing has not been performed for these methods. Therefore, users are advised to develop their own laboratory precision and to check against standard reference materials. Subcommittee C07.05 encourages comments and evaluation of these methods.

X1.1 *Scope*—This test method permits a more accurate analysis of the trace amounts of iron that may be present because a larger sample is used.

X1.2 *Summary of Test Method*—The sample is dissolved in HCl and the SiO_2 is dehydrated and separated from the soluble salts by filtration. The small amount of iron left in the insoluble residue is dissolved with sulfuric acid after SiO_2 is expelled with HF, and the recovered iron is combined with the bulk of the iron in the main filtrate. Iron is reduced with $SnCl_2$ and titrated with $KMnO_4$ solution.

X1.3 *Special Solutions:*

X1.3.1 *Manganese Sulfate Solution* (70 g/L)—Dissolve 70 g of crystalline manganese sulfate ($MnSO_4$) in 500 mL of water. Add 140 mL H_3PO_4 and 130 mL H_2SO_4. Dilute to 1 L.

X1.3.2 *Potassium Permanganate, Standard Solution* (0.05 *N*):

X1.3.2.1 Dissolve 1.60 g of potassium permanganate ($KMnO_4$) in 1 L of water and boil gently in a flask for 20 to 30 min. Cool, dilute again to 1 L, stopper, and allow to stand for several days in the dark. Filter through purified asbestos or a wad of glass fiber and standardize against the National Institute of Standards and Technology's standard sample 40C, sodium oxalate ($Na_2C_2O_4$), or equivalent in accordance with X1.3.2.2 through X1.3.2.4.

NOTE X1.1—Alternatively, potassium dichromate may be used in place of potassium permanganate as in the procedure of 13.4.

X1.3.2.2 Transfer 0.15 g of the standard sodium oxalate, dried at 105 °C, to a 400-mL beaker. Add 250 mL of diluted H_2SO_4(5 + 95), which has been previously boiled for 10 min and cooled to 27 ± 3 °C. Stir until the oxalate has dissolved. Add 40 to 42 mL of the standard $KMnO_4$ solution at the rate of 25 to 30 mL/min, while stirring slowly. Let stand until the pink color disappears (about 60 s).

NOTE X1.2—If the pink color should persist because of the addition of too much $KMnO_4$ solution, discard and begin again, adding a few millilitres less of the $KMnO_4$ solution initially.

X1.3.2.3 Heat the contents of the beaker to 60 °C and complete the titration at this temperature by adding $KMnO_4$ solution until a slight pink color persists for 30 s. Add the last 0.5 to 1 mL dropwise, allowing each drop to become decolorized before the next one is added.

X1.3.2.4 One millilitre of standard $KMnO_4$ solution will be approximately equivalent to 0.004 g of ferric oxide (Fe_2O_3). Determine the exact Fe_2O_3 equivalent of the solution from the following:

$$N=(W/V)\times 14.925 \quad \text{(X1.1)}$$

where:

N = normality of $KMnO_4$ solution,

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W = sodium oxalate, g,
V = $KMnO_4$ solution used to titrate the sodium oxalate solution, mL, and
14.925 = sodium oxalate equivalent to 1 mL of 1 *N* $KMnO_4$ solution, g.

Fe_2O_3 equivalent of $KMnO_4 = N \times 0.07984$, where 0.07984 = g Fe_2O_3 equivalent to 1 mL of 1 *N* $KMnO_4$ solution.

X1.4 *Procedure:*

X1.4.1 Weigh 2 to 5 g (depending upon the amount of iron present) of the properly prepared sample into a beaker and add 25 mL of HCl (1 + 1). After the reaction ceases, evaporate the solution to dryness. Add 50 mL of HCl (1 + 4), heat to dissolve the salts, filter the insoluble matter including SiO_2 using a medium-textured paper, then wash the paper and contents several times with hot water. Retain the filter paper. Heat the solution to boiling, add a few drops of methyl red indicator, and precipitate the iron by adding enough NH_4OH to change the color of the indicator from red to distinct yellow. Allow the precipitate to settle slightly, filter, and wash using hot water. Dissolve contents of the paper by placing paper and contents in 50 mL of hot HCl (1 + 3). Filter into a clean beaker and wash. Reserve filtrate.

X1.4.2 Place the paper containing the insoluble matter from the evaporated HCl solution in a platinum crucible. Char the paper without inflaming, at low heat, increase the heat to ash the paper, and ignite at 1000 °C for 15 min. Cool, add 1 mL of H_2SO_4 and 10 to 15 mL of HF, and evaporate to fumes of sulfur trioxide. Cool, dilute the contents of the crucible with water, and warm to dissolve salts. Transfer the acidified solution to the main solution containing the bulk of the iron.

X1.4.3 Heat the solution to near boiling. Reduce the iron by adding $SnCl_2$ dropwise from a pipet, while swirling the beaker constantly, until the yellow color of the ferric iron just disappears (See Note 21). Add 2 or 3 drops of $SnCl_2$ in excess, but no more. Cool the beaker quickly in running water, then add all at once 10 mL of $HgCl_2$ solution. Stir and allow to stand for 3 to 5 min (See Note 22). Transfer with washing to a 600-mL of 1-L beaker containing 300 mL of cold water and 25 mL of the $MnSO_4$ solution. Titrate with standard 0.05 *N* $KMnO_4$ solution, added very slowly while stirring constantly, until a permanent pink end point is obtained. A blank should also be determined.

X1.5 *Calculation*—Calculate the percent iron oxide (Fe_2O_3) to the nearest 0.01 % as follows:

$$Fe_2O_3, \% = (A \times B)/C \times 100 \quad \text{(X1.2)}$$

where:
A = 0.05 *N* $KMnO_4$ solution used in titration, mL,
B = Fe_2O_3 equivalent of $KMnO_4$, and
C = sample weighed, g.

X1.6 *Precision and Bias*—The precision and bias of this test method have not been determined.

X2. STRONTIUM OXIDE BY THE GRAVIMETRIC SULFATE (ETHER) METHOD

X2.1 *Scope*—There may be certain applications that require a separate determination of strontium content or an exact determination of calcium. This test method is designed to determine the SrO present which will allow a correction for the percent CaO as obtained in previous sections.

X2.2 *Summary of Test Method*—The alkaline earth oxides are converted to nitrates. The different solubilities of calcium and strontium nitrate in absolute alcohol and ether are used to separate the two metals from each other. After filtration, the strontium nitrate precipitate is dissolved with water and the strontium precipitated with H_2SO_4 filtered, ignited, and weighed as strontium sulfate ($SrSO_4$).

X2.3 *Procedure:*

X2.3.1 Transfer the weighed oxides obtained in the gravimetric determination of calcium oxide (See Section 5.1.4) to a small flask of 20-mL capacity and dissolve in HNO_3. Evaporate to dryness and heat at 150 to 160 °C. Treat the thoroughly dried nitrates with as little (rarely over 2 mL) of a mixture of equal parts of absolute alcohol and ether as may be needed to dissolve the calcium salt, hastening solution by occasional, gentle agitation. After standing overnight in the stoppered flask, collect the insoluble matter on the smallest possible filter and wash with more of the above mixture of alcohol and ether.

Warning—Ethers tend to form peroxides by air oxidation on standing which are highly explosive. Peroxide containing ethers should not be distilled unless the peroxide is first destroyed by a suitable agent such as sodium sulfate or ferrous sulfate and should not be allowed to stand indefinitely in the laboratory.

X2.3.2 Let the filter air dry, then pass a few millilitres of hot water through the filter to dissolve the strontium nitrate. A few tenths of a milligram of residue may remain, consisting of material other than lime or alkaline earth, whose mass should therefore be deducted from the mass of the lime determined by the gravimetric method (See Section 16).

NOTE X2.1—This correction is unnecessary if it can be shown that the impurities are derived from the glass of the small flask in which the nitrates of calcium and strontium were evaporated.

X2.3.3 To the solution of strontium nitrate, in a small beaker add a few drops of H_2SO_4 and a quantity of alcohol equal to the volume of the nitrate solution. The precipitate of strontium sulfate is allowed to develop and settle at room temperature for a period of 12 h.

X2.3.4 Filter the $SrSO_4$ on a small filter paper, and wash with 50 % alcohol. Ignite at low temperature, cool, moisten with dilute H_2SO_4(1 + 1), evaporate to dryness, again ignite, and weigh as strontium sulfate ($SrSO_4$). The sulfate may be tested spectroscopically for traces of calcium and barium if it is considered necessary.

X2.4 *Calculation:*

X2.4.1 Calculate the mass of strontium oxide as follows:

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$$SrO, \% = (A/B) \times 56.41 \quad (X2.1)$$

where:

A = mass of $SrSO_4$,
B = original mass of sample, g, and
56.41 = molecular ratio of SrO to $SrSO_4$ × 100.

X2.4.2 Deduct the percent SrO from the percent CaO determined in Section 17.

X2.5 *Precision and Bias*—This test method was originally approved for publication before the inclusion of precision and bias statements within standards was mandated. The user is cautioned to verify by the use of reference materials, if available, that the precision and bias of this test method are adequate for the contemplated use.

X3. PHOSPHORUS BY THE TITRIMETRIC METHOD

X3.1 *Scope*—This is a titrimetric test method for determining phosphorus in samples of limestone, quicklime, or lime hydrate. A fairly large sample weight is required because this test method is not sensitive enough for an accurate analysis at the low levels of phosphorus frequently encountered in limestone rock.

X3.2 *Summary of Test Method*—The sample is dissolved in dilute nitric acid, the solution filtered, the residue fused with a little sodium carbonate and its nitric acid solution added to the other. An HF-HNO_3 treatment is included if the rock contains more than 3 % SiO_2. Ammonium molybdate is added to the nitric acid solution to precipitate phosphorus as ammonium phosphomolybdate. The phosphomolybdate is dissolved in an excess of a standard solution of sodium hydroxide which is then back-titrated with standard acid in the presence of phenolphthalein indicator.

X3.3 *Special Solutions:*

X3.3.1 *Ammonium Molybdate Solution:*

X3.3.1.1 *Solution A*—Add 400 mL of nitric acid to 600 mL of water. Mix and cool.

X3.3.1.2 *Solution B*—Dissolve 118 g of 85 % molybdic acid with 400 mL of water and add 80 mL of NH_4OH. Cool.

X3.3.1.3 Add Solution B to Solution A slowly with constant stirring, let solution stand for 24 h. Filter immediately before using.

X3.3.2 *Potassium Nitrate Solution* (10 g/L)—Dissolve 10 g of potassium nitrate (KNO_3) in water freshly boiled to expel CO_2 and cooled. Dilute to 1 L.

X3.3.3 *Sodium Hydroxide, Standard Solution* (0.3 *N*)—Dissolve 12 g of sodium hydroxide (NaOH) in 1 L of water that has been freshly boiled to expel CO_2, and cooled. Add 10 mL of a freshly filtered, saturated solution of barium hydroxide $Ba(OH)_2$ (See Note X3.1). Shake the solution frequently for several hours and filter it. Store in a stoppered flask protected from the CO_2 of the air by means of a guard tube packed with Ascarite. Standardize against standard acid phthalate such as NIST Standard Sample No. 84 or benzoic acid, NIST Standard Sample No. 39 furnished by the National Institute of Standards and Technology[4] , as follows:

NOTE X3.1—$Ba(OH)_2$ precipitates the carbonate as insoluble $BaCO_3$.

X3.3.3.1 Lightly crush 5 to 6 g of standard acid potassium phthalate to a fineness of approximately 10 mesh and dry for 2 h at 100 °C. Place in a small glass-stoppered container and cool in a desiccator.

X3.3.3.2 Accurately weigh about 1 g of the dried standard and transfer it to a 500-mL Erlenmeyer flask.

X3.3.3.3 Add 50 mL of CO_2-free distilled water and swirl gently to dissolve. Add 3 drops of phenolphthalein indicator and titrate with the sodium hydroxide to the first pink color.

X3.3.3.4 Calculate the normality of NaOH as follows:

$$N = W/V \times 204.228 \quad (X3.1)$$

where:

N = normality of NaOH solution,
W = grams of potassium acid phthalate,
V = millilitres of NaOH used, and
204.228 = gram equivalent weight of potassium acid phthalate.

X3.3.3.5 Calculate the phosphorus pentoxide (P_2O_5) equivalent (See Note X3.2) of the NaOH solution in grams per millilitre as follows:

$$E = N \times 0.003086 \quad (X3.2)$$

where:

E = P_2O_5 equivalent of the NaOH solution, g/mL,
N = normality of the NaOH solution, and
0.003086 = P_2O_5 equivalent of 1 *N* NaOH solution, g/mL.

NOTE X3.2—Phosphorus reacts to form ammonium phosphomolybdate $2(NH_4)_3PO_4 \cdot 12MoO_3$. The precipitate reacts with the NaOH solution thus:

2(NH4)3PO4 · 12MoO3 + 46NaOH = 2(NH4)2HPO4
+ (NH4)2MoO4 + 23Na2MoO4 + 22H2O

The equivalent weight of P_2O_5(0.003086) is obtained by dividing the molecular weight of P_2O_5(141.96) by 46 (for 46 moles of NaOH in the equation) and by 1000 (number of millilitres in 1 L). As the actual composition of the precipitate is influenced by the conditions under which the precipitation is made, it is essential that all the details of the procedure be followed closely as prescribed.

X3.3.4 *Sulfuric Acid, Standard* (0.15 *N*)—Dilute 4.0 mL of H_2SO_4 to 1 L with water that has been freshly boiled and cooled. Standardize against the standard NaOH solution. Determine the ratio in strength of the standard H_2SO_4 solution to the standard NaOH solution by dividing the volume of NaOH solution by the volume of H_2SO_4 solution used in titration.

X3.4 *Procedure:*

X3.4.1 Dissolve 10 g of the prepared sample by adding 80 mL of dilute HNO_3(1 + 1) and heating on hot plate. Add 350 mg of ferric nitrate salt ($Fe(NO_3)3 \cdot 9\ H_2O$) (See Note X3.3) and 15 g of ammonium chloride (NH_4Cl), make ammoniacal,

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then add 5 mL of NH_4OH (1 + 1) in excess. Heat to boiling, filter on medium-textured paper and wash with diluted NH_4OH (5 + 95). Discard the filtrate.

NOTE X3.3—Small amounts of phosphorus in the sample can be concentrated very easily this way. The iron combines with the phosphate to form $FePO_4$ that is very insoluble in NH_4OH and affords the analyst the opportunity to separate it from major matrix elements.

X3.4.2 Place the precipitating beaker under the funnel and punch a small hole in the tip of the filter cone by pushing a platinum wire through it. Pour 25 mL of hot HNO_3(1 + 4) through the paper and wash free of iron with hot 5 % HNO_3. Discard the paper.

X3.4.3 Evaporate the nitric acid of solution to dryness and to the dry salts add 30 mL of aqua regia mix (160 mL of HNO_3 + 40 mL HCl (1 + 1). Boil on hot plate until reddish-brown fumes cease to come off and for several minutes thereafter. Add 100 mL of water and boil.

X3.4.4 Filter into a 500-mL Erlenmeyer flask and wash with hot water. Ignite the residue, cool, add 1 mL of HNO_3 and 10 mL of HF and evaporate to dryness (See Note X3.4). Evaporate twice with nitric acid to expel all the HF. Fuse residue with a pinch of Na_2CO_3(0.5 g), dissolve in dilute nitric acid, and add to the filtrate in the Erlenmeyer flask.

NOTE X3.4—The treatment of the residue with HF and HNO_3 may be omitted if the SiO_2 in the sample is low, <3 %.

X3.4.5 Neutralize the nitric acid solution with NH_4OH until iron hydroxide just begins to form. Reacidify with nitric acid slowly until precipitate just dissolves, then add 1 mL of HNO_3 for every 100 mL of solution. Heat the solution to 40 °C and add 40 mL of ammonium molybdate ($(NH_4)_2MoO_4$) (filtered). Stopper the flask, shake for several minutes, and allow to settle overnight (12 h).

X3.4.6 Filter through a retentive paper. Wash the flask and precipitate five times with 15-mL portions of a 1 % solution of KNO_3 and then wash the paper ten times with 10-mL portions of the same solution. The paper should be carefully washed each time from the rim downward and then allowed to drain completely before washing with the next portion of wash solution. (The wash solution must be free of CO_2.)

X3.4.7 Return the paper and precipitate to the flask, add about 75 mL of CO_2-free water, and add enough standard sodium hydroxide solution to decompose the precipitate and leave approximately 2 mL in excess. Record the millilitres of NaOH solution added.

X3.4.8 Stopper the flask and shake to disintegrate the paper. Wash the stopper and sides of the flask with CO_2-free water, add 6 drops of phenolphthalein indicator solution, and titrate the excess sodium hydroxide with standard H_2SO_4 until the pink color of indicator just disappears. Record the millilitres of standard acid.

X3.5 *Calculation:*

NOTE X3.5—Titanium and vanadium interfere in this determination but should not be encountered in significant amounts in this class of material.

X3.5.1 Calculate the percent P_2O_5 as follows:

$$P_2O_5,\ \% = \{E(V_1 - V_2R)\}/W \times 100 \qquad \text{(X3.3)}$$

where:

E = P_2O_5 equivalent of the NaOH solution, g/mL,
V_1 = NaOH solution used, mL,
V_2 = H_2SO_4 solution used, mL,
R = ratio in strength of the NaOH solution to the H_2SO_4 solution, and
W = mass of sample, g.

X3.6 *Precision and Bias*—The precision and bias of this method have not been determined.

X4. MANGANESE BY THE BISMUTHATE METHOD

X4.1 *Scope*—This is the standard titrimetric method that may be used to determine manganese in lime and limestone samples when the concentration of manganese is at least 0.05 %.

X4.2 *Summary of Test Method*—After dissolution of the sample, bivalent manganese is oxidized to permanganic acid by the use of sodium bismuthate ($NaBiO_3$) in nitric acid solution, filtering, washing with nitric acid, adding a measured excess of ferrous sulfate and then determining this excess by titration with a standard solution of permanganate.

X4.3 *Apparatus:*

X4.3.1 *Filtering Crucible*—An asbestos Gooch crucible or a fritted glass crucible of fine porosity.

X4.4 *Reagents:*

X4.4.1 *Sodium Bismuthate*—The sodium bismuthate shall contain enough active oxygen to correspond to at least 75 % $NaBiO_3$.

X4.4.2 *Ferrous Ammonium Sulfate Solution* (12 g/L)—Dissolve 12 g of $Fe(NH_4)_2(SO_4)_2 \cdot 6H_2O$ in 1 L of cool H_2SO_4(5 + 95).

X4.4.3 *Standardization of Ferrous Ammonium Sulfate Solution*—Measure into a 250-mL Erlenmeyer flask, 50 mL of cold nitric acid (3 + 97). Add about 0.5 g of sodium bismuthate ($NaBiO_3$), agitate, dilute with 50 mL of HNO_3(3 + 97) and filter through asbestos or a fritted glass crucible. To the filtrate add 50 mL of the ferrous ammonium sulfate solution and titrate with standard $KMnO_4$ solution to pink color. Determine the ratio (R) of the standard $KMnO_4$ solution to the standard ferrous ammonium sulfate solution by dividing the volume of $KMnO_4$ solution by the volume of $Fe(NH_4)_2(SO_4)_2$ solution used in the titration.

X4.4.4 *Nitric Acid* (3 + 97).

X4.4.5 *Potassium Permanganate Standard Solution* (0.05 *N*)—The same solution as prepared in the Total Iron, Standard Method, Section 13.

X4.5 *Procedure:*

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X4.5.1 Dissolve 10 g of the sample in 100 mL of diluted HNO_3(1 + 1), filter, and wash the residue with hot water. Ignite the residue in platinum, fuse with a little Na_2CO_3, and add the nitric acid solution of the melt to the main filtrate.

X4.5.2 Dilute the solution to 150 mL and add 0.5 g of sodium bismuthate. Heat for a few minutes or until the pink color has disappeared and MnO_2 has precipitated. If MnO_2 does not precipitate, add more bismuthate.

X4.5.3 Clear the solution by slowly adding ferrous ammonium sulfate solution (12 g/L) until the MnO_2 dissolves. Boil to expel brown fumes, cool to 10 to 15 °C, add 0.5 to 1.5 g of $NaBiO_3$(or an amount equal to at least 26 times the weight of manganese present), and agitate vigorously for 1 min. Add 50 mL of cold HNO_3(3 + 97) and filter through a Gooch crucible or fritted glass crucible of fine porosity. Wash with 50 mL of cold HNO_3(3 + 97) or until the washings run colorless.

X4.5.4 Add enough ferrous ammonium sulfate solution (12 g/L) from a buret to discharge completely the permanganate color and then add 1.0 to 2.0 mL in excess. Record the buret reading. Titrate the excess ferrous with 0.05 *N* $KMnO_4$ solution to a faint pink end point.

X4.6 *Calculation*—Calculate the percentage of manganese as follows:

$$\text{Mn, } \% = (V_1 R - V_2)\text{N/W} \times 1.0988 \quad \text{(X4.1)}$$

where:

V_1 = $Fe(NH_4)_2(SO_4)_2$ solution used, mL,
R = ratio in strength of $KMnO_4$ solution to the $Fe(NH_4)_2(SO_4)_2$ solution,
V_2 = $KMnO_4$ solution used, mL,
N = normality of $KMnO_4$ solution,
W = mass of sample, g, and
1.0988 = manganese equivalent of $KMnO_4 \times 100$.

X4.7 *Precision and Bias*—The precision and bias of this test method have not been determined.

X5. FERROUS IRON BY TITRATION WITH POTASSIUM PERMANGANATE

X5.1 *Scope*—The determination of ferrous iron in carbonate rocks is difficult if not impossible in the presence of carbonaceous matter. Nevertheless, acceptable results are sometimes obtainable if there is not much of such matter, and if it does not give a colored solution with acid. But even then, it is only the soluble iron, existing chiefly if not wholly as carbonate, that is determinable.

X5.2 *Summary of Test Method*—The limestone sample is decomposed with dilute sulfuric acid in a steam or CO_2 atmosphere and the soluble ferrous iron is titrated with $KMnO_4$. In the absence of carbonaceous matter, it is possible to determine ferrous iron in the insoluble residue. Metallic iron, if introduced by grinding media, will also be determined as ferrous iron, and precautions should be taken to avoid this contaminate.

X5.3 *Special Solutions:*

X5.3.1 Potassium Permanganate, *Standard Solution* (0.05 *N*)—Prepare as in Total Iron, Standard Method (See Section 13).

X5.3.2 *Diphenylamine Sulfonate Indicator Solution*—Dissolve 0.2 g of sodium diphenylamine sulfonate in 100 mL of water.

X5.3.3 *Potassium Dichromate, Standard Solution* (0.028 *N*)—Weigh 2.728 g of dry National Institute of Standards and Technology potassium dichromate ($K_2Cr_2O_7$) or other pure, dry $K_2Cr_2O_7$ and dilute to 2 L in a volumetric flask. The solution contains the equivalent of 0.002 g FeO/mL.

X5.4 *Procedure:*

X5.4.1 *In Absence of Carbonaceous Matter:*

X5.4.1.1 Weigh several grams of prepared sample into a flask of about 250-mL capacity, add 25 mL of water, and boil water until air is expelled. While still boiling, add diluted H_2SO_4(1 + 1) a little at a time until effervescence ceases, then add a few millilitres in excess (See Note X5.1). Calcium sulfate precipitates, but the iron will remain in solution. Remove the flame and tightly insert a stopper through which passes a small stopcock funnel. When the flask is cool, or nearly so, pour cold water into the funnel and cautiously open the cock so the water may be drawn into the flask. Keep filling the funnel as fast as it empties until the solution in the flask amounts to 100 to 150 mL (See Note X5.2). Immediately titrate the iron solution in the flask with 0.05 *N* $KMnO_4$ solution (See Note X5.3). The ferrous iron thus found is mostly, if not altogether, that existing as carbonate.

Warning—The contents of the flask may erupt violently unless this addition is made with care.

NOTE X5.1—With a carbonate that is wholly decomposable without the aid of heat, solution may be accomplished in a flask filled with CO_2, using cold acid. This mode of acid decomposition lessens the danger of attacking silicates if these are present.

NOTE X5.2—Such precaution to exclude air is hardly necessary, in most cases; however, since in the presence of H_2SO_4 the oxidation of ferrous iron is exceedingly slow. It is ordinarily quite sufficient to equalize the internal and external pressures by opening the cock, removing the stopper, and pouring in cold water.

NOTE X5.3—If MnO_2 is absent, the potassium dichromate method of titration may be substituted and HCl used instead of H_2SO_4. In this case, there is no separation of an insoluble calcium salt which renders easier the subsequent determination of iron in the insoluble residue.

X5.4.2 *Ferrous Iron in the Insoluble Residue in Absence of Carbonaceous Matter:*

X5.4.2.1 Filter the titrated solution (See X5.4.1.1) through a medium-sized, hardened filter. Transfer the residue completely to the paper and wash with hot water. Rinse the contents of the paper into a large platinum crucible (80 to 100-mL capacity) with a snugly fitting cover of transparent polypropylene and having a plastic tube for the introduction of CO_2 and a small plastic funnel for the addition of acid and the escape of vapors and steam.

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X5.4.2.2 Add 18 mL of $H_2SO_4(1 + 1)$ and air-free water until the crucible is at least half full. Drop in a small coil of platinum wire to prevent bumping, fit the cover tightly, and pass CO_2 through for at least 10 min as the mixture is gradually brought to boiling. Stop the stream of gas as soon as steam escapes, immediately add 7 mL of HF through the funnel, and boil gently for 10 to 15 min, or until decomposition is complete.

X5.4.2.3 Prepare an 800-mL beaker containing 500 mL of air-free water, 12 g of boric acid, and 20 mL of $H_2SO_4(1 + 3)$. Quickly transfer the crucible cover and contents to the 800-mL beaker. With the aid of a stirring rod, remove the crucible and cover from the beaker and rinse it off with water. Add 3 to 5 drops of sodium diphenylamine sulfonate indicator and titrate with the $K_2Cr_2O_7$ standard solution to a purple color that persists for 20 to 30 s.

NOTE X5.4—Potassium dichromate is preferred because it reacts much less rapidly on organic matter than permanganate.

X5.4.3 *Ferrous Iron in Presence of Insoluble Carbonaceous Matter:*

X5.4.3.1 Weigh 2 to 5 g of prepared sample into a flask of about 250-mL capacity, pass in a stream of CO_2 through a delivery tube and introduce dilute $H_2SO_4(1 + 1)$ till effervescence ceases, then add a few more millilitres in excess. Heat if necessary to decompose the limestone (See Note X5.5) and filter quickly (See Note X5.6) through asbestos or sintered glass fiber (in an atmosphere of carbon dioxide if much iron is present). Wash the filter and the residue a few times with water and titrate the filtrate at once with 0.05 *N* $KMnO_4$ solutions. Discard the residue (See Note X5.7).

NOTE X5.5—Heat is not needed with limestone if active agitation is used; but with dolomites, heat is necessary.

NOTE X5.6—It is important to allow the acid to act no longer than is necessary and to filter quickly.

NOTE X5.7—A determination of the ferrous iron in the insoluble matter is usually not worth attempting because of the admixed organic matter.

X5.5 *Calculation*—Calculate the percent FeO as follows:

$$\text{FeO, } \% = V \times N \times 7.184/W \quad \text{(X5.1)}$$

where:

V = titrant ($KMnO_4$ or $K_2Cr_2O_7$), mL,
N = normality of $KMnO_4$ or $K_2Cr_2O_7$ solution,
W = weight of sample, g, and
7.184 = equivalent weight of FeO × 100.

X5.6 *Precision and Bias*—The precision and bias of this test method have not been determined.

X6. TEST METHOD FOR FREE CALCIUM OXIDE IN HIGH-CALCIUM HYDRATED LIME[8]

X6.1 Scope

X6.1.1 This test method covers the determination of the amount of free calcium oxide (CaO) in high-calcium hydrated lime capable of being hydrated by steam at atmospheric pressure.

X6.2 Summary of Test Method

X6.2.1 This test method is based on the principle of gain in weight of CaO when it is hydrated to form calcium hydroxide ($Ca(OH)_2$).

X6.2.2 The sample is dried, subjected to steam at atmospheric pressure, again dried, and the gain in weight calculated to CaO.

X6.3 Apparatus

X6.3.1 *Drying Oven,* thermostatically controlled, CO_2-free atmosphere.

X6.3.2 *Analytical Balance.*

X6.3.3 *Steam Bath,* as shown in Fig. X6.1.

X6.4 Procedure

X6.4.1 Weigh a clean, dry, 10-mL Erlenmeyer flask on an analytical balance.

NOTE X6.1—Once started, complete the test without interruption.

X6.4.2 Add to the flask, by means of a widestem funnel, 3 to 5 g of the lime to be tested. Reweigh to get the exact sample weight.

NOTE X6.2—The flask should be kept stoppered at all times, except when weighing, drying, or steaming.

X6.4.3 Place the flask in the drying oven that has been previously heated to 120 °C, and maintain at this temperature for 30 min. Remove, stopper, cool in a desiccator, and weigh.

NOTE X6.3—Oven atmosphere can be kept CO_2 free by placing therein a container of soda lime, quicklime, or other suitable CO_2-absorbing medium.

X6.4.4 Place the flask and the sample in a vigorously boiling steam bath and steam for 30 min. Protect the flask in the steam bath by a drip shield during the steaming period. Remove the flask to the oven, dry for 30 min at 120 °C, stopper, cool in a desiccator, and weigh.

X6.4.5 Record all weighings to the fourth decimal place.

X6.5 Calculation

X6.5.1 Calculate the percentage of water and CaO as follows:

$$\text{Free water, } \% = [(W_1 - W_2)/S] \times 100 \quad \text{(X6.1)}$$

$$\text{Free CaO, } \% = \frac{(W_3 - W_2) \times 3.114}{S} \times 100$$

where:

W_1 = weight of sample and flask before drying,
W_2 = weight of sample and flask after drying,
W_3 = weight of sample and flask after steaming and drying, and
S = weight of sample.

[8] This test method was taken from the Appendix of Specification C 911.

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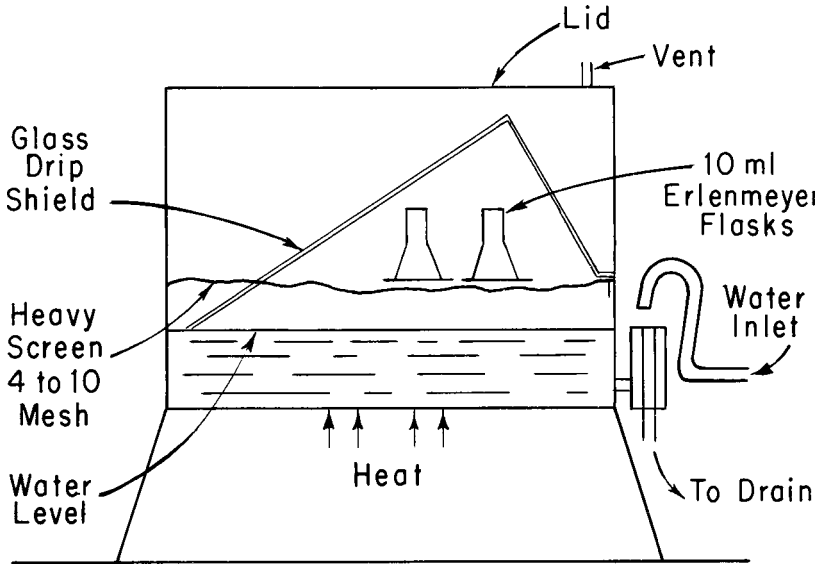

FIG. X6.1 Steam Chamber

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Designation: C 28/C 28M – 00 (Reapproved 2005)

Standard Specification for Gypsum Plasters[1]

This standard is issued under the fixed designation C 28/C 28M; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

This standard has been approved for use by agencies of the Department of Defense.

1. Scope

1.1 This specification covers four gypsum plasters; gypsum mill-mixed plaster, gypsum neat plaster, gypsum wood fibered plaster and gypsum gauging plaster.

NOTE 1—Specification C 842 contains application procedures for interior gypsum plaster.

1.2 The values stated in either inch-pound or SI (metric) units are to be regarded separately as the standard. Within the text, the SI units are shown in brackets. The values stated in each system shall be used independently of the other. Values from the two systems shall not be combined. This paragraph does not apply to the appendix.

1.3 The text of this standard references notes and footnotes which provide explanatory material. These notes and footnotes (excluding those in tables and figures) shall not be considered as requirements of the standard.

1.4 The following safety hazards caveat pertains only to the test methods described in the appendix to this specification. *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

2. Referenced Documents

2.1 *ASTM Standards:* [2]

C 11 Terminology Relating to Gypsum and Related Building Materials and Systems

C 22 Specification for Gypsum

C 35 Specification for Inorganic Aggregates for Use in Gypsum Plaster

C 471M Test Methods for Chemical Analysis of Gypsum and Gypsum Products

C 472 Test Methods for Physical Testing of Gypsum, Gypsum Plasters, and Gypsum Concrete

C 778 Specification for Standard Sand

C 842 Specification for Application of Interior Gypsum Plaster

E 11 Specification for Wire-Cloth and Sieves for Testing Purposes

3. Terminology

3.1 *Definitions*—Definitions shall be in accordance with Terminology C 11.

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *gypsum gauging plaster for finish coat*, *n*—a calcined gypsum plaster designed to be mixed with lime putty for the finish coat.

3.2.2 *gypsum neat plaster*, *n*—calcined gypsum mixed at the mill with other ingredients to control working quality and setting time.

3.2.2.1 *Discussion*—Neat plaster is either fibered or unfibered. The addition of aggregate is required on the job.

3.2.3 *gypsum mill-mixed plaster*, *n*—calcined gypsum plaster, mixed at the mill with a mineral aggregate, designed to function as a base coat to receive various finish coats.

3.2.3.1 *Discussion*—Other materials are not prohibited from being added to control setting time and other desirable working properties.

3.2.4 *gypsum wood-fibered plaster*, *n*—A calcined gypsum plaster in which wood fiber is used as an aggregate.

4. Materials

4.1 *Calcined Gypsum*—Calcined gypsum shall be manufactured from gypsum meeting the requirements of Specification C 22.

4.2 *Vermiculite Aggregate*, Specification C 35.

4.3 *Perlite Aggregate*, Specification C 35.

[1] This specification is under the jurisdiction of ASTM Committee C11 on Gypsum and Related Building Materials and Systems and is the direct responsibility of Subcommittee C11.01 on Specifications and Test Methods for Gypsum Products.

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[2] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

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4.4 *Sand Aggregate*, Specification C 35.
4.5 *Ottawa Sand*, Specification C 778 for 20–30 sand.
4.6 *Wood Fiber*, non staining wood fiber.

TABLE 1 Composition and Physical Properties

Product	Aggregate Type	Composition, Aggregate per 100 lb of Plaster, not more than		Setting Time[A]	Compressive Strength[B] not less than	
		ft³	m³	hours	psi	MPa
Mill-Mixed Plaster over Lath Base	Vermiculite	2	0.057	1½ to 8	450	3.1
	Perlite	2	0.057	1½ to 8	600	4.1
	Sand	2.5	0.071	1½ to 8	700	4.8
Mill-Mixed Plaster over Masonry	Vermiculite	3	0.085	1½ to 8	325	2.2
	Perlite	3	0.085	1½ to 8	400	2.8
	Sand	3	0.085	1½ to 8	400	2.8
Neat Plaster	none	...	...	2 to 16[C]	750[D]	5.2
Wood Fibered Plaster	none	...	...	1½ to 8	1200	8.3
Gauging Plaster	none	...	...	[E]	1200	8.3

[A] Setting time shall be not less than the shorter time shown nor more than the longer time shown.
[B] Compressive strengths are as tested at the setting times specified in Test Methods C 472.
[C] When mixed with 3 parts by weight of Ottawa sand.
[D] When mixed with 2 parts by weight of Ottawa sand.
[E] When not retarded, the setting time shall be not less than 20 nor more than 40 minutes and, when retarded, not less than 40 minutes.

5. Composition

5.1 When tested in accordance with Test Methods C 471M, calcined gypsum shall contain no less than 66.0 weight % $CaSO_4 \cdot ½ H_2O$.

5.2 *Aggregate*—plasters shall contain a volume of aggregate not more than that shown in Table 1.

NOTE 2—An approximation of the aggregate content may be made by using the test methods in the appendix. A more accurate method for determining sand in plaster is described in Test Methods C 471M. Test Methods C 471M requires that the original sand and plaster components be available separately.

6. Mechanical Properties

6.1 *Compressive Strength*—When tested in accordance with Test Methods C 472 the compressive strength shall be as specified in Table 1.

6.2 *Setting Time*—When tested in accordance with Test Methods C 472 using the Vicat method, the setting time shall be as specified in Table 1.

NOTE 3—*Setting Time*—Attention is directed to conditions affecting job set of gypsum plasters that are usually beyond the control of the producer. Materials added at the site of application such as water and aggregates affect job sets. In addition, the various bases with different absorptive values may affect job performance. The plaster may be retarded to provide a setting time of not more than 4 h. Setting times more than 2 h may result in lower compressive strengths.

6.3 *Fineness of Gauging Plaster for Finish Coat*—When tested in accordance with Test Method C 472 all shall pass a No. 14 [1.4 mm] sieve and not less than 60 % shall pass a No. 100 [150 µm] sieve.[3]

7. Sampling

7.1 At least 1 % of the packages, but not less than 5 packages, shall be sampled. Packages to be sampled shall be selected at random. Samples shall be taken both from the outer portion and the center of each package. The materials so obtained shall be thoroughly mixed to provide a composite sample of not less than 7 lb [3.2 kg]. This composite sample shall be placed immediately in a clean, dry, airtight container for delivery to the laboratory.

8. Packaging and Package Marking

8.1 Gypsum plasters shall be dry and free of lumps, and shall be shipped in packages.

8.2 When shipped for resale, the following information shall be legibly marked on each package or on a tag of suitable size attached to the package:

8.2.1 Name of manufacturer or seller,
8.2.2 Brand, and
8.2.3 Net weight of the package.

9. Inspection

9.1 Inspection of the gypsum plaster shall be agreed upon between the purchaser and the supplier as part of the purchase agreement.

10. Rejection

10.1 Rejection of gypsum plaster that fails to conform to the requirements of this specification shall be reported to the producer or supplier promptly and in writing. The notice of rejection shall contain a statement documenting requirements of this specification.

11. Certification

11.1 When specified in the purchase agreement, a manufacturer's or supplier's report shall be furnished at the time of shipment certifying that the product is in compliance with this specification.

12. Keywords

12.1 aggregate; gauging plaster; gypsum plaster; mill-mixed plaster; neat plaster; plaster; wood fibered plaster

[3] Detailed requirements for these sieves are given in Specification E 11.

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APPENDIX

(Nonmandatory Information)

X1. DETERMINATION OF AGGREGATE CONTENT OF MILL-MIXED PLASTER

INTRODUCTION

The determination of the aggregate content of mill-mixed plaster is normally not precise. Most gypsum plasters contain natural impurities that cannot be separated from the aggregate by either mechanical or chemical means. A better estimate can be made by obtaining the approximate purity of the gypsum plaster used in the product from the manufacturer.

An accurate method for determining sand in set plaster is contained in Test Methods C 471M. Separate specimens of the sand and gypsum plaster used in the mill-mixed plaster are required for Test Methods C 471M.

X1.1 Scope

X1.1.1 This appendix covers mechanical and chemical test methods for separating the aggregate from gypsum plaster.

X1.2 Mechanical Separation

X1.2.1 *Significance and Use*:

X1.2.1.1 This test method is used to estimate the weight or volume of aggregate contained in mill-mixed gypsum plasters by mechanical separation.

X1.2.2 *Interferences*:

X1.2.2.1 It is assumed by this test method that the aggregate meets Specification C 35 and that only a minor portion of the aggregate passes through a 100-mesh (150 μm) sieve. To the extent that a greater portion passes the 100 mesh sieve, the results will show lower values for volume of the aggregate, and higher values for the weight of the gypsum plaster, than actually in the sample.

X1.2.3 *Apparatus*:

X1.2.3.1 *Sieve*—Specification E 11, 100 mesh (150 μm).

X1.2.3.2 *Balance*—with a capacity of not less than 100 g and a precision of at least 0.1 g.

X1.2.4 *Procedure*:

X1.2.4.1 Weigh 100 g of the sample to ±0.1 g.

X1.2.4.2 Sieve the 100 g specimen through the 100 mesh (150 μm) sieve. Examine the material on the sieve to be sure small lumps or agglomerates of plaster are not retained. The retained portion is assumed to be aggregate. If the weight ratio of the aggregate and plaster is to be determined, weigh each portion to the nearest 0.1 g. If the volume ratio of aggregate to the weight of plaster is to be determined, measure the volume of aggregate retained on the sieve to the nearest mL and weigh the material passing through the sieve to the nearest 0.1 g.

X1.2.5 *Calculation and Report*:

X1.2.5.1 *Weight Ratio*— Calculate and report the weight ratio as pounds of aggregate/100 lb (45 kg) of plaster per Eq X1.1.

$$W_R = \frac{w_a}{w_p} \times 100 \quad \text{(X1.1)}$$

where:

W_R = weight ratio, lbs of aggregate/100 lbs (45 kg) of plaster,
w_a = weight of aggregate, g, and,
w_p = weight of plaster, g.

X1.2.5.2 *Volume Ratio*— Calculate and report the volume ratio as cubic feet of aggregate/100 lbs (45 kg) of plaster per Eq X1.2.

$$V_R = \frac{v_a}{w_p} \times 1.60 \quad \text{(X1.2)}$$

where:

V_R = Volume ratio, cubic feet of aggregate per 100 lbs of plaster,
v_a = volume of aggregate, mL, and
w_p = weight of plaster, g.

X1.2.6 *Precision and Bias*:

X1.2.6.1 It is not practical to specify the precision or the bias of this test method because of the unknown variabilities in the particle sizes of the aggregates.

X1.3 Chemical Separation

X1.3.1 *Significance and Use*:

X1.3.1.1 This test method is used to estimate the weight or volume of aggregate contained in mill-mixed gypsum plasters by chemical separation.

X1.3.2 *Interferences*:

X1.3.2.1 It is assumed in this test method that all of the material insoluble in ammonium acetate is aggregate and the soluble material is plaster. In many cases there is a significant amount of insoluble material in the plaster. To the extent that this is true it will produce erroneous calculated amounts of aggregate and plaster. If possible, obtain the approximate purity of the plaster from the manufacturer. This information will greatly increase the accuracy of the results.

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X1.3.2.2 In the volume calculation it is assumed that the volume of the insoluble material in the plaster is insignificant compared to the volume of the aggregate. This is usually the case.

X1.3.3 *Apparatus*:

X1.3.3.1 *Analytical Balance*—with a precision of 0.001 g.

X1.3.3.2 *Drying Oven*— capable of maintaining a temperature of 100 to 110°C.

X1.3.4 *Reagents*:

X1.3.4.1 *Ammonium Acetate Solution (250 g/L)*—dissolve 250 g of ammonium acetate ($NH_4C_2H_3O_2$) in water and dilute to 1 L.

X1.3.4.2 *Ammonium Hydroxide (1+59)*—Mix one volume of concentrated (NH_4OH) (sp gr 0.90) with 59 volumes of water.

X1.3.5 *Procedure*:

X1.3.5.1 Accurately weigh 40 ± 0.05 g of the sample into a 1-L beaker. Add 600 to 700 mL of ($NH_4C_2H_3O_2$) solution that is slightly alkaline to litmus paper. If acidic, add a few mL of (NH_4OH) (1+59) to the stock ($NH_4C_2H_3O_2$) solution to render it slightly alkaline prior to the addition of the test sample.

X1.3.5.2 Warm the suspension to a temperature of 70 ± 5°C and stir continuously for 20 to 30 min. Filter the warm suspension through a small Buchner funnel or Gooch crucible in which filter paper has previously been formed, the funnel and mat having been dried at 110°C to a constant weight within 0.01 g. Refilter the first 100 mL of the filtrate. Wash the aggregate remaining in the beaker onto the filter with an additional 100 mL of warm ($NH_4C_2H_3O_2$) solution. Wash the beaker and residue with 200 to 300 mL of water, dry the funnel and aggregate at 100°C to constant weight.

X1.3.6 *Calculation and Report*:

X1.3.6.1 *Weight Ratio*— Calculate and report the weight ratio as pounds of aggregate/100 lbs (45 kg) of plaster per Eq X1.3.

$$W_R = \frac{w_1 - \frac{w_1 - w_2}{p}}{\frac{w_1 - w_2}{p}} \times 100 \qquad \text{(X1.3)}$$

where:

W_R = weight ratio, lbs of aggregate/100 lbs (45 kg) of plaster,
w_1 = Weight of original specimen, g,
w_2 = weight of insoluble residue retained on filter, g, and
p = Purity of gypsum plaster expressed as a decimal (that is, 85 % purity = 0.85). If purity is unknown use 0.9 (90 %) as an estimate.

X1.3.6.2 *Volume Ratio*— Calculate the volume ratio as cubic feet of aggregate/100 lbs (45 kg) of plaster per Eq X1.4.

$$V_R = \frac{v_1}{\frac{w_1 - w_2}{p}} \times 1.6 \qquad \text{(X1.4)}$$

where:

V_R = volume ratio, cubic feet of aggregate/100 lbs (45 kg) of plaster,
v_1 = volume of insoluble residue retained on filter, mL,
w_1 = weight of original specimen, g,
w_2 = weight of insoluble residue retained on filter, g, and
p = purity of gypsum plaster expressed as a decimal (that is, 85 % purity = 0.85). If purity is unknown use 0.9 (90 %) as an estimate.

X1.3.7 *Precision and Bias*:

X1.3.7.1 It is not practical to specify the precision or the bias of this test method because of the unknown variabilities in the purity of the plaster.

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Designation: C29/C29M – 09

American Association of State
Highway and Transportation Officials Standard
AASHTO No.: T19/T19M

Standard Test Method for Bulk Density ("Unit Weight") and Voids in Aggregate[1]

This standard is issued under the fixed designation C29/C29M; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

This standard has been approved for use by agencies of the Department of Defense.

1. Scope*

1.1 This test method covers the determination of bulk density ("unit weight") of aggregate in a compacted or loose condition, and calculated voids between particles in fine, coarse, or mixed aggregates based on the same determination. This test method is applicable to aggregates not exceeding 125 mm [5 in.] in nominal maximum size.

NOTE 1—Unit weight is the traditional terminology used to describe the property determined by this test method, which is weight per unit volume (more correctly, mass per unit volume or density).

1.2 The values stated in either SI units or inch-pound units are to be regarded separately as standard, as appropriate for a specification with which this test method is used. An exception is with regard to sieve sizes and nominal size of aggregate, in which the SI values are the standard as stated in Specification E11. Within the text, inch-pound units are shown in brackets. The values stated in each system may not be exact equivalents; therefore, each system shall be used independently of the other. Combining values from the two systems may result in nonconformance with the standard.

1.3 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

2. Referenced Documents

2.1 *ASTM Standards:*[2]

C125 Terminology Relating to Concrete and Concrete Aggregates

C127 Test Method for Density, Relative Density (Specific Gravity), and Absorption of Coarse Aggregate

C128 Test Method for Density, Relative Density (Specific Gravity), and Absorption of Fine Aggregate

C138/C138M Test Method for Density (Unit Weight), Yield, and Air Content (Gravimetric) of Concrete

C670 Practice for Preparing Precision and Bias Statements for Test Methods for Construction Materials

C702 Practice for Reducing Samples of Aggregate to Testing Size

D75 Practice for Sampling Aggregates

D123 Terminology Relating to Textiles

E11 Specification for Woven Wire Test Sieve Cloth and Test Sieves

2.2 *AASHTO Standard:*

T19/T19M Method of Test for Unit Weight and Voids in Aggregate[3]

3. Terminology

3.1 *Definitions*—Definitions are in accordance with Terminology C125 unless otherwise indicated.

3.1.1 *bulk density*, *n—of aggregate*, the mass of a unit volume of bulk aggregate material, in which the volume includes the volume of the individual particles and the volume of the voids between the particles. Expressed in kg/m^3 [lb/ft^3].

3.1.2 *unit weight*, *n*—weight (mass) per unit volume. (Deprecated term used–preferred term **bulk density**.)

3.1.2.1 *Discussion*—Weight is equal to the mass of the body multiplied by the acceleration due to gravity. Weight may be expressed in absolute units (newtons, poundals) or in gravitational units (kgf, lbf), for example: on the surface of the earth, a body with a mass of 1 kg has a weight of 1 kgf (approximately 9.81 N), or a body with a mass of 1 lb has a weight of 1 lbf (approximately 4.45 N or 32.2 poundals). Since weight is equal to mass times the acceleration due to gravity, the weight of a body will vary with the location where the weight is determined, while the mass of the body remains constant. On the surface of the earth, the force of gravity imparts to a body that is free to fall an acceleration of approximately 9.81 m/s^2 [32.2 ft/s^2]. **D123**

[1] This test method is under the jurisdiction of ASTM Committee C09 on Concrete and Concrete Aggregates and is the direct responsibility of Subcommittee C09.20 on Normal Weight Aggregates.

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[2] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

[3] Available from American Association of State Highway and Transportation Officials (AASHTO), 444 N. Capitol St., NW, Suite 249, Washington, DC 20001, http://www.transportation.org.

***A Summary of Changes section appears at the end of this standard.**

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3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *voids, n—in unit volume of aggregate,* the space between particles in an aggregate mass not occupied by solid mineral matter.

3.2.1.1 *Discussion*—Voids within particles, either permeable or impermeable, are not included in voids as determined by this test method.

4. Significance and Use

4.1 This test method is often used to determine bulk density values that are necessary for use for many methods of selecting proportions for concrete mixtures.

4.2 The bulk density also may be used for determining mass/volume relationships for conversions in purchase agreements. However, the relationship between degree of compaction of aggregates in a hauling unit or stockpile and that achieved in this test method is unknown. Further, aggregates in hauling units and stockpiles usually contain absorbed and surface moisture (the latter affecting bulking), while this test method determines the bulk density on a dry basis.

4.3 A procedure is included for computing the percentage of voids between the aggregate particles based on the bulk density determined by this test method.

5. Apparatus

5.1 *Balance*—A balance or scale accurate within 0.1 % of the test load at any point within the range of use, graduated to at least 0.05 kg [0.1 lb]. The range of use shall be considered to extend from the mass of the measure empty to the mass of the measure plus its contents at 1920 kg/m^3 [120 lb/ft^3].

5.2 *Tamping Rod*—A round, straight steel rod, 16 mm [⅝ in.] in diameter and approximately 600 mm [24 in.] in length, having the tamping end, or both ends, rounded to a hemispherical tip, the diameter of which is 16 mm [⅝ in.].

5.3 *Measure*—A cylindrical metal measure, preferably provided with handles. It shall be watertight, with the top and bottom true and even, and sufficiently rigid to retain its form under rough usage. The measure shall have a height approximately equal to the diameter, but in no case shall the height be less than 80 % nor more than 150 % of the diameter. The capacity of the measure shall conform to the limits in Table 1 for the aggregate size to be tested. The thickness of metal in the measure shall be as described in Table 2. The top rim shall be smooth and plane within 0.25 mm [0.01 in.] and shall be parallel to the bottom within 0.5° (See Note 2). The interior wall of the measure shall be a smooth and continuous surface.

TABLE 1 Capacity of Measures

Nominal Maximum Size of Aggregate		Capacity of Measure[A]	
mm	in.	m^3[L]	ft^3
12.5	½	0.0028[2.8]	1/10
25.0	1	0.0093 [9.3]	⅓
37.5	1½	0.014 [14]	½
75	3	0.028 [28]	1
100	4	0.070 [70]	2½
125	5	0.100 [100]	3½

[A] The indicated size of measure shall be used to test aggregates of a nominal maximum size equal to or smaller than that listed. The actual volume of the measure shall be at least 95 % of the nominal volume listed.

TABLE 2 Requirements for Measures

Capacity of Measure	Thickness of Metal, min		
	Bottom	Upper 38 mm or 1½ in. of wall[A]	Remainder of wall
Less than 11 L	5.0 mm	2.5 mm	2.5 mm
11 to 42 L, incl	5.0 mm	5.0 mm	3.0 mm
over 42 to 80 L, incl	10.0 mm	6.4 mm	3.8 mm
over 80 to 133 L, incl	13.0 mm	7.6 mm	5.0 mm
Less than 0.4 ft^3	0.20 in.	0.10 in.	0.10 in.
0.4 ft^3 to 1.5 ft^3, incl	0.20 in.	0.20 in.	0.12 in.
over 1.5 to 2.8 ft^3, incl	0.40 in.	0.25 in.	0.15 in.
over 2.8 to 4.0 ft^3, incl	0.50 in.	0.30 in.	0.20 in.

[A] The added thickness in the upper portion of the wall may be obtained by placing a reinforcing band around the top of the measure.

NOTE 2—The top rim is satisfactorily plane if a 0.25-mm [0.01-in.] feeler gage cannot be inserted between the rim and a piece of 6-mm [¼-in.] or thicker plate glass laid over the measure. The top and bottom are satisfactorily parallel if the slope between pieces of plate glass in contact with the top and bottom does not exceed 0.87 % in any direction.

5.3.1 If the measure is to also be used for testing for bulk density of freshly-mixed concrete according to Test Method C138/C138M, the measure shall be made of steel or other suitable metal not readily subject to attack by cement paste. Reactive materials, such as aluminum alloys are permitted, where as a consequence of an initial reaction, a surface film is formed which protects the metal against further corrosion.

5.3.2 Measures larger than nominal 28 L [1 ft^3] capacity shall be made of steel for rigidity, or the minimum thicknesses of metal listed in Table 2 shall be suitably increased.

5.4 *Shovel or Scoop*—A shovel or scoop of convenient size for filling the measure with aggregate.

5.5 *Calibration Equipment*:

5.5.1 *Plate Glass*—A piece of plate glass, at least 6 mm [¼ in.] thick and at least 25 mm [1 in.] larger than the diameter of the measure to be calibrated.

5.5.2 *Grease*—A supply of water-pump, chassis, or similar grease.

5.5.3 *Thermometer*—A thermometer having a range of at least 10 to 32 °C [50 to 90 °F] and that is readable to at least 0.5 °C [1 °F].

5.5.4 *Balance*—A balance as described in 5.1.

6. Sampling

6.1 Obtain the sample in accordance with Practice D75, and reduce to test sample size in accordance with Practice C702.

7. Test Sample

7.1 The size of the sample shall be approximately 125 to 200 % of the quantity required to fill the measure, and shall be handled in a manner to avoid segregation. Dry the aggregate sample to essentially constant mass, preferably in an oven at 110 ± 5 °C [230 ± 9 °F].

8. Calibration of Measure

8.1 Measures shall be recalibrated at least once a year or whenever there is reason to question the accuracy of the calibration.

8.2 Determine the mass of the plate glass and measure the nearest 0.05 kg [0.1 lb].

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8.3 Place a thin layer of grease on the rim of the measure to prevent leakage of water from the measure.

8.4 Fill the measure with water that is at room temperature and cover with the plate glass in such a way as to eliminate bubbles and excess water. Remove any water that may have overflowed onto the measure or plate glass.

8.5 Determine the mass of the water, plate glass, and measure to the nearest 0.05 kg [0.1 lb].

8.6 Measure the temperature of the water to the nearest 0.5 °C [1 °F] and determine its density from Table 3, interpolating if necessary.

8.7 Calculate the volume, *V*, of the measure. Alternatively, calculate the factor, F, for the measure.

NOTE 3—For the calculation of bulk density, the volume of the measure in SI units should be expressed in cubic metres, or the factor as $1/m^3$. However, for convenience the size of the measure may be expressed in litres.

9. Selection of Procedure

9.1 The shoveling procedure for loose bulk density shall be used only when specifically stipulated. Otherwise, the compact bulk density shall be determined by the rodding procedure for aggregates having a nominal maximum size of 37.5 mm [1½ in.] or less, or by the jigging procedure for aggregates having a nominal maximum size greater than 37.5 mm [1½ in.] and not exceeding 125 mm [5 in.].

10. Rodding Procedure

10.1 Fill the measure one-third full and level the surface with the fingers. Rod the layer of aggregate with 25 strokes of the tamping rod evenly distributed over the surface. Fill the measure two-thirds full and again level and rod as above. Finally, fill the measure to overflowing and rod again in the manner previously mentioned. Level the surface of the aggregate with the fingers or a straightedge in such a way that any slight projections of the larger pieces of the coarse aggregate approximately balance the larger voids in the surface below the top of the measure.

10.2 In rodding the first layer, do not allow the rod to strike the bottom of the measure forcibly. In rodding the second and third layers, use vigorous effort, but not more force than to cause the tamping rod to penetrate to the previous layer of aggregate.

NOTE 4—In rodding the larger sizes of coarse aggregate, it may not be possible to penetrate the layer being consolidated, especially with angular aggregates. The intent of the procedure will be accomplished if vigorous effort is used.

TABLE 3 Density of Water

Temperature		kg/m³	lb/ft³
°C	°F		
15.6	60	999.01	62.366
18.3	65	998.54	62.336
21.1	70	997.97	62.301
23.0	73.4	997.54	62.274
23.9	75	997.32	62.261
26.7	80	996.59	62.216
29.4	85	995.83	62.166

10.3 Determine the mass of the measure plus its contents, and the mass of the measure alone, and record the values to the nearest 0.05 kg [0.1 lb].

11. Jigging Procedure

11.1 Fill the measure in three approximately equal layers as described in 10.1, compacting each layer by placing the measure on a firm base, such as a cement-concrete floor, raising the opposite sides alternately about 50 mm [2 in.], and allowing the measure to drop in such a manner as to hit with a sharp, slapping blow. The aggregate particles, by this procedure, will arrange themselves in a densely compacted condition. Compact each layer by dropping the measure 50 times in the manner described, 25 times on each side. Level the surface of the aggregate with the fingers or a straightedge in such a way that any slight projections of the larger pieces of the coarse aggregate approximately balance the larger voids in the surface below the top of the measure.

11.2 Determine the mass of the measure plus its contents, and the mass of the measure alone, and record the values to the nearest 0.05 kg [0.1 lb].

12. Shoveling Procedure

12.1 Fill the measure to overflowing by means of a shovel or scoop, discharging the aggregate from a height not to exceed 50 mm [2 in.] above the top of the measure. Exercise care to prevent, so far as possible, segregation of the particle sizes of which the sample is composed. Level the surface of the aggregate with the fingers or a straightedge in such a way that any slight projections of the larger pieces of the coarse aggregate approximately balance the larger voids in the surface below the top of the measure.

12.2 Determine the mass of the measure plus its contents, and the mass of the measure alone, and record the values to the nearest 0.05 kg [0.1 lb].

13. Calculation

13.1 *Bulk Density*—Calculate the bulk density for the rodding, jigging, or shoveling procedure as follows:

$$M = (G - T)/V \quad (1)$$

or

$$M = (G - T) \times F \quad (2)$$

where:

M = bulk density of the aggregate, kg/m^3 [lb/ft^3],
G = mass of the aggregate plus the measure, kg [lb],
T = mass of the measure, kg [lb],
V = volume of the measure, m^3 [ft^3], and
F = factor for measure, m^{-3} [ft^{-3}].

13.1.1 The bulk density determined by this test method is for aggregate in an oven-dry condition. If the bulk density in terms of saturated-surface-dry (SSD) condition is desired, use the exact procedure in this test method, and then calculate the SSD bulk density using the following formula:

$$Mssd = M[1 + (A/100)] \quad (3)$$

where:

M_{SSD} = bulk density in SSD condition, kg/m^3 [lb/ft^3], and

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A = % absorption, determined in accordance with Test Method C127 or Test Method C128.

13.2 *Void Content*—Calculate the void content in the aggregate using the bulk density determined by either the rodding, jigging, or shoveling procedure, as follows:

$$\%\ Voids = 100[(S \times W) - M]/(S \times W) \quad (4)$$

where:

M = bulk density of the aggregate, kg/m^3 [lb/ft^3],
S = bulk specific gravity (dry basis) as determined in accordance with Test Method C127 or Test Method C128, and
W = density of water, 998 kg/m^3 [62.3 lb/ft^3].

13.3 *Volume of Measure*—Calculate the volume of a measure as follows:

$$V = (W - M)/D \quad (5)$$

$$F = D/(W - M) \quad (6)$$

where:

V = volume of the measure, m^3 [ft^3]
W = mass of the water, plate glass, and measure, kg [lb]
M = mass of the plate glass and measure, kg [lb]
D = density of the water for the measured temperature, kg/m^3 [lb/ft^3], and
F = factor for the measure, 1/m^3 [1/ft^3]

14. Report

14.1 Report the results for the bulk density to the nearest 10 kg/m^3 [1 lb/ft^3] as follows:

14.1.1 Bulk density by rodding, or
14.1.2 Bulk density by jigging, or
14.1.3 Loose bulk density.

14.2 Report the results for the void content to the nearest 1 % as follows:

14.2.1 Voids in aggregate compacted by rodding, %, or
14.2.2 Voids in aggregate compacted by jigging, %, or
14.2.3 Voids in loose aggregate, %.

15. Precision and Bias

15.1 The following estimates of precision for this test method are based on results from the AASHTO Materials Reference Laboratory (AMRL) Proficiency Sample Program, with testing conducted using this test method and AASHTO Method T 19/T19M. There are no significant differences between the two test methods. The data are based on the analyses of more than 100 paired test results from 40 to 100 laboratories.

15.2 *Coarse Aggregate (bulk density)*:

15.2.1 *Single-Operator Precision*—The single-operator standard deviation has been found to be 14 kg/m^3 [0.88 lb/ft^3] (1s). Therefore, results of two properly conducted tests by the same operator on similar material should not differ by more than 40 kg/m^3 [2.5 lb/ft^3] (d2s).

15.2.2 *Multilaboratory Precision*—The multilaboratory standard deviation has been found to be 30 kg/m^3 [1.87 lb/ft^3] (1s). Therefore, results of two properly conducted tests from two different laboratories on similar material should not differ by more than 85 kg/m^3 [5.3 lb/ft^3] (d2s).

15.2.3 These numbers represent, respectively, the (1s) and (d2s) limits as described in Practice C670. The precision estimates were obtained from the analysis of AMRL proficiency sample data for bulk density by rodding of normal weight aggregates having a nominal maximum aggregate size of 25.0 mm [1 in.], and using a 14-L [½-ft^3] measure.

15.3 *Fine Aggregate (bulk density)*:

15.3.1 *Single-Operator Precision*—The single-operator standard deviation has been found to be 14 kg/m^3 [0.88 lb/ft^3] (1s). Therefore, results of two properly conducted tests by the same operator on similar material should not differ by more than 40 kg/m^3 [2.5 lb/ft^3] (d2s).

15.3.2 *Multilaboratory Precision*—The multilaboratory standard deviation has been found to be 44 kg/m^3 [2.76 lb/ft^3] (1s). Therefore, results of two properly conducted tests from two different laboratories on similar material should not differ by more than 125 kg/m^3 [7.8 lb/ft^3] (d2s).

15.3.3 These numbers represent, respectively, the (1s) and (d2s) limits as described in Practice C670. The precision estimates were obtained from the analysis of AMRL proficiency sample data for loose bulk density from laboratories using a 2.8-L [⅒-ft^3] measure.

15.4 No precision data on void content are available. However, as the void content in aggregate is calculated from bulk density and bulk specific gravity, the precision of the voids content reflects the precision of these measured parameters given in 15.2 and 15.3 of this test method and in Test Methods C127 and C128.

15.5 *Bias*—The procedure in this test method for measuring bulk density and void content has no bias because the values for bulk density and void content can be defined only in terms of a test method.

16. Keywords

16.1 aggregates; bulk density; coarse aggregate; density; fine aggregate; unit weight; voids in aggregates

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SUMMARY OF CHANGES

Committee C09 has identified the location of selected changes to this test method since the last issue, C29/C29M – 07, that may impact the use of this test method. (Approved December 1, 2009)

(*1*) Revised 5.5.1.

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Designation: C29/C29M – 09

American Association of State
Highway and Transportation Officials Standard
AASHTO No.: T19/T19M

Standard Test Method for Bulk Density ("Unit Weight") and Voids in Aggregate[1]

This standard is issued under the fixed designation C29/C29M; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

This standard has been approved for use by agencies of the Department of Defense.

1. Scope*

1.1 This test method covers the determination of bulk density ("unit weight") of aggregate in a compacted or loose condition, and calculated voids between particles in fine, coarse, or mixed aggregates based on the same determination. This test method is applicable to aggregates not exceeding 125 mm [5 in.] in nominal maximum size.

NOTE 1—Unit weight is the traditional terminology used to describe the property determined by this test method, which is weight per unit volume (more correctly, mass per unit volume or density).

1.2 The values stated in either SI units or inch-pound units are to be regarded separately as standard, as appropriate for a specification with which this test method is used. An exception is with regard to sieve sizes and nominal size of aggregate, in which the SI values are the standard as stated in Specification E11. Within the text, inch-pound units are shown in brackets. The values stated in each system may not be exact equivalents; therefore, each system shall be used independently of the other. Combining values from the two systems may result in nonconformance with the standard.

1.3 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

2. Referenced Documents

2.1 *ASTM Standards:*[2]

C125 Terminology Relating to Concrete and Concrete Aggregates

C127 Test Method for Density, Relative Density (Specific Gravity), and Absorption of Coarse Aggregate

C128 Test Method for Density, Relative Density (Specific Gravity), and Absorption of Fine Aggregate

C138/C138M Test Method for Density (Unit Weight), Yield, and Air Content (Gravimetric) of Concrete

C670 Practice for Preparing Precision and Bias Statements for Test Methods for Construction Materials

C702 Practice for Reducing Samples of Aggregate to Testing Size

D75 Practice for Sampling Aggregates

D123 Terminology Relating to Textiles

E11 Specification for Woven Wire Test Sieve Cloth and Test Sieves

2.2 *AASHTO Standard:*

T19/T19M Method of Test for Unit Weight and Voids in Aggregate[3]

3. Terminology

3.1 *Definitions*—Definitions are in accordance with Terminology C125 unless otherwise indicated.

3.1.1 *bulk density*, *n—of aggregate*, the mass of a unit volume of bulk aggregate material, in which the volume includes the volume of the individual particles and the volume of the voids between the particles. Expressed in kg/m^3 [lb/ft^3].

3.1.2 *unit weight*, *n*—weight (mass) per unit volume. (Deprecated term used–preferred term **bulk density**.)

3.1.2.1 *Discussion*—Weight is equal to the mass of the body multiplied by the acceleration due to gravity. Weight may be expressed in absolute units (newtons, poundals) or in gravitational units (kgf, lbf), for example: on the surface of the earth, a body with a mass of 1 kg has a weight of 1 kgf (approximately 9.81 N), or a body with a mass of 1 lb has a weight of 1 lbf (approximately 4.45 N or 32.2 poundals). Since weight is equal to mass times the acceleration due to gravity, the weight of a body will vary with the location where the weight is determined, while the mass of the body remains constant. On the surface of the earth, the force of gravity imparts to a body that is free to fall an acceleration of approximately 9.81 m/s^2 [32.2 ft/s^2]. **D123**

[1] This test method is under the jurisdiction of ASTM Committee C09 on Concrete and Concrete Aggregates and is the direct responsibility of Subcommittee C09.20 on Normal Weight Aggregates.

Current edition approved Dec. 1, 2009. Published January 2010. Originally approved in 1920. Last previous edition approved in 2007 as C29/C29M – 07. DOI: 10.1520/C0029_C0029M-09.

[2] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

[3] Available from American Association of State Highway and Transportation Officials (AASHTO), 444 N. Capitol St., NW, Suite 249, Washington, DC 20001, http://www.transportation.org.

***A Summary of Changes section appears at the end of this standard.**

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3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *voids, n—in unit volume of aggregate,* the space between particles in an aggregate mass not occupied by solid mineral matter.

3.2.1.1 *Discussion*—Voids within particles, either permeable or impermeable, are not included in voids as determined by this test method.

4. Significance and Use

4.1 This test method is often used to determine bulk density values that are necessary for use for many methods of selecting proportions for concrete mixtures.

4.2 The bulk density also may be used for determining mass/volume relationships for conversions in purchase agreements. However, the relationship between degree of compaction of aggregates in a hauling unit or stockpile and that achieved in this test method is unknown. Further, aggregates in hauling units and stockpiles usually contain absorbed and surface moisture (the latter affecting bulking), while this test method determines the bulk density on a dry basis.

4.3 A procedure is included for computing the percentage of voids between the aggregate particles based on the bulk density determined by this test method.

5. Apparatus

5.1 *Balance*—A balance or scale accurate within 0.1 % of the test load at any point within the range of use, graduated to at least 0.05 kg [0.1 lb]. The range of use shall be considered to extend from the mass of the measure empty to the mass of the measure plus its contents at 1920 kg/m^3 [120 lb/ft^3].

5.2 *Tamping Rod*—A round, straight steel rod, 16 mm [⅝ in.] in diameter and approximately 600 mm [24 in.] in length, having the tamping end, or both ends, rounded to a hemispherical tip, the diameter of which is 16 mm [⅝ in.].

5.3 *Measure*—A cylindrical metal measure, preferably provided with handles. It shall be watertight, with the top and bottom true and even, and sufficiently rigid to retain its form under rough usage. The measure shall have a height approximately equal to the diameter, but in no case shall the height be less than 80 % nor more than 150 % of the diameter. The capacity of the measure shall conform to the limits in Table 1 for the aggregate size to be tested. The thickness of metal in the measure shall be as described in Table 2. The top rim shall be smooth and plane within 0.25 mm [0.01 in.] and shall be parallel to the bottom within 0.5° (See Note 2). The interior wall of the measure shall be a smooth and continuous surface.

TABLE 1 Capacity of Measures

Nominal Maximum Size of Aggregate		Capacity of Measure[A]	
mm	in.	m^3[L]	ft^3
12.5	½	0.0028[2.8]	1/10
25.0	1	0.0093 [9.3]	⅓
37.5	1½	0.014 [14]	½
75	3	0.028 [28]	1
100	4	0.070 [70]	2½
125	5	0.100 [100]	3½

[A] The indicated size of measure shall be used to test aggregates of a nominal maximum size equal to or smaller than that listed. The actual volume of the measure shall be at least 95 % of the nominal volume listed.

TABLE 2 Requirements for Measures

Capacity of Measure	Thickness of Metal, min		
	Bottom	Upper 38 mm or 1½ in. of wall[A]	Remainder of wall
Less than 11 L	5.0 mm	2.5 mm	2.5 mm
11 to 42 L, incl	5.0 mm	5.0 mm	3.0 mm
over 42 to 80 L, incl	10.0 mm	6.4 mm	3.8 mm
over 80 to 133 L, incl	13.0 mm	7.6 mm	5.0 mm
Less than 0.4 ft^3	0.20 in.	0.10 in.	0.10 in.
0.4 ft^3 to 1.5 ft^3, incl	0.20 in.	0.20 in.	0.12 in.
over 1.5 to 2.8 ft^3, incl	0.40 in.	0.25 in.	0.15 in.
over 2.8 to 4.0 ft^3, incl	0.50 in.	0.30 in.	0.20 in.

[A] The added thickness in the upper portion of the wall may be obtained by placing a reinforcing band around the top of the measure.

NOTE 2—The top rim is satisfactorily plane if a 0.25-mm [0.01-in.] feeler gage cannot be inserted between the rim and a piece of 6-mm [¼-in.] or thicker plate glass laid over the measure. The top and bottom are satisfactorily parallel if the slope between pieces of plate glass in contact with the top and bottom does not exceed 0.87 % in any direction.

5.3.1 If the measure is to also be used for testing for bulk density of freshly-mixed concrete according to Test Method C138/C138M, the measure shall be made of steel or other suitable metal not readily subject to attack by cement paste. Reactive materials, such as aluminum alloys are permitted, where as a consequence of an initial reaction, a surface film is formed which protects the metal against further corrosion.

5.3.2 Measures larger than nominal 28 L [1 ft^3] capacity shall be made of steel for rigidity, or the minimum thicknesses of metal listed in Table 2 shall be suitably increased.

5.4 *Shovel or Scoop*—A shovel or scoop of convenient size for filling the measure with aggregate.

5.5 *Calibration Equipment*:

5.5.1 *Plate Glass*—A piece of plate glass, at least 6 mm [¼ in.] thick and at least 25 mm [1 in.] larger than the diameter of the measure to be calibrated.

5.5.2 *Grease*—A supply of water-pump, chassis, or similar grease.

5.5.3 *Thermometer*—A thermometer having a range of at least 10 to 32 °C [50 to 90 °F] and that is readable to at least 0.5 °C [1 °F].

5.5.4 *Balance*—A balance as described in 5.1.

6. Sampling

6.1 Obtain the sample in accordance with Practice D75, and reduce to test sample size in accordance with Practice C702.

7. Test Sample

7.1 The size of the sample shall be approximately 125 to 200 % of the quantity required to fill the measure, and shall be handled in a manner to avoid segregation. Dry the aggregate sample to essentially constant mass, preferably in an oven at 110 ± 5 °C [230 ± 9 °F].

8. Calibration of Measure

8.1 Measures shall be recalibrated at least once a year or whenever there is reason to question the accuracy of the calibration.

8.2 Determine the mass of the plate glass and measure the nearest 0.05 kg [0.1 lb].

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8.3 Place a thin layer of grease on the rim of the measure to prevent leakage of water from the measure.

8.4 Fill the measure with water that is at room temperature and cover with the plate glass in such a way as to eliminate bubbles and excess water. Remove any water that may have overflowed onto the measure or plate glass.

8.5 Determine the mass of the water, plate glass, and measure to the nearest 0.05 kg [0.1 lb].

8.6 Measure the temperature of the water to the nearest 0.5 °C [1 °F] and determine its density from Table 3, interpolating if necessary.

8.7 Calculate the volume, *V*, of the measure. Alternatively, calculate the factor, F, for the measure.

NOTE 3—For the calculation of bulk density, the volume of the measure in SI units should be expressed in cubic metres, or the factor as $1/m^3$. However, for convenience the size of the measure may be expressed in litres.

9. Selection of Procedure

9.1 The shoveling procedure for loose bulk density shall be used only when specifically stipulated. Otherwise, the compact bulk density shall be determined by the rodding procedure for aggregates having a nominal maximum size of 37.5 mm [1½ in.] or less, or by the jigging procedure for aggregates having a nominal maximum size greater than 37.5 mm [1½ in.] and not exceeding 125 mm [5 in.].

10. Rodding Procedure

10.1 Fill the measure one-third full and level the surface with the fingers. Rod the layer of aggregate with 25 strokes of the tamping rod evenly distributed over the surface. Fill the measure two-thirds full and again level and rod as above. Finally, fill the measure to overflowing and rod again in the manner previously mentioned. Level the surface of the aggregate with the fingers or a straightedge in such a way that any slight projections of the larger pieces of the coarse aggregate approximately balance the larger voids in the surface below the top of the measure.

10.2 In rodding the first layer, do not allow the rod to strike the bottom of the measure forcibly. In rodding the second and third layers, use vigorous effort, but not more force than to cause the tamping rod to penetrate to the previous layer of aggregate.

NOTE 4—In rodding the larger sizes of coarse aggregate, it may not be possible to penetrate the layer being consolidated, especially with angular aggregates. The intent of the procedure will be accomplished if vigorous effort is used.

TABLE 3 Density of Water

Temperature		kg/m³	lb/ft³
°C	°F		
15.6	60	999.01	62.366
18.3	65	998.54	62.336
21.1	70	997.97	62.301
23.0	73.4	997.54	62.274
23.9	75	997.32	62.261
26.7	80	996.59	62.216
29.4	85	995.83	62.166

10.3 Determine the mass of the measure plus its contents, and the mass of the measure alone, and record the values to the nearest 0.05 kg [0.1 lb].

11. Jigging Procedure

11.1 Fill the measure in three approximately equal layers as described in 10.1, compacting each layer by placing the measure on a firm base, such as a cement-concrete floor, raising the opposite sides alternately about 50 mm [2 in.], and allowing the measure to drop in such a manner as to hit with a sharp, slapping blow. The aggregate particles, by this procedure, will arrange themselves in a densely compacted condition. Compact each layer by dropping the measure 50 times in the manner described, 25 times on each side. Level the surface of the aggregate with the fingers or a straightedge in such a way that any slight projections of the larger pieces of the coarse aggregate approximately balance the larger voids in the surface below the top of the measure.

11.2 Determine the mass of the measure plus its contents, and the mass of the measure alone, and record the values to the nearest 0.05 kg [0.1 lb].

12. Shoveling Procedure

12.1 Fill the measure to overflowing by means of a shovel or scoop, discharging the aggregate from a height not to exceed 50 mm [2 in.] above the top of the measure. Exercise care to prevent, so far as possible, segregation of the particle sizes of which the sample is composed. Level the surface of the aggregate with the fingers or a straightedge in such a way that any slight projections of the larger pieces of the coarse aggregate approximately balance the larger voids in the surface below the top of the measure.

12.2 Determine the mass of the measure plus its contents, and the mass of the measure alone, and record the values to the nearest 0.05 kg [0.1 lb].

13. Calculation

13.1 *Bulk Density*—Calculate the bulk density for the rodding, jigging, or shoveling procedure as follows:

$$M = (G - T)/V \quad (1)$$

or

$$M = (G - T) \times F \quad (2)$$

where:

M = bulk density of the aggregate, kg/m^3 [lb/ft^3],
G = mass of the aggregate plus the measure, kg [lb],
T = mass of the measure, kg [lb],
V = volume of the measure, m^3 [ft^3], and
F = factor for measure, m^{-3} [ft^{-3}].

13.1.1 The bulk density determined by this test method is for aggregate in an oven-dry condition. If the bulk density in terms of saturated-surface-dry (SSD) condition is desired, use the exact procedure in this test method, and then calculate the SSD bulk density using the following formula:

$$Mssd = M[1 + (A/100)] \quad (3)$$

where:

M_{SSD} = bulk density in SSD condition, kg/m^3 [lb/ft^3], and

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A = % absorption, determined in accordance with Test Method C127 or Test Method C128.

13.2 *Void Content*—Calculate the void content in the aggregate using the bulk density determined by either the rodding, jigging, or shoveling procedure, as follows:

$$\%\ Voids = 100[(S \times W) - M]/(S \times W) \quad (4)$$

where:

M = bulk density of the aggregate, kg/m^3 [lb/ft^3],
S = bulk specific gravity (dry basis) as determined in accordance with Test Method C127 or Test Method C128, and
W = density of water, 998 kg/m^3 [62.3 lb/ft^3].

13.3 *Volume of Measure*—Calculate the volume of a measure as follows:

$$V = (W - M)/D \quad (5)$$

$$F = D/(W - M) \quad (6)$$

where:

V = volume of the measure, m^3 [ft^3]
W = mass of the water, plate glass, and measure, kg [lb]
M = mass of the plate glass and measure, kg [lb]
D = density of the water for the measured temperature, kg/m^3 [lb/ft^3], and
F = factor for the measure, 1/m^3 [1/ft^3]

14. Report

14.1 Report the results for the bulk density to the nearest 10 kg/m^3 [1 lb/ft^3] as follows:

14.1.1 Bulk density by rodding, or
14.1.2 Bulk density by jigging, or
14.1.3 Loose bulk density.

14.2 Report the results for the void content to the nearest 1 % as follows:

14.2.1 Voids in aggregate compacted by rodding, %, or
14.2.2 Voids in aggregate compacted by jigging, %, or
14.2.3 Voids in loose aggregate, %.

15. Precision and Bias

15.1 The following estimates of precision for this test method are based on results from the AASHTO Materials Reference Laboratory (AMRL) Proficiency Sample Program, with testing conducted using this test method and AASHTO Method T 19/T19M. There are no significant differences between the two test methods. The data are based on the analyses of more than 100 paired test results from 40 to 100 laboratories.

15.2 *Coarse Aggregate (bulk density)*:

15.2.1 *Single-Operator Precision*—The single-operator standard deviation has been found to be 14 kg/m^3 [0.88 lb/ft^3] (1s). Therefore, results of two properly conducted tests by the same operator on similar material should not differ by more than 40 kg/m^3 [2.5 lb/ft^3] (d2s).

15.2.2 *Multilaboratory Precision*—The multilaboratory standard deviation has been found to be 30 kg/m^3 [1.87 lb/ft^3] (1s). Therefore, results of two properly conducted tests from two different laboratories on similar material should not differ by more than 85 kg/m^3 [5.3 lb/ft^3] (d2s).

15.2.3 These numbers represent, respectively, the (1s) and (d2s) limits as described in Practice C670. The precision estimates were obtained from the analysis of AMRL proficiency sample data for bulk density by rodding of normal weight aggregates having a nominal maximum aggregate size of 25.0 mm [1 in.], and using a 14-L [½-ft^3] measure.

15.3 *Fine Aggregate (bulk density)*:

15.3.1 *Single-Operator Precision*—The single-operator standard deviation has been found to be 14 kg/m^3 [0.88 lb/ft^3] (1s). Therefore, results of two properly conducted tests by the same operator on similar material should not differ by more than 40 kg/m^3 [2.5 lb/ft^3] (d2s).

15.3.2 *Multilaboratory Precision*—The multilaboratory standard deviation has been found to be 44 kg/m^3 [2.76 lb/ft^3] (1s). Therefore, results of two properly conducted tests from two different laboratories on similar material should not differ by more than 125 kg/m^3 [7.8 lb/ft^3] (d2s).

15.3.3 These numbers represent, respectively, the (1s) and (d2s) limits as described in Practice C670. The precision estimates were obtained from the analysis of AMRL proficiency sample data for loose bulk density from laboratories using a 2.8-L [⅒-ft^3] measure.

15.4 No precision data on void content are available. However, as the void content in aggregate is calculated from bulk density and bulk specific gravity, the precision of the voids content reflects the precision of these measured parameters given in 15.2 and 15.3 of this test method and in Test Methods C127 and C128.

15.5 *Bias*—The procedure in this test method for measuring bulk density and void content has no bias because the values for bulk density and void content can be defined only in terms of a test method.

16. Keywords

16.1 aggregates; bulk density; coarse aggregate; density; fine aggregate; unit weight; voids in aggregates

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SUMMARY OF CHANGES

Committee C09 has identified the location of selected changes to this test method since the last issue, C29/C29M – 07, that may impact the use of this test method. (Approved December 1, 2009)

(*1*) Revised 5.5.1.

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Designation: C 31/C 31M – 09

Standard Practice for Making and Curing Concrete Test Specimens in the Field[1]

This standard is issued under the fixed designation C 31/C 31M; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

This standard has been approved for use by agencies of the Department of Defense.

1. Scope*

1.1 This practice covers procedures for making and curing cylinder and beam specimens from representative samples of fresh concrete for a construction project.

1.2 The concrete used to make the molded specimens shall be sampled after all on-site adjustments have been made to the mixture proportions, including the addition of mix water and admixtures. This practice is not satisfactory for making specimens from concrete not having measurable slump or requiring other sizes or shapes of specimens.

1.3 The values stated in either SI units or inch-pound units are to be regarded separately as standard. The values stated in each system may not be exact equivalents; therefore, each system shall be used independently of the other. Combining values from the two systems may result in non-conformance with the standard.

1.4 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.* (**Warning**—Fresh hydraulic cementitious mixtures are caustic and may cause chemical burns to exposed skin and tissue upon prolonged exposure.[2])

1.5 The text of this standard references notes which provide explanatory material. These notes shall not be considered as requirements of the standard.

2. Referenced Documents

2.1 *ASTM Standards:*[3]

C 125 Terminology Relating to Concrete and Concrete Aggregates

C 138/C 138M Test Method for Density (Unit Weight), Yield, and Air Content (Gravimetric) of Concrete

C 143/C 143M Test Method for Slump of Hydraulic-Cement Concrete

C 172 Practice for Sampling Freshly Mixed Concrete

C 173/C 173M Test Method for Air Content of Freshly Mixed Concrete by the Volumetric Method

C 231 Test Method for Air Content of Freshly Mixed Concrete by the Pressure Method

C 330 Specification for Lightweight Aggregates for Structural Concrete

C 403/C 403M Test Method for Time of Setting of Concrete Mixtures by Penetration Resistance

C 470/C 470M Specification for Molds for Forming Concrete Test Cylinders Vertically

C 511 Specification for Mixing Rooms, Moist Cabinets, Moist Rooms, and Water Storage Tanks Used in the Testing of Hydraulic Cements and Concretes

C 617 Practice for Capping Cylindrical Concrete Specimens

C 1064/C 1064M Test Method for Temperature of Freshly Mixed Hydraulic-Cement Concrete

2.2 *American Concrete Institute Publication:*[4]

CP-1 Concrete Field Testing Technician, Grade I

309R Guide for Consolidation of Concrete

3. Terminology

3.1 For definitions of terms used in this practice, refer to Terminology C 125.

4. Significance and Use

4.1 This practice provides standardized requirements for making, curing, protecting, and transporting concrete test specimens under field conditions.

4.2 If the specimens are made and standard cured, as stipulated herein, the resulting strength test data when the specimens are tested are able to be used for the following purposes:

4.2.1 Acceptance testing for specified strength,

4.2.2 Checking adequacy of mixture proportions for strength, and

[1] This practice is under the jurisdiction of ASTM Committee C09 on Concrete and Concrete Aggregates and is the direct responsibility of Subcommittee C09.61 on Testing for Strength.

Current edition approved May 1, 2009. Published May 2009. Originally approved in 1920. Last previous edition approved in 2008 as C 31/C 31M – 08b.

[2] See Section on Safety Precautions, Manual of Aggregate and Concrete Testing, *Annual Book of ASTM Standards*, Vol. 04.02.

[3] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

[4] Available from American Concrete Institute (ACI), P.O. Box 9094, Farmington Hills, MI 48333-9094, http://www.aci-int.org.

***A Summary of Changes section appears at the end of this standard.**

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4.2.3 Quality control.

4.3 If the specimens are made and field cured, as stipulated herein, the resulting strength test data when the specimens are tested are able to be used for the following purposes:

4.3.1 Determination of whether a structure is capable of being put in service,

4.3.2 Comparison with test results of standard cured specimens or with test results from various in-place test methods,

4.3.3 Adequacy of curing and protection of concrete in the structure, or

4.3.4 Form or shoring removal time requirements.

5. Apparatus

5.1 *Molds, General*— Molds for specimens or fastenings thereto in contact with the concrete shall be made of steel, cast iron, or other nonabsorbent material, nonreactive with concrete containing portland or other hydraulic cements. Molds shall hold their dimensions and shape under all conditions of use. Molds shall be watertight during use as judged by their ability to hold water poured into them. Provisions for tests of water leakage are given in the Test Methods for Elongation, Absorption, and Water Leakage section of Specification C 470/C 470M. A suitable sealant, such as heavy grease, modeling clay, or microcrystalline wax shall be used where necessary to prevent leakage through the joints. Positive means shall be provided to hold base plates firmly to the molds. Reusable molds shall be lightly coated with mineral oil or a suitable nonreactive form release material before use.

5.2 *Cylinder Molds*— Molds for casting concrete test specimens shall conform to the requirements of Specification C 470/C 470M.

5.3 *Beam Molds*—Beam molds shall be of the shape and dimensions required to produce the specimens stipulated in 6.2. The inside surfaces of the molds shall be smooth. The sides, bottom, and ends shall be at right angles to each other and shall be straight and true and free of warpage. Maximum variation from the nominal cross section shall not exceed ⅛ in. [3 mm] for molds with depth or breadth of 6 in. [150 mm] or more. Molds shall produce specimens at least as long but not more than 1/16 in. [2 mm] shorter than the required length in 6.2.

5.4 *Tamping Rod*—A round, straight, steel rod with a diameter conforming to the requirements in Table 1. The length of the tamping rod shall be at least 4 in. [100 mm] greater than the depth of the mold in which rodding is being performed, but not greater than 24 in. [600 mm] in overall length (see Note 1). The length tolerance for the tamping rod shall be ± ⅛ in. [4 mm]. The rod shall have the tamping end or both ends rounded to a hemispherical tip of the same diameter as the rod.

NOTE 1—A rod length of 16 in. [400 mm] to 24 in. [600 mm] meets the requirements of the following: Practice C 31/C 31M, Test Method C 138/C 138M, Test Method C 143/C 143M, Test Method C 173/C 173M, and Test Method C 231.

5.5 *Vibrators*—Internal vibrators shall be used. The vibrator frequency shall be at least 9000 vibrations per minute [150 Hz] while the vibrator is operating in the concrete. The diameter of a round vibrator shall be no more than one-fourth the diameter of the cylinder mold or one-fourth the width of the beam mold. Other shaped vibrators shall have a perimeter equivalent to the circumference of an appropriate round vibrator. The combined length of the vibrator shaft and vibrating element shall exceed the depth of the section being vibrated by at least 3 in. [75 mm]. The vibrator frequency shall be checked periodically with a vibrating-reed tachometer or other suitable device.

TABLE 1 Tamping Rod Diameter Requirements

Diameter of Cylinder or Width of Beam in. [mm]	Diameter or Rod in. [mm]
<6 [150]	⅜ ± 1/16 [10 ± 2]
≥6 [150]	⅝ ± 1/16 [16 ± 2]

NOTE 2—For information on size and frequency of various vibrators and a method to periodically check vibrator frequency see ACI 309R.

5.6 *Mallet*—A mallet with a rubber or rawhide head weighing 1.25 ± 0.50 lb [0.6 ± 0.2 kg] shall be used.

5.7 *Placement Tools*—of a size large enough so each amount of concrete obtained from the sampling receptacle is representative and small enough so concrete is not spilled during placement in the mold. For placing concrete in a cylinder mold, the acceptable tool is a scoop. For placing concrete in a beam mold, either a shovel or scoop is permitted.

5.8 *Finishing Tools*—a handheld float or a trowel.

5.9 *Slump Apparatus*— The apparatus for measurement of slump shall conform to the requirements of Test Method C 143/C 143M.

5.10 *Sampling Receptacle*—The receptacle shall be a suitable heavy gauge metal pan, wheelbarrow, or flat, clean nonabsorbent board of sufficient capacity to allow easy remixing of the entire sample with a shovel or trowel.

5.11 *Air Content Apparatus*—The apparatus for measuring air content shall conform to the requirements of Test Methods C 173/C 173M or C 231.

5.12 *Temperature Measuring Devices*—The temperature measuring devices shall conform to the applicable requirements of Test Method C 1064/C 1064M.

6. Testing Requirements

6.1 *Cylindrical Specimens*—Compressive or splitting tensile strength specimens shall be cylinders cast and allowed to set in an upright position. The number and size of cylinders cast shall be as directed by the specifier of the tests. In addition, the length shall be twice the diameter and the cylinder diameter shall be at least 3 times the nominal maximum size of the coarse aggregate. When the nominal maximum size of the coarse aggregate exceeds 2 in. [50 mm], the concrete sample shall be treated by wet sieving through a 2-in. [50-mm] sieve as described in Practice C 172. For acceptance testing for specified compressive strength, cylinders shall be 6 by 12 in. [150 by 300 mm] or 4 × 8 in. [100 × 200 mm] (Note 3).

NOTE 3—When molds in SI units are required and not available, equivalent inch-pound unit size mold should be permitted.

6.2 *Beam Specimens*— Flexural strength specimens shall be beams of concrete cast and hardened in the horizontal position. The number of beams cast shall be as directed by the specifier of the tests. The length shall be at least 2 in. [50 mm] greater than three times the depth as tested. The ratio of width to depth

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as molded shall not exceed 1.5. The standard beam shall be 6 by 6 in. [150 by 150 mm] in cross section, and shall be used for concrete with nominal maximum size coarse aggregate up to 2 in. [50 mm]. When the nominal maximum size of the coarse aggregate exceeds 2 in. [50 mm], the smaller cross sectional dimension of the beam shall be at least three times the nominal maximum size of the coarse aggregate. Unless required by project specifications, beams made in the field shall not have a width or depth of less than 6 in. [150 mm].

6.3 *Field Technicians*—The field technicians making and curing specimens for acceptance testing shall be certified ACI Field Testing Technicians, Grade I or equivalent. Equivalent personnel certification programs shall include both written and performance examinations, as outlined in ACI CP-1.

7. Sampling Concrete

7.1 The samples used to fabricate test specimens under this standard shall be obtained in accordance with Practice C 172 unless an alternative procedure has been approved.

7.2 Record the identification of the sample with respect to the location of the concrete represented and the time of casting.

8. Slump, Air Content, and Temperature

8.1 *Slump*—Measure and record the slump of each batch of concrete from which specimens are made immediately after remixing in the receptacle, as required in Test Method C 143/C 143M.

8.2 *Air Content*— Determine and record the air content in accordance with either Test Method C 173/C 173M or Test Method C 231. The concrete used in performing the air content test shall not be used in fabricating test specimens.

8.3 *Temperature*— Determine and record the temperature in accordance with Test Method C 1064/C 1064M.

NOTE 4—Some specifications may require the measurement of the unit weight of concrete. The volume of concrete produced per batch may be desired on some projects. Also, additional information on the air content measurements may be desired. Test Method C 138/C 138M is used to measure the unit weight, yield, and gravimetric air content of freshly mixed concrete.

9. Molding Specimens

9.1 *Place of Molding*— Mold specimens promptly on a level, rigid surface, free of vibration and other disturbances, at a place as near as practicable to the location where they are to be stored.

9.2 *Casting Cylinders*—Select the proper tamping rod from 5.4 and Table 1 or the proper vibrator from 5.5. Determine the method of consolidation from Table 2, unless another method is specified. If the method of consolidation is rodding, determine molding requirements from Table 3. If the method of consolidation is vibration, determine molding requirements from Table 4. Select a scoop of the size described in 5.7. While placing the concrete in the mold, move the scoop around the perimeter of the mold opening to ensure an even distribution of the concrete with minimal segregation. Each layer of concrete shall be consolidated as required. In placing the final layer, add an amount of concrete that will fill the mold after consolidation.

TABLE 2 Method of Consolidation Requirements

Slump in. [mm]	Method of Consolidation
≥ 1 [25]	rodding or vibration
< 1 [25]	vibration

TABLE 3 Molding Requirements by Rodding

Specimen Type and Size	Number of Layers of Approximately Equal Depth	Number of Roddings per Layer
Cylinders:		
Diameter, in. [mm]		
4 [100]	2	25
6 [150]	3	25
9 [225]	4	50
Beams:		
Width, in. [mm]		
6 [150] to 8 [200]	2	see 9.3
>8 [200]	3 or more equal depths, each not to exceed 6 in. [150 mm].	see 9.3

TABLE 4 Molding Requirements by Vibration

Specimen Type and Size	Number of Layers	Number of Vibrator Insertions per Layer	Approximate Depth of Layer, in. [mm]
Cylinders:			
Diameter, in. [mm]			
4 [100]	2	1	one-half depth of specimen
6 [150]	2	2	one-half depth of specimen
9 [225]	2	4	one-half depth of specimen
Beams:			
Width, in. [mm]			
6 [150] to 8 [200]	1	see 9.4.2	depth of specimen
over 8 [200]	2 or more	see 9.4.2	8 [200] as near as practicable

9.3 *Casting Beams*— Select the proper tamping rod from 5.4 and Table 1 or proper vibrator from 5.5. Determine the method of consolidation from Table 2, unless another method is specified. If the method of consolidation is rodding, determine the molding requirements from Table 3. If the method of consolidation is vibration, determine the molding requirements from Table 4. Determine the number of roddings per layer, one for each 2 in.^{2} [14 cm^2] of the top surface area of the beam. Select a placement tool as described in 5.7. Using the scoop or shovel, place the concrete in the mold to the height required for each layer. Place the concrete so that it is uniformly distributed within each layer with minimal segregation. Each layer shall be consolidated as required. In placing the final layer, add an amount of concrete that will fill the mold after consolidation.

9.4 *Consolidation*— The methods of consolidation for this practice are rodding or internal vibration.

9.4.1 *Rodding*—Place the concrete in the mold in the required number of layers of approximately equal volume. Rod each layer uniformly over the cross section with the rounded end of the rod using the required number of strokes. Rod the bottom layer throughout its depth. In rodding this layer, use care not to damage the bottom of the mold. For each upper layer, allow the rod to penetrate through the layer being rodded and into the layer below approximately 1 in. [25 mm]. After

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each layer is rodded, tap the outsides of the mold lightly 10 to 15 times with the mallet to close any holes left by rodding and to release any large air bubbles that may have been trapped. Use an open hand to tap light-gauge single-use cylinder molds which are susceptible to damage if tapped with a mallet. After tapping, spade each layer of the concrete along the sides and ends of beam molds with a trowel or other suitable tool. Underfilled molds shall be adjusted with representative concrete during consolidation of the top layer. Overfilled molds shall have excess concrete removed.

9.4.2 *Vibration*—Maintain a uniform duration of vibration for the particular kind of concrete, vibrator, and specimen mold involved. The duration of vibration required will depend upon the workability of the concrete and the effectiveness of the vibrator. Usually sufficient vibration has been applied as soon as the surface of the concrete has become relatively smooth and large air bubbles cease to break through the top surface. Continue vibration only long enough to achieve proper consolidation of the concrete (see Note 5). Fill the molds and vibrate in the required number of approximately equal layers. Place all the concrete for each layer in the mold before starting vibration of that layer. In compacting the specimen, insert the vibrator slowly and do not allow it to rest on the bottom or sides of the mold. Slowly withdraw the vibrator so that no large air pockets are left in the specimen. When placing the final layer, avoid overfilling by more than ¼ in. [6 mm].

NOTE 5—Generally, no more than 5 s of vibration should be required for each insertion to adequately consolidate concrete with a slump greater than 3 in. [75 mm]. Longer times may be required for lower slump concrete, but the vibration time should rarely have to exceed 10 s per insertion.

9.4.2.1 *Cylinders*—The number of insertions of the vibrator per layer is given in Table 4. When more than one insertion per layer is required distribute the insertion uniformly within each layer. Allow the vibrator to penetrate through the layer being vibrated, and into the layer below, about 1 in. [25 mm]. After each layer is vibrated, tap the outsides of the mold at least 10 times with the mallet, to close holes that remain and to release entrapped air voids. Use an open hand to tap cardboard and single-use metal molds that are susceptible to damage if tapped with a mallet.

9.4.2.2 *Beams*—Insert the vibrator at intervals not exceeding 6 in. [150 mm] along the center line of the long dimension of the specimen. For specimens wider than 6 in., use alternating insertions along two lines. Allow the shaft of the vibrator to penetrate into the bottom layer about 1 in. [25 mm]. After each layer is vibrated, tap the outsides of the mold sharply at least 10 times with the mallet to close holes left by vibrating and to release entrapped air voids.

9.5 *Finishing*—Perform all finishing with the minimum manipulation necessary to produce a flat even surface that is level with the rim or edge of the mold and that has no depressions or projections larger than ⅛ in. [3.3 mm].

9.5.1 *Cylinders*—After consolidation, finish the top surfaces by striking them off with the tamping rod where the consistency of the concrete permits or with a handheld float or trowel. If desired, cap the top surface of freshly made cylinders with a thin layer of stiff portland cement paste which is permitted to harden and cure with the specimen. See section on Capping Materials of Practice C 617.

9.5.2 *Beams*—After consolidation of the concrete, use a handheld float or trowel to strike off the top surface to the required tolerance to produce a flat, even surface.

9.6 *Identification*— Mark the specimens to positively identify them and the concrete they represent. Use a method that will not alter the top surface of the concrete. Do not mark the removable caps. Upon removal of the molds, mark the test specimens to retain their identities.

10. Curing

10.1 *Standard Curing*— Standard curing is the curing method used when the specimens are made and cured for the purposes stated in 4.2.

10.1.1 *Storage*—If specimens cannot be molded at the place where they will receive initial curing, immediately after finishing move the specimens to an initial curing place for storage. The supporting surface on which specimens are stored shall be level to within ¼ in. per ft [20 mm per m]. If cylinders in the single use molds are moved, lift and support the cylinders from the bottom of the molds with a large trowel or similar device. If the top surface is marred during movement to place of initial storage, immediately refinish.

10.1.2 *Initial Curing*— Immediately after molding and finishing, the specimens shall be stored for a period up to 48 h in a temperature range from 60 and 80 °F [16 and 27 °C] and in an environment preventing moisture loss from the specimens. For concrete mixtures with a specified strength of 6000 psi [40 MPa] or greater, the initial curing temperature shall be between 68 and 78 °F [20 and 26 °C]. Various procedures are capable of being used during the initial curing period to maintain the specified moisture and temperature conditions. An appropriate procedure or combination of procedures shall be used (Note 6). Shield all specimens from the direct sunlight and, if used, radiant heating devices. The storage temperature shall be controlled by use of heating and cooling devices, as necessary. Record the temperature using a maximum-minimum thermometer. If cardboard molds are used, protect the outside surface of the molds from contact with wet burlap or other sources of water.

NOTE 6—A satisfactory moisture environment can be created during the initial curing of the specimens by one or more of the following procedures: (1) immediately immerse molded specimens with plastic lids in water saturated with calcium hydroxide, (2) store in properly constructed wooden boxes or structures, (3) place in damp sand pits, (4) cover with removable plastic lids, (5) place inside plastic bags, or (6) cover with plastic sheets or nonabsorbent plates if provisions are made to avoid drying and damp burlap is used inside the enclosure, but the burlap is prevented from contacting the concrete surfaces. A satisfactory temperature environment can be controlled during the initial curing of the specimens by one or more of the following procedures: (1) use of ventilation, (2) use of ice, (3) use of thermostatically controlled heating or cooling devices, or (4) use of heating methods such as stoves or light bulbs. Other suitable methods may be used provided the requirements limiting specimen storage temperature and moisture loss are met. For concrete mixtures with a specified strength of 6000 psi [40 MPa] or greater, heat generated during the early ages may raise the temperature above the required storage temperature. Immersion in water saturated with calcium hydroxide may be the easiest method to maintain the required storage temperature. When specimens are to be immersed in water

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saturated with calcium hydroxide, specimens in cardboard molds or other molds that expand when immersed in water should not be used. Early-age strength test results may be lower when stored at 60 °F [16 °C] and higher when stored at 80 °F [27 °C]. On the other hand, at later ages, test results may be lower for higher initial storage temperatures.

10.1.3 *Final Curing:*

10.1.3.1 *Cylinders*—Upon completion of initial curing and within 30 min after removing the molds, cure specimens with free water maintained on their surfaces at all times at a temperature of 73.5 ± 3.5 °F [23.0 ± 2.0 °C] using water storage tanks or moist rooms complying with the requirements of Specification C 511, except when capping with sulfur mortar capping compound and immediately prior to testing. When capping with sulfur mortar capping compound, the ends of the cylinder shall be dry enough to preclude the formation of steam or foam pockets under or in cap larger than ¼ in. [6 mm] as described in Practice C 617. For a period not to exceed 3 h immediately prior to test, standard curing temperature is not required provided free moisture is maintained on the cylinders and ambient temperature is between 68 and 86 °F [20 and 30 °C].

10.1.3.2 *Beams*—Beams are to be cured the same as cylinders (see 10.1.3.1) except that they shall be stored in water saturated with calcium hydroxide at 73.5 ± 3.5 °F [23.0 ± 2.0 °C] at least 20 h prior to testing. Drying of the surfaces of the beam shall be prevented between removal from water storage and completion of testing.

NOTE 7—Relatively small amounts of surface drying of flexural specimens can induce tensile stresses in the extreme fibers that will markedly reduce the indicated flexural strength.

10.2 *Field Curing*— Field curing is the curing method used for the specimens made and cured as stated in 4.3.

10.2.1 *Cylinders*—Store cylinders in or on the structure as near to the point of deposit of the concrete represented as possible. Protect all surfaces of the cylinders from the elements in as near as possible the same way as the formed work. Provide the cylinders with the same temperature and moisture environment as the structural work. Test the specimens in the moisture condition resulting from the specified curing treatment. To meet these conditions, specimens made for the purpose of determining when a structure is capable of being put in service shall be removed from the molds at the time of removal of form work.

10.2.2 *Beams*—As nearly as practicable, cure beams in the same manner as the concrete in the structure. At the end of 48 ± 4 h after molding, take the molded specimens to the storage location and remove from the molds. Store specimens representing pavements of slabs on grade by placing them on the ground as molded, with their top surfaces up. Bank the sides and ends of the specimens with earth or sand that shall be kept damp, leaving the top surfaces exposed to the specified curing treatment. Store specimens representing structure concrete as near the point in the structure they represent as possible, and afford them the same temperature protection and moisture environment as the structure. At the end of the curing period leave the specimens in place exposed to the weather in the same manner as the structure. Remove all beam specimens from field storage and store in water saturated with calcium hydroxide at 73.5 ± 3.5 °F [23.0 ± 2.0 °C] for 24 ± 4 h immediately before time of testing to ensure uniform moisture condition from specimen to specimen. Observe the precautions given in 10.1.3.2 to guard against drying between time of removal from curing to testing.

10.3 *Structural Lightweight Concrete Curing*—Cure structural lightweight concrete cylinders in accordance with Specification C 330.

11. Transportation of Specimens to Laboratory

11.1 Prior to transporting, cure and protect specimens as required in Section 10. Specimens shall not be transported until at least 8 h after final set. (See Note 8). During transporting, protect the specimens with suitable cushioning material to prevent damage from jarring. During cold weather, protect the specimens from freezing with suitable insulation material. Prevent moisture loss during transportation by wrapping the specimens in plastic, wet burlap, by surrounding them with wet sand, or tight fitting plastic caps on plastic molds. Transportation time shall not exceed 4 h.

NOTE 8—Setting time may be measured by Test Method C 403/C 403M.

12. Report

12.1 Report the following information to the laboratory that will test the specimens:

12.1.1 Identification number,

12.1.2 Location of concrete represented by the samples,

12.1.3 Date, time and name of individual molding specimens,

12.1.4 Slump, air content, and concrete temperature, test results and results of any other tests on the fresh concrete and any deviations from referenced standard test methods, and

12.1.5 Curing method. For standard curing method, report the initial curing method with maximum and minimum temperatures and final curing method. For field curing method, report the location where stored, manner of protection from the elements, temperature and moisture environment, and time of removal from molds.

13. Keywords

13.1 beams; casting samples; concrete; curing; cylinders; testing

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SUMMARY OF CHANGES

Committee C09 has identified the location of selected changes to this practice since the last issue, C 31/C 31M – 08b, that may impact the use of this practice. (Approved May 1, 2009)

(*1*) Revised 5.4, Table 1, and 9.4.1 so that similar wording is used in several standards regarding the requirements for the tamping rod.

(*2*) Added new Note 1 to describe an acceptable tamping rod length for several standards.

(*3*) Revised 5.5 to change the vibrator frequency from 7000 vibrations per minute to 9000 vibrations per minute

Committee C09 has identified the location of selected changes to this practice since the last issue, C 31/C 31M – 08a, that may impact the use of this practice. (Approved December 15, 2008)

(*1*) Changed the laboratory curing temperature range from "73 ± 3 °F [23 ± 2 °C]" to "73.5 ± 3.5 °F [23.0 ± 2.0 °C]" in 10.1.3.1, 10.1.3.2, and 10.2.2.

Committee C09 has identified the location of selected changes to this practice since the last issue, C 31/C 31M – 08, that may impact the use of this practice. (Approved April 1, 2008)

(*1*) Revised 5.5, 5.7, 9.2, 9.3, and 9.5.

(*2*) Added new 5.8 and renumbered subsequent paragraphs.

Committee C09 has identified the location of selected changes to this practice since the last issue, C 31/C 31M – 06, that may impact the use of this practice. (Approved February 1, 2008)

(*1*) Revised 6.1.

(*2*) Revised 6.2.

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Designation: C 31/C 31M – 09

Standard Practice for Making and Curing Concrete Test Specimens in the Field[1]

This standard is issued under the fixed designation C 31/C 31M; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

This standard has been approved for use by agencies of the Department of Defense.

1. Scope*

1.1 This practice covers procedures for making and curing cylinder and beam specimens from representative samples of fresh concrete for a construction project.

1.2 The concrete used to make the molded specimens shall be sampled after all on-site adjustments have been made to the mixture proportions, including the addition of mix water and admixtures. This practice is not satisfactory for making specimens from concrete not having measurable slump or requiring other sizes or shapes of specimens.

1.3 The values stated in either SI units or inch-pound units are to be regarded separately as standard. The values stated in each system may not be exact equivalents; therefore, each system shall be used independently of the other. Combining values from the two systems may result in non-conformance with the standard.

1.4 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.* (**Warning**—Fresh hydraulic cementitious mixtures are caustic and may cause chemical burns to exposed skin and tissue upon prolonged exposure.[2])

1.5 The text of this standard references notes which provide explanatory material. These notes shall not be considered as requirements of the standard.

2. Referenced Documents

2.1 *ASTM Standards:*[3]

C 125 Terminology Relating to Concrete and Concrete Aggregates

C 138/C 138M Test Method for Density (Unit Weight), Yield, and Air Content (Gravimetric) of Concrete

C 143/C 143M Test Method for Slump of Hydraulic-Cement Concrete

C 172 Practice for Sampling Freshly Mixed Concrete

C 173/C 173M Test Method for Air Content of Freshly Mixed Concrete by the Volumetric Method

C 231 Test Method for Air Content of Freshly Mixed Concrete by the Pressure Method

C 330 Specification for Lightweight Aggregates for Structural Concrete

C 403/C 403M Test Method for Time of Setting of Concrete Mixtures by Penetration Resistance

C 470/C 470M Specification for Molds for Forming Concrete Test Cylinders Vertically

C 511 Specification for Mixing Rooms, Moist Cabinets, Moist Rooms, and Water Storage Tanks Used in the Testing of Hydraulic Cements and Concretes

C 617 Practice for Capping Cylindrical Concrete Specimens

C 1064/C 1064M Test Method for Temperature of Freshly Mixed Hydraulic-Cement Concrete

2.2 *American Concrete Institute Publication:*[4]

CP-1 Concrete Field Testing Technician, Grade I

309R Guide for Consolidation of Concrete

3. Terminology

3.1 For definitions of terms used in this practice, refer to Terminology C 125.

4. Significance and Use

4.1 This practice provides standardized requirements for making, curing, protecting, and transporting concrete test specimens under field conditions.

4.2 If the specimens are made and standard cured, as stipulated herein, the resulting strength test data when the specimens are tested are able to be used for the following purposes:

4.2.1 Acceptance testing for specified strength,

4.2.2 Checking adequacy of mixture proportions for strength, and

[1] This practice is under the jurisdiction of ASTM Committee C09 on Concrete and Concrete Aggregates and is the direct responsibility of Subcommittee C09.61 on Testing for Strength.

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[2] See Section on Safety Precautions, Manual of Aggregate and Concrete Testing, *Annual Book of ASTM Standards*, Vol. 04.02.

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[4] Available from American Concrete Institute (ACI), P.O. Box 9094, Farmington Hills, MI 48333-9094, http://www.aci-int.org.

***A Summary of Changes section appears at the end of this standard.**

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4.2.3 Quality control.

4.3 If the specimens are made and field cured, as stipulated herein, the resulting strength test data when the specimens are tested are able to be used for the following purposes:

4.3.1 Determination of whether a structure is capable of being put in service,

4.3.2 Comparison with test results of standard cured specimens or with test results from various in-place test methods,

4.3.3 Adequacy of curing and protection of concrete in the structure, or

4.3.4 Form or shoring removal time requirements.

5. Apparatus

5.1 *Molds, General*— Molds for specimens or fastenings thereto in contact with the concrete shall be made of steel, cast iron, or other nonabsorbent material, nonreactive with concrete containing portland or other hydraulic cements. Molds shall hold their dimensions and shape under all conditions of use. Molds shall be watertight during use as judged by their ability to hold water poured into them. Provisions for tests of water leakage are given in the Test Methods for Elongation, Absorption, and Water Leakage section of Specification C 470/C 470M. A suitable sealant, such as heavy grease, modeling clay, or microcrystalline wax shall be used where necessary to prevent leakage through the joints. Positive means shall be provided to hold base plates firmly to the molds. Reusable molds shall be lightly coated with mineral oil or a suitable nonreactive form release material before use.

5.2 *Cylinder Molds*— Molds for casting concrete test specimens shall conform to the requirements of Specification C 470/C 470M.

5.3 *Beam Molds*—Beam molds shall be of the shape and dimensions required to produce the specimens stipulated in 6.2. The inside surfaces of the molds shall be smooth. The sides, bottom, and ends shall be at right angles to each other and shall be straight and true and free of warpage. Maximum variation from the nominal cross section shall not exceed ⅛ in. [3 mm] for molds with depth or breadth of 6 in. [150 mm] or more. Molds shall produce specimens at least as long but not more than 1/16 in. [2 mm] shorter than the required length in 6.2.

5.4 *Tamping Rod*—A round, straight, steel rod with a diameter conforming to the requirements in Table 1. The length of the tamping rod shall be at least 4 in. [100 mm] greater than the depth of the mold in which rodding is being performed, but not greater than 24 in. [600 mm] in overall length (see Note 1). The length tolerance for the tamping rod shall be ± ⅛ in. [4 mm]. The rod shall have the tamping end or both ends rounded to a hemispherical tip of the same diameter as the rod.

NOTE 1—A rod length of 16 in. [400 mm] to 24 in. [600 mm] meets the requirements of the following: Practice C 31/C 31M, Test Method C 138/C 138M, Test Method C 143/C 143M, Test Method C 173/C 173M, and Test Method C 231.

5.5 *Vibrators*—Internal vibrators shall be used. The vibrator frequency shall be at least 9000 vibrations per minute [150 Hz] while the vibrator is operating in the concrete. The diameter of a round vibrator shall be no more than one-fourth the diameter of the cylinder mold or one-fourth the width of the beam mold. Other shaped vibrators shall have a perimeter equivalent to the circumference of an appropriate round vibrator. The combined length of the vibrator shaft and vibrating element shall exceed the depth of the section being vibrated by at least 3 in. [75 mm]. The vibrator frequency shall be checked periodically with a vibrating-reed tachometer or other suitable device.

TABLE 1 Tamping Rod Diameter Requirements

Diameter of Cylinder or Width of Beam in. [mm]	Diameter or Rod in. [mm]
<6 [150]	⅜ ± 1/16 [10 ± 2]
≥6 [150]	⅝ ± 1/16 [16 ± 2]

NOTE 2—For information on size and frequency of various vibrators and a method to periodically check vibrator frequency see ACI 309R.

5.6 *Mallet*—A mallet with a rubber or rawhide head weighing 1.25 ± 0.50 lb [0.6 ± 0.2 kg] shall be used.

5.7 *Placement Tools*—of a size large enough so each amount of concrete obtained from the sampling receptacle is representative and small enough so concrete is not spilled during placement in the mold. For placing concrete in a cylinder mold, the acceptable tool is a scoop. For placing concrete in a beam mold, either a shovel or scoop is permitted.

5.8 *Finishing Tools*—a handheld float or a trowel.

5.9 *Slump Apparatus*— The apparatus for measurement of slump shall conform to the requirements of Test Method C 143/C 143M.

5.10 *Sampling Receptacle*—The receptacle shall be a suitable heavy gauge metal pan, wheelbarrow, or flat, clean nonabsorbent board of sufficient capacity to allow easy remixing of the entire sample with a shovel or trowel.

5.11 *Air Content Apparatus*—The apparatus for measuring air content shall conform to the requirements of Test Methods C 173/C 173M or C 231.

5.12 *Temperature Measuring Devices*—The temperature measuring devices shall conform to the applicable requirements of Test Method C 1064/C 1064M.

6. Testing Requirements

6.1 *Cylindrical Specimens*—Compressive or splitting tensile strength specimens shall be cylinders cast and allowed to set in an upright position. The number and size of cylinders cast shall be as directed by the specifier of the tests. In addition, the length shall be twice the diameter and the cylinder diameter shall be at least 3 times the nominal maximum size of the coarse aggregate. When the nominal maximum size of the coarse aggregate exceeds 2 in. [50 mm], the concrete sample shall be treated by wet sieving through a 2-in. [50-mm] sieve as described in Practice C 172. For acceptance testing for specified compressive strength, cylinders shall be 6 by 12 in. [150 by 300 mm] or 4 × 8 in. [100 × 200 mm] (Note 3).

NOTE 3—When molds in SI units are required and not available, equivalent inch-pound unit size mold should be permitted.

6.2 *Beam Specimens*— Flexural strength specimens shall be beams of concrete cast and hardened in the horizontal position. The number of beams cast shall be as directed by the specifier of the tests. The length shall be at least 2 in. [50 mm] greater than three times the depth as tested. The ratio of width to depth

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as molded shall not exceed 1.5. The standard beam shall be 6 by 6 in. [150 by 150 mm] in cross section, and shall be used for concrete with nominal maximum size coarse aggregate up to 2 in. [50 mm]. When the nominal maximum size of the coarse aggregate exceeds 2 in. [50 mm], the smaller cross sectional dimension of the beam shall be at least three times the nominal maximum size of the coarse aggregate. Unless required by project specifications, beams made in the field shall not have a width or depth of less than 6 in. [150 mm].

6.3 *Field Technicians*—The field technicians making and curing specimens for acceptance testing shall be certified ACI Field Testing Technicians, Grade I or equivalent. Equivalent personnel certification programs shall include both written and performance examinations, as outlined in ACI CP-1.

7. Sampling Concrete

7.1 The samples used to fabricate test specimens under this standard shall be obtained in accordance with Practice C 172 unless an alternative procedure has been approved.

7.2 Record the identification of the sample with respect to the location of the concrete represented and the time of casting.

8. Slump, Air Content, and Temperature

8.1 *Slump*—Measure and record the slump of each batch of concrete from which specimens are made immediately after remixing in the receptacle, as required in Test Method C 143/C 143M.

8.2 *Air Content*— Determine and record the air content in accordance with either Test Method C 173/C 173M or Test Method C 231. The concrete used in performing the air content test shall not be used in fabricating test specimens.

8.3 *Temperature*— Determine and record the temperature in accordance with Test Method C 1064/C 1064M.

NOTE 4—Some specifications may require the measurement of the unit weight of concrete. The volume of concrete produced per batch may be desired on some projects. Also, additional information on the air content measurements may be desired. Test Method C 138/C 138M is used to measure the unit weight, yield, and gravimetric air content of freshly mixed concrete.

9. Molding Specimens

9.1 *Place of Molding*— Mold specimens promptly on a level, rigid surface, free of vibration and other disturbances, at a place as near as practicable to the location where they are to be stored.

9.2 *Casting Cylinders*—Select the proper tamping rod from 5.4 and Table 1 or the proper vibrator from 5.5. Determine the method of consolidation from Table 2, unless another method is specified. If the method of consolidation is rodding, determine molding requirements from Table 3. If the method of consolidation is vibration, determine molding requirements from Table 4. Select a scoop of the size described in 5.7. While placing the concrete in the mold, move the scoop around the perimeter of the mold opening to ensure an even distribution of the concrete with minimal segregation. Each layer of concrete shall be consolidated as required. In placing the final layer, add an amount of concrete that will fill the mold after consolidation.

TABLE 2 Method of Consolidation Requirements

Slump in. [mm]	Method of Consolidation
≥ 1 [25]	rodding or vibration
< 1 [25]	vibration

TABLE 3 Molding Requirements by Rodding

Specimen Type and Size	Number of Layers of Approximately Equal Depth	Number of Roddings per Layer
Cylinders:		
Diameter, in. [mm]		
4 [100]	2	25
6 [150]	3	25
9 [225]	4	50
Beams:		
Width, in. [mm]		
6 [150] to 8 [200]	2	see 9.3
>8 [200]	3 or more equal depths, each not to exceed 6 in. [150 mm].	see 9.3

TABLE 4 Molding Requirements by Vibration

Specimen Type and Size	Number of Layers	Number of Vibrator Insertions per Layer	Approximate Depth of Layer, in. [mm]
Cylinders:			
Diameter, in. [mm]			
4 [100]	2	1	one-half depth of specimen
6 [150]	2	2	one-half depth of specimen
9 [225]	2	4	one-half depth of specimen
Beams:			
Width, in. [mm]			
6 [150] to 8 [200]	1	see 9.4.2	depth of specimen
over 8 [200]	2 or more	see 9.4.2	8 [200] as near as practicable

9.3 *Casting Beams*— Select the proper tamping rod from 5.4 and Table 1 or proper vibrator from 5.5. Determine the method of consolidation from Table 2, unless another method is specified. If the method of consolidation is rodding, determine the molding requirements from Table 3. If the method of consolidation is vibration, determine the molding requirements from Table 4. Determine the number of roddings per layer, one for each 2 in.^{2} [14 cm^2] of the top surface area of the beam. Select a placement tool as described in 5.7. Using the scoop or shovel, place the concrete in the mold to the height required for each layer. Place the concrete so that it is uniformly distributed within each layer with minimal segregation. Each layer shall be consolidated as required. In placing the final layer, add an amount of concrete that will fill the mold after consolidation.

9.4 *Consolidation*— The methods of consolidation for this practice are rodding or internal vibration.

9.4.1 *Rodding*—Place the concrete in the mold in the required number of layers of approximately equal volume. Rod each layer uniformly over the cross section with the rounded end of the rod using the required number of strokes. Rod the bottom layer throughout its depth. In rodding this layer, use care not to damage the bottom of the mold. For each upper layer, allow the rod to penetrate through the layer being rodded and into the layer below approximately 1 in. [25 mm]. After

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each layer is rodded, tap the outsides of the mold lightly 10 to 15 times with the mallet to close any holes left by rodding and to release any large air bubbles that may have been trapped. Use an open hand to tap light-gauge single-use cylinder molds which are susceptible to damage if tapped with a mallet. After tapping, spade each layer of the concrete along the sides and ends of beam molds with a trowel or other suitable tool. Underfilled molds shall be adjusted with representative concrete during consolidation of the top layer. Overfilled molds shall have excess concrete removed.

9.4.2 *Vibration*—Maintain a uniform duration of vibration for the particular kind of concrete, vibrator, and specimen mold involved. The duration of vibration required will depend upon the workability of the concrete and the effectiveness of the vibrator. Usually sufficient vibration has been applied as soon as the surface of the concrete has become relatively smooth and large air bubbles cease to break through the top surface. Continue vibration only long enough to achieve proper consolidation of the concrete (see Note 5). Fill the molds and vibrate in the required number of approximately equal layers. Place all the concrete for each layer in the mold before starting vibration of that layer. In compacting the specimen, insert the vibrator slowly and do not allow it to rest on the bottom or sides of the mold. Slowly withdraw the vibrator so that no large air pockets are left in the specimen. When placing the final layer, avoid overfilling by more than ¼ in. [6 mm].

NOTE 5—Generally, no more than 5 s of vibration should be required for each insertion to adequately consolidate concrete with a slump greater than 3 in. [75 mm]. Longer times may be required for lower slump concrete, but the vibration time should rarely have to exceed 10 s per insertion.

9.4.2.1 *Cylinders*—The number of insertions of the vibrator per layer is given in Table 4. When more than one insertion per layer is required distribute the insertion uniformly within each layer. Allow the vibrator to penetrate through the layer being vibrated, and into the layer below, about 1 in. [25 mm]. After each layer is vibrated, tap the outsides of the mold at least 10 times with the mallet, to close holes that remain and to release entrapped air voids. Use an open hand to tap cardboard and single-use metal molds that are susceptible to damage if tapped with a mallet.

9.4.2.2 *Beams*—Insert the vibrator at intervals not exceeding 6 in. [150 mm] along the center line of the long dimension of the specimen. For specimens wider than 6 in., use alternating insertions along two lines. Allow the shaft of the vibrator to penetrate into the bottom layer about 1 in. [25 mm]. After each layer is vibrated, tap the outsides of the mold sharply at least 10 times with the mallet to close holes left by vibrating and to release entrapped air voids.

9.5 *Finishing*—Perform all finishing with the minimum manipulation necessary to produce a flat even surface that is level with the rim or edge of the mold and that has no depressions or projections larger than ⅛ in. [3.3 mm].

9.5.1 *Cylinders*—After consolidation, finish the top surfaces by striking them off with the tamping rod where the consistency of the concrete permits or with a handheld float or trowel. If desired, cap the top surface of freshly made cylinders with a thin layer of stiff portland cement paste which is permitted to harden and cure with the specimen. See section on Capping Materials of Practice C 617.

9.5.2 *Beams*—After consolidation of the concrete, use a handheld float or trowel to strike off the top surface to the required tolerance to produce a flat, even surface.

9.6 *Identification*— Mark the specimens to positively identify them and the concrete they represent. Use a method that will not alter the top surface of the concrete. Do not mark the removable caps. Upon removal of the molds, mark the test specimens to retain their identities.

10. Curing

10.1 *Standard Curing*— Standard curing is the curing method used when the specimens are made and cured for the purposes stated in 4.2.

10.1.1 *Storage*—If specimens cannot be molded at the place where they will receive initial curing, immediately after finishing move the specimens to an initial curing place for storage. The supporting surface on which specimens are stored shall be level to within ¼ in. per ft [20 mm per m]. If cylinders in the single use molds are moved, lift and support the cylinders from the bottom of the molds with a large trowel or similar device. If the top surface is marred during movement to place of initial storage, immediately refinish.

10.1.2 *Initial Curing*— Immediately after molding and finishing, the specimens shall be stored for a period up to 48 h in a temperature range from 60 and 80 °F [16 and 27 °C] and in an environment preventing moisture loss from the specimens. For concrete mixtures with a specified strength of 6000 psi [40 MPa] or greater, the initial curing temperature shall be between 68 and 78 °F [20 and 26 °C]. Various procedures are capable of being used during the initial curing period to maintain the specified moisture and temperature conditions. An appropriate procedure or combination of procedures shall be used (Note 6). Shield all specimens from the direct sunlight and, if used, radiant heating devices. The storage temperature shall be controlled by use of heating and cooling devices, as necessary. Record the temperature using a maximum-minimum thermometer. If cardboard molds are used, protect the outside surface of the molds from contact with wet burlap or other sources of water.

NOTE 6—A satisfactory moisture environment can be created during the initial curing of the specimens by one or more of the following procedures: (1) immediately immerse molded specimens with plastic lids in water saturated with calcium hydroxide, (2) store in properly constructed wooden boxes or structures, (3) place in damp sand pits, (4) cover with removable plastic lids, (5) place inside plastic bags, or (6) cover with plastic sheets or nonabsorbent plates if provisions are made to avoid drying and damp burlap is used inside the enclosure, but the burlap is prevented from contacting the concrete surfaces. A satisfactory temperature environment can be controlled during the initial curing of the specimens by one or more of the following procedures: (1) use of ventilation, (2) use of ice, (3) use of thermostatically controlled heating or cooling devices, or (4) use of heating methods such as stoves or light bulbs. Other suitable methods may be used provided the requirements limiting specimen storage temperature and moisture loss are met. For concrete mixtures with a specified strength of 6000 psi [40 MPa] or greater, heat generated during the early ages may raise the temperature above the required storage temperature. Immersion in water saturated with calcium hydroxide may be the easiest method to maintain the required storage temperature. When specimens are to be immersed in water

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saturated with calcium hydroxide, specimens in cardboard molds or other molds that expand when immersed in water should not be used. Early-age strength test results may be lower when stored at 60 °F [16 °C] and higher when stored at 80 °F [27 °C]. On the other hand, at later ages, test results may be lower for higher initial storage temperatures.

10.1.3 *Final Curing:*

10.1.3.1 *Cylinders*—Upon completion of initial curing and within 30 min after removing the molds, cure specimens with free water maintained on their surfaces at all times at a temperature of 73.5 ± 3.5 °F [23.0 ± 2.0 °C] using water storage tanks or moist rooms complying with the requirements of Specification C 511, except when capping with sulfur mortar capping compound and immediately prior to testing. When capping with sulfur mortar capping compound, the ends of the cylinder shall be dry enough to preclude the formation of steam or foam pockets under or in cap larger than ¼ in. [6 mm] as described in Practice C 617. For a period not to exceed 3 h immediately prior to test, standard curing temperature is not required provided free moisture is maintained on the cylinders and ambient temperature is between 68 and 86 °F [20 and 30 °C].

10.1.3.2 *Beams*—Beams are to be cured the same as cylinders (see 10.1.3.1) except that they shall be stored in water saturated with calcium hydroxide at 73.5 ± 3.5 °F [23.0 ± 2.0 °C] at least 20 h prior to testing. Drying of the surfaces of the beam shall be prevented between removal from water storage and completion of testing.

NOTE 7—Relatively small amounts of surface drying of flexural specimens can induce tensile stresses in the extreme fibers that will markedly reduce the indicated flexural strength.

10.2 *Field Curing*— Field curing is the curing method used for the specimens made and cured as stated in 4.3.

10.2.1 *Cylinders*—Store cylinders in or on the structure as near to the point of deposit of the concrete represented as possible. Protect all surfaces of the cylinders from the elements in as near as possible the same way as the formed work. Provide the cylinders with the same temperature and moisture environment as the structural work. Test the specimens in the moisture condition resulting from the specified curing treatment. To meet these conditions, specimens made for the purpose of determining when a structure is capable of being put in service shall be removed from the molds at the time of removal of form work.

10.2.2 *Beams*—As nearly as practicable, cure beams in the same manner as the concrete in the structure. At the end of 48 ± 4 h after molding, take the molded specimens to the storage location and remove from the molds. Store specimens representing pavements of slabs on grade by placing them on the ground as molded, with their top surfaces up. Bank the sides and ends of the specimens with earth or sand that shall be kept damp, leaving the top surfaces exposed to the specified curing treatment. Store specimens representing structure concrete as near the point in the structure they represent as possible, and afford them the same temperature protection and moisture environment as the structure. At the end of the curing period leave the specimens in place exposed to the weather in the same manner as the structure. Remove all beam specimens from field storage and store in water saturated with calcium hydroxide at 73.5 ± 3.5 °F [23.0 ± 2.0 °C] for 24 ± 4 h immediately before time of testing to ensure uniform moisture condition from specimen to specimen. Observe the precautions given in 10.1.3.2 to guard against drying between time of removal from curing to testing.

10.3 *Structural Lightweight Concrete Curing*—Cure structural lightweight concrete cylinders in accordance with Specification C 330.

11. Transportation of Specimens to Laboratory

11.1 Prior to transporting, cure and protect specimens as required in Section 10. Specimens shall not be transported until at least 8 h after final set. (See Note 8). During transporting, protect the specimens with suitable cushioning material to prevent damage from jarring. During cold weather, protect the specimens from freezing with suitable insulation material. Prevent moisture loss during transportation by wrapping the specimens in plastic, wet burlap, by surrounding them with wet sand, or tight fitting plastic caps on plastic molds. Transportation time shall not exceed 4 h.

NOTE 8—Setting time may be measured by Test Method C 403/C 403M.

12. Report

12.1 Report the following information to the laboratory that will test the specimens:

12.1.1 Identification number,

12.1.2 Location of concrete represented by the samples,

12.1.3 Date, time and name of individual molding specimens,

12.1.4 Slump, air content, and concrete temperature, test results and results of any other tests on the fresh concrete and any deviations from referenced standard test methods, and

12.1.5 Curing method. For standard curing method, report the initial curing method with maximum and minimum temperatures and final curing method. For field curing method, report the location where stored, manner of protection from the elements, temperature and moisture environment, and time of removal from molds.

13. Keywords

13.1 beams; casting samples; concrete; curing; cylinders; testing

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SUMMARY OF CHANGES

Committee C09 has identified the location of selected changes to this practice since the last issue, C 31/C 31M – 08b, that may impact the use of this practice. (Approved May 1, 2009)

(*1*) Revised 5.4, Table 1, and 9.4.1 so that similar wording is used in several standards regarding the requirements for the tamping rod.

(*2*) Added new Note 1 to describe an acceptable tamping rod length for several standards.

(*3*) Revised 5.5 to change the vibrator frequency from 7000 vibrations per minute to 9000 vibrations per minute

Committee C09 has identified the location of selected changes to this practice since the last issue, C 31/C 31M – 08a, that may impact the use of this practice. (Approved December 15, 2008)

(*1*) Changed the laboratory curing temperature range from "73 ± 3 °F [23 ± 2 °C]" to "73.5 ± 3.5 °F [23.0 ± 2.0 °C]" in 10.1.3.1, 10.1.3.2, and 10.2.2.

Committee C09 has identified the location of selected changes to this practice since the last issue, C 31/C 31M – 08, that may impact the use of this practice. (Approved April 1, 2008)

(*1*) Revised 5.5, 5.7, 9.2, 9.3, and 9.5.

(*2*) Added new 5.8 and renumbered subsequent paragraphs.

Committee C09 has identified the location of selected changes to this practice since the last issue, C 31/C 31M – 06, that may impact the use of this practice. (Approved February 1, 2008)

(*1*) Revised 6.1.

(*2*) Revised 6.2.

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Designation: C 33/C 33M – 08

Standard Specification for Concrete Aggregates[1]

This standard is issued under the fixed designation C 33/C 33M; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

This standard has been approved for use by agencies of the Department of Defense.

1. Scope*

1.1 This specification defines the requirements for grading and quality of fine and coarse aggregate (other than lightweight or heavyweight aggregate) for use in concrete.[2]

1.2 This specification is for use by a contractor, concrete supplier, or other purchaser as part of the purchase document describing the material to be furnished.

NOTE 1—This specification is regarded as adequate to ensure satisfactory materials for most concrete. It is recognized that, for certain work or in certain regions, it may be either more or less restrictive than needed. For example, where aesthetics are important, more restrictive limits may be considered regarding impurities that would stain the concrete surface. The specifier should ascertain that aggregates specified are or can be made available in the area of the work, with regard to grading, physical, or chemical properties, or combination thereof.

1.3 This specification is also for use in project specifications to define the quality of aggregate, the nominal maximum size of the aggregate, and other specific grading requirements. Those responsible for selecting the proportions for the concrete mixture shall have the responsibility of determining the proportions of fine and coarse aggregate and the addition of blending aggregate sizes if required or approved.

1.4 The values stated in either SI units or inch-pound units are to be regarded separately as standard. The values stated in each system may not be exact equivalents; therefore, each system shall be used independently of the other. Combining values from the two systems may result in non-conformance with the standard.

1.5 The text of this standard references notes and footnotes which provide explanatory material. These notes and footnotes (excluding those in tables and figures) shall not be considered as requirements of this standard.

2. Referenced Documents

2.1 *ASTM Standards:*[3]

C 29/C 29M Test Method for Bulk Density ("Unit Weight") and Voids in Aggregate

C 40 Test Method for Organic Impurities in Fine Aggregates for Concrete

C 87 Test Method for Effect of Organic Impurities in Fine Aggregate on Strength of Mortar

C 88 Test Method for Soundness of Aggregates by Use of Sodium Sulfate or Magnesium Sulfate

C 117 Test Method for Materials Finer than 75-μm (No. 200) Sieve in Mineral Aggregates by Washing

C 123 Test Method for Lightweight Particles in Aggregate

C 125 Terminology Relating to Concrete and Concrete Aggregates

C 131 Test Method for Resistance to Degradation of Small-Size Coarse Aggregate by Abrasion and Impact in the Los Angeles Machine

C 136 Test Method for Sieve Analysis of Fine and Coarse Aggregates

C 142 Test Method for Clay Lumps and Friable Particles in Aggregates

C 150 Specification for Portland Cement

C 227 Test Method for Potential Alkali Reactivity of Cement-Aggregate Combinations (Mortar-Bar Method)

C 289 Test Method for Potential Alkali-Silica Reactivity of Aggregates (Chemical Method)

C 294 Descriptive Nomenclature for Constituents of Concrete Aggregates

C 295 Guide for Petrographic Examination of Aggregates for Concrete

C 311 Test Methods for Sampling and Testing Fly Ash or Natural Pozzolans for Use in Portland-Cement Concrete

C 330 Specification for Lightweight Aggregates for Structural Concrete

[1] This specification is under the jurisdiction of ASTM Committee C09 on Concrete and Concrete Aggregates and is the direct responsibility of Subcommittee C09.20 on Normal Weight Aggregates.

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[2] For lightweight aggregates, see Specifications C 330, C 331, and C 332; for heavyweight aggregates see Specification C 637 and Descriptive Nomenclature C 638.

[3] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

***A Summary of Changes section appears at the end of this standard.**

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C 331 Specification for Lightweight Aggregates for Concrete Masonry Units
C 332 Specification for Lightweight Aggregates for Insulating Concrete
C 342 Test Method for Potential Volume Change of Cement-Aggregate Combinations[4]
C 441 Test Method for Effectiveness of Pozzolans or Ground Blast-Furnace Slag in Preventing Excessive Expansion of Concrete Due to the Alkali-Silica Reaction
C 535 Test Method for Resistance to Degradation of Large-Size Coarse Aggregate by Abrasion and Impact in the Los Angeles Machine
C 586 Test Method for Potential Alkali Reactivity of Carbonate Rocks as Concrete Aggregates (Rock-Cylinder Method)
C 595 Specification for Blended Hydraulic Cements
C 618 Specification for Coal Fly Ash and Raw or Calcined Natural Pozzolan for Use in Concrete
C 637 Specification for Aggregates for Radiation-Shielding Concrete
C 638 Descriptive Nomenclature of Constituents of Aggregates for Radiation-Shielding Concrete
C 666/C 666M Test Method for Resistance of Concrete to Rapid Freezing and Thawing
C 989 Specification for Ground Granulated Blast-Furnace Slag for Use in Concrete and Mortars
C 1105 Test Method for Length Change of Concrete Due to Alkali-Carbonate Rock Reaction
C 1157 Performance Specification for Hydraulic Cement
C 1240 Specification for Silica Fume Used in Cementitious Mixtures
C 1260 Test Method for Potential Alkali Reactivity of Aggregates (Mortar-Bar Method)
C 1293 Test Method for Determination of Length Change of Concrete Due to Alkali-Silica Reaction
C 1567 Test Method for Determining the Potential Alkali-Silica Reactivity of Combinations of Cementitious Materials and Aggregate (Accelerated Mortar-Bar Method)
D 75 Practice for Sampling Aggregates
D 3665 Practice for Random Sampling of Construction Materials
E 11 Specification for Wire Cloth and Sieves for Testing Purposes

3. Terminology

3.1 For definitions of terms used in this standard, refer to Terminology C 125.

4. Ordering and Specifying Information

4.1 The direct purchaser of aggregates shall include the information in 4.2 in the purchase order as applicable. A project specifier shall include in the project documents information to describe the aggregate to be used in the project from the applicable items in 4.3.

4.2 Include in the purchase order for aggregates the following information, as applicable:

4.2.1 Reference to this specification, as C 33____,

4.2.2 Whether the order is for fine aggregate or for coarse aggregate,

4.2.3 Quantity, in metric tons or tons,

4.2.4 When the order is for fine aggregate:

4.2.4.1 Whether the restriction on reactive materials in 7.3 applies,

4.2.4.2 In the case of the sulfate soundness test (see 8.1) which salt is to be used. If none is stated, either sodium sulfate or magnesium sulfate shall be used,

4.2.4.3 The appropriate limit for material finer than 75-µm (No. 200) sieve (see Table 1). If not stated, the 3.0 % limit shall apply,

4.2.4.4 The appropriate limit for coal and lignite (see Table 1). If not stated, the 1.0 % limit shall apply,

4.2.5 When the order is for coarse aggregate:

4.2.5.1 The grading (size number) (see 10.1 and Table 2), or alternate grading as agreed between the purchaser and aggregate supplier.

4.2.5.2 The class designation (see 11.1 and Table 3),

4.2.5.3 Whether the restriction on reactive materials in 11.2 applies,

4.2.5.4 In the case of the sulfate soundness test (see Table 3), which salt is to be used. If none is stated, either sodium sulfate or magnesium sulfate shall be used, and

4.2.6 Any exceptions or additions to this specification (see Note 1).

4.3 Include in project specifications for aggregates the following information, as applicable:

4.3.1 Reference to this specification, as C 33____.

4.3.2 When the aggregate being described is fine aggregate:

4.3.2.1 Whether the restriction on reactive materials in 7.3 applies,

4.3.2.2 In the case of the sulfate soundness test (see 8.1) which salt is to be used. If none is stated, either sodium sulfate or magnesium sulfate shall be used.

4.3.2.3 The appropriate limit for material finer than the 75-µm (No. 200) sieve (see Table 1). If not stated, the 3.0 % limit shall apply, and

4.3.2.4 The limit that applies with regard to coal and lignite (Table 1). If not stated, the 1.0 % limit shall apply.

TABLE 1 Limits for Deleterious Substances in Fine Aggregate for Concrete

Item	Mass Percent of Total Sample, max
Clay lumps and friable particles	3.0
Material finer than 75-µm (No. 200) sieve:	
Concrete subject to abrasion	3.0[A]
All other concrete	5.0[A]
Coal and lignite:	
Where surface appearance of concrete is of importance	0.5
All other concrete	1.0

[A] In the case of manufactured sand, if the material finer than the 75-µm (No. 200) sieve consists of the dust of fracture, essentially free of clay or shale, these limits are permitted to be increased to 5 and 7 %, respectively.

[4] Withdrawn. The last approved version of this historical standard is referenced on www.astm.org.

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TABLE 2 Grading Requirements for Coarse Aggregates

Size Number	Nominal Size (Sieves with Square Openings)	Amounts Finer than Each Laboratory Sieve (Square-Openings), Mass Percent													
		100 mm (4 in.)	90 mm (3½ in.)	75 mm (3 in.)	63 mm (2½ in.)	50 mm (2 in.)	37.5 mm (1½ in.)	25.0 mm (1 in.)	19.0 mm (¾ in.)	12.5 mm (½ in.)	9.5 mm (⅜ in.)	4.75 mm (No. 4)	2.36 mm (No. 8)	1.18 mm (No. 16)	300 µm (No.50)
1	90 to 37.5 mm (3½ to 1½ in.)	100	90 to 100	...	25 to 60	...	0 to 15	...	0 to 5	...	...	...	...	...	...
2	63 to 37.5 mm (2½ to 1½ in.)	...	...	100	90 to 100	35 to 70	0 to 15	...	0 to 5	...	...	...	...	...	...
3	50 to 25.0 mm (2 to 1 in.)	...	...	...	100	90 to 100	35 to 70	0 to 15	...	0 to 5	...	...	...	...	...
357	50 to 4.75 mm (2 in. to No. 4)	...	...	...	100	95 to 100	...	35 to 70	...	10 to 30	...	0 to 5	...	...	...
4	37.5 to 19.0 mm (1½ to ¾ in.)	...	...	...	...	100	90 to 100	20 to 55	0 to 15	...	0 to 5	...	...	...	...
467	37.5 to 4.75 mm (1½ in. to No. 4)	...	...	...	...	100	95 to 100	...	35 to 70	...	10 to 30	0 to 5	...	...	...
5	25.0 to 12.5 mm (1 to ½ in.)	...	...	...	...	...	100	90 to 100	20 to 55	0 to 10	0 to 5	...	...	...	...
56	25.0 to 9.5 mm (1 to ⅜ in.)	...	...	...	...	...	100	90 to 100	40 to 85	10 to 40	0 to 15	0 to 5	...	...	...
57	25.0 to 4.75 mm (1 in. to No. 4)	...	...	...	...	...	100	95 to 100	...	25 to 60	...	0 to 10	0 to 5	...	...
6	19.0 to 9.5 mm (¾ to ⅜ in.)	...	...	...	...	...	...	100	90 to 100	20 to 55	0 to 15	0 to 5	...	...	...
67	19.0 to 4.75 mm (¾ in. to No. 4)	...	...	...	...	...	...	100	90 to 100	...	20 to 55	0 to 10	0 to 5	...	...
7	12.5 to 4.75 mm (½ in. to No. 4)	...	...	...	...	...	...	...	100	90 to 100	40 to 70	0 to 15	0 to 5	...	...
8	9.5 to 2.36 mm (⅜ in. to No. 8)	...	...	...	...	...	...	...	...	100	85 to 100	10 to 30	0 to 10	0 to 5	...
89	9.5 to 1.18 mm (⅜ in. to No. 16)	...	...	...	...	...	...	...	...	100	90 to 100	20 to 55	5 to 30	0 to 10	0 to 5
9[A]	4.75 to 1.18 mm (No. 4 to No. 16)	...	...	...	...	...	...	...	...	...	100	85 to 100	10 to 40	0 to 10	0 to 5

[A] Size number 9 aggregate is defined in Terminology C 125 as a fine aggregate. It is included as a coarse aggregate when it is combined with a size number 8 material to create a size number 89, which is a coarse aggregate as defined by Terminology C 125.

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TABLE 3 Limits for Deleterious Substances and Physical Property Requirements of Coarse Aggregate for Concrete

NOTE 1—See Fig. 1 for the location of the weathering regions and Note 9 for guidance in using the map. The weathering regions are defined as follows:
(S) Severe Weathering Region—A cold climate where concrete is exposed to deicing chemicals or other aggressive agents, or where concrete may become saturated by continued contact with moisture or free water prior to repeated freezing and thawing.
(M) Moderate Weathering Region—A climate where occasional freezing is expected, but where concrete in outdoor service will not be continually exposed to freezing and thawing in the presence of moisture or to deicing chemicals.
(N) Negligible Weathering Region—A climate where concrete is rarely exposed to freezing in the presence of moisture.

Class Designation	Type or Location of Concrete Construction	Maximum Allowable, %						
		Clay Lumps and Friable Particles	Chert (Less Than 2.40 sp gr SSD)	Sum of Clay Lumps, Friable Particles, and Chert (Less Than 2.40 sp gr SSD)	Material Finer Than 75-µm (No. 200) Sieve	Coal and Lignite	Abrasion[A]	Magnesium Sulfate Soundness (5 cycles)[B]
		Severe Weathering Regions						
1S	Footings, foundations, columns and beams not exposed to the weather, interior floor slabs to be given coverings	10.0	...	...	1.0[C]	1.0	50	...
2S	Interior floors without coverings	5.0	...	...	1.0[C]	0.5	50	...
3S	Foundation walls above grade, retaining walls, abutments, piers, girders, and beams exposed to the weather	5.0	5.0	7.0	1.0[C]	0.5	50	18
4S	Pavements, bridge decks, driveways and curbs, walks, patios, garage floors, exposed floors and porches, or waterfront structures, subject to frequent wetting	3.0	5.0	5.0	1.0[C]	0.5	50	18
5S	Exposed architectural concrete	2.0	3.0	3.0	1.0[C]	0.5	50	18
		Moderate Weathering Regions						
1M	Footings, foundations, columns, and beams not exposed to the weather, interior floor slabs to be given coverings	10.0	...	...	1.0[C]	1.0	50	...
2M	Interior floors without coverings	5.0	...	...	1.0[C]	0.5	50	...
3M	Foundation walls above grade, retaining walls, abutments, piers, girders, and beams exposed to the weather	5.0	8.0	10.0	1.0[C]	0.5	50	18
4M	Pavements, bridge decks, driveways and curbs, walks, patios, garage floors, exposed floors and porches, or waterfront structures subject to frequent wetting	5.0	5.0	7.0	1.0[C]	0.5	50	18
5M	Exposed architectural concrete	3.0	3.0	5.0	1.0[C]	0.5	50	18
		Negligible Weathering Regions						
1N	Slabs subject to traffic abrasion, bridge decks, floors, sidewalks, pavements	5.0	...	...	1.0[C]	0.5	50	...
2N	All other classes of concrete	10.0	...	...	1.0[C]	1.0	50	...

[A] Crushed air-cooled blast-furnace slag is excluded from the abrasion requirements. The rodded or jigged bulk density (unit weight) of crushed air-cooled blast-furnace slag shall be not less than 1120 kg/m ^{3} [70 lb/ft^3]. The grading of slag used in the bulk density (unit weight) test shall conform to the grading to be used in the concrete. Abrasion loss of gravel, crushed gravel, or crushed stone shall be determined on the test size or sizes most nearly corresponding to the grading or gradings to be used in the concrete. When more than one grading is to be used, the limit on abrasion loss shall apply to each.

[B] The allowable limits for soundness shall be 12 % if sodium sulfate is used.

[C] This percentage under either of the following conditions: (*1*) is permitted to be increased to 1.5 if the material is essentially free of clay or shale; or (*2*) if the source of the fine aggregate to be used in the concrete is known to contain less than the specified maximum amount passing the 75-µm (No. 200) sieve (Table 1) the percentage limit *(L)* on the amount in the coarse aggregate is permitted to be increased to $L = 1 + [(P)/(100 - P)] (T - A)$, where P = percentage of sand in the concrete as a percent of total aggregate, T = the Table 1 limit for the amount permitted in the fine aggregate, and A = the actual amount in the fine aggregate. (This provides a weighted calculation designed to limit the maximum mass of material passing the 75-µm (No. 200) sieve in the concrete to that which would be obtained if both the fine and coarse aggregate were supplied at the maximum tabulated percentage for each of these ingredients.)

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4.3.3 When the aggregate being described is coarse aggregate, include:

4.3.3.1 The nominal maximum size or sizes permitted, based on thickness of section or spacing of reinforcing bars or other criteria. In lieu of stating the nominal maximum size, the specifier shall designate an appropriate size number or numbers (see 10.1 and Table 2). Designation of a size number to indicate a nominal size shall not restrict the person responsible for selecting proportions from combining two or more gradings of aggregate to obtain a desired grading, provided that the gradings are not otherwise restricted by the project specifier and the nominal maximum size indicated by the size number is not exceeded,

4.3.3.2 The class designation (see 11.1 and Table 3),

4.3.3.3 Whether the restriction on reactive materials in 11.2 applies,

4.3.3.4 In the case of the sulfate soundness test (see Table 3), which salt is to be used. If none is stated, either sodium sulfate or magnesium sulfate shall be used, and

4.3.4 The person responsible for selecting the concrete proportions if other than the concrete producer.

4.3.5 Any exceptions or additions to this specification (see Note 1).

FINE AGGREGATE

5. General Characteristics

5.1 Fine aggregate shall consist of natural sand, manufactured sand, or a combination thereof.

6. Grading

6.1 *Sieve Analysis*—Fine aggregate, except as provided in 6.2 and 6.3 shall be graded within the following limits:

Sieve (Specification E 11)	Percent Passing
9.5-mm (⅜-in.)	100
4.75-mm (No. 4)	95 to 100
2.36-mm (No. 8)	80 to 100
1.18-mm (No. 16)	50 to 85
600-µm (No. 30)	25 to 60
300-µm (No. 50)	5 to 30
150-µm (No. 100)	0 to 10

NOTE 2—Concrete with fine aggregate gradings near the minimums for percent passing the 300 µm (No.50) and 150 µm (No.100) sometimes have difficulties with workability, pumping or excessive bleeding. The addition of entrained air, additional cement, or the addition of an approved mineral admixture to supply the deficient fines, are methods used to alleviate such difficulties.

6.2 The fine aggregate shall have not more than 45 % passing any sieve and retained on the next consecutive sieve of those shown in 6.1, and its fineness modulus shall be not less than 2.3 nor more than 3.1.

6.3 Fine aggregate failing to meet these grading requirements shall meet the requirements of this section provided that the supplier can demonstrate to the purchaser or specifier that concrete of the class specified, made with fine aggregate under consideration, will have relevant properties (see Note 4) at least equal to those of concrete made with the same ingredients, with the exception that the reference fine aggregate shall be selected from a source having an acceptable performance record in similar concrete construction.

NOTE 3—Fine aggregate that conforms to the grading requirements of a specification, prepared by another organization such as a state transportation agency, which is in general use in the area, should be considered as having a satisfactory service record with regard to those concrete properties affected by grading.

NOTE 4—Relevant properties are those properties of the concrete that are important to the particular application being considered. STP 169D[5] provides a discussion of important concrete properties.

6.4 For continuing shipments of fine aggregate from a given source, the fineness modulus shall not vary more than 0.20 from the base fineness modulus. The base fineness modulus shall be that value that is typical of the source. The purchaser or specifier has the authority to approve a change in the base fineness modulus.

NOTE 5—The base fineness modulus should be determined from previous tests, or if no previous tests exist, from the average of the fineness modulus values for the first ten samples (or all preceding samples if less than ten) on the order. The proportioning of a concrete mixture may be dependent on the base fineness modulus of the fine aggregate to be used. Therefore, when it appears that the base fineness modulus is considerably different from the value used in the concrete mixture, a suitable adjustment in the mixture may be necessary.

7. Deleterious Substances

7.1 The amount of deleterious substances in fine aggregate shall not exceed the limits prescribed in Table 1.

7.2 *Organic Impurities*:

7.2.1 Fine aggregate shall be free of injurious amounts of organic impurities. Except as herein provided, aggregates subjected to the test for organic impurities and producing a color darker than the standard shall be rejected.

7.2.2 Use of a fine aggregate failing in the test is not prohibited, provided that the discoloration is due principally to the presence of small quantities of coal, lignite, or similar discrete particles.

7.2.3 Use of a fine aggregate failing in the test is not prohibited, provided that, when tested for the effect of organic impurities on strength of mortar, the relative strength at 7 days, calculated in accordance with Test Method C 87, is not less than 95 %.

7.3 Fine aggregate for use in concrete that will be subject to wetting, extended exposure to humid atmosphere, or contact with moist ground shall not contain any materials that are deleteriously reactive with the alkalies in the cement in an amount sufficient to cause excessive expansion of mortar or concrete, except that if such materials are present in injurious amounts, use of the fine aggregate is not prohibited when used with a cement containing less than 0.60 % alkalies calculated as sodium oxide equivalent ($Na_2O + 0.658K_2O$) or with the addition of a material that has been shown to prevent harmful expansion due to the alkali-aggregate reaction. (See Appendix X1.)

8. Soundness

8.1 Except as provided in 8.2 and 8.3, fine aggregate subjected to five cycles of the soundness test shall have a

[5] *Significance of Tests and Properties of Concrete and Concrete Making Materials, STP 169D*, ASTM, 2006.

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weighted average loss not greater than 10 % when sodium sulfate is used or 15 % when magnesium sulfate is used.

8.2 Fine aggregate failing to meet the requirements of 8.1 shall be regarded as meeting the requirements of this section provided that the supplier demonstrates to the purchaser or specifier that concrete of comparable properties, made from similar aggregate from the same source, has given satisfactory service when exposed to weathering similar to that to be encountered.

8.3 Fine aggregate not having a demonstrable service record and failing to meet the requirements of 8.1 shall be regarded as meeting the requirements of this section provided that the supplier demonstrates to the purchaser or specifier it gives satisfactory results in concrete subjected to freezing and thawing tests (see Test Method C 666/C 666M).

COARSE AGGREGATE

9. General Characteristics

9.1 Coarse aggregate shall consist of gravel, crushed gravel, crushed stone, air-cooled blast furnace slag, or crushed hydraulic-cement concrete (see Note 6), or a combination thereof, conforming to the requirements of this specification.

NOTE 6—Although crushed hydraulic-cement concrete has been used as an aggregate with reported satisfactory results, its use may require some additional precautions. Mixing water requirements may be increased because of the harshness of the aggregate. Partially deteriorated concrete, used as aggregate, may reduce freeze-thaw resistance, affect air void properties or degrade during handling, mixing, or placing. Crushed concrete may have constituents that would be susceptible to alkali-aggregate reactivity or sulfate attack in the new concrete or may bring sulfates, chlorides, or organic material to the new concrete in its pore structure.

10. Grading

10.1 Coarse aggregates shall conform to the requirements prescribed in Table 2 for the size number specified.

NOTE 7—The ranges shown in Table 2 are by necessity very wide in order to accommodate nationwide conditions. For quality control of any specific operation, a producer should develop an average grading for the particular source and production facilities, and should control the production gradings within reasonable tolerances from this average. Where coarse aggregate size numbers 357 or 467 are used, the aggregate should be furnished in at least two separate sizes.

11. Deleterious Substances

11.1 Except for the provisions of 11.3, the limits given in Table 3 shall apply for the class of coarse aggregate designated in the purchase order or other document (see Note 8 and Note 9). If the class is not specified, the requirements for Class 3S, 3M, or 1N shall apply in the severe, moderate, and negligible weathering regions, respectively (see Table 3 and Fig. 1).

NOTE 8—The specifier of the aggregate should designate the class of coarse aggregate to be used in the work, based on weathering severity, abrasion, and other factors of exposure (see Table 3 and Fig. 1) . The limits

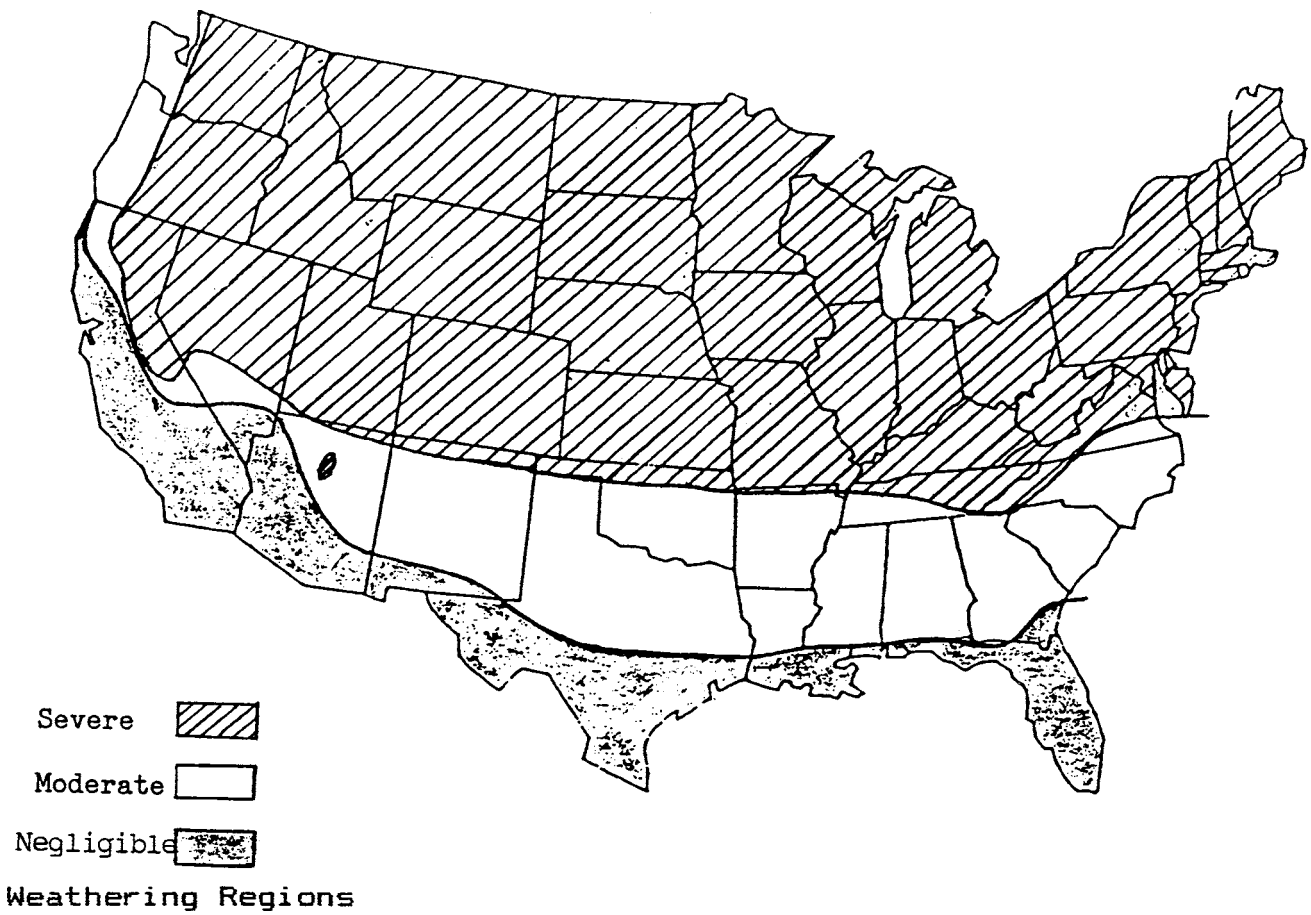

FIG. 1 Location of Weathering Regions

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for coarse aggregate corresponding to each class designation are expected to ensure satisfactory performance in concrete for the respective type and location of construction. Selecting a class with unduly restrictive limits may result in unnecessary cost if materials meeting those requirements are not locally available. Selecting a class with lenient limits may result in unsatisfactory performance and premature deterioration of the concrete. While concrete in different parts of a single structure may be adequately made with different classes of coarse aggregate, the specifier may wish to require the coarse aggregate for all concrete to conform to the same more restrictive class to reduce the chance of furnishing concrete with the wrong class of aggregate, especially on smaller projects.

NOTE 9—For coarse aggregate in concrete exposed to weathering, the map with the weathering regions shown in Fig. 1 is intended to serve only as a guide to probable weathering severity. Those undertaking construction, especially near the boundaries of weathering regions, should consult local weather bureau records for amount of winter precipitation and number of freeze-thaw cycles to be expected, for determining the weathering severity for establishing test requirements of the coarse aggregate. For construction at altitudes exceeding 1520 m [5000 ft] above sea level, the likelihood of more severe weathering than indicated by the map should be considered. In arid areas, severity of weathering may be less than that indicated. In either case, the definitions of weathering severity in Table 3 would govern. If there is doubt in choosing between two regions, select the more severe weathering region.

11.2 Coarse aggregate for use in concrete that will be subject to wetting, extended exposure to humid atmosphere, or contact with moist ground shall not contain any materials that are deleteriously reactive with the alkalies in the cement in an amount sufficient to cause excessive expansion of mortar or concrete except that if such materials are present in injurious amounts, the coarse aggregate is not prohibited when used with a cement containing less than 0.60 % alkalies calculated as sodium oxide equivalent ($Na_2O + 0.658K_2O$) or with the addition of a material that has been shown to prevent harmful expansion due to the alkali-aggregate reaction. (See Appendix X1.)

11.3 Coarse aggregate having test results exceeding the limits specified in Table 3 shall be regarded as meeting the requirements of this section provided the supplier demonstrates to the purchaser or specifier that concrete made with similar aggregate from the same source has given satisfactory service when exposed in a similar manner to that to be encountered; or, in the absence of a demonstrable service record, provided that the aggregate produces concrete having satisfactory relevant properties (see Note 4).

METHODS OF SAMPLING AND TESTING

12. Methods of Sampling and Testing

12.1 Sample and test the aggregates in accordance with the following methods, except as otherwise provided in this specification. Make the required tests on test specimens that comply with requirements of the designated test methods. It is not prohibited to use the same test specimen for sieve analysis and for determination of material finer than the 75-µm (No. 200) sieve. The use of separated sizes from the sieve analysis is acceptable for soundness or abrasion tests, however, additional test specimen preparation is required (see Note 10). For other test procedures and the evaluation of potential alkali reactivity, when required, use independent test specimens.

NOTE 10—The material used for the soundness test requires resieving to allow proper test specimen preparation as specified in Test Method C 88.

12.1.1 *Sampling*—Practice D 75 and Practice D 3665.

12.1.2 *Grading and Fineness Modulus*—Test Method C 136.

12.1.3 *Amount of Material Finer than 75-µm (No. 200) Sieve*—Test Method C 117.

12.1.4 *Organic Impurities*—Test Method C 40.

12.1.5 *Effect of Organic Impurities on Strength*—Test Method C 87.

12.1.6 *Soundness*—Test Method C 88.

12.1.7 *Clay Lumps and Friable Particles*— Test Method C 142.

12.1.8 *Coal and Lignite*—Test Method C 123, using a liquid of 2.0 specific gravity to remove the particles of coal and lignite. Only material that is brownish-black, or black, shall be considered coal or lignite. Coke shall not be classed as coal or lignite.

12.1.9 *Bulk Density (Unit Weight) of Slag*—Test Method C 29/C 29M.

12.1.10 *Abrasion of Coarse Aggregate*—Test Method C 131 or Test Method C 535.

12.1.11 *Reactive Aggregates*—See Appendix X1.

12.1.12 *Freezing and Thawing*—Procedures for making freezing and thawing tests of concrete are described in Test Method C 666/C 666M.

12.1.13 *Chert*—Test Method C 123 is used to identify particles in a sample of coarse aggregate lighter than 2.40 specific gravity, and Guide C 295 to identify which of the particles in the light fraction are chert.

13. Keywords

13.1 aggregates; coarse aggregate; concrete aggregates; fine aggregate

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APPENDIX

(Nonmandatory Information)

X1. METHODS FOR EVALUATING POTENTIAL FOR DELETERIOUS EXPANSION DUE TO ALKALI REACTIVITY OF AN AGGREGATE

X1.1 Introduction

X1.1.1 *Laboratory Methods*—Many test methods for evaluating the potential for deleterious expansion due to alkali reactivity of an aggregate have been proposed and some have been adopted as ASTM standards. However, there is no general agreement on the relation between the results of these tests and the amount of expansion to be expected or tolerated in service. Therefore, evaluation of the suitability of an aggregate should be based upon judgment, interpretation of test data, and results of examinations of concrete structures containing the same aggregates and similar cementitious materials having similar levels of alkalies. Results of the tests referred to in this appendix may assist in making the evaluation. When interpreting expansion of laboratory specimens, consideration should be given not only to expansion values at specific ages, but also to the shape of the expansion curve, which may indicate whether the expansion is leveling off or continuing at a constant or accelerating rate.

X1.1.2 *Service Record Evaluation*—Valid, comparable concrete service record data, if available, should take precedence over laboratory test results in most cases. To be considered valid, a record of satisfactory service should be available for at least 10 years for aggregates, cementitious materials, and exposures sufficiently similar to those in which an aggregate is being considered for future use. Longer periods of documented service may be required for proposed work designed for a particularly long service life in moist conditions, or if laboratory test results show that the aggregate may be deleteriously reactive.

X1.1.3 *Mitigation of Alkali-Aggregate Reaction*—If an aggregate has been judged to be potentially deleteriously reactive in concrete either through laboratory or service record evaluation, use of the aggregate should be considered with measures known to prevent excessive expansion due to alkali-aggregate reaction. See the mitigation sections in this appendix under X1.3 Alkali-Silica Reaction and X1.4 Alkali-Carbonate Rock Reaction and References cited for discussion of prevention strategies for new concrete.

X1.2 Background

X1.2.1 Background information on alkali-aggregate reaction can be found in Ref **(1)**[6], Descriptive Nomenclature C 294, and Guide C 295 as discussed as follows. Additional discussion is included in Refs **(2)** **(3)**. These references address both alkali-silica reaction and alkali-carbonate rock reaction.

X1.2.1.1 *Descriptive Nomenclature C 294 for Constituents of Concrete Aggregates*—This nomenclature provides descriptions of constituents of mineral aggregates and includes discussion of which have been associated with deleterious expansion due to alkali reaction.

X1.2.1.2 *Guide C 295 (Petrographic Examination of Aggregates)*—This guide outlines the procedures for examining an aggregate sample or a sample from a potential aggregate source to determine whether substances that are potentially deleteriously reactive are present; and, if so, in what amounts.

X1.2.1.3 *Alkali-Silica Reaction*—Certain materials are known to be potentially deleteriously alkali-silica reactive. These include forms of silica such as opal, chalcedony, tridymite, and cristobalite; cryptocrystalline and microcrystalline, strained, or highly fractured quartz; and intermediate to acid (silica-rich) volcanic glass such as is likely to occur in rhyolite, andesite, or dacite. Determination of the presence and quantities of these materials by petrographic examination is helpful in evaluating potential alkali reactivity. An aggregate can be potentially deleteriously reactive when some of these materials, such as opal, are present in very small quantities (for example, 1 %).

X1.2.1.4 *Alkali-Carbonate Rock Reaction*—The reaction of dolomite in certain carbonate rocks with alkalies has been associated with deleterious expansion of concrete containing such rocks as coarse aggregate. The most rapidly reactive carbonate rocks possess a characteristic texture in which relatively large crystals of dolomite are scattered in a finer-grained matrix of calcite and clay. These rocks also have a composition in which the carbonate portion consists of substantial amounts of both dolomite and calcite, and the acid-insoluble residue contains a significant amount of clay. Certain purely dolomitic rocks also may produce slow expansion in concrete.

X1.3 Alkali-Silica Reaction

X1.3.1 *Test Method C 289 (Chemical Method)*—The results of the test are values for the quantities of dissolved silica (S_c) and reduction in alkalinity (R_c) for each of the three test portions from the prepared aggregate test sample. Aggregates represented by plotted points (S_c, R_c), which lie on the deleterious side of the solid curve of Fig. X1.1 of Test Method C 289 usually should be considered potentially reactive. Three regions are delineated in the figure: (*1*) aggregates considered innocuous; (*2*) aggregates considered potentially deleterious; and (*3*) aggregates considered deleterious. Aggregates represented by points lying in the potentially deleterious region above the dashed line in Fig. X1.1 of Test Method C 289 may give relatively low expansions in mortar or concrete even though they are extremely reactive with alkalies. The test can be made quickly and can provide helpful information, except for slowly reactive rocks such as some granitic gneiss and quartzite. Also, as pointed out in the appendix to Test Method C 289, the results may not be correct for aggregates containing

[6] The boldface numbers in parentheses refer to the list of references at the end of this standard.

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carbonates or magnesium silicates, such as antigorite (serpentine), or constituents producing late-slow reactivity. See the appendix to Test Method C 289 for a discussion of the interpretation of results and applicable references. If test results indicate deleterious or potentially deleterious character, the aggregates should be tested in accordance with Test Methods C 227 or C 1293 to verify the potential for expansion in concrete.

X1.3.2 *Test Method C 227 (Mortar-Bar Method for Cement-Aggregate Combinations)*—The results of this test method, when a high-alkali cement is used, furnish information on the likelihood of potentially deleterious expansion occurring. The alkali content of the portland cement should be at least 0.8 %, expressed as percent sodium oxide equivalent ($\%Na_2O + 0.658 \times \%K_2O$). Combinations of aggregate and cementitious materials that have produced excessive expansions in this test method should be considered potentially reactive. While the line of demarcation between innocuous and potentially deleterious combinations is not clearly defined, expansion is generally considered to be excessive if it exceeds 0.05 % at 3 months or 0.10 % at 6 months. Expansions greater than 0.05 % at 3 months should not be considered excessive when the 6-month expansion remains below 0.10 %. Data for the 3-month tests should be considered only when 6-month results are not available. The limits may not be conservative for slowly reactive aggregates. Test Method C 227 is not suitable for slowly reactive aggregates, and its use for this purpose is not advised (**1, 2**). Aggregates suspected of being slowly reactive should be evaluated using Test Method C 1260 or Test Method C 1293. Test Method C 227 is also used with a specific reactive glass aggregate to verify the mitigation effectiveness of blended cements meeting Specification C 595, with the Table 2 optional mortar expansion requirement, and meeting Performance Specification C 1157 with Option R. These procedures are similar to the provisions of Test Method C 441 discussed as follows for mineral admixtures and ground slag.

X1.3.3 *Test Method C 342 (Mortar Bars Subjected to Changes in Moisture and Temperature)*—This withdrawn test method was intended for research concerning the potential expansion of cement-aggregate combinations involving selected aggregates found in parts of Oklahoma, Kansas, Nebraska, and Iowa. Due to the specimen conditioning procedures, the expansion of mortar bars in this test method may not be related to alkali-silica reaction under normal-temperature conditioning. Data on the use of this test method are given in the references cited in a footnote in the test method. It is indicated that cement-aggregate combinations tested by this procedure in which expansion equals or exceeds 0.20 % at an age of 1 year may be considered unsatisfactory for use in concrete exposed to wide variations of temperature and degree of saturation with water. This test method is not recommended for use in regions other than previously cited.

X1.3.4 *Test Method C 1260 (Mortar-Bar Method for Potential Alkali Reactivity of Aggregate)*—This test method is an accelerated screening technique developed for the detection of materials that develop deleterious expansions slowly over a long period of time. Some aggregates that perform well in the field have been shown to fail this test (**4, 5**). Results of this test method should not be used for rejection of aggregates unless it has been established using the sources of supplementary information cited in the test method that the detected expansion is actually due to alkali-silica reaction. There is good agreement in the published literature cited in the test method for the expansion limits: (*1*) expansions of less than 0.10 % at 16 days after casting are indicative of innocuous behavior in most cases; (*2*) expansions of more than 0.20 % at 16 days are indicative of potentially deleterious expansion; and (*3*) expansions between 0.10 and 0.20 % at 16 days include both aggregates that are known to be innocuous and deleterious in field performance. If test results indicate expansion greater than 0.10 % at 16 days, the aggregate should be tested in accordance with Test Method C 1293 unless appropriate field experience demonstrates that it does not cause deleterious expansion in concrete. (See X1.3.6.)

X1.3.5 *Test Method C 1293 (Concrete Prism Method for Alkali-Silica Reactivity)*—The test method evaluates the aggregates independently, or combinations of aggregate with pozzolan or slag for potential alkali-silica reaction expansion using concrete prisms. The test method is accelerated by using an elevated alkali content and Test Method C 227 exposure conditions. The appendix to Test Method C 1293 provides guidance on interpretation of the results. When evaluating aggregates independently, those with expansions equal to or greater than 0.04 % at one year are considered potentially deleteriously reactive. When evaluating combinations of pozzolan or slag, the test is extended to two years using the 0.04 % expansion limit. This test method is considered to be the most reliable procedure among ASTM Test Methods for the evaluation of aggregates for alkali-silica reaction.

X1.3.6 *Mitigation of Alkali-Silica Reaction*—Normally if an aggregate is shown to be nonreactive or innocuous by producing little or no expansion in Test Method C 1260 or Test Method C 1293, no mitigation is necessary. Similarly, if the aggregate has a long satisfactory service record with similar cementitious materials having similar or higher alkali levels, no mitigation is necessary. On the other hand, use of aggregates judged to be potentially deleteriously alkali-silica reactive should be considered with the use of measures known to prevent excessive expansion. These include measures such as: low-alkali cement (Specification C 150 with the low-alkali option); blended cements (Specification C 595 with the Table 2 optional mortar expansion requirement or Performance Specification C 1157 with Option R); pozzolanic materials (meeting the optional physical requirement on effectiveness in controlling alkali-silica reaction in Specification C 618 or reactivity with cement alkalies in Specification C 1240 for silica fume); or ground slag (shown to be effective in preventing excessive expansion of concrete due to alkali-aggregate reaction as discussed in Appendix X3 of Specification C 989). The effectiveness of the cementitious materials or admixtures, or both, chosen to mitigate a potentially reactive aggregate should be demonstrated through tests of the individual materials, or tests of the proposed combination in concrete.

X1.3.7 *Test Method C 441 (Mortar-Bar Method for Effectiveness of Mineral Admixtures or Ground Blast-Furnace Slag in Preventing Excessive Expansion of Concrete Due to the*

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Alkali-Silica Reaction)—This test method evaluates cementitious materials in mortar bars as in Test Method C 227 using highly-reactive borosilicate glass as the aggregate. Specification C 618 provides a criterion for its use as applied to fly ash and raw or calcined natural pozzolans when sampled and tested in accordance with Test Methods C 311 by comparison with a control mortar made with low-alkali cement. Specification C 1240 provides criteria for the use of Test Method C 441 to evaluate silica fume for controlling expansion. Appendix X3 to Specification C 989 describes its use for ground granulated blast-furnace slag. Project specific materials can be evaluated by proportioning the mortars according to the *Job Mixture* clause. In evaluating the results of this test, it should be recognized that borosilicate glass is more reactive than most construction aggregates; therefore, the amount of a given pozzolan or ground slag necessary to control expansion with a portland cement of given alkali content may be higher than needed to avoid deleterious expansion with a particular construction aggregate.

X1.3.8 *Test Method C 1567 (Accelerated Mortar-Bar Method for Determining the Potential Alkali-Silica Reactivity of Combinations of Cementitious Materials and Aggregate)*—This test method evaluates specific combinations of aggregate and cementitious materials composed of hydraulic cement and pozzolans or ground granulated blast-furnace slag under storage conditions described in Test Method C 1260. Since the mortar specimens are stored in 1N NaOH solution, the test may underestimate the effectiveness of cementitious materials that rely to a significant degree on low alkali content for mitigation. In general, expansions less than 0.10 % at 16 days are considered to indicate effective control of potential ASR-related expansion of the aggregate by the specific combination of cementitious materials.

X1.3.9 The use of Test Method C 1293 to evaluate the mitigation of potentially reactive aggregates is discussed in X1.3.5.

X1.4 Alkali-Carbonate Rock Reaction

X1.4.1 *Test Method C 586 (Rock Cylinders Method for Alkali-Carbonate Rock Reaction)*—Rocks that are capable of potentially deleterious carbonate rock reaction are relatively infrequent and seldom constitute a significant proportion of a deposit of rock being considered for use in making aggregate for concrete. Test Method C 586 has been successfully used in research and in preliminary screening of aggregate sources to indicate the presence of material with a potential for deleterious expansions when used in concrete.

X1.4.2 *Test Method C 1105 (Concrete-Prism Method for Alkali-Carbonate Rock Reaction)*—This test method is intended to evaluate specific combinations of materials in concrete when the aggregate is regarded as susceptible to deleterious expansion in service due to the alkali-carbonate rock reaction. The appendix to Test Method C 1105 provides general information and references concerning the interpretation of results. A cement-aggregate combination might reasonably be classified as potentially deleteriously reactive if the average expansion of six concrete specimens is equal to or greater than: 0.015 % at 3 months; 0.025 % at 6 months; or 0.030 % at 1 year. Data for later ages are preferred.

X1.4.3 *Mitigation of Alkali-Carbonate Rock Reaction*—Normally, if a carbonate rock does not show the characteristic texture and composition associated with this type of reaction, or if it does not produce expansion in rock cylinders (Test Method C 586) or concrete prisms (Test Method C 1105), no mitigation is necessary for alkali-carbonate rock reaction. Similarly, if the aggregate has a long satisfactory service record with similar materials and conditions, no mitigation is necessary. On the other hand, use of aggregates judged to be potentially deleteriously alkali-carbonate reactive in concrete is not recommended unless it can be shown that mitigation methods will be effective. Pozzolans generally have not been found to control alkali-carbonate rock reaction. Measures suggested for mitigation includes: avoiding reactive carbonate rocks; selective quarrying; diluting reactive rock to less than 20 % of the aggregate in the concrete; use of smaller maximum size; and the use of very low alkali cement.

REFERENCES

(1) *Significance of Tests and Properties of Concrete and Concrete-Making Materials*, Klieger, Paul and Lamond, Joseph F., Eds, *ASTM STP 169C*, 1994, 623 pages. See Chapter 31 on "Petrographic Evaluation of Concrete Aggregates," by Richard C. Mielenz, Chapter 32 on "Alkali-Silica Reactions in Concrete" by David Stark, and Chapter 33 on "Alkali-Carbonate Rock Reaction" by Michael A. Ozol.

(2) "State-of-the-Art Report on Alkali-Aggregate Reactivity" by ACI Committee 221 on Aggregates, ACI 221.1R-98, American Concrete Institute, Farmington Hills, MI, 1998, 31 pages.

(3) *Alkali-Aggregate Reaction in Concrete,* Berube, M. A., Fournier, B., and Durand, Eds, *Proceedings of the 11th International Conference,* Quebec City, Canada, June 2000, 1402 pages. (Note—This conference and proceedings includes information on ASR and ACR in concrete by researchers and experts from all over the world. Copies of the volume can be obtained from the International Centre for Sustainable Development of Cement and Concrete, 405 Rochester Street, Ottawa, Ontario, Canada, K1A 0G1.)

(4) Hooton, R.D., and Rogers, C.A., "Evaluation of Rapid Test Methods for Detecting Alkali-Reactive Aggregates," *Proceedings of Eighth International Conference on Alkali-Aggregate Reaction,* Kyoto, 1989, pp. 439–444.

(5) Fournier, B., and Berube, M.A.," Application of the NBRI Accelerated Mortar Bar Test to Siliceous Carbonate Aggregates Produced in the St. Lawrence Lowlands, Part 2: Proposed Limits, Rates of Expansion, and Microstructure of Reaction Products," *Cement and Concrete Research*, Vol 21, 1991, pp. 1069–1082.

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SUMMARY OF CHANGES

Committee C09 has identified the location of selected changes to this specification since the last issue, C 33 – 07, that may impact the use of this specification. (Approved December 1, 2008)

(*1*) Revised the document as a combined units specification.

Committee C09 has identified the location of selected changes to this specification since the last issue, C 33 – 03, that may impact the use of this specification. (Approved December 15, 2007)

(*1*) Updated reference in Note 4.
(*2*) Reversed the order of X1.3.6 and X1.3.7 and added information regarding Test Method C 441 in X1.3.7.
(*3*) Revised X1.3.5.
(*4*) Added new X1.3.8 to reference Test Method C 1567.
(*5*) Added new X1.3.9 to reference Test Method C 1293.

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Designation: C 35 – 01 (Reapproved 2009)

Standard Specification for Inorganic Aggregates for Use in Gypsum Plaster[1]

This standard is issued under the fixed designation C 35; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

This standard has been approved for use by agencies of the Department of Defense.

1. Scope

1.1 This specification covers perlite, vermiculite, natural and manufactured sand for use as gypsum plaster aggregates.

1.2 The values stated in inch-pound units are to be regarded as standard. The values given in parentheses are mathematical conversions to SI units that are provided for information only and are not considered standard.

1.3 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

1.4 The text of this specification references notes and footnotes that provide explanatory material. These notes and footnotes (excluding those in tables and figures) shall not be considered as requirements of the specification.

2. Referenced Documents

2.1 *ASTM Standards:*[2]

C 11 Terminology Relating to Gypsum and Related Building Materials and Systems

C 29/C 29M Test Method for Bulk Density ("Unit Weight") and Voids in Aggregate

C 40 Test Method for Organic Impurities in Fine Aggregates for Concrete

C 136 Test Method for Sieve Analysis of Fine and Coarse Aggregates

C 471M Test Methods for Chemical Analysis of Gypsum and Gypsum Products (Metric)

D 75 Practice for Sampling Aggregates

E 11 Specification for Woven Wire Test Sieve Cloth and Test Sieves

3. Terminology

3.1 Definitions shall be in accordance with Terminology C 11.

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *manufactured sand*, *n*—the fine material resulting from the crushing and classification by screening, or otherwise, of rock, gravel, or blast furnace slag.

3.2.2 *natural sand*, *n*—the fine granular material resulting from the natural disintegration of rock or from the crushing of friable sandstone.

3.2.3 *perlite aggregate*, *n*—a siliceous volcanic glass expanded by heat.

3.2.4 *vermiculite aggregate*, *n*—a micaceous mineral expanded by heat.

4. Chemical Composition

4.1 Water-soluble impurities in sand shall not exceed 0.15 weight % and sodium ion content shall not exceed 0.02 weight % when tested in accordance with Section 7.

4.2 Sand shall develop a color no darker than the standard, when subjected to the colorimetric test for organic impurities in accordance with Test Method C 40, unless it is established by adequate tests that the impurities causing the color are not harmful in plaster.

5. Mechanical Requirements

5.1 *Grading*—Shall be as follows when tested in accordance with Section 7:

5.1.1 Perlite and vermiculite shall be graded within the limits specified in Table 1.

5.1.2 *Natural and Manufactured Sand*—Shall be graded with not more than 50 % retained between any two consecutive sieves shown in Table 1, nor more than 25 % between the No. 50 (300 µm) and No. 100 (150 µm) sieves.

5.2 *Density*:

5.2.1 Perlite shall have a density of not less than 6 nor more than 12 lb/ft^3(96 to 192 kg/m^3) when tested in accordance with Test Method C 29/C 29M using the shoveling procedure.

5.2.2 Vermiculite shall have a density of not less than 6 nor more than 10 lb/ft^3(96 to 160 kg/m^3) when tested in accordance with Test Method C 29/C 29M using the shoveling procedure.

[1] This specification is under the jurisdiction of ASTM Committee C11 on Gypsum and Related Building Materials and Systems and is the direct responsibility of Subcommittee C11.02 on Specifications and Test Methods for Accessories and Related Products.

Current edition approved Sept. 1, 2009. Published September 2009. Originally approved in 1921. Last previous edition approved in 2005 as C 35 – 01(2005).

[2] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

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TABLE 1 Grading Requirements

Sieve Size	Percentage Retained on Each Sieve, Cumulative					
	Perlite, by volume		Vermiculite, by volume		Sand, by weight	
	Max	Min	Max	Min	Max	Min
No. 4 (4.75-mm)	0	...	0	...	0	...
No. 8 (2.36-mm)	5	0	10	0	5	0
No. 16 (1.18-mm)	60	5	75	40	30	5
No. 30 (600-µm)	95	45	95	65	65	30
No. 50 (300-µm)	98	75	98	75	95	65
No. 100 (150-µm)	100	85	100	90	100	90
No. 200 (15-µm)					100	95

6. Sampling

6.1 *Apparatus*—Suitable thief tube.

6.2 *Bulk Aggregate*—Obtain specimens of sand in accordance with Practice D 75.

6.3 *Bagged Aggregate*—Obtain from 1 bag randomly selected from each 100 bags but not less than 6 bags from the shipment. For smaller shipments, not less than 6 % of the number of bags shall constitute the sample.

6.3.1 Secure specimens by inserting a suitable thief tube the full distance between diagonally opposite corners of the bag with the bag lying in a horizontal position. Combine the portions to produce a composite specimen having a volume not less than 1 ft^3(0.028 m^3). Prepare and test not less than 1 composite specimen separately for each 2000 bags of aggregate.

6.4 Reduce specimens obtained in accordance with 6.2 or 6.3 by quartering or riffling to obtain specimens of proper size for individual tests.

7. Test Methods

7.1 *Apparatus*:

7.1.1 *Sieve*—Specification E 11, Nos. 4, 8, 16, 30, 50, 100, 200 (4.75, 2.36, 1.18 mm, 600 µm, 300 µm, 150 µm, 15 µm).

7.1.2 *Graduated 250 mL Cylinder.*

7.1.3 *250 mL Beaker.*

7.1.4 *Tared Evaporating Dish.*

7.1.5 *Fast Paper Filter.*

7.1.6 *100 mL Volumetric Flask.*

7.1.7 *Deionized Water.*

7.1.8 *Spatula.*

7.1.9 *Weighing Scale.*

7.1.10 *Oven.*

7.1.11 *Desiccator.*

7.1.12 *Mechanical Shaker.*

7.1.13 *500 mL Graduated Cylinder.*

7.2 *Sieve Analysis for Sand*—Use Test Method C 136.

7.3 *Sieve Analysis for Perlite or Vermiculite*—Use Test Method C 136 except as modified as follows:

7.3.1 Use a specimen of 500 mL bulk volume.

7.3.1.1 Measure the volume of each sieve fraction in a 250 mL graduated cylinder. Pour the specimen loosely into the graduate without tamping or shaking. Level the surface with a spatula and read the volume to within ±2 mL.

7.3.2 Express the volumes of the individual sieve fractions as percentages of the sum of the volumes of all fractions.

7.3.3 Calculate the cumulative percentages on each designated sieve by summing the individual percentages of all fractions larger than that sieve.

7.4 *Density of Lightweight Aggregate*— Test Method C 29/C 29M; use shoveling procedure.

7.5 *Water Soluble Impurities of Sand*:

7.5.1 *Significance and Use*—Impurities can affect the setting properties, strength, and bond performance of gypsum plaster. These procedures determine the water soluble impurities of the sand being evaluated.

7.5.2 *Apparatus*:

7.5.2.1 *Analytical Balance*, with a precision of 0.0001 g.

7.5.2.2 *Balance*, capable of weighing at least 10 g to a precision of 0.1 g.

7.5.2.3 *Desiccator*, containing calcium chloride or equivalent desiccant.

7.5.2.4 *Drying Oven*, capable of being controlled to 250°F (121°C).

7.5.2.5 *Filter Paper*—A "fast" filter paper shall be used.[3]

7.5.2.6 *Atomic Absorption or Ion Chromatography Equipment.*

7.5.2.7 *Mechanical Shaker.*

7.5.3 *Procedure (Water Soluble Impurities)*:

7.5.3.1 Weigh approximately 10 g of air-dried sand and record the weight to 0.1 g. Transfer to a 250-mL beaker. Add 100 mL of distilled water. Heat to boiling and allow to simmer on a hot plate for 5 min. Filter through a fast paper into a tared evaporating dish. Wash with hot distilled water until the volume of filtrate is about 125 mL. Evaporate to dryness in an oven without allowing the temperature of the dish to rise above 250°F (121°C). Cool residue in a dessicator, weigh to 0.001 g and calculate the percentage of residue on the initial weight of sand.

7.5.3.2 *Report*—Report percentage as water soluble impurities.

7.5.3.3 *Precision and Bias*—No estimate of the precision or bias, or both, is available at this time.

7.5.4 *Procedure (Sodium Ion Content)*:

7.5.4.1 Weigh approximately 5 g of sand and record the weight to 0.01 g. Transfer to 100-mL volumetric flask. Add approximately 80 mL of deionized water to the flask. Shake on a mechanical shaker for 4 h. Remove and bring to a full volume with deionized water and allow to settle. Analyze for Na ion according to general atomic absorption in accordance with Test Methods C 471M or ion chromatography procedures.[4]

NOTE 1—To minimize contamination, care must be exercised to be sure all equipment is clean.

7.5.4.2 *Calculation and Report*—Calculate and report the percent Na as follows:

[3] The sole source of supply of the apparatus known to the committee at this time is VWR Scientific. If you are aware of alternative suppliers, please provide this information to ASTM International Headquarters. Your comments will receive careful consideration at a meeting of the responsible technical committee,[1] which you may attend.

[4] The sole source of supply of ion chromatographs known to the committee at this time is Dionex Inc., Sunnyvale, CA. If you are aware of alternative suppliers, please provide this information to ASTM International Headquarters. Your comments will receive careful consideration at a meeting of the responsible technical committee,[1] which you may attend.

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$$\mu g/g = \frac{\text{Curve concentration} \times \text{any dilution factor} \times 100 \text{ mL final volume}}{\text{initial weight of sample}}$$

$$\frac{\mu g/g}{10\,000} = \%\ \text{metal ion } (Na^{+})$$

7.5.4.3 *Precision and Bias*—No estimate of the precision or bias is available at this time.

7.5.5 *Organic Impurities*—Test Method C 40.

8. Inspection

8.1 Inspection of the material shall be agreed upon between the purchaser and the producer or supplier as part of the purchase agreement.

9. Rejection and Rehearing

9.1 Rejection of material shall be reported to the producer or supplier within ten working days from the receipt of the shipment by the purchaser. Rejection of the material shall be based either on the specific cause of failure to conform to the requirements of this specification or the failure of the material to meet the minimum weight or approximate volume as stated on the shipment.

9.2 Failure to meet the minimum weight or approximate volume shall be determined as follows:

9.2.1 *Individual Packages*:

9.2.1.1 The contents, on a weight basis, are 5 % less than that indicated on the packages, or

9.2.1.2 The contents, on a volume basis, are 10 % less than that indicated on the package.

9.2.2 *The Entire Shipment*:

9.2.2.1 On a weight basis when the average contents of 2 packages for each 100 but not less than 6 packages selected at random, in any one shipment, are less than that indicated on the package. The net weight of the contents shall be determined by weighing the package or packages and deducting the weight of the container.

9.2.2.2 On a volume basis when the average contents of 2 packages for each 100 but not less than 6 packages selected at random, in any one shipment, differ by more than 5 % more or 10 % less from that indicated on the package. The volume of the contents in the package shall be calculated by determining the weight of the contents of the package and then obtaining the weight per unit of volume of the aggregate, from an average weight package of the samples selected in 6.3.1, by the shoveling procedure given in Test Method C 29/C 29M, and then dividing the weight of the contents of the bag by the unit of volume of the aggregate.

10. Certification

10.1 When specified in the purchase order, the producer's or supplier's certification shall be furnished to the purchaser stating that the material was prepared or manufactured in accordance with this specification and has been found to meet the specified requirements.

11. Packaging and Package Marking

11.1 When lightweight aggregates covered by this specification are delivered in packages, the name of the type of aggregate, and minimum weight and approximate volume of the contents shall be plainly indicated thereon.

11.2 When delivered in bulk quantities, the bill of lading shall show the quantity by weight or unit of volume, and the name of the supplier.

11.2.1 Bulk materials shall be delivered in clean transport vessels, free of contaminants.

12. Keywords

12.1 aggregates; gypsum plaster; inorganic; manufactured sand; natural sand; perlite; vermiculite

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Designation: C39/C39M – 09a

Standard Test Method for Compressive Strength of Cylindrical Concrete Specimens[1]

This standard is issued under the fixed designation C39/C39M; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

This standard has been approved for use by agencies of the Department of Defense.

1. Scope*

1.1 This test method covers determination of compressive strength of cylindrical concrete specimens such as molded cylinders and drilled cores. It is limited to concrete having a density in excess of 800 kg/m^3 [50 lb/ft^3].

1.2 The values stated in either SI units or inch-pound units are to be regarded separately as standard. The inch-pound units are shown in brackets. The values stated in each system may not be exact equivalents; therefore, each system shall be used independently of the other. Combining values from the two systems may result in non-conformance with the standard.

1.3 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.* (**Warning**—Means should be provided to contain concrete fragments during sudden rupture of specimens. Tendency for sudden rupture increases with increasing concrete strength and it is more likely when the testing machine is relatively flexible. The safety precautions given in the Manual of Aggregate and Concrete Testing are recommended.)

1.4 The text of this standard references notes which provide explanatory material. These notes shall not be considered as requirements of the standard.

2. Referenced Documents

2.1 *ASTM Standards:*[2]

C31/C31M Practice for Making and Curing Concrete Test Specimens in the Field

C42/C42M Test Method for Obtaining and Testing Drilled Cores and Sawed Beams of Concrete

C192/C192M Practice for Making and Curing Concrete Test Specimens in the Laboratory

C617 Practice for Capping Cylindrical Concrete Specimens

C670 Practice for Preparing Precision and Bias Statements for Test Methods for Construction Materials

C873 Test Method for Compressive Strength of Concrete Cylinders Cast in Place in Cylindrical Molds

C1077 Practice for Laboratories Testing Concrete and Concrete Aggregates for Use in Construction and Criteria for Laboratory Evaluation

C1231/C1231M Practice for Use of Unbonded Caps in Determination of Compressive Strength of Hardened Concrete Cylinders

E4 Practices for Force Verification of Testing Machines

E74 Practice of Calibration of Force-Measuring Instruments for Verifying the Force Indication of Testing Machines

Manual of Aggregate and Concrete Testing

3. Summary of Test Method

3.1 This test method consists of applying a compressive axial load to molded cylinders or cores at a rate which is within a prescribed range until failure occurs. The compressive strength of the specimen is calculated by dividing the maximum load attained during the test by the cross-sectional area of the specimen.

4. Significance and Use

4.1 Care must be exercised in the interpretation of the significance of compressive strength determinations by this test method since strength is not a fundamental or intrinsic property of concrete made from given materials. Values obtained will depend on the size and shape of the specimen, batching, mixing

[1] This test method is under the jurisdiction of ASTM Committee C09 on Concrete and Concrete Aggregates and is the direct responsibility of Subcommittee C09.61 on Testing for Strength.

Current edition approved Dec. 15, 2009. Published February 2010. Originally approved in 1921. Last previous edition approved in 2009 as C39/C39M – 09. DOI: 10.1520/C0039_C0039M-09a.

[2] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

***A Summary of Changes section appears at the end of this standard.**

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procedures, the methods of sampling, molding, and fabrication and the age, temperature, and moisture conditions during curing.

4.2 This test method is used to determine compressive strength of cylindrical specimens prepared and cured in accordance with Practices C31/C31M, C192/C192M, C617, and C1231/C1231M and Test Methods C42/C42M and C873.

4.3 The results of this test method are used as a basis for quality control of concrete proportioning, mixing, and placing operations; determination of compliance with specifications; control for evaluating effectiveness of admixtures; and similar uses.

4.4 The individual who tests concrete cylinders for acceptance testing shall meet the concrete laboratory technician requirements of Practice C1077, including an examination requiring performance demonstration that is evaluated by an independent examiner.

NOTE 1—Certification equivalent to the minimum guidelines for ACI Concrete Laboratory Technician, Level I or ACI Concrete Strength Testing Technician will satisfy this requirement.

5. Apparatus

5.1 *Testing Machine*—The testing machine shall be of a type having sufficient capacity and capable of providing the rates of loading prescribed in 7.5.

5.1.1 Verify calibration of the testing machines in accordance with Practices E4, except that the verified loading range shall be as required in 5.3. Verification is required under the following conditions:

5.1.1.1 At least annually, but not to exceed 13 months,

5.1.1.2 On original installation or immediately after relocation,

5.1.1.3 Immediately after making repairs or adjustments that affect the operation of the force applying system or the values displayed on the load indicating system, except for zero adjustments that compensate for the mass of bearing blocks or specimen, or both, or

5.1.1.4 Whenever there is reason to suspect the accuracy of the indicated loads.

5.1.2 *Design*—The design of the machine must include the following features:

5.1.2.1 The machine must be power operated and must apply the load continuously rather than intermittently, and without shock. If it has only one loading rate (meeting the requirements of 7.5), it must be provided with a supplemental means for loading at a rate suitable for verification. This supplemental means of loading may be power or hand operated.

5.1.2.2 The space provided for test specimens shall be large enough to accommodate, in a readable position, an elastic calibration device which is of sufficient capacity to cover the potential loading range of the testing machine and which complies with the requirements of Practice E74.

NOTE 2—The types of elastic calibration devices most generally available and most commonly used for this purpose are the circular proving ring or load cell.

5.1.3 *Accuracy*—The accuracy of the testing machine shall be in accordance with the following provisions:

5.1.3.1 The percentage of error for the loads within the proposed range of use of the testing machine shall not exceed ±1.0 % of the indicated load.

5.1.3.2 The accuracy of the testing machine shall be verified by applying five test loads in four approximately equal increments in ascending order. The difference between any two successive test loads shall not exceed one third of the difference between the maximum and minimum test loads.

5.1.3.3 The test load as indicated by the testing machine and the applied load computed from the readings of the verification device shall be recorded at each test point. Calculate the error, E, and the percentage of error, E_p, for each point from these data as follows:

$$E = A - B \tag{1}$$

$$E_p = 100(A - B)/B$$

where:

A = load, kN [lbf] indicated by the machine being verified, and

B = applied load, kN [lbf] as determined by the calibrating device.

5.1.3.4 The report on the verification of a testing machine shall state within what loading range it was found to conform to specification requirements rather than reporting a blanket acceptance or rejection. In no case shall the loading range be stated as including loads below the value which is 100 times the smallest change of load estimable on the load-indicating mechanism of the testing machine or loads within that portion of the range below 10 % of the maximum range capacity.

5.1.3.5 In no case shall the loading range be stated as including loads outside the range of loads applied during the verification test.

5.1.3.6 The indicated load of a testing machine shall not be corrected either by calculation or by the use of a calibration diagram to obtain values within the required permissible variation.

5.2 The testing machine shall be equipped with two steel bearing blocks with hardened faces (Note 3), one of which is a spherically seated block that will bear on the upper surface of the specimen, and the other a solid block on which the specimen shall rest. Bearing faces of the blocks shall have a minimum dimension at least 3 % greater than the diameter of the specimen to be tested. Except for the concentric circles described below, the bearing faces shall not depart from a plane by more than 0.02 mm [0.001 in.] in any 150 mm [6 in.] of blocks 150 mm [6 in.] in diameter or larger, or by more than 0.02 mm [0.001 in.] in the diameter of any smaller block; and new blocks shall be manufactured within one half of this tolerance. When the diameter of the bearing face of the spherically seated block exceeds the diameter of the specimen by more than 13 mm [0.5 in.], concentric circles not more than 0.8 mm [0.03 in.] deep and not more than 1 mm [0.04 in.] wide shall be inscribed to facilitate proper centering.

NOTE 3—It is desirable that the bearing faces of blocks used for compression testing of concrete have a Rockwell hardness of not less than 55 HRC.

5.2.1 Bottom bearing blocks shall conform to the following requirements:

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5.2.1.1 The bottom bearing block is specified for the purpose of providing a readily machinable surface for maintenance of the specified surface conditions (Note 4). The top and bottom surfaces shall be parallel to each other. If the testing machine is so designed that the platen itself is readily maintained in the specified surface condition, a bottom block is not required. Its least horizontal dimension shall be at least 3 % greater than the diameter of the specimen to be tested. Concentric circles as described in 5.2 are optional on the bottom block.

NOTE 4—The block may be fastened to the platen of the testing machine.

5.2.1.2 Final centering must be made with reference to the upper spherical block. When the lower bearing block is used to assist in centering the specimen, the center of the concentric rings, when provided, or the center of the block itself must be directly below the center of the spherical head. Provision shall be made on the platen of the machine to assure such a position.

5.2.1.3 The bottom bearing block shall be at least 25 mm [1 in.] thick when new, and at least 22.5 mm [0.9 in.] thick after any resurfacing operations.

5.2.2 The spherically seated bearing block shall conform to the following requirements:

5.2.2.1 The maximum diameter of the bearing face of the suspended spherically seated block shall not exceed the values given below:

Diameter of Test Specimens, mm [in.]	Maximum Diameter of Bearing Face, mm [in.]
50 [2]	105 [4]
75 [3]	130 [5]
100 [4]	165 [6.5]
150 [6]	255 [10]
200 [8]	280 [11]

NOTE 5—Square bearing faces are permissible, provided the diameter of the largest possible inscribed circle does not exceed the above diameter.

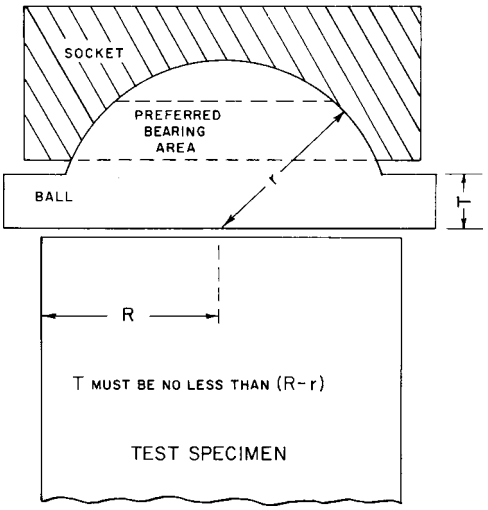
5.2.2.2 The center of the sphere shall coincide with the surface of the bearing face within a tolerance of ±5 % of the radius of the sphere. The diameter of the sphere shall be at least 75 % of the diameter of the specimen to be tested.

5.2.2.3 The ball and the socket shall be designed so that the steel in the contact area does not permanently deform when loaded to the capacity of the testing machine.

NOTE 6—The preferred contact area is in the form of a ring (described as "preferred bearing area") as shown on Fig. 1.

5.2.2.4 The curved surfaces of the socket and of the spherical portion shall be kept clean and shall be lubricated with a petroleum-type oil such as conventional motor oil, not with a pressure type grease. After contacting the specimen and application of small initial load, further tilting of the spherically seated block is not intended and is undesirable.

5.2.2.5 If the radius of the sphere is smaller than the radius of the largest specimen to be tested, the portion of the bearing face extending beyond the sphere shall have a thickness not less than the difference between the radius of the sphere and radius of the specimen. The least dimension of the bearing face shall be at least as great as the diameter of the sphere (see Fig. 1).



NOTE—Provision shall be made for holding the ball in the socket and for holding the entire unit in the testing machine.

FIG. 1 Schematic Sketch of a Typical Spherical Bearing Block

5.2.2.6 The movable portion of the bearing block shall be held closely in the spherical seat, but the design shall be such that the bearing face can be rotated freely and tilted at least 4° in any direction.

5.2.2.7 If the ball portion of the upper bearing block is a two-piece design composed of a spherical portion and a bearing plate, a mechanical means shall be provided to ensure that the spherical portion is fixed and centered on the bearing plate.

5.3 *Load Indication*:

5.3.1 If the load of a compression machine used in concrete testing is registered on a dial, the dial shall be provided with a graduated scale that is readable to at least the nearest 0.1 % of the full scale load (Note 7). The dial shall be readable within 1 % of the indicated load at any given load level within the loading range. In no case shall the loading range of a dial be considered to include loads below the value that is 100 times the smallest change of load that can be read on the scale. The scale shall be provided with a graduation line equal to zero and so numbered. The dial pointer shall be of sufficient length to reach the graduation marks; the width of the end of the pointer shall not exceed the clear distance between the smallest graduations. Each dial shall be equipped with a zero adjustment located outside the dialcase and easily accessible from the front of the machine while observing the zero mark and dial pointer. Each dial shall be equipped with a suitable device that at all times, until reset, will indicate to within 1 % accuracy the maximum load applied to the specimen.

NOTE 7—Readability is considered to be 0.5 mm [0.02 in.] along the arc described by the end of the pointer. Also, one half of a scale interval is readable with reasonable certainty when the spacing on the load indicating mechanism is between 1 mm [0.04 in.] and 2 mm [0.06 in.]. When the spacing is between 2 and 3 mm [0.06 and 0.12 in.], one third of a scale interval is readable with reasonable certainty. When the spacing is 3 mm [0.12 in.] or more, one fourth of a scale interval is readable with reasonable certainty.

5.3.2 If the testing machine load is indicated in digital form, the numerical display must be large enough to be easily read.

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The numerical increment must be equal to or less than 0.10 % of the full scale load of a given loading range. In no case shall the verified loading range include loads less than the minimum numerical increment multiplied by 100. The accuracy of the indicated load must be within 1.0 % for any value displayed within the verified loading range. Provision must be made for adjusting to indicate true zero at zero load. There shall be provided a maximum load indicator that at all times until reset will indicate within 1 % system accuracy the maximum load applied to the specimen.

6. Specimens

6.1 Specimens shall not be tested if any individual diameter of a cylinder differs from any other diameter of the same cylinder by more than 2 %.

NOTE 8—This may occur when single use molds are damaged or deformed during shipment, when flexible single use molds are deformed during molding, or when a core drill deflects or shifts during drilling.

6.2 Prior to testing, neither end of test specimens shall depart from perpendicularity to the axis by more than 0.5° (approximately equivalent to 1 mm in 100 mm [0.12 in. in 12 in.]). The ends of compression test specimens that are not plane within 0.050 mm [0.002 in.] shall be sawed or ground to meet that tolerance, or capped in accordance with either Practice C617 or, when permitted, Practice C1231/C1231M. The diameter used for calculating the cross-sectional area of the test specimen shall be determined to the nearest 0.25 mm [0.01 in.] by averaging two diameters measured at right angles to each other at about midheight of the specimen.

6.3 The number of individual cylinders measured for determination of average diameter is not prohibited from being reduced to one for each ten specimens or three specimens per day, whichever is greater, if all cylinders are known to have been made from a single lot of reusable or single-use molds which consistently produce specimens with average diameters within a range of 0.5 mm [0.02 in.]. When the average diameters do not fall within the range of 0.5 mm [0.02 in.] or when the cylinders are not made from a single lot of molds, each cylinder tested must be measured and the value used in calculation of the unit compressive strength of that specimen. When the diameters are measured at the reduced frequency, the cross-sectional areas of all cylinders tested on that day shall be computed from the average of the diameters of the three or more cylinders representing the group tested that day.

6.4 If the purchaser of the testing services requests measurement of density of test specimens, determine the mass of specimens before capping. Remove any surface moisture with a towel and measure the mass of the specimen using a balance or scale that is accurate to within 0.3 % of the mass being measured. Measure the length of the specimen to the nearest 1 mm [0.05 in.] at three locations spaced evenly around the circumference. Compute the average length and record to the nearest 1 mm [0.05 in.]. Alternatively, determine the cylinder density by weighing the cylinder in air and then submerged under water at 23.0 ± 2.0 °C [73.5 ± 3.5 °F], and computing the volume according to 8.3.1.

6.5 When density determination is not required and the length to diameter ratio is less than 1.8 or more than 2.2, measure the length of the specimen to the nearest 0.05 D.

7. Procedure

7.1 Compression tests of moist-cured specimens shall be made as soon as practicable after removal from moist storage.

7.2 Test specimens shall be kept moist by any convenient method during the period between removal from moist storage and testing. They shall be tested in the moist condition.

7.3 All test specimens for a given test age shall be broken within the permissible time tolerances prescribed as follows:

Test Age	Permissible Tolerance
24 h	± 0.5 h or 2.1 %
3 days	2 h or 2.8 %
7 days	6 h or 3.6 %
28 days	20 h or 3.0 %
90 days	2 days 2.2 %

7.4 *Placing the Specimen*—Place the plain (lower) bearing block, with its hardened face up, on the table or platen of the testing machine directly under the spherically seated (upper) bearing block. Wipe clean the bearing faces of the upper and lower bearing blocks and of the test specimen and place the test specimen on the lower bearing block. Carefully align the axis of the specimen with the center of thrust of the spherically seated block.

7.4.1 *Zero Verification and Block Seating*—Prior to testing the specimen, verify that the load indicator is set to zero. In cases where the indicator is not properly set to zero, adjust the indicator (Note 9). As the spherically seated block is brought to bear on the specimen, rotate its movable portion gently by hand so that uniform seating is obtained.

NOTE 9—The technique used to verify and adjust load indicator to zero will vary depending on the machine manufacturer. Consult your owner's manual or compression machine calibrator for the proper technique.

7.5 *Rate of Loading*—Apply the load continuously and without shock.

7.5.1 The load shall be applied at a rate of movement (platen to crosshead measurement) corresponding to a stress rate on the specimen of 0.25 ± 0.05 MPa/s [35 ± 7 psi/s] (See Note 10). The designated rate of movement shall be maintained at least during the latter half of the anticipated loading phase.

NOTE 10—For a screw-driven or displacement-controlled testing machine, preliminary testing will be necessary to establish the required rate of movement to achieve the specified stress rate. The required rate of movement will depend on the size of the test specimen, the elastic modulus of the concrete, and the stiffness of the testing machine.

7.5.2 During application of the first half of the anticipated loading phase, a higher rate of loading shall be permitted. The higher loading rate shall be applied in a controlled manner so that the specimen is not subjected to shock loading.

7.5.3 Make no adjustment in the rate of movement (platen to crosshead) as the ultimate load is being approached and the stress rate decreases due to cracking in the specimen.

7.6 Apply the compressive load until the load indicator shows that the load is decreasing steadily and the specimen displays a well-defined fracture pattern (Types 1 to 4 in Fig. 2). For a testing machine equipped with a specimen break detector,

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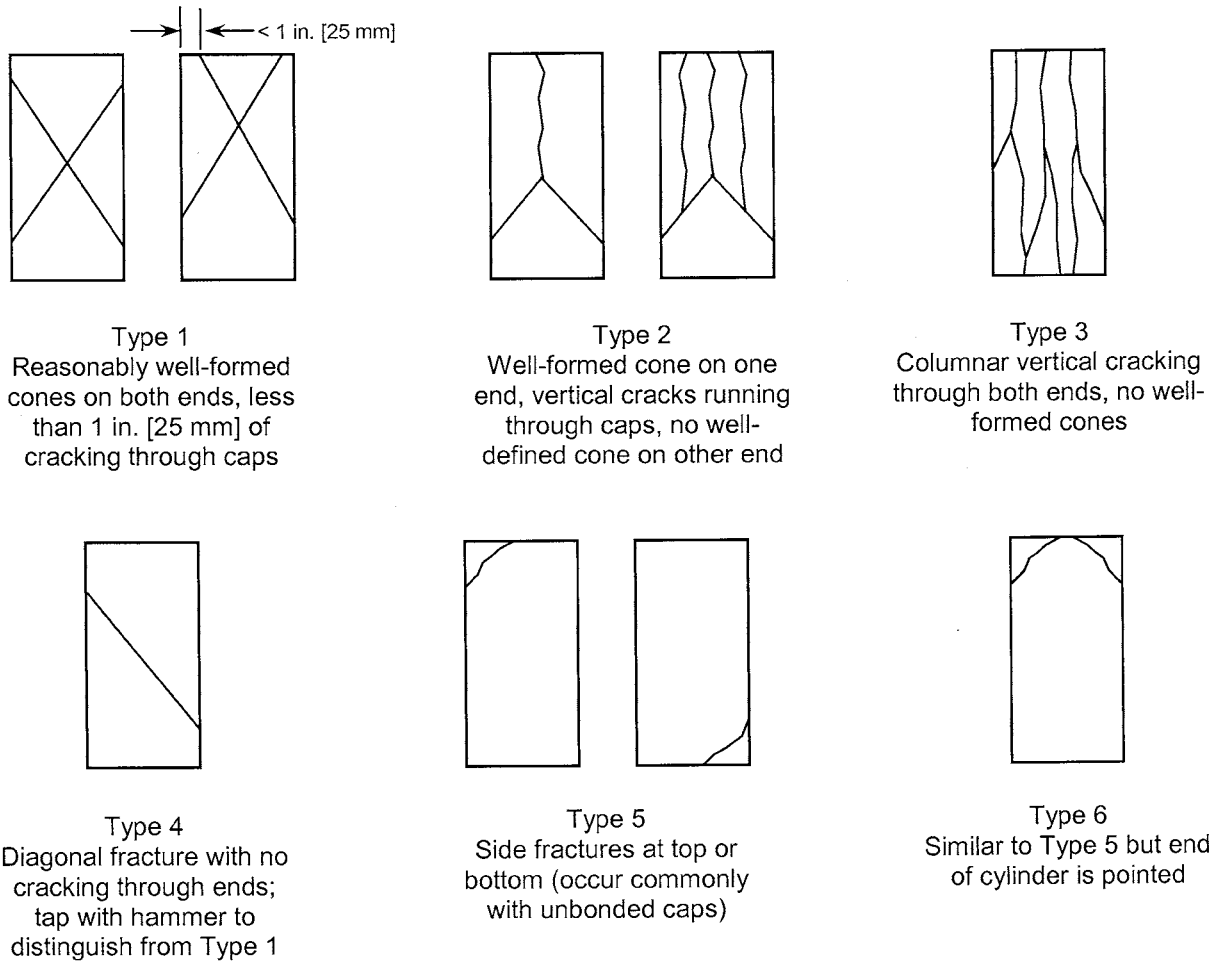

FIG. 2 Schematic of Typical Fracture Patterns

automatic shut-off of the testing machine is prohibited until the load has dropped to a value that is less than 95 % of the peak load. When testing with unbonded caps, a corner fracture similar to a Type 5 or 6 pattern shown in Fig. 2 may occur before the ultimate capacity of the specimen has been attained. Continue compressing the specimen until the user is certain that the ultimate capacity has been attained. Record the maximum load carried by the specimen during the test, and note the type of fracture pattern according to Fig. 2. If the fracture pattern is not one of the typical patterns shown in Fig. 2, sketch and describe briefly the fracture pattern. If the measured strength is lower than expected, examine the fractured concrete and note the presence of large air voids, evidence of segregation, whether fractures pass predominantly around or through the coarse aggregate particles, and verify end preparations were in accordance with Practice C617 or Practice C1231/C1231M.

8. Calculation

8.1 Calculate the compressive strength of the specimen by dividing the maximum load carried by the specimen during the test by the average cross-sectional area determined as described in Section 6 and express the result to the nearest 0.1 MPa [10 psi].

8.2 If the specimen length to diameter ratio is 1.75 or less, correct the result obtained in 8.1 by multiplying by the appropriate correction factor shown in the following table Note 11:

L/D:	1.75	1.50	1.25	1.00
Factor:	0.98	0.96	0.93	0.87

Use interpolation to determine correction factors for L/D values between those given in the table.

NOTE 11—Correction factors depend on various conditions such as moisture condition, strength level, and elastic modulus. Average values are given in the table. These correction factors apply to low-density concrete weighing between 1600 and 1920 kg/m^3 [100 and 120 lb/ft^3] and to normal-density concrete. They are applicable to concrete dry or soaked at the time of loading and for nominal concrete strengths from 14 to 42 MPa [2000 to 6000 psi]. For strengths higher than 42 MPai [6000 ps] correction factors may be larger than the values listed above[3].

8.3 When required, calculate the density of the specimen to the nearest 10 kg/m^3 [1 lb/ft^3] as follows:

$$Density = \frac{W}{V} \quad (2)$$

[3] Bartlett, F.M. and MacGregor, J.G., "Effect of Core Length-to-Diameter Ratio on Concrete Core Strength," *ACI Materials Journal*, Vol 91, No. 4, July-August, 1994 , pp. 339-348.

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where:
W = mass of specimen, kg [lb], and
V = volume of specimen computed from the average diameter and average length or from weighing the cylinder in air and submerged, m^3 [ft^3]

8.3.1 When the volume is determined from submerged weighing, calculate the volume as follows:

$$V = \frac{W - W_s}{\gamma_w} \quad (3)$$

where:
W_s = apparent mass of submerged specimen, kg [lb], and
γ_w = density of water at 23 °C [73.5 °F] = 997.5 kg/m^3 [62.27 lbs/ft^3].

9. Report

9.1 Report the following information:
9.1.1 Identification number,
9.1.2 Diameter (and length, if outside the range of 1.8 *D* to 2.2 *D*), in millimetres [inches],
9.1.3 Cross-sectional area, in square millimetres [square inches],
9.1.4 Maximum load, in kilonewtons [pounds-force],
9.1.5 Compressive strength calculated to the nearest 0.1 MPa [10 psi],
9.1.6 Type of fracture, if other than the usual cone (see Fig. 2),
9.1.7 Defects in either specimen or caps, and,
9.1.8 Age of specimen.
9.1.9 When determined, the density to the nearest 10 kg/m^3 [1 lb/ft^3].

10. Precision and Bias

10.1 *Precision*

10.1.1 *Within-Test Precision*—The following table provides the within-test precision of tests of 150 by 300 mm [6 by 12 in.] and 100 by 200 mm [4 by 8 in.] cylinders made from a well-mixed sample of concrete under laboratory conditions and under field conditions (see 10.1.2).

	Coefficient of Variation[4]	Acceptable Range[4] of Individual Cylinder Strengths	
		2 cylinders	3 cylinders
150 by 300 mm [6 by 12 in.]			
Laboratory conditions	2.4 %	6.6 %	7.8 %
Field conditions	2.9 %	8.0 %	9.5 %
100 by 200 mm [4 by 8 in.]			
Laboratory conditions	3.2 %	9.0 %	10.6 %

10.1.2 The within-test coefficient of variation represents the expected variation of measured strength of companion cylinders prepared from the same sample of concrete and tested by one laboratory at the same age. The values given for the within-test coefficient of variation of 150 by 300 mm [6 by 12 in.] cylinders are applicable for compressive strengths between 2000 and 15 to 55 MPa [8000 psi] and those for 100 by 200 mm [4 by 8 in.] cylinders are applicable for compressive strengths between 17 to 32 MPa [2500 and 4700 psi]. The within-test coefficients of variation for 150 by 300 mm [6 by 12 in.] cylinders are derived from CCRL concrete proficiency sample data for laboratory conditions and a collection of 1265 test reports from 225 commercial testing laboratories in 1978.[5] The within-test coefficient of variation of 100 by 200 mm [4 by 8 in.] cylinders are derived from CCRL concrete proficiency sample data for laboratory conditions.

10.1.3 *Multilaboratory Precision*—The multi-laboratory coefficient of variation for compressive strength test results of 150 by 300 mm [6 by 12 in.] cylinders has been found to be 5.0 %[4]; therefore, the results of properly conducted tests by two laboratories on specimens prepared from the same sample of concrete are not expected to differ by more than 14 %[4] of the average (See Note 12). A strength test result is the average of two cylinders tested at the same age.

NOTE 12—The multilaboratory precision does not include variations associated with different operators preparing test specimens from split or independent samples of concrete. These variations are expected to increase the multilaboratory coefficient of variation.

10.1.4 The multilaboratory data were obtained from six separate organized strength testing round robin programs where 150 x 300 mm [6 x 12 in.] cylindrical specimens were prepared at a single location and tested by different laboratories. The range of average strength from these programs was 17.0 to 90 MPa [2500 to 13 000 psi].

NOTE 13—Subcommittee C09.61 will continue to examine recent concrete proficiency sample data and field test data and make revisions to precisions statements when data indicate that they can be extended to cover a wider range of strengths and specimen sizes.

10.2 *Bias*—Since there is no accepted reference material, no statement on bias is being made.

[4] These numbers represent respectively the (1s %) and (d2s %) limits as described in Practice C670.

[5] Supporting data have been filed at ASTM International Headquarters and may be obtained by requesting Research Report RR:C09-1006.

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SUMMARY OF CHANGES

Committee C09 has identified the location of selected changes to this test method since the last issue, C39/C39M–09, that may impact the use of this test method. (Approved December 15, 2009)

(*1*) Revised 1.1 to replace the term "unit weight" with the preferred term "density."

Committee C09 has identified the location of selected changes to this test method since the last issue, C39/C39M–05$^{\varepsilon 2}$, that may impact the use of this test method. (Approved November 1, 2009)

(*1*) Revised Note 6 to clarify the reference to Fig. 1.

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Designation: C 40 – 04

American Association State
Highway and Transportation Officials Standard
AASHTO No.: T 21

Standard Test Method for Organic Impurities in Fine Aggregates for Concrete[1]

This standard is issued under the fixed designation C 40; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

This standard has been approved for use by agencies of the Department of Defense.

1. Scope

1.1 This test method covers two procedures for an approximate determination of the presence of injurious organic impurities in fine aggregates that are to be used in hydraulic cement mortar or concrete. One procedure uses a standard color solution and the other uses a glass color standard.

1.2 The values given in SI units are to be regarded as the standard. The values given in parentheses are for information only.

1.3 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

2. Referenced Documents

2.1 *ASTM Standards:* [2]

C 33 Specification for Concrete Aggregates
C 87 Test Method for Effect of Organic Impurities in Fine Aggregate on Strength of Mortar
C 125 Terminology Relating to Concrete and Concrete Aggregates
C 702 Practice for Reducing Samples of Aggregate to Testing Size
D 75 Practice for Sampling Aggregates
D 1544 Test Method for Color of Transparent Liquids (Gardner Color Scale)

3. Significance and Use

3.1 This test method is used in making a preliminary determination of the acceptability of fine aggregates with respect to the requirements of Specification C 33 that relate to organic impurities.

3.2 The principal value of this test method is to furnish a warning that injurious amounts of organic impurities may be present. When a sample subjected to this test produces a color darker than the standard color it is advisable to perform the test for the effect of organic impurities on the strength of mortar in accordance with Test Method C 87.

4. Apparatus

4.1 *Glass Bottles*—Colorless glass graduated bottles, approximately 240 to 470-mL (8 to 16-oz) nominal capacity, equipped with watertight stoppers or caps, not soluble in the specified reagents. In no case shall the maximum outside thickness of the bottles, measured along the line of sight used for the color comparison, be greater than 63.5 mm (2.5 in.) or less than 38.1 mm (1.5 in.). The graduations on the bottles shall be in millilitres, or ounces (U.S. fluid), except that unmarked bottles may be calibrated and scribed with graduations by the user. In such case, graduation marks are required at only three points as follows:

4.1.1 *Standard Color Solution Level*—75 mL (2½ oz (U.S. fluid)),

4.1.2 *Fine Aggregate Level*—130 mL (4½ oz (U.S. fluid)), and

4.1.3 *NaOH Solution Level*—200 mL (7 oz (U.S. fluid)).

4.2 *Glass Color Standard*

4.2.1 Glass standard colors shall be used as described in Table 1 of Test Method D 1544.

NOTE 1—A suitable instrument consists of five glass color standards mounted in a plastic holder. Only the glass identified as Gardner Color Standard No. 11 is to be used as the Glass Color Standard in 9.2.

5. Reagent and Standard Color Solution

5.1 *Reagent Sodium Hydroxide Solution (3 %)*—Dissolve 3 parts by mass of reagent grade sodium hydroxide (NaOH) in 97 parts of water.

5.2 *Standard Color Solution*—Dissolve reagent grade potassium dichromate ($K_2Cr_2O_7$) in concentrated sulfuric acid (sp gr 1.84) at the rate of 0.250 g/100 mL of acid. The solution must be freshly made for the color comparison using gentle heat if necessary to effect solution.

[1] This test method is under the jurisdiction of ASTM Committee C09 on Concrete and Concrete Aggregates and is the direct responsibility of Subcommittee C09.20 on Normal Weight Aggregates.

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[2] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

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6. Sampling

6.1 The sample shall be selected in general accordance with Practice D 75.

7. Test Sample

7.1 The test sample shall have a mass of about approximately 450 g (1 lb) and be taken from the larger sample in accordance with Practice C 702.

8. Procedure

8.1 Fill a glass bottle to the approximately 130-mL (4½-fluid oz) level with the sample of the fine aggregate (see Terminology C 125) to be tested.

8.2 Add the sodium hydroxide solution until the volume of the fine aggregate and liquid, indicated after shaking, is approximately 200 mL (7 fluid oz).

8.3 Stopper the bottle, shake vigorously, and then allow to stand for 24 h.

9. Determination of Color Value

9.1 *Standard Color Solution Procedure*—At the end of the 24-h standing period, fill a glass bottle to the approximately 75-mL (2½-fluid oz) level with the fresh standard color solution, prepared not longer than 2 h previously, as prescribed in 5.2. Hold the bottle with the test sample and the bottle with the standard color solution side-by-side, and compare the color of light transmitted through the supernatant liquid above the sample with the color of light transmitted through the standard color solution. Record whether the color of the supernatant liquid is lighter, darker, or equal to the color of the standard color solution.

9.2 *Glass Color Standard Procedure*—To define more precisely the color of the supernatant liquid of the test sample, five glass standard colors shall be used using the following colors:

Gardner Color Standard No.	Organic Plate No.
5	1
8	2
11	3 (standard)
14	4
16	5

The comparison procedure described in 9.1 shall be used, except that the organic plate number which is nearest the color of the supernatant liquid above the test specimen shall be reported. When using this procedure, it is not necessary to prepare the standard color solution.

10. Interpretation

10.1 When a sample subjected to this procedure produces a color darker than the standard color, or Organic Plate No. 3 (Gardner Color Standard No. 11), the fine aggregate under test shall be considered to possibly contain injurious organic impurities. It is advisable to perform further tests before approving the fine aggregate for use in concrete.

11. Precision and Bias

11.1 Since this test produces no numerical values, determination of the precision and bias is not possible.

12. Keywords

12.1 colorimetric test; fine aggregate; organic impurities

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Designation: C 42/C 42M – 04

American Association State
Highway and Transportation Officials Standard
AASHTO No.: T24

Standard Test Method for Obtaining and Testing Drilled Cores and Sawed Beams of Concrete[1]

This standard is issued under the fixed designation C 42/C 42M; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

This standard has been approved for use by agencies of the Department of Defense.

1. Scope*

1.1 This test method covers obtaining, preparing, and testing (*1*) cores drilled from concrete for length or compressive strength or splitting tensile strength determinations and (*2*) beams sawed from concrete for flexural strength determinations.

1.2 The values stated in either inch-pound units or SI units shall be regarded separately as standard. SI units are shown in brackets. The values stated in each system may not be exact equivalents; therefore, each system must be used independently of the other. Combining values from the two systems may result in non-conformance with the standard.

1.3 The text of this standard references notes and footnotes that provide explanatory material. These notes and footnotes (excluding those in tables and figures) shall not be considered as requirements of the standard.

1.4 *This standard does not purport to address the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

2. Referenced Documents

2.1 *ASTM Standards:* [2]

C 39/C 39M Test Method for Compressive Strength of Cylindrical Concrete Specimens

C 78 Test Method for Flexural Strength of Concrete (Using Simple Beam with Third-Point Loading)

C 174/C 174M Test Method for Measuring Length of Drilled Concrete Cores

C 496 Test Method for Splitting Tensile Strength of Cylindrical Concrete Specimens

C 617 Practice for Capping Cylindrical Concrete Specimens

C 642 Test Method for Density, Absorption, and Voids in Hardened Concrete

C 670 Practice for Preparing Precision and Bias Statements for Test Methods for Construction Materials

C 823 Practice for Examination and Sampling of Hardened Concrete in Constructions

C 1231/C 1231M Practice for Use of Unbonded Caps in Determination of Compressive Strength of Hardened Concrete Cylinders

2.2 *ACI Standards:*

318 Building Code Requirements for Structural Concrete[3]

3. Significance and Use

3.1 This test method provides standardized procedures for obtaining and testing specimens to determine the compressive, splitting tensile, and flexural strength of in-place concrete.

3.2 Generally, test specimens are obtained when doubt exists about the in-place concrete quality due either to low strength test results during construction or signs of distress in the structure. Another use of this method is to provide strength information on older structures.

3.3 Concrete strength is affected by the location of the concrete in a structural element, with the concrete at the bottom tending to be stronger than the concrete at the top. Core strength is also affected by core orientation relative to the horizontal plane of the concrete as placed, with strength tending to be lower when measured parallel to the horizontal plane.[4] These factors shall be considered in planning the locations for obtaining concrete samples and in comparing strength test results.

3.4 The strength of concrete measured by tests of cores and beams is affected by the amount and distribution of moisture in the specimen at the time of test. There is no standard procedure to condition a specimen that will ensure that, at the time of test,

[1] This test method is under the jurisdiction of ASTM Committee C09 on Concrete and Concrete Aggregates and is the direct responsibility of Subcommittee C09.61 on Testing for Strength.

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[2] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

[3] Available from American Concrete Institute (ACI), P.O. Box 9094, Farmington Hills, MI 48333.

[4] Neville, A., "Core Tests: Easy to Perform, Not Easy to Interpret," *Concrete International*, Vol. 23, No. 11, November 2001, pp. 59-68.

***A Summary of Changes section appears at the end of this standard.**

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it will be in the identical moisture condition as concrete in the structure. The moisture conditioning procedures in this test method are intended to provide reproducible moisture conditions that minimize within-laboratory and between-laboratory variations and to reduce the effects of moisture introduced during specimen preparation.

3.5 There is no universal relationship between the compressive strength of a core and the corresponding compressive strength of standard-cured molded cylinders. The relationship is affected by many factors such as the strength level of the concrete, the in-place temperature and moisture history, and the strength gain characteristics of the concrete. Historically, it has been assumed that core strengths are generally 85 % of the corresponding standard-cured cylinder strengths, but this is not applicable to all situations. The acceptance criteria for core strength are to be established by the specifier of the tests. ACI 318 provides core strength acceptance criteria for new construction.

4. Apparatus

4.1 *Core Drill*, for obtaining cylindrical core specimens with diamond impregnated bits attached to a core barrel.

4.2 *Saw*, for cutting beam specimens to size for flexural strength tests and to trim ends of cores. The saw shall have a diamond or silicon-carbide cutting edge and shall be capable of cutting specimens that conform to the prescribed dimensions, without excessive heating or shock.

5. Sampling

5.1 *General*:

5.1.1 Samples of hardened concrete for use in the preparation of strength test specimens shall not be taken until the concrete is strong enough to permit sample removal without disturbing the bond between the mortar and the coarse aggregate (see Note 1 and Note 2). When preparing strength test specimens from samples of hardened concrete, samples that have been damaged during removal shall not be used unless the damaged portion(s) are removed and the resulting test specimen is of suitable length (see 7.2). Samples of defective or damaged concrete that cannot be tested shall be reported along with the reason that prohibits use of the sample for preparing strength test specimens.

NOTE 1—Practice C 823 provides guidance on the development of a sampling plan for concrete in constructions.

NOTE 2—It is not possible to specify a minimum age when concrete is strong enough to withstand damage during removal, because the strength at any age depends on the curing history and strength grade of the concrete. If time permits, the concrete should not be removed before it is 14 days old. If this is not practical, removal of concrete can proceed if the cut surfaces do not display erosion of the mortar and the exposed coarse aggregate particles are embedded firmly in the mortar. In-place test methods may be used to estimate the level of strength development prior to attempting removal of concrete samples.

5.1.2 Specimens containing embedded reinforcement shall not be used for determining compressive, splitting tensile, or flexural strength.

5.2 *Core Drilling*—A core specimen shall be drilled perpendicular to the surface and not near formed joints or obvious edges of a unit of deposit. Record and report the approximate angle between the longitudinal axis of the drilled core and the horizontal plane of the concrete as placed. A specimen drilled perpendicular to a vertical surface, or perpendicular to a surface with a batter, shall be taken from near the middle of a unit of deposit when possible.

5.3 *Slab Removal*—Remove a slab sufficiently large to secure the desired test specimens without the inclusion of any concrete that has been cracked, spalled, undercut, or otherwise damaged.

DRILLED CORES

6. Measuring the Length of Drilled Cores

6.1 Cores for determining the thickness of pavements, slabs, walls or other structural elements shall have a diameter of at least 3.75 in. [95 mm] when the lengths of such cores are stipulated to be measured in accordance with Test Method C 174/C 174M.

6.2 For cores that are not intended for determining structural dimensions, measure the longest and shortest lengths on the cut surface along lines parallel to the core axis. Record the average length to the nearest ¼ in. [5 mm].

7. Cores for Compressive Strength

7.1 *Diameter*—The diameter of core specimens for the determination of compressive strength in load bearing structural members shall be at least 3.70 in. [94 mm]. For non-load bearing structural members or when it is impossible to obtain cores with length-diameter ratio (L/D) greater than or equal to 1, core diameters less than 3.70 in. [94 mm] are not prohibited (see Note 3). For concrete with nominal maximum aggregate size greater than or equal to 1½ in. [37.5 mm], the core diameters shall be as directed by the specifier of the tests (see Note 4).

NOTE 3—The compressive strengths of nominal 2-in. [50-mm] diameter cores are known to be somewhat lower and more variable than those of nominal 4-in. [100-mm] diameter cores. In addition, smaller diameter cores appear to be more sensitive to the effect of the length-diameter ratio.[5]

NOTE 4—The preferred minimum core diameter is three times the nominal maximum size of the coarse aggregate, but it should be at least two times the nominal maximum size of the coarse aggregate.

7.2 *Length*—The preferred length of the capped or ground specimen is between 1.9 and 2.1 times the diameter. If the ratio of the length to the diameter (L/D) of the core exceeds 2.1, reduce the length of the core so that the ratio of the capped or ground specimen is between 1.9 and 2.1. Core specimens with length-diameter ratios equal to or less than 1.75 require corrections to the measured compressive strength (see 7.9.1). A strength correction factor is not required for L/D greater than 1.75. A core having a maximum length of less than 95 % of its diameter before capping or a length less than its diameter after capping or end grinding shall not be tested.

7.3 *Moisture Conditioning*—Test cores after moisture conditioning as specified in this test method or as directed by the

[5] Bartlett, F.M. and MacGregor, J.G., "Effect of Core Diameter on Concrete Core Strengths," *ACI Materials Journal*, Vol. 91, No. 5, September-October 1994, pp. 460-470.

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specifier of the tests. The moisture conditioning procedures specified in this test method are intended to preserve the moisture of the drilled core and to provide a reproducible moisture condition that minimizes the effects of moisture gradients introduced by wetting during drilling and specimen preparation.

7.3.1 After cores have been drilled, wipe off surface drill water and allow remaining surface moisture to evaporate. When surfaces appear dry, but not later than 1 h after drilling, place cores in separate plastic bags or nonabsorbent containers and seal to prevent moisture loss. Maintain cores at ambient temperature, and protect cores from exposure to direct sunlight. Transport the cores to the testing laboratory as soon as possible. Keep cores in the sealed plastic bags or nonabsorbent containers at all times except during end preparation and for a maximum time of 2 h to permit capping before testing.

7.3.2 If water is used during sawing or grinding of core ends, complete these operations as soon as possible, but no later than 2 days after drilling of cores unless stipulated otherwise by the specifier of tests. After completing end preparation, wipe off surface moisture, allow the surfaces to dry, and place the cores in sealed plastic bags or nonabsorbent containers. Minimize the duration of exposure to water during end preparation.

7.3.3 Allow the cores to remain in the sealed plastic bags or nonabsorbent containers for at least 5 days after last being wetted and before testing, unless stipulated otherwise by the specifier of tests.

NOTE 5—The waiting period of at least 5 days is intended to reduce moisture gradients introduced when the core is drilled or wetted during sawing or grinding.

7.3.4 When direction is given to test cores in a moisture condition other than achieved by conditioning according to 7.3.1, 7.3.2, and 7.3.3, report the alternative procedure.

7.4 *Sawing of Ends*—The ends of core specimens to be tested in compression shall be flat, and perpendicular to the longitudinal axis in accordance with Test Method C 39/C 39M. If necessary, saw the ends of cores that will be capped so that prior to capping, the following requirements are met:

7.4.1 Projections, if any, shall not extend more than 0.2 in. [5 mm] above the end surfaces.

7.4.2 The end surfaces shall not depart from perpendicularity to the longitudinal axis by a slope of more than 1:8*d* or [1:0.3*d*] where *d* is the average core diameter in inches [or mm].

7.5 *Density*—When required by the specifier of the tests, determine the density by weighing the core before capping and dividing the mass by the volume of the core calculated from the average diameter and length. Alternatively, determine the density from the mass in air and submerged mass in accordance with Test Method C 642. After submerged weighing, dry cores in accordance with 7.3.2 and store in sealed plastic bags or nonabsorbent containers for at least 5 days before testing.

7.6 *Capping*—If the ends of the cores do not conform to the perpendicularity and planeness requirements of Test Method C 39/C 39M, they shall be sawed or ground to meet those requirements or capped in accordance with Practice C 617. If cores are capped in accordance with Practice C 617, the capping device shall accommodate actual core diameters and produce caps that are concentric with the core ends. Measure core lengths to the nearest 0.1 in. [2 mm] before capping. Unbonded caps in accordance with Practice C 1231/C 1231M are not permitted.

7.7 *Measurement*—Before testing, measure the length of the capped or ground specimen to the nearest 0.1 in. [2 mm] and use this length to compute the length-diameter (L/D) ratio. Determine the average diameter by averaging two measurements taken at right angles to each other at the mid-height of the specimen. Measure core diameters to the nearest 0.01 in. [0.2 mm] when the difference in core diameters does not exceed 2 % of their average, otherwise measure to the nearest 0.1 in. [2 mm]. Do not test cores if the difference between the largest and smallest diameter exceeds 5 % of their average.

7.8 *Testing*—Test the specimens in accordance with Test Method C 39/C 39M. Test the specimens within 7 days after coring, unless specified otherwise.

7.9 *Calculation*—Calculate the compressive strength of each specimen using the computed cross-sectional area based on the average diameter of the specimen.

7.9.1 If the ratio of length to diameter (L/D) of the specimen is 1.75 or less, correct the result obtained in 7.9 by multiplying by the appropriate correction factor shown in the following table (see Note 6):

Ratio of Length to Diameter (L/D)	Strength Correction Factor
1.75	0.98
1.50	0.96
1.25	0.93
1.00	0.87

Use interpolation to determine correction factors for L/D values not given in the table.

NOTE 6—Correction factors depend on various conditions such as moisture condition, strength level, and elastic modulus. Average values for corrections due to length-diameter ratio are given in the table. These correction factors apply to low-density concrete having a density between 100 and 120 lb/ft^3 [1600 and 1920 kg/m^3] and to normal density concrete. They are applicable to both dry and wet concrete for strengths between 2000 psi and 6000 psi [14 MPa to 42 MPa]. For strengths above 10 000 psi [70 MPa], test data on cores show that the correction factors may be larger than the values listed above.[6]

7.10 *Report*—Report the results as required by Test Method C 39/C 39M with the addition of the following information:

7.10.1 Length of core as drilled to the nearest ¼ in. [5 mm],

7.10.2 Length of test specimen before and after capping or end grinding to the nearest 0.1 in. [2 mm], and average diameter of core to the nearest 0.01 in. [0.2 mm] or 0.1 in. [2 mm],

7.10.3 Compressive strength to the nearest 10 psi [0.1 MPa] when the diameter is measured to the nearest 0.01 in. [0.2 mm] and to the nearest 50 psi [0.5 MPa] when the diameter is measured to the nearest 0.1 in. [2 mm], after correction for length-diameter ratio when required,

[6] Bartlett, F.M. and MacGregor, J.G, "Effect of Core Length-to-Diameter Ratio on Concrete Core Strengths," *ACI Materials Journal*, Vol. 91, No. 4, July-August 1994, pp. 339-348.

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7.10.4 Direction of application of the load on the specimen with respect to the horizontal plane of the concrete as placed,

7.10.5 The moisture conditioning history:

7.10.5.1 The date and time core was obtained and first placed in sealed bag or nonabsorbent container,

7.10.5.2 If water was used during end preparation, the date and time end preparation was completed and core placed in sealed bag or nonabsorbent container,

7.10.6 The date and time when tested,

7.10.7 Nominal maximum size of concrete aggregate.

7.10.8 If determined, the density,

7.10.9 If applicable, description of defects in cores that could not be tested, and

7.10.10 If any deviation from this test method was required, describe the deviation and explain why it was necessary.

7.11 *Precision:*[7]

7.11.1 The single-operator coefficient of variation on cores has been found to be 3.2 %[8] for a range of compressive strength between 4500 psi [32.0 MPa] and 7000 psi [48.3 MPa]. Therefore, results of two properly conducted tests of single cores by the same operator on the same sample of material should not differ from each other by more than 9 %[8] of their average.

7.11.2 The multi-laboratory coefficient of variation on cores has been found to be 4.7 %[8] for a range of compressive strength between 4500 psi [32.0 MPa] and 7000 psi [48.3 MPa]. Therefore, results of two properly conducted tests on cores sampled from the same hardened concrete (where a single test is defined as the average of two observations (cores), each made on separate adjacent drilled 4 in. [100 mm] diameter cores), and tested by two different laboratories should not differ from each other by more than 13 %[8] of their average.

7.12 *Bias*—Since there is no accepted reference material suitable for determining the bias for the procedure in this test method, no statement on bias is being made.

8. Cores for Splitting Tensile Strength

8.1 *Test Specimens*—The specimens shall conform to the dimensional requirements in 7.1, 7.2, 7.4.1, and 7.4.2. Ends are not to be capped.

8.2 *Moisture Conditioning*—Condition the specimens as described in 7.3, or as directed by the specifier of tests.

8.3 *Bearing Surfaces*—The line of contact between the specimen and each bearing strip shall be straight and free of any projections or depressions higher or deeper than 0.01 in. [0.2 mm]. When the line of contact is not straight or contains projections or depressions having heights or depths greater than 0.01 in., grind or cap the specimen so as to produce bearing lines meeting these requirements. Do not test specimens with projections or depressions greater than 0.1 in. [2.0 mm]. When capping is employed, the caps shall be as thin as practicable and shall be formed of high-strength gypsum plaster.

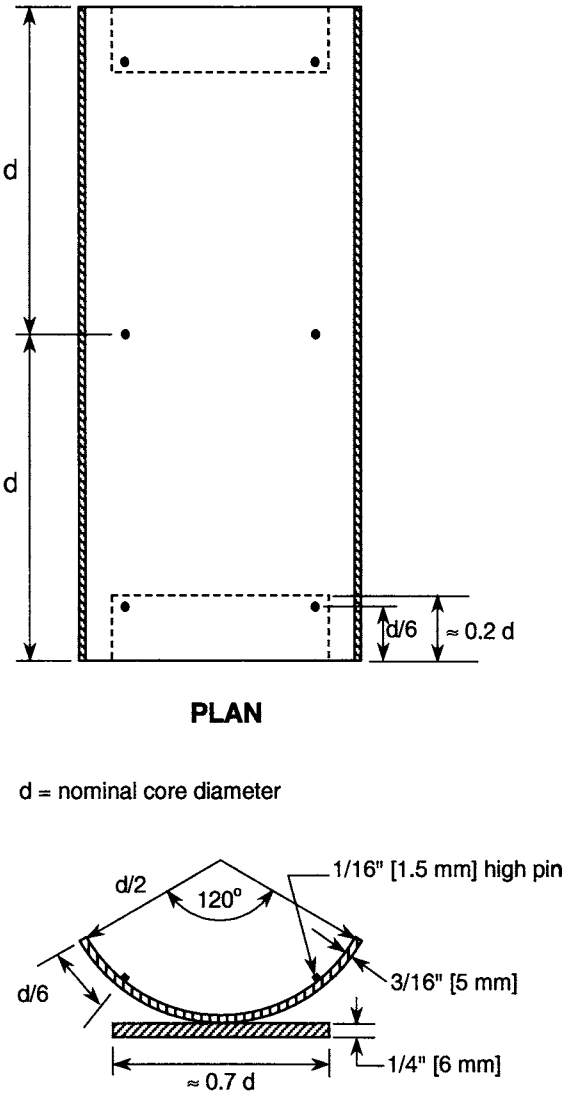

FIG. 1 Suitable Capping Device for Splitting Tensile Strength Test

NOTE 7—Fig. 1 illustrates a device suitable for applying caps to the bearing surfaces of core specimens.

8.4 *Testing*—Test the specimens in accordance with Test Method C 496.

8.5 *Calculation and Report*—Calculate the splitting tensile strength and report the results as required in Test Method C 496. When grinding or capping of the bearing surfaces is required, measure the diameter between the finished surfaces. Indicate that the specimen was a core and provide the moisture conditioning history as in 7.10.5.

8.6 *Precision:*[9]

8.6.1 The within laboratory single operator coefficient of variation for splitting tensile strength between 520 psi [3.6 MPa] and 590 psi [4.1 MPa] of cores has been found to be

[7] Bollin, G. E., "Development of Precision and Bias Statements for Testing Drilled Cores in Accordance with ASTM C 42," *ASTM Journal of Cement, Concrete, and Aggregates*, Vol 15, No. 1, 1993.

[8] These numbers represent, respectively, the (1s %) and (d2s %) limits as described in Practice C 670.

[9] Steele, G.W., "Portland Cement Concrete Core Proficiency Sample Program," Strategic Highway Research Program, SHRP-P-636, National Research Council, Washington, D.C., 1993.

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5.3 %.[8] Therefore, results of two properly conducted tests by the same operator in the same laboratory on the same sample of material should not differ by more than 14.9 %[8] of their average.

8.6.2 The multi-laboratory coefficient of variation for splitting tensile strength between 520 psi [3.6 MPa] and 590 psi [4.1 MPa] of cores has been found to be 15.0 %.[8] Therefore, results of two properly conducted tests on the same sample of material of hardened concrete and tested by two different laboratories should not differ from each other by more than 42.3 %[8] of their average.

8.7 *Bias*—Since there is no accepted reference material suitable for determining the bias for the procedure in this test method, no statement on bias is being made.

BEAMS FOR FLEXURAL TESTING

9. Flexural Strength

9.1 *Test Specimens*—Unless otherwise specified, a beam specimen for the determination of flexural strength shall have a nominal cross section of 6 by 6 in. [150 by 150 mm] (Note 8). The specimen shall be at least 21 in. [530 mm] in length, but when two tests for flexural strength are to be made in one beam specimen, it shall be at least 33 in. [840 mm] in length. Perform the sawing operation so that the concrete will not be weakened by shock or by heating. The sawed surfaces shall be smooth, plane, parallel, and free from steps, ridges, and grooves. Take care in handling sawed beam specimens to avoid chipping or cracking.

NOTE 8—In many cases, particularly with prisms cut from pavement slabs, the width will be governed by the size of the coarse aggregate and the depth by the thickness of the slab.

9.2 *Moisture Conditioning*—Protect the surfaces of sawed specimens from evaporation by covering them with wet burlap and plastic sheeting during transportation and storage. Test the specimens within 7 days of sawing. Submerge the test specimens in lime-saturated water at 73.5 ± 3.5°F [23.0 ± 2.0°C] for at least 40 h immediately prior to the flexure test. Test the specimens promptly after removal from water storage. During the period between removal from water storage and testing, keep the specimens moist by covering with a wet blanket of burlap or other suitable absorbent fabric.

9.2.1 When the specifier of tests so directs, beams shall be tested in a moisture condition other than that achieved by conditioning in accordance with 9.2.

NOTE 9—Relatively small amounts of drying of the surface of flexural specimens induce tensile stresses in the extreme fibers that will markedly reduce the indicated flexural strength.

9.3 *Testing*—Test the specimens in accordance with the applicable provisions of Test Method C 78.

NOTE 10—Sawing may greatly reduce the indicated flexural strength; beams shall, therefore, be tested with a molded surface in tension whenever possible. The location of the tension face with respect to the position of the concrete as placed and the position of the sawed surfaces should be reported.

9.4 *Report*—Report the results in accordance with the applicable provisions of Test Method C 78 and the requirements of this test method, including the moisture condition at the time of testing. Identify orientation of the specimen's finished, sawed, and tension faces with respect to their positions in the test apparatus.

10. Precision and Bias

10.1 *Precision*—Data are not available for preparing a statement on the precision of flexural strength measured on sawed beams.

NOTE 11—Users of this method who have replicate test data that may be appropriate for a statement on repeatability are encouraged to contact the chairman of the subcommittee.

10.2 *Bias*—Since there is no accepted reference material suitable for determining the bias for the procedure in this test method, no statement on bias is being made.

11. Keywords

11.1 compressive strength; concrete coring; concrete sawing; concrete strength; flexural strength; splitting tensile strength

SUMMARY OF CHANGES

Committee C09 has identified the location of selected changes to this test method since the last issue (C 42/C 42M – 03) that may impact its use (Approved July 1, 2004).

(1) The wording in 7.4 was clarified and the requirements in 7.4.2 were revised.

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Designation: C 50 – 00 (Reapproved 2006)

Standard Practice for Sampling, Sample Preparation, Packaging, and Marking of Lime and Limestone Products[1]

This standard is issued under the fixed designation C 50; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

This standard has been approved for use by agencies of the Department of Defense.

1. Scope

1.1 This practice covers procedures for the collection and reduction of samples of lime and limestone products to be used for physical and chemical tests.

1.2 This practice further covers inspection, rejection, retesting, packing, and marking of lime and limestone products as it may be used in the chemical, agricultural, and process industries.

1.3 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

2. Referenced Documents

2.1 *ASTM Standards:* [2]

C 51 Terminology Relating to Lime and Limestone (as used by the Industry)

C 702 Practice for Reducing Samples of Aggregate to Testing Size

D 75 Practice for Sampling Aggregates

D 2234/D 2234M Practice for Collection of a Gross Sample of Coal

D 3665 Practice for Random Sampling of Construction Materials

E 11 Specification for Wire Cloth and Sieves for Testing Purposes

E 105 Practice for Probability Sampling Of Materials

E 122 Practice for Calculating Sample Size to Estimate, With a Specified Tolerable Error, the Average for a Characteristic of a Lot or Process

E 141 Practice for Acceptance of Evidence Based on the Results of Probability Sampling

E 177 Practice for Use of the Terms Precision and Bias in ASTM Test Methods

3. Terminology

3.1 *accuracy*—a term generally used to indicate the reliability of a sample, a measurement, or an observation and is a measure of closeness of agreement between an experimental result and the true value.

3.2 *bias (systematic error)*—an error that is consistently negative or consistently positive. The mean of errors resulting from a series of observations which does not tend towards zero.

3.3 *chance error*—error that has equal probability of being positive or negative. The mean of the chance errors resulting from a series of observations that tends toward zero as the number of observations approach infinity.

3.4 *combined water*—water that is chemically bonded to calcium or magnesium oxide to form hydrate.

3.5 *error*—the difference of an observation or a group of observations from the best obtainable estimate of the true value.

3.6 *free water*—water that is not chemically bonded to calcium or magnesium oxide.

3.7 *gross sample*—a sample representing one lot of material and composed of a number of increments on which neither reduction nor division has been performed.

3.8 *increment*—a small portion of the lot collected by one operation of a sampling device and normally combined with other increments from the lot to make a gross sample.

3.9 *laboratory sample*—refers to the sample after the initial preparation from which the analytical sample is obtained.

3.10 *lot*—a discrete quantity of material for which the overall quality to a particular precision needs to be determined.

3.11 *precision*—a term used to indicate the capability of a person, an instrument, or a method to obtain repeatable results; specifically, a measure of the chance error as expressed by the variance, the standard error, or a multiple of the standard error (see Practice E 177).

[1] This practice is under the jurisdiction of ASTM Committee C07 on Lime and is the direct responsibility of Subcommittee C07.06 on Physical Tests.

Current edition approved Nov. 15, 2006. Published December 2006. Originally approved in 1922. Last previous edition approved in 2000 as C 50 – 00.

[2] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

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3.12 *representative sample*—a sample collected in such a manner that every particle in the lot to be sampled is equally represented in the gross or divided sample.

3.13 *sample*—a quantity of material taken from a larger quantity for the purpose of estimating properties or composition of the larger quantity.

3.14 *sample division*—the process whereby a sample is reduced in weight without change in particle size.

3.15 *sample preparation*—the process that may include crushing, dividing, and mixing of a gross or divided sample for the purpose of obtaining a representative analysis sample.

3.16 *sampling unit*—a quantity of material from which a gross sample is obtained. A lot may contain several sampling units.

3.17 *segregation variance of increment collection, Ss^2*—the variance caused by nonrandom distribution of inert material or other constituent in the lot.

3.18 *size consist*—the particle size distribution of quicklime or hydrated lime.

3.19 *standard deviation*—the square root of the variance.

3.20 *subsample*—a sample taken from another sample.

3.21 *top size*—the opening of the smallest screen in the series upon which is retained less than 5 % of the sample.

3.22 *total variance, So^2*—the overall variance resulting from collecting single increments, and including division and analysis of the single increments.

3.23 *unbiased sample*—a sample free of bias or a representative sample.

3.24 *unit variance (random variance of increment collection), Sr^2*—the theoretical variance calculated for a uniformly mixed lot and extrapolate to 0.5-kg (1-lb) increment size.

3.25 *variance*—the mean square of deviation (or errors) of a set of observations; the sum of squared deviations (or errors) of individual observations with respect to their arithmetic mean divided by the number of observations less one (degrees of freedom); the square of the standard deviation (or standard error).

4. Significance and Use

4.1 The following practices are to be used in obtaining samples that are representative of the lot being sampled. The methodology used will be dependent upon the size and type of material sampled and testing requirements.

4.2 The following practices are intended for use in obtaining samples from material that is ready for sale and are not intended as sampling procedures for quality control purposes. These practices are to be used in obtaining a laboratory sample that will yield results serving as a basis for acceptance or rejection of the lot of material sampled. This does not preclude the use of these practices for quality control purposes.

4.3 The following practices can be used to eliminate bias in sampling. The person or persons responsible for using these practices must be trained and they will be conscientious and timely in their use.

4.4 An agreement between the producer and the consumer on location of sampling, either at the producer's plant or at the destination, is encouraged. Product quality can be affected through careless handling, improper protection, and delayed shipment. It is preferable to sample at the point of loading. The consumer has the right to witness the sampling practices being used.

4.5 This practice may be used to provide a representative sample of lime or limestone products. Due to the variability of limestone and lime and the wide variety of sampling equipment, caution must be exercised in all stages of sampling, from system specification and equipment procurement to equipment acceptance testing and actually taking the final sample.

5. Incremental Collection

5.1 For the number and weight of increments refer to Practice E 122.

5.2 The number of samples required depends on the intended use of the material, the quantity of material involved, and the variations both in quality and size. A sufficient number of samples shall be obtained to cover all variations in the material.

5.3 The quantity of sample to be taken will depend on the size of the material to be sampled and the amount of information to be obtained from the sample. Caution must be taken to ensure a statistically correct amount of material is selected for all testing, and sufficient quantities of material retained for reserved purposes. Recommended reference documents would include Practices E 105 and E 122.

5.4 *Particle Size*:

5.4.1 Generally, a large range of particle sizes for a given material requires a larger bulk sample size. The amount of the sample increment is then dependent upon the largest particle size encountered. The sample amount is determined by repeated testing to determine the bias between successive increments, and then to reduce this bias to acceptable limits.

5.4.2 The chemistry may change relative to the particle size. It is important that all particle sizes proportioned relative to their distribution be in the parent material.

5.5 Large material transfer rates result in large incremental samples. The sample must be representative of the entire cross-section flow of material. The amount of sample and number of increments must be determined prior to sampling. Randomized sampling should be used where appropriate to minimize unintentional bias.

6. Random Sampling

6.1 Practices D 3665, E 105, and E 122 can be used to minimize unintentional bias when obtaining a representative sample. Depending upon what comprises the lot of material, sampling can be extended to specific shipping units chosen on a random basis.

6.2 Collect increments with such frequency that the entire quantity of material will be represented in the gross sample. Due to the variability of lime and limestone products and the wide variety of sampling equipment, caution must exercised in all stages of sampling.

7. Sampling Plan

7.1 *Purpose*:

7.1.1 Adequate methods for obtaining representative samples for testing the chemical and physical properties of a

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shipment of lime or limestone are essential. The sale and use are dependent upon the chemical or physical properties, or both.

7.1.2 The sampling plan specifies the minimum weights and the number of increments required in each step of the procedure to meet the objectives of the testing.

7.1.3 The sampling plan should include the personnel doing the sampling, preservation or protection of the samples, location of sampling, the sampling procedure to be used, sample preparation required, and the tests to be performed.

7.1.4 Proper sampling involves understanding and consideration of the minimum number and weight of increments, the particle size of the material, sample preparation, variability of the constituent sought, and the degree of precision required.

7.2 *Personnel*:

7.2.1 It is imperative that a sample is collected carefully and conscientiously. If the sampling is done improperly, the sample is in error and any subsequent analysis is not representative of the lot being sampled. Further, a second sample may be impossible to obtain. If an analysis is in error, another analysis is impractical on an incorrectly obtained sample. Whereas, a second analysis is possible, if the first was in error, if the initial sampling was correct.

7.2.2 Because of the importance of proper sampling and the resulting information, individuals engaged in sampling and sample preparation must be qualified by training and experience and possess a thorough understanding of sampling practices and techniques or under the direct supervision of such an individual.

7.3 *Preservation of Sample*:

7.3.1 Due to the hygroscopic nature of quicklime, samples must be immediately stored in airtight, moisture-proof containers to avoid air-slaking and subsequent absorption of carbon dioxide.

7.3.2 Due to the generally soft characteristics of quicklime, proper handling to avoid degradation must be practiced if the sample is to be used for particle size determination.

7.4 *Location of Sampling*—The process type and the process measurements required determine the sampling location. Sites should be selected to allow for safe, easy access to a representative cross section of the process material.

7.5 *Choice of Sampling Procedure*—The choice of sampling procedure to be used is dependent on three things. First, it is necessary to define the lot or batch of material to be sampled. Second, it is necessary to determine the number of incremental samples to be taken from the lot. Third, the choice of sampling procedure needs to be determined from Section 8 utilizing the preceding criteria.

7.6 *Recommended Number and Weight of Increments*:

7.6.1 Refer to Table 1 for the recommended number and weight of increments for general purpose sampling. The number of increments required listed in Table 1 are based upon a 1000–ton lot size. To determine the number of increments recommended for a specific lot size, use Eq 1. To determine the recommended weight for a bulk sample, multiply the increment requirement times the minimum increment weight from Table 1.

TABLE 1 Recommended Number and Weight of Increments for General Purpose Sampling

Particle Size	– 1/4 in.	+ 1/4 by – 3/4 in.	+ 3/4 in.
Minimum number of increments	10	10	10
Minimum weight of increment, lb	5	10	15

7.6.2 The increments and weights listed in Table 1 are only recommendations and are not based upon a statistical model. For more accurate methods to determine weights and increments required, refer to Practices E 105, E 122, and E 141 and Test Methods D 2234.

7.6.3 For randomized sampling, refer to Practice D 3665.

$$N_2 = N_1\ [\text{specific lot size (tons)} / 1000\ \text{tons}]^{1/2} \quad (1)$$

where:

N_1 = minimum increments required, per 1000 ton lot, and
N_2 = increments required for specified lot size.

7.7 *Mechanical Sampling Devices*—There are several different types of mechanical sampling devices available for many of the sampling procedures mentioned in Section 8. Due to the variety of types, it is impractical to specifically identify each device. Prior to using any mechanical sampling device, it needs to be determined that the device is capable of taking an unbiased, representative sample of the material in question.

8. Sampling Procedures (See Sampling Procedure Flow Chart (Fig. 1) for Location of Specific Methods)

LIMESTONE

8.1 *Surface Sampling*:

8.1.1 Surface sampling is limited in use due to the nonrepresentative sample obtained. For exploration purposes, a surface sample can produce information with respect to the characteristics of a deposit. It is critical to remember that a surface sample is not representative and can only be used to determine if more detailed sampling and testing may be justified.

8.1.2 Obtain the necessary information to determine a suitable location for sampling. Choose sites that will best satisfy the purpose of sampling. Describe and record observations on the characteristics of the portion of the deposit being sampled to the extent required by the sampling plan. It is imperative for the sample collected to be of sufficient size to perform any required testing.

8.2 *Face Sampling*—Describe and record observations on the characteristics of the portion of the face being sampled to the extent required by the sampling plan. With suitable marking equipment, identify the sampling site in accordance with the sampling plan. It is imperative for the sample collected to be of sufficient size to perform any required testing.

8.3 *Drill Hole Samples*—The type of drilling equipment required will be determined by the sampling plan. Sample the drill hole in intervals as specified in the sampling plan.

8.3.1 *Drill Cuttings*:

8.3.1.1 Drill cuttings are deposited on the surface by the drilling equipment. Many drills use compressed air to blow the drill cuttings out of the drill hole. These cuttings collect on the surface in a circular mound surrounding the hole. Collect a

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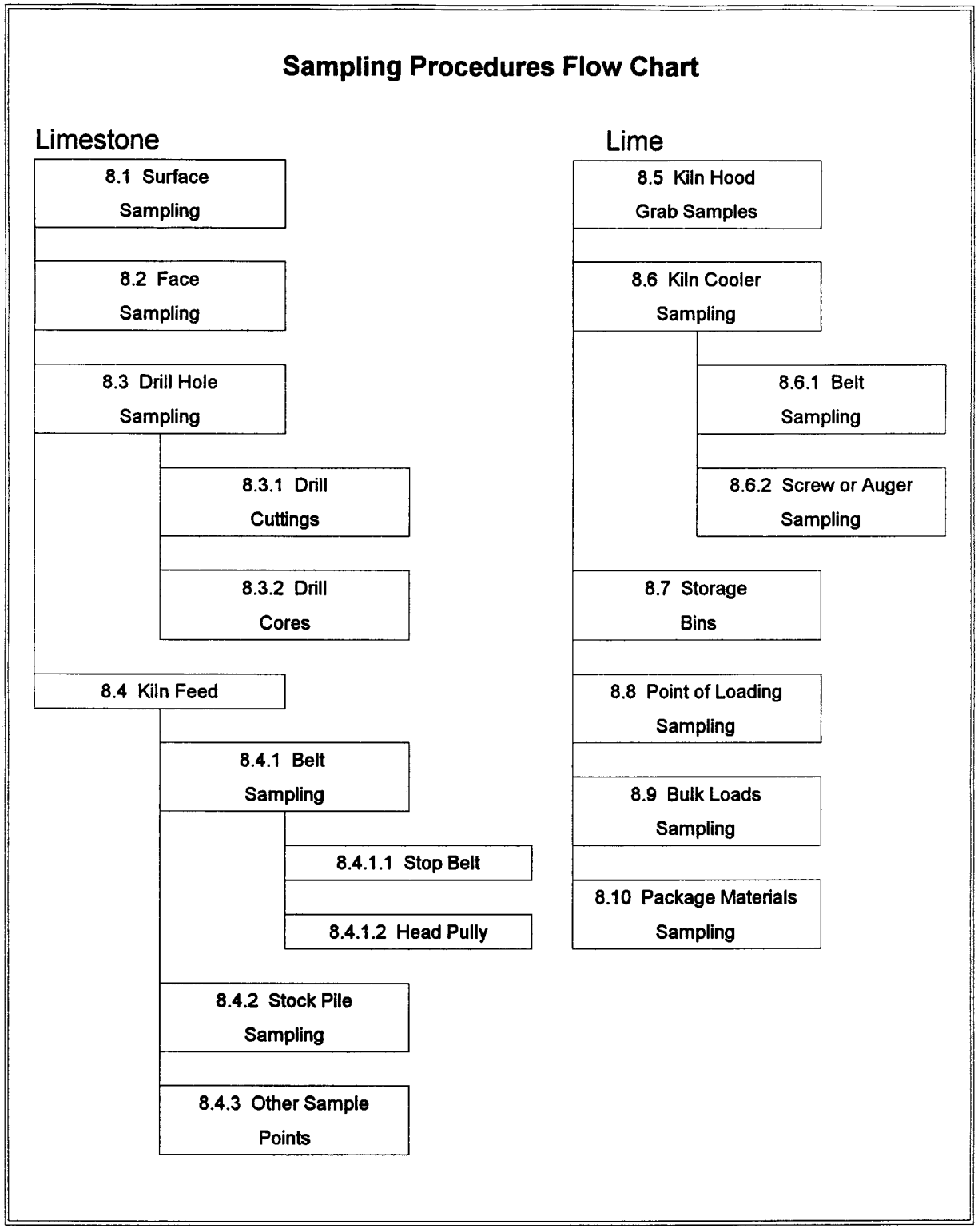

FIG. 1 Sampling Procedures Flow Chart

crosscut representative sample of the drill cuttings, taking care not to contaminate with surface material.

8.3.1.2 Recirculated drill cuttings are produced from another type of drilling equipment using compressed air to blow the drill cuttings through the hollow center of equipment drill steel into a collection chamber. Empty this chamber at intervals determined in the sampling plan.

8.3.2 *Drill Core*:

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8.3.2.1 Some drilling equipment cuts and removes solid cylindrical cores of material from a drill hole. Sample these drill cores at intervals determined in the sampling plan.

8.3.2.2 Drill cores are split as determined by the sampling plans. One portion of the split core is preserved intact, maintaining its orientation and order as it is removed from the drill hole. These samples are invaluable for historical purposes and are often saved for the life of the quarry.

8.4 *Limestone Kiln Feed Sampling*:

8.4.1 *Belt Sampling*—Two conditions exist from which samples can manually be obtained from a conveyor belt.

8.4.1.1 *Stop-Belt Sample*:

(1) Before stopping, the conveyor must be loaded with a constant flow of material in order to be sampled. The conveyor must then be secured consistent with proper safety procedures.

(2) Carefully remove the sample increment of material from completely across the belt, removing all material in the selected area including fines with, for example, a brush. Templates, whose bottom edge are shaped to match the belt contour, are useful in bracketing the sample location, thus preventing contamination of sample from material adjacent to the sampling area. It is important that the sample increment is composed of the entire cross section of material flow. Repeat the preceding process to remove the number of increments necessary to compose the bulk sample.

8.4.1.2 *Head-Pulley Sample*:

(1) When looking at a granular or pebble material conveyed with a belt, the fines tend to sift though the coarser material and ride on the bottom and toward the middle of the belt. The coarse and fines thus become segregated to an extent dependent upon gradation and physical conditions of the material being sampled. As the material is projected from the head-pulley, the coarser material is thrown slightly further with the fines dropping closer to the head-pulley. The most important considerations, therefore, in sampling at a head-pulley is that the entire cross section of material flow (fines and coarse) is obtained with the pass of the sampling apparatus. And further, that the movement of the sampling apparatus is accomplished in a timely manner, so as to reduce any bias in sampling from the lateral movement of the sampler.

(2) Head-pulley sampling can only be accomplished manually if the flow of material is at a minimum for safety reasons, otherwise an automatic sampler is recommended.

8.4.2 *Stockpile Sampling*:

8.4.2.1 Sampling from stockpiles, although occasionally necessary, is not recommended, because of the difficulty in guaranteeing an unbiased sample. When sized material is stockpiled, segregation occurs, with coarser particles rolling to the outside base of the pile and finer particles sifting toward the center. It is very difficult to ensure representative samples, due to the segregation, which usually occurs when material is stockpiled, with the coarser particles rolling to the outside base of the pile. When it is necessary to sample stockpiles, every effort should be made to enlist the services of power equipment that is capable of exposing the material at various levels and locations. Separate samples shall be taken from different areas of the stockpiles to represent the material in that portion. Test results of the individual samples will indicate the extent of segregation existing in the stockpiles.

8.4.2.2 If it is necessary to sample stockpiles, numerous increments should be obtained from various points and combined to create the bulk sample. The number of increments must be sufficient to indicate the degree of variability existing within the pile. This is of particular importance when testing for material gradation.

8.4.2.3 If power equipment is available, larger increments can be obtained and then combined to form a smaller stockpile from which the bulk sample can be removed. The increments must be of a sufficient number and from various locations on the main stockpile to ensure formation of a representative and unbiased sampling stockpile. After mixing the smaller stockpile, several increments from different locations can be combined to form the bulk sample. Depending upon the size of the main stockpile, several sampling stockpiles can be formed from which bulk samples can be then obtained.

8.4.2.4 When manually sampling a stockpile (see Note 1), its shape dictates the methodology to be used. If the stockpile has a large flat upper surface, increments can be taken from various locations on the top surface. Otherwise, increments must be taken from the side, on a line from the base to the top of the stockpile. At no time should material be taken directly from the surface, but should be obtained from at least a foot below the surface, because of segregation. When a stockpile is active, increments can be obtained from the working location.

NOTE 1—Safety is a major concern when taking this type of sample due to material slides. Caution must be used at all times, as the individual sampling is at risk. Two people should be involved in this type of sampling with one individual at a distance from the pile, mindful of the sampler's safety. An inspection of the locations must be made beforehand for possible sliding hazards with those locations avoided. This is not a recommended practice.

8.4.2.5 When sampling from the side of a stockpile, on a line from top to bottom, select a minimum of five locations from which increments are to be taken (refer to Practice E 122). Remove the surface material from the increment location to the proper depth in order to create a small working bench. Use of a shield is recommended above the sampling point to prevent further segregation and contamination. From the exposed bench remove an increment from as far inside the pile as possible. Repeat this procedure for each of the selected locations and composite increments to form the bulk sample.

8.4.2.6 When sampling on top of a flat stockpile, increment locations must be spaced over the entire surface and be of a number to ensure a representative bulk sample. Again, the increments must come from a depth of at least 1 ft.

8.4.2.7 When sampling from the working face of an active stockpile, select a minimum of five to ten spots from the entire working face for which to withdraw an increment. The increment sites should be at least 2 ft from the base of the stockpile, and must not include accumulated material, which has fallen from the sides of the active face due to further segregation. Combine the increments to form the bulk sample.

8.4.3 *Other Sampling Points*:

8.4.3.1 Other sampling points include stockpile feeders, cascade feeders, chutes, and so forth. As before, the most

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important consideration is in obtaining a representative sample. This means obtaining a complete cross section of the material flow.

NOTE 2—Consideration must be given to the flow of material to the sampling point from a surge (from a bin, stockpile, etc.). As material goes into a surge point, segregation of material occurs. Likewise, as material flows from a surge, its character can change with time. As sample increments are obtained, an unintentional bias can be obtained relative to the bulk sample. This may not be the case if the flow of material is directly from a process or system, such as a specific screening deck. In any case, misleading results can be obtained if this consideration is ignored, even with conscientious sampling techniques.

LIME

8.5 *Kiln Hood Grab Sample*:

8.5.1 The Kiln Hood Grab Sample is a nonrepresentative and bias sample that only indicates chemical condition of the material flow from which it was obtained. It indicates the degree of calcination, relative to particle size, at that point in time and assists the operator in making decisions concerning the operation of the kiln. Because of the nature of the kiln calcination process, it is the closest to the process and most timely indication of the material quality that can be obtained. Therefore, is very important, regardless of the bias nature of the sample.

NOTE 3—Safety issues, relative to the kiln process, involve the high-calcination temperatures and draft conditions at the time of sampling. Protective equipment must be used.

8.5.2 A scoop or large ladle attached to a long metal pole is used to obtain the sample. It is passed parallel to the axis of the kiln through the process flow to obtain all size fractions of the material. Several increments, to increase the probability of representation, should be obtained and combined to form the bulk sample. This is extremely critical as chemistry can vary with particle (pebble) size. It is also preferable that several minutes elapse between incremental addition to the bulk sample as particle size of the material flow can change. The sample should be stored in a large dust-protected container, allowed to cool to ambient temperature, and then processed for chemical analysis.

8.5.3 To increase the homogeneity, the entire bulk sample must be crushed initially before reduction in the amount of material.

8.6 *Kiln Cooler Sampling*—As with Kiln discharge samples, the purpose of sampling dictates the methods to be used. If chemical results are required as a process control, the frequency of increments and amount of material composing a bulk sample may be reduced. If the results are to be used as a tool for process control, the timing becomes critical, and a snapshot of the chemical characteristics of the process product becomes more important. The frequency of sampling is then determined by the variability of the process and the resulting product. This would be true for any of the methods used for sampling.

8.6.1 *Belt Sampling, Pans or Chutes*—Cooler sampling can involve a number of different methods. As with sampling limestones, many of the techniques are similar, such as with belts. Other techniques involve discharge points, such as chutes and feeders. For these techniques please refer to the previous sections referring to limestone sampling.

NOTE 4—When sampling at a kiln cooler, the material may be quite hot and the area very dusty. Appropriate safety precautions must be followed.

8.6.2 *Screw or Auger*:

8.6.2.1 One method involves the use of an opening placed along the axis of the screw conveyor, which is closed off by either a gate or valve. The smallest dimension of the opening must be at a minimum of three times the longest dimension of the largest particle of the material being conveyed.

NOTE 5—In obtaining samples from a screw or auger, the particle size can be altered as a result of the conveying process. Therefore a sample obtained in this fashion can not be used to determine sizing characteristics. The chemical nature of the material, though, can be determined from samples obtained in this fashion.

8.6.2.2 This is important to obtain a free flow of material into the sampling apparatus, and to ensure a representative sample relative to the material chemical characteristics. The number of increments and their amounts to compose the bulk sample must be determined beforehand, so as to obtained an unbiased, representative sample (refer to Practice E 122).

8.6.2.3 A second method involves sampling the discharge of the screw or auger. In this case, the entire cross section of material flow must be obtained for proper representation. Again the number of increments and their amounts must be determined beforehand (refer to Practice E 122).

8.7 *Storage Bins*—If the samples are taken from a bin, they shall be taken from the entire cross section of the flow of material as it is being discharged. At the beginning of the discharge from the bins, sufficient material should be permitted to flow to ensure normal uniformity before the sample is collected.

8.8 *Sampling at Point of Loading*:

NOTE 6—The sampling plan including sample size, frequency of sampling, and so forth (as well as possible problems with sampling, such as product degradation) should be reviewed with customers prior to purchase.

8.8.1 Bins, railcars, trucks, and barges should be sampled while being loaded. Sampling from bulk shipments (trucks, railcars, or barges) is not a recommended practice, because of the bias relative to particle size and obtaining a representative sample. If there is a bias, it is generally proportional to the particle size range. True particle representation from bulk shipments is difficult to obtain. Safety is a major concern when sampling from bulk shipments. It is preferred, whenever practical, to sample product as it is being transferred to a shipping unit.

8.8.2 Sampling may be done by cutting the stream of material going into the bin, railcar, truck, or barge with a suitable sampling device, diverting the entire product stream briefly to a sample container, or by stopping a belt and thoroughly cleaning the material into a sample container. For sampling practices involving conveyor belts, refer to 8.4.1.

8.8.3 If loading directly from a chute or a bin, it may not be practical to sample the stream, because of the volume, weight and speed of the material. For sampling practices involving bins, refer to 8.7.1.

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8.8.4 Sampling may also consist of intermittent cutting of a stream with a suitable automatic sampling device to yield a representative composite sample. Mechanical sampling systems must be checked to ensure that the particle size is not degraded.

8.8.5 If necessary, fine lime products can be sampled from bulk shipments with the use of special devises that allow sampling through the depth of the shipping unit. These devises generally consist of two cylindrical hollow spears, one inside the other with consistent openings. The narrowest dimension of the openings must allow free flow in the material being sampled. As one spear is rotated the openings close or open, relative to the positions of both spears. The spear is forced down through the depth of the product with the openings closed. At maximum depth, the one spear is rotated to allow the product to flow into the inner spear and thus to collect a sample. The spear is rotated to close the openings and the sampling device is withdrawn from the material. The sample is collected from the top of the hollow spears. It is recommended that a number of increments be obtained from different equally spaced locations across the shipping unit to compose the bulk sample relative to the size of the shipping unit and sampling plan.

8.9 *Sampling of Bulk Loads*:

8.9.1 If necessary, for methods of sampling directly from bulk shipments use those practices in accordance with 8.4.2.

8.9.2 Separate samples shall be taken from as many points in the shipment unit as necessary to represent the material, realizing the probability of segregation as the material was loaded. These separate samples will usually be combined to form a composite sample. This sample shall be reduced, but if information on variation is desired, the separate samples shall be tested.

8.10 *Sampling of Packaged Material*:

8.10.1 *Random Sample*—Random sample may be taken using a combination of methods. Bags may be taken at random from within the pallet or among multiple pallets. A sample may then be taken from each bag. A composite of all bags is then formed and tested.

8.10.2 *Thief Sample*—Material to be taken from a bag may be taken from the available opening (see 8.8.5).

8.10.3 Samples must not be taken from packages whose integrity has been compromised.

9. Preparation of Laboratory Samples

9.1 Sample preparation is the reduction of the bulk sample in both particle size and amount of material to the suitable laboratory sample, so as to maintain representation of the initial bulk sample. Procedures as outlined must be followed in a conscientious and thorough manner in order to maintain that representation. The method of sample preparation to be used depends upon the type of material, tests to be performed, and the characteristics of the bulk sample in relation to particle size and quantity of material.

9.2 Generally when a screen analysis is required, a larger bulk sample is needed compared to a chemical analysis. But the key objective is to maintain representation of the bulk sample, so that the final test values reflect the characteristics of the initial material. Working with coarse materials, segregation of the different size fractions is a major problem, as different size fractions will have varying properties. Segregation must be avoided through the conscientious use of splitting devices and strict adherence to procedure.

9.3 Splitting gross samples can be accomplished in multiple stages of reduction in both size and amount. Reduction in the particle size of the material or crushing should precede the lowering in the amount or splitting of the gross sample to retain the representative nature of the initial sample, and is relative to the amount of material present at each stage of reduction.

NOTE 7—High-moisture content in limestone causes problems relative to reduction of the bulk sample (splitting) to the test sample, as well as, in the sizing operations. In this case drying becomes a necessity.

9.4 *Splitting Devices*:

9.4.1 *Riffle Splitter*—A riffle splitter is a device that should have an equal number of adjacent chutes of identical widths opening into adjacent buckets or collection pans. The bucket or pan feeding an open splitter should be of an identical width to the chutes. The width of the chutes should be at least three times the width of the nominal top size of the material being split. Some splitters have a catch basin, which holds the material before reduction. In this case, the material must be spread across the entire width of the splitter. The important consideration is that each chute has an equal selection probability.

9.4.2 *Sectorial Splitter*—A sectorial splitter is a radial device with either a revolving or stationary feeder, useful for obtaining identical samples for comparative testing. With this type of device, the revolving speed and material flow rate must be as constant and uniform as possible. All sectors of the splitter must be radial and equal in size with no escape of material from any sector.

9.4.3 *Coning and Quartering*—Coning and quartering is an old method that can be used for small or large lots, in which a conical pile is created and quartered to obtain a sample.

9.4.3.1 Mix and spread the sample material on a clean surface, and then heap into a conical pile by placing shovels of material onto the apex of the cone. Flatten the cone symmetrically from the center to form flat circular pile.

9.4.3.2 The divide the pile into equal and identical quarters with a shovel or straightedge. Randomly select the subsample from one or more of the quarters. To further divide the subsample, the coning and quartering process must be repeated.

9.5 *Sizing Samples for Laboratory Analysis*:

9.5.1 As necessary, crush the sample (Note 8) by a suitable means to a size small enough to be easily handled by the laboratory's pulverizing equipment or to a size required by the analytical method.

NOTE 8—If physical testing is to be carried out on the sample, it is recommended that a second sample be sent to the laboratory solely for the purpose of physical testing. If screening of the sample is required to determine physical size characteristics, the second sample, or a representative subsample of the original sample, must not be further prepared from "as received" by the laboratory.

9.5.2 Utilizing suitable pulverizing equipment, further reduce the sample (or subsample) to an appropriate size for the

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analytical procedure to be performed on the sample. (Note 9). Please refer to Table 2 as a reference for pulverizing.

NOTE 9—When pulverizing sample to a specific mesh size, it is incorrect to screen a sample on the desired mesh and discard the fraction of the sample retained on the sieve. It is imperative that the whole (total) sample be used. Through previous experience with the particular grinding equipment, the grind produced should already be known so that no actual screening is required.

10. Rejection

10.1 Specific circumstances between the manufacturer and the purchaser may dictate that contractual agreements will supersede the recommendations of rejection.

10.2 Rejection of material based on failure to pass tests prescribed in the specification shall be reported to the manufacturer within 1 week after tests have been completed or within 30 days after shipment has been received, and the cause for rejection shall be stated.

10.3 The samples that represent rejected material shall be kept in airtight, moisture-proof containers for at least 2 weeks from the date of the original test report as reported to the manufacturer.

11. Retesting

11.1 Specific circumstances between the manufacturer and the purchaser may dictate that contractual agreements will supercede the recommendations of retesting.

11.2 Either of the contracting parties may make claim for a retest within 2 weeks of the date of the original test report. The expense of the retest shall be borne by the party demanding such retest.

11.3 Should the contracting parties be unable to reach a mutually satisfactory agreement based upon the results of the original test, the third sample of the material shall be delivered unopened to a mutually satisfactory referee laboratory for test. The results of this referee test shall be binding on both parties.

12. Packaging

12.1 Lime and limestone products may be shipped in bulk or in containers agreed upon between the manufacturer and the purchaser.

12.2 All packages shall be in good condition at the time of inspection.

13. Marking

13.1 Unless otherwise agreed upon between the manufacturer and the purchaser, each package shall have legibly marked thereon the name of the product, the net weight of its contents, the name of the manufacturer, the place of manufacture, and the brand name, if any.

13.2 In addition to the preceding information, the following may be marked on each package of shipment: “The contents meet the requirements of ASTM Practice C 50.”

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TABLE 2 Sample Preparation Equipment[A,B,C]

Sample Size	Particle Size of Analytical Sample (Nominal Top Size)	Type of Equipment	Applicable Test Procedures
> 50 grams	6 mesh	Jaw Crusher Hammermill Roll Crusher Disc Mill Others- if adjustable	C 110
> 1 gram < 50 grams	50 mesh	Hammermill (with appropriate discharge screen) Disc Mill	C 25 C 110 C 400
> 0.5 gram < 1 gram	100 mesh	Mechanical Mortar and Pestle[D] Ring and Puck Mill	C 25
< 0.5 gram	< 200 mesh	Mechanical Mortar and Pestle[D] Ring and Puck Mill	C 25 C 1271[E] C 1301[E]

[A] The Precision, associated with specific analytical procedures in relation to the sample weight, can be greatly effected by the particle size of the analytical sample. Therefore this chart is provided as a guide to obtain the desired particle size with the equipment suggested.

[B] Depending upon the testing requirements, such as for color (whiteness) or trace elements (iron, aluminum, chrome, nickel, tungsten, etc.), contamination may result from the preparation equipment, particularly when grinding to finer than 50 mesh. Therefore, materials of equipment construction must be considered in regard to testing requirements and sample particle size.

[C] The above list is not complete as comparable equipment may exist.

[D] Due to the hydroscopic nature of quicklime and the time involved in pulverizing, use of a hand Mortar is not recommended.

[E] Because of the nature of the test described within this standard, a finely pulverized homogenous sample is required regardless of the analytical sample size.

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Designation: C 51 – 07

Standard Terminology Relating to Lime and Limestone (as used by the Industry)[1]

This standard is issued under the fixed designation C 51; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

This standard has been approved for use by agencies of the Department of Defense.

1. Scope*

1.1 This terminology refers to the terms relating to lime and limestone products as used by the industry.

1.2 Where appropriate, the various terms defined below should be prefixed with one or other of the adjectives "high-calcium," "magnesian," or "dolomitic." (Examples: dolomitic quicklime; high-calcium hydraulic hydrated lime; magnesian or dolomitic limestone.)

1.3 The composition of a limestone should be given in terms of a percentage of the carbonates present. In limestone of interest to the lime industry, it is usually assumed that the material consists almost entirely of carbonates. Where this assumption is not valid, the percentage of noncarbonate material should be determined, and the composition expressed in terms of the carbonate material present.

1.4 For specific application of lime or a limestone product, see the appropriate ASTM specification.

2. Referenced Documents

2.1 *ASTM Standards:*[2]

C 270 Specification for Mortar for Unit Masonry

C 602 Specification for Agricultural Liming Materials

3. Terminology

agricultural lime—either ground quicklime or hydrated lime whose calcium and magnesium content is capable of neutralizing soil acidity.

agricultural limestone—ground or pulverized limestone whose calcium and magnesium content is capable of neutralizing soil acidity.

DISCUSSION—Agricultural lime is a very powerful neutralizing agent. Agricultural limestone, often referred to as "aglime" is the predominate material for soil pH adjustment. See Specification C 602.

air-slaked lime—the product containing various proportions of the oxides, hydroxides, and carbonates of calcium and magnesium which results from the exposure of quicklime to the air in sufficient quantity to show physical signs of hydration (difficult to determine visually in pulverized quicklime).

alkaline earth solutions (AES)—an aqueous solution of the oxide or hydroxide of an element of group IIa in the periodic table, such as calcium or magnesium. These solutions may be strongly alkaline. See **pH**.

available lime index—those constituents of a lime which enter into a desired reaction under the conditions of a specific method or process.

building or construction lime—a lime whose chemical and physical characteristics and method of processing make it suitable for the ordinary or special construction uses of the product.

by-product lime—by-product limes include a variety of Calcium and/or Calcium/Magnesium compounds that are usable for specific applications but generally do not meet one or more specifications required of primary lime products. Examples include lime kiln dust and lime hydrator rejects. It is advised that the specific compositions, physical properties, performance characteristics, and anticipated variabilities of such materials be evaluated for the service intended.

calcareous—originating from predominately calcium carbonate or one of its derivative forms.

calcia—the chemical compound calcium oxide (CaO).

calcined pozzolans—materials that are produced by calcination of natural siliceous or alumino-siliceous earths, such calcination being for the purpose of activation of pozzolanic properties.

Cement-Lime Mortar—Cement-Lime Mortar primarily consists of hydraulic cement, hydrated lime or lime putty, mason's sand and water.

DISCUSSION—These mortars can be specified by proportions or properties indicated in Specification C 270.

chemical lime—a quicklime or hydrated lime whose chemical and physical characteristics and method of processing make it suitable for one or more of the many and varied chemical

[1] This terminology is under the jurisdiction of ASTM Committee C07 on Lime and is the direct responsibility of Subcommittee C07.08 on Editorial and Nomenclature

Current edition approved July 15, 2007. Published August 2007. Originally approved in 1922. Last previous edition approved in 2006 as C 51 – 06.

[2] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

***A Summary of Changes section appears at the end of this standard.**

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and industrial uses of the product.

DISCUSSION—The chemical forms of calcium oxide (CaO), calcium hydroxide ($Ca(OH)_2$), magnesium oxide (MgO), or magnesium hydroxide ($Mg(OH)_2$) alone or in combination may be produced either primarily or as a by-product of materials other than limestone, for example, $Ca(OH)_2$ formed by acetylene generation from calcium carbide (CaC_2), water treatment sludges, etc.

dead burned dolomite—dolomitic limestone that has been heated with or without additives to a temperature sufficiently high and for a long enough time to decompose the carbonate structure so as to form calcium oxide and periclase in a matrix that provides resistance to subsequent hydration and recombination with carbon dioxide.

dolomitic—indicates the presence of 35 to 46 % magnesium carbonate ($MgCO_3$) in the limestone from which the material was formed.

dolomitic limestone—see **limestone.**

di-hydrated or double hydrated lime—dolomitic lime which has been hydrated under greater than atmospheric pressure and contains less than 8 % unhydrated oxides.

finishing hydrated lime—hydrated lime suitable for use in the finish coat of plaster.

finishing quicklime—quicklime suitable (after slaking to a lime putty) for use in the finish coat of plaster.

fluxing lime—a term referring to quicklime used as an agent in the manufacture of steel or glass.

fluxstone—a term referring to limestone (high-calcium, magnesian, or dolomitic) used as an agent in the manufacture of iron and steel or glass.

high-calcium—indicates the presence of 0 to 5 % magnesium carbonate ($MgCO_3$) in the limestone from which the material was formed.

high-calcium limestone—see **limestone.**

hydrated lime—a dry powder obtained by treating quicklime with water enough to satisfy its chemical affinity for water under the conditions of its hydration. It consists essentially of calcium hydroxide or a mixture of calcium hydroxide and magnesium oxide or magnesium hydroxide, or both.

DISCUSSION—The chemical forms of calcium oxide (CaO), calcium hydroxide ($Ca(OH)_2$), magnesium oxide (MgO), or magnesium hydroxide ($Mg(OH)_2$) alone or in combination may be produced either primarily or as a by-product of materials other than limestone, for example, $Ca(OH)_2$ formed by acetylene generation from calcium carbide (CaC_2), water treatment sludges, etc.

hydraulic hydrated lime—the hydrated dry cementitious product obtained by calcining a limestone containing silica and alumina to a temperature short of incipient fusion so as to form sufficient free lime (CaO) to permit hydration, and at the same time, leaving unhydrated sufficient calcium silicates to give a dry powder meeting hydraulic property requirements.

lime—a general term which includes the various chemical and physical forms of quicklime, hydrated lime, and hydraulic lime. It may be high-calcium, magnesian, or dolomitic.

DISCUSSION—The chemical forms of calcium oxide (CaO), calcium hydroxide ($Ca(OH)_2$), magnesium oxide (MgO), or magnesium hydroxide ($Mg(OH)_2$) alone or in combination may be produced either primarily or as a by-product of materials other than limestone, for example, $Ca(OH)_2$ formed by acetylene generation from calcium carbide (CaC_2), water treatment sludges, etc.

lime mortar—a lime putty mixed with an aggregate, suitable for masonry purposes.

lime putty—the product obtained by slaking quicklime with water according to the directions of the manufacturer or by mixing hydrated lime and water to a desired consistency.

limestone—an initially sedimentary rock consisting chiefly of calcium carbonate or of the carbonates of calcium and magnesium. Limestone may be of high calcium, magnesian, or dolomitic.

(*1*) *dolomitic limestone*—limestone containing from 35 to 46 % magnesium carbonate ($MgCO_3$).

(*2*) *magnesium limestone*—a limestone containing from 5 to 35 % $MgCO_3$.

(*3*) *high-calcium limestone*—a limestone containing from 0 to 5 % $MgCO_3$.

liming material—a general term which includes the various chemical and physical forms of matierals such as lime, limestone, mollusk shells, marl, byproduct lime, and slag whose calcium and magnesium compounds are capable of neutralizing acidity.

magnesia—the chemical compound magnesium oxide (MgO).

magnesian—indicates the presence of 5 to 35 % magnesium carbonate ($MgCO_3$) in the limestone from which the material was formed.

magnesian limestone—see **limestone.**

masons hydrated lime—hydrated lime suitable for use for masonry purposes.

masons quicklime—quicklime suitable (after slaking to a lime putty) for use for masonry purposes.

milk of lime—a suspension of hydrated lime (or slaked quicklime) in water in such proportions as to resemble milk in appearance.

DISCUSSION—The chemical forms of calcium oxide (CaO), calcium hydroxide ($Ca(OH)_2$), magnesium oxide (MgO), or magnesium hydroxide ($Mg(OH)_2$) alone or in combination may be produced either primarily or as a by-product of materials other than limestone, for example, $Ca(OH)_2$ formed by acetylene generation from calcium carbide (CaC_2), water treatment sludges, etc.

mono-hydrated lime—dolomitic lime which has been hydrated at atmospheric pressure and contains more than 8 % unhydrated oxides.

natural pozzolans—materials that, in the natural state, exhibit pozzolanic properties, such as some volcanic ash and lava deposits.

non-volatile—term used to denote the calculated chemical basis of a material in which the volatile fraction of that material is removed, relative to a specific temperature. For example, in lime and limestone, the loss on ignition is considered to be the volatile fraction.

pH—the negative logarithm of the hydrogen ion concentration, which can be greatly affected by temperature, particularly under alkaline conditions. It is therefore important to measure alkaline earth solutions (AES) at a specific recommended temperature of 25 °C.

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plasticity—a comparative physical property of a standard consistency lime putty to resist the loss of plastic state workability when subjected to pressure against the suction of an absorptive surface as measured by the Emley Plasticimeter.

Portland Cement-Lime Mortar (PCL)—See Cement-Lime Mortar.

pozzolan—a siliceous or alumino-siliceous material that in itself possesses little or no cementitious value but that in finely divided form and in the presence of moisture will chemically react with alkali and alkaline earth hydroxides at ordinary temperatures to form or assist in forming compounds possessing cementitious properties.

quicklime—a calcined limestone, the major part of which is calcium oxide or calcium oxide in association with magnesium oxide, capable of slaking with water.

DISCUSSION—The chemical forms of calcium oxide (CaO), calcium hydroxide ($Ca(OH)_2$), magnesium oxide (MgO), or magnesium hydroxide ($Mg(OH)_2$) alone or in combination may be produced either primarily or as a by-product of materials other than limestone, for example, $Ca(OH)_2$ formed by acetylene generation from calcium carbide (CaC_2), water treatment sludges, etc.

quicklime sizes—the different sizes depending upon the type of limestone, kind of kiln used, or treatment subsequent to calcining. The sizes commonly recognized are as follows:

(*1*) *large lump*—8 in. (203 mm) and smaller,

(*2*) *pebble or crushed*—2½ in. (64 mm) and smaller,

(*3*) *ground, screened or granular*—¼ in. (6.4 mm) and smaller, and

(*4*) *pulverized*—substantially all passing a No. 20 (850-μm) sieve.

reactivity—reactivity is the reaction between substances, which can be monitored by some measure, either qualitative or quantitative. In the Lime Industry, it is commonly used to refer to the reaction between limestone, quicklime and/or a related material and another substance such as water, acid or SO_x

refractory lime—lime (usually of a dolomitic type) that has been extremely hard burned so that it will possess little or no tendency for conversion of the oxides to hydroxides.

run-of-kiln quicklime—quicklime as drawn or discharged from a kiln.

slaking—the chemical reaction that produces hydrated lime when quicklime and water are mixed.

spray lime—a hydrated lime of such fineness that at least 95 % of the particles will pass a No. 325 (45-μm) sieve.

stucco—an exterior cementious-lime-finishing system applied to a suitable substrate on the surfaces of buildings and structures.

white wash—a combination of hydrated lime (or slaked quicklime), water, and other materials to be used as a paintlike coating.

SUMMARY OF CHANGES

Committee C07 has identified the location of selected changes to this terminology since the last issue, C51–06, that may impact the use of this terminology. (Approved July 15, 2007)

(*1*) Added a Discussion to **agricultural limestone**.

(*2*) Revised the definition of **liming material**.

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Designation: C 59/C 59M – 00 (Reapproved 2006)

Standard Specification for Gypsum Casting Plaster and Gypsum Molding Plaster[1]

This standard is issued under the fixed designation C 59/C 59M; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

This standard has been approved for use by agencies of the Department of Defense.

1. Scope

1.1 This specification covers gypsum casting plaster and gypsum molding plaster materials consisting essentially of calcined gypsum.

1.2 The values stated in either inch-pound or SI (metric) units are to be regarded as standard. Within the text, the SI units are shown in brackets. The values stated in each system shall be used independently of the other. Values from the two systems shall not be combined.

1.3 The text of this standard references notes and footnotes that provide explanatory material. These notes and footnotes shall not be considered as requirements of the standard.

2. Referenced Documents

2.1 *ASTM Standards:* [2]

C 11 Terminology Relating to Gypsum and Related Building Materials and Systems

C 471M Test Methods for Chemical Analysis of Gypsum and Gypsum Products [Metric]

C 472 Test Methods for Physical Testing of Gypsum, Gypsum Plasters and Gypsum Concrete

E 11 Specification for Wire Cloth and Sieves for Testing Purposes

3. Terminology

3.1 Definitions of terms shall be in accordance with Terminology C 11.

3.2 *Description of Terms Specific to This Standard:*

3.2.1 *gypsum casting plaster, n*—a calcined gypsum plaster used primarily to form objects, such as lamp bases, art ware, and novelties, etc.

3.2.2 *gypsum molding plaster, n*—a calcined gypsum plaster used primarily for plaster casts or molds, sometimes used as a gauging plaster.

4. Chemical Composition

4.1 Gypsum casting plaster and gypsum molding plaster shall have a purity of not less than 85 % $CaSO_4 \cdot 2H_2O$ when tested in accordance with Test Methods C 471M.

5. Physical Properties

5.1 Specimens shall be tested in accordance with Test Methods C 472.

5.1.1 *Setting Time*—Gypsum casting plaster and gypsum molding plaster shall set in not less than 10 nor more than 50 min using the procedure for gypsum concrete and all gypsum plasters, except gypsum neat plaster.

5.1.2 *Compressive Strength*—Gypsum casting plaster and gypsum molding plaster shall have a compressive strength of not less than 1800 psi [12.4 MPa].

5.1.3 *Fineness*—Gypsum casting plaster and gypsum molding plaster shall all pass a No. 30 [600-μm] sieve and not less than 90 % shall pass a No. 100 [150-μm] sieve.[3]

6. Sampling

6.1 Randomly select not less than 1 % of the packages, but not less than 5 packages. Take samples of approximately equal amounts both from the outer portion and the center of each package. Mix the samples so obtained to provide a composite sample of not less than 7 lb [3 kg]. Immediately place the composite sample in a clean, dry, airtight container for delivery to the laboratory.

7. Inspection

7.1 Inspection of the gypsum casting and molding plaster shall be agreed upon by the purchaser and the supplier as part of the purchase agreement.

8. Rejection

8.1 Rejection of gypsum casting plaster and gypsum molding plaster that fails to conform to the requirements of this specification shall be reported to the producer or supplier promptly and in writing. The notice of rejection shall contain a statement documenting how the gypsum casting and molding plaster have failed to conform to the requirements of this specification.

[1] This specification is under the jurisdiction of ASTM Committee C11 on Gypsum and Related Building Materials and Systems and is the direct responsibility of Subcommittee C11.01 on Specifications and Test Methods for Gypsum Products.

Current edition approved May 1, 2006. Published May 2006. Originally approved in 1926. Last previous edition approved in 2000 as C 59/C 59M – 00.

[2] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

[3] Detailed requirements for these sieves are given in ASTM Specification E 11.

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9. Certification

9.1 When specified in the purchase agreement, a producer's or supplier's report shall be furnished at the time of shipment certifying that the product is in compliance with this specification.

10. Packaging and Package Marking

10.1 Gypsum casting plaster and gypsum molding plasters shall be dry and free of lumps and shall be shipped in packages.

10.2 When shipped, the following information shall be legibly marked on each package or on a tag of suitable size attached thereto:

10.2.1 Name of manufacturer or seller,

10.2.2 Brand,

10.2.3 Description, and

10.2.4 Net weight of package. Gross weight shall be shown where required.

11. Keywords

11.1 casting plaster; gypsum; gypsum plaster; molding plaster

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Designation: C 61/C 61M – 00 (Reapproved 2006)

Standard Specification for Gypsum Keene's Cement[1]

This standard is issued under the fixed designation C 61/C 61M; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

This standard has been approved for use by agencies of the Department of Defense.

1. Scope

1.1 This specification covers various grades of anhydrous calcined gypsum known as gypsum Keene's cement, designed for use in the base and finish coats of gypsum plaster.

NOTE 1—The setting time is accelerated by the addition of other materials.

NOTE 2—Keene's cements are generally available as quick-setting and standard-setting types. However, various grades of gypsum Keene's cement of different fineness and setting time are available. Grades intended for use in scagliola castings and other special purposes should conform to the requirements of this specification in all respects except fineness and setting time.

1.2 The values stated in either inch-pound or SI (metric) units are to be regarded separately as standard. Within the text, the SI units are shown in brackets. The values stated in each system shall be used independently of the other. Values from the two systems shall not be combined.

1.3 The text of this standard references notes and footnotes that provide explanatory material. These notes and footnotes shall not be considered as requirements of the standard.

1.4 The following safety hazards caveat pertains only to the test method in the appendix of this specification: *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

2. Referenced Documents

2.1 *ASTM Standards:* [2]

C 11 Terminology Relating to Gypsum and Related Building Materials and Systems

C 471M Test Methods for Chemical Analysis of Gypsum and Gypsum Products [Metric]

C 472 Test Methods for Physical Testing of Gypsum, Gypsum Plasters and Gypsum Concrete

E 11 Specification for Wire Cloth and Sieves for Testing Purposes

3. Terminology

3.1 *Definitions*—Definitions of terms used in this specification shall be as defined in Terminology C 11.

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *scagliola*, *n*—an imitation marble used for ornamental interior work.

4. Chemical Composition

4.1 *Combined Water*—The cement shall show a combined water content not more than 2 % when tested in accordance with Test Methods C 471M.

5. Physical Properties

5.1 Testing shall be in accordance with Test Methods C 472, except that in the determination of the setting time and compressive strength, the consistency used shall be such that a 35–g conical plunger, described in Test Methods C 472, shall give a penetration of 30 ± 2 mm, 20 s after release, the measurement being made 5 min after the addition of the gypsum Keene's cement to the gauging water.

5.1.1 *Setting Time*— The cement shall set in not less than 20 min and not more than 6 h when determined by the Vicat method.

5.1.2 *Compressive Strength*—Gypsum Keene's cement shall have a compressive strength of not less than 2500 psi [17 MPa]. Soak standard Keene's cement in water for 20 min with occasional stirring before filling the mold in the compressive strength determination.

5.1.3 *Fineness*—The cement shall all pass a No. 14 [1.40 mm] sieve; not less than 98 % shall pass a No. 40 [425–μm] sieve, and not less than 80 % shall pass a No. 100 [150–μm] sieve.[3]

6. Sampling

6.1 Randomly select not less than 1 % of the packages, but not less than 5 packages. Take samples of approximately equal

[1] This specification is under the jurisdiction of ASTM Committee C11 on Gypsum and Related Building Materials and Systems and is the direct responsibility of Subcommittee C11.01 on Specifications and Test Methods for Gypsum Products.

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[2] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

[3] Detailed requirements for these sieves are given in ASTM Specification E 11.

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amounts from both the outer portion and the center of each package. Mix the samples so obtained to provide a composite sample of not less than 15 lb [6.8 kg]. Immediately place the sample in a clean, dry, airtight container for delivery to the laboratory.

7. Inspection

7.1 Inspection of the gypsum Keene's cement shall be agreed upon between the producer or supplier and the purchaser as part of the purchase agreement.

8. Rejection

8.1 Rejection of gypsum Keene's cement that fails to conform to the requirements of this specification shall be reported to the producer or supplier promptly and in writing. The written notice of rejection shall contain a statement documenting how the gypsum Keene's cement has failed to conform to the requirements of this specification.

9. Certification

9.1 When specified in the purchase agreement, a producer's or supplier's report shall be furnished at the time of shipment certifying that the product is in compliance with this specification.

10. Packaging and Marking

10.1 Gypsum Keene's cement shall be dry, free of lumps, and shipped in packages.

10.2 When shipped for resale, the following information shall be legibly marked on each package or on a tag of suitable size attached thereto:

10.2.1 Name of producer or supplier,

10.2.2 Brand,

10.2.3 Description, and

10.2.4 Net weight of package. Gross weight shall be shown where required.

11. Keywords

11.1 anhydrous gypsum; gypsum; gypsum Keene's cement; gypsum plaster; Keene's cement; plaster

APPENDIX

(Nonmandatory Information)

X1. FIELD TEST FOR GYPSUM KEENE'S CEMENT

X1.1 Scope

X1.1.1 This method is a simple field test for the identification of gypsum Keene's cement. It does not indicate the quality of the cement, which shall be determined by the laboratory tests in the body of this specification.

X1.2 Significance and Use

X1.2.1 This method is of value to users in determining whether the material at hand is gypsum Keene's cement or some other material.

X1.3 Procedure

X1.3.1 Take a cupful of the material, mix with water to the consistency of a thick paste, and transfer to a plate or piece of glass. Let stand until fairly firm and definite signs of set having begun are manifest. This will be some time less than 2 h, depending on climatic conditions.

X1.3.2 Divide the sample, allowing one half to remain undisturbed. Take the other half, add a little water, remix, and then allow it to "set up" again on the plate or glass.

X1.4 Interpretation of Results

X1.4.1 If the material is gypsum Keene's cement, the remixed portion will, within a few hours, become as hard and strong as the portion that was not remixed.

X1.5 Precision and Bias

X1.5.1 It is not possible to state either the precision or bias of this test method because the method only determines whether a material is or is not gypsum Keene's cement and there are no numerical results generated.

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Designation: C 70 – 06

American Association State
Highway and Transportation Officials Standard
AASHTO No.: T142

Standard Test Method for Surface Moisture in Fine Aggregate[1]

This standard is issued under the fixed designation C 70; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

This standard has been approved for use by agencies of the Department of Defense.

1. Scope*

1.1 This test method covers field determination of the amount of surface moisture in fine aggregate by displacement in water.

1.2 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

1.3 The values stated in SI units are to be regarded as the standard. The values in parentheses are provided for information purposes only.

2. Referenced Documents

2.1 *ASTM Standards:* [2]

C 128 Test Method for Density, Relative Density (Specific Gravity), and Absorption of Fine Aggregate

C 566 Test Method for Total Evaporable Moisture Content of Aggregate by Drying

C 670 Practice for Preparing Precision and Bias Statements for Test Methods for Construction Materials

3. Significance and Use

3.1 This test method is not widely used. However, it is a convenient procedure for field or plant determination of moisture content of fine aggregate if specific gravity values are known and if drying facilities are not available. It can be used to adjust the aggregate mass for moisture content and to determine surface moisture contribution to mixing water in portland cement concrete.

3.2 The accuracy of the test method depends upon accurate information on the bulk specific gravity of the material in a saturated surface-dry condition.

4. Apparatus

4.1 *Balance*, having a capacity of 2 kg or more and sensitive to 0.5 g or less.

4.2 *Flask*—A suitable container or flask, preferably of glass or noncorrosive metal. The container may be a pycnometer, a volumetric flask, a graduated volumetric flask, or other suitable measuring device. The volume of the container shall be from two to three times the loose volume of the sample. The container shall be so designed that it can be filled to the mark, or the volume of its contents read, within 0.5 mL or less.

5. Sample

5.1 Select a representative sample of the fine aggregate to be tested for surface moisture content. It shall weigh not less than 200 g. Larger samples will yield more accurate results.

6. Procedure

6.1 The surface water content may be determined either by mass or volume. In each case the test shall be made at a temperature range of 18 to 29°C (65 to 85°F).

6.2 *Determination by Mass*—Determine the mass of the container, in grams, filled to the mark with only water. Before placing the sample into the container, adjust the level of the water so that it will be sufficient to cover the sample without going over the original mark. Introduce the weighed sample of fine aggregate into the container and remove the entrained air. Fill the container to the original mark, and determine the mass in grams. Calculate the amount of water displaced by the sample, as follows:

$$M_d = M_c + M_s - M \quad (1)$$

where:

M_d = mass of water displaced by the sample, g,
M_c = mass of container filled to the mark with water, g,
M_s = mass of sample, g, and
M = mass of container and sample, filled to the mark with water, g.

6.3 *Determination by Volume*—Measure a volume of water, in millilitres, sufficient to cover the sample and place in the container. Introduce the weighed sample of fine aggregate into the container and remove the entrained air. Determine the combined volume of the sample and the water by direct reading

[1] This test method is under the jurisdiction of ASTM Committee C09 on Concrete and Concrete Aggregates and is the direct responsibility of Subcommittee C09.20 on Normal Weight Aggregates.

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[2] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

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when a graduated flask is used. When a pycnometer or volumetric flask of known volume is used, fill the container to the known volume mark with an additional measured volume of water. The flask or pycnometer volume is then equal to the combined volume of sample and water. Calculate the amount of water displaced by the sample, as follows:

$$V_s = V_2 - V_1 \quad (2)$$

where:

V_s = volume of water displaced by the sample, mL,
V_2 = combined volume of sample and water, mL, and
V_1 = total volume of water in the flask or pycnometer required to cover the sample and bring the level up to the known volume mark, mL.

7. Calculation

7.1 Calculate the percentage of surface moisture in terms of the saturated surface-dry fine aggregate (see Appendix X1), as follows:

$$P = [(M_d - V_d)/(M_s - M_d)] \times 100 \quad (3)$$

where:

P = surface moisture in terms of saturated surface-dry fine aggregate, %,
V_d = mass of the sample (M_s in 6.2) divided by the bulk specific gravity of the fine aggregate in a saturated surface-dry condition, determined as prescribed in Test Method C 128, and
M_d = mass of water displaced, g, and
M_s = mass of sample, g

7.2 Calculate the percentage of surface moisture in terms of dry aggregate if the absorption of the aggregate is known as follows:

$$P_d = P[1 + (P_a/100)] \quad (4)$$

where:

P_d = surface moisture in terms of dry fine aggregate, %, and
P_a = absorption of the fine aggregate, %, determined in accordance with Test Method C 128.

Total moisture content, on a dry aggregate basis, is the sum of the surface moisture, P_d, and the absorption, P_a.

8. Report

8.1 Report surface moisture test results as determined by this method to the nearest 0.1 %.

9. Precision and Bias

9.1 This procedure is estimated to be less precise than properly conducted moisture content tests by drying (Test Method C 566). Accurate specific gravity information is essential to the bias of this method. Test Method C 566 can be used to verify the level of bias.

9.2 *Precision*—These estimates of precision are based on results from the AASHTO Materials Reference Laboratory (AMRL) Proficiency Sample Program, of testing conducted on Fine Aggregate Proficiency Sample Numbers 99 and 100. The precision limits are based on test results submitted by 144 laboratories that tested two fine aggregate test samples of approximately 500 g mass with average surface moisture contents of 2.323 % and 2.075 % respectively.

9.2.1 *Single-Operator Precision*—The single-operator standard deviation of a single test result has been found to be 0.50 %.[3] Therefore, results of two properly conducted tests by the same operator should not differ by more than 1.39 %.

9.2.2 *Multilaboratory Precision*—The multilaboratory standard deviation of a single test result has been found to be 0.82 %.[3] Therefore, results of two properly conducted tests in different laboratories on the same material should not differ by more than 2.31 %.[3]

9.3 *Bias*—Since there is no accepted reference material suitable for determining the bias of this test procedure, no statement on bias (other than that in 9.1) is made.

10. Keywords

10.1 fine aggregate; fine aggregate moisture; surface moisture

[3] These numbers represent, respectively, the (1s) and d2s) limits as described in Practice C 670.

APPENDIX

(Nonmandatory Information)

X1. DEVELOPMENT OF EQUATIONS

X1.1 These equations are readily derived from basic relationships. For convenience express P in terms of the ratio r, that is, the ratio of the mass of surface moisture to the mass of the saturated, surface-dry sample. It follows that:

$$r = \frac{M_s - [M_s/(1 + r)]}{M_s/(1 + r)} \quad (X1.1)$$

X1.1.1 If G is bulk specific gravity of the saturated, surface-dry fine aggregate, then

$$M_d = \frac{M_s}{G(1 + r)} + M_s - \frac{M_s}{1 + r} \quad (X1.2)$$

where the first term gives the water displaced by the saturated surface-dry fine aggregate and the second that displaced by the surface moisture.

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X1.1.2 From Eq X1.2:

$$\frac{M_s}{1+r} = \frac{M_d - M_s}{\frac{1}{\overline{G}} - 1} \quad \text{(X1.3)}$$

By definition,

$$M_s = V_d G \quad \text{(X1.4)}$$

X1.1.3 Substituting for $M_s/(1 + r)$ and M_s in Eq X1.1 and simplifying,

$$r = (M_d - V_d)/(M_s - M_d) \quad \text{(X1.5)}$$

SUMMARY OF CHANGES

Committee C09 has identified the location of selected changes to this test method since the last issue, C 70 – 94(2001), that may impact the use of this test method. (Approved February 15, 2006)

(*1*) Added new paragraph 1.3.
(*2*) Revised paragraph 6.1.
(*3*) Changed "weight" to "mass" throughout.

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Designation: C 78 – 09

Standard Test Method for Flexural Strength of Concrete (Using Simple Beam with Third-Point Loading)[1]

This standard is issued under the fixed designation C 78; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

This standard has been approved for use by agencies of the Department of Defense.

1. Scope*

1.1 This test method covers the determination of the flexural strength of concrete by the use of a simple beam with third-point loading.

1.2 The values stated in inch-pound units are to be regarded as standard. The values given in parentheses are mathematical conversions to SI units that are provided for information only and are not considered standard.

1.3 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

2. Referenced Documents

2.1 *ASTM Standards:*[2]

C 31/C 31M Practice for Making and Curing Concrete Test Specimens in the Field

C 42/C 42M Test Method for Obtaining and Testing Drilled Cores and Sawed Beams of Concrete

C 192/C 192M Practice for Making and Curing Concrete Test Specimens in the Laboratory

C 617 Practice for Capping Cylindrical Concrete Specimens

C 1077 Practice for Laboratories Testing Concrete and Concrete Aggregates for Use in Construction and Criteria for Laboratory Evaluation

E 4 Practices for Force Verification of Testing Machines

3. Significance and Use

3.1 This test method is used to determine the flexural strength of specimens prepared and cured in accordance with Test Methods C 42/C 42M or Practices C 31/C 31M or C 192/C 192M. Results are calculated and reported as the modulus of rupture. The strength determined will vary where there are differences in specimen size, preparation, moisture condition, curing, or where the beam has been molded or sawed to size.

3.2 The results of this test method may be used to determine compliance with specifications or as a basis for proportioning, mixing and placement operations. It is used in testing concrete for the construction of slabs and pavements.

4. Apparatus

4.1 The testing machine shall conform to the requirements of the sections on Basis of Verification, Corrections, and Time Interval Between Verifications of Practices E 4. Hand operated testing machines having pumps that do not provide a continuous loading in one stroke are not permitted. Motorized pumps or hand operated positive displacement pumps having sufficient volume in one continuous stroke to complete a test without requiring replenishment are permitted and shall be capable of applying loads at a uniform rate without shock or interruption.

4.2 *Loading Apparatus*—The third point loading method shall be used in making flexure tests of concrete employing bearing blocks which will ensure that forces applied to the beam will be perpendicular to the face of the specimen and applied without eccentricity. A diagram of an apparatus that accomplishes this purpose is shown in Fig. 1.

4.2.1 All apparatus for making flexure tests of concrete shall be capable of maintaining the specified span length and distances between load-applying blocks and support blocks constant within ±0.05 in. (±1.3 mm).

4.2.2 The ratio of the horizontal distance between the point of application of the load and the point of application of the nearest reaction to the depth of the beam shall be 1.0 ± 0.03.

4.2.3 If an apparatus similar to that illustrated in Fig. 1 is used: the load-applying and support blocks should not be more than 2½ in. (64 mm) high, measured from the center or the axis of pivot, and should extend entirely across or beyond the full width of the specimen. Each case-hardened bearing surface in contact with the specimen shall not depart from a plane by more than 0.002 in. (0.05 mm) and shall be a portion of a cylinder, the axis of which is coincidental with either the axis of the rod or center of the ball, whichever the block is pivoted

[1] This test method is under the jurisdiction of ASTM Committee C09 on Concrete and Concrete Aggregates and is the direct responsibility of Subcommittee C09.61 on Testing for Strength.

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[2] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

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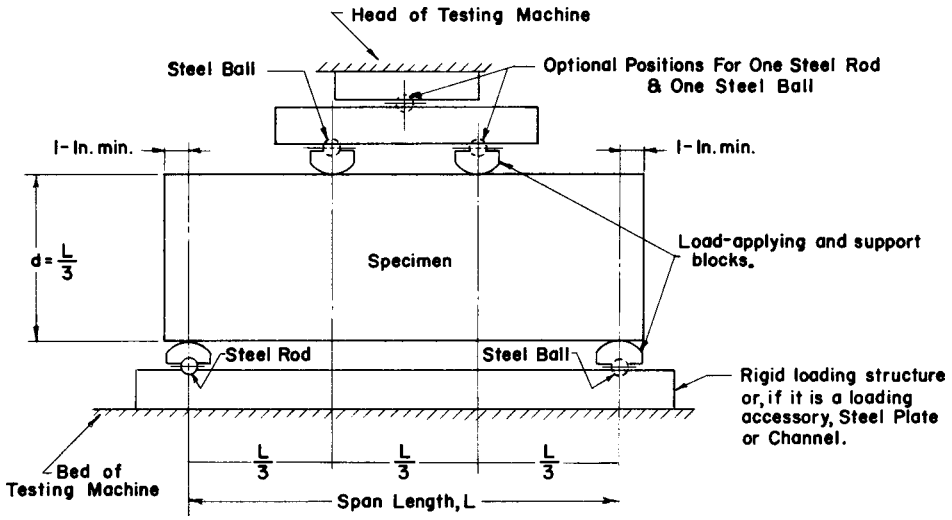

NOTE 1—This apparatus may be used inverted. If the testing machine applies force through a spherically seated head, the center pivot may be omitted, provided one load-applying block pivots on a rod and the other on a ball.

NOTE 2—1 in. = 25.4 mm.

FIG. 1 Diagrammatic View of a Suitable Apparatus for Flexure Test of Concrete by Third-Point Loading Method

upon. The angle subtended by the curved surface of each block should be at least 45° (0.79 rad). The load-applying and support blocks shall be maintained in a vertical position and in contact with the rod or ball by means of spring-loaded screws that hold them in contact with the pivot rod or ball. The uppermost bearing plate and center point ball in Fig. 1 may be omitted when a spherically seated bearing block is used, provided one rod and one ball are used as pivots for the upper load-applying blocks.

5. Testing

5.1 The test specimen shall conform to all requirements of Test Method C 42/C 42M or Practices C 31/C 31M or C 192/C 192M applicable to beam specimens and shall have a test span within 2 % of being three times its depth as tested. The sides of the specimen shall be at right angles with the top and bottom. All surfaces shall be smooth and free of scars, indentations, holes, or inscribed identification marks.

5.2 The individual who tests concrete beams for acceptance testing shall meet the concrete laboratory technician requirements of Practice C 1077 including Test Method C 78 as a relevant test.

NOTE 1—The testing laboratory performing this test method may be evaluated in accordance with Practice C 1077.

6. Procedure

6.1 Flexural tests of moist-cured specimens shall be made as soon as practical after removal from moist storage. Surface drying of the specimen results in a reduction in the measured flexural strength.

6.2 When using molded specimens, turn the test specimen on its side with respect to its position as molded and center it on the support blocks. When using sawed specimens, position the specimen so that the tension face corresponds to the top or bottom of the specimen as cut from the parent material. Center the loading system in relation to the applied force. Bring the load-applying blocks in contact with the surface of the specimen at the third points and apply a load of between 3 and 6 % of the estimated ultimate load. Using 0.004 in. (0.10 mm) and 0.015 in. (0.38 mm) leaf-type feeler gages, determine whether any gap between the specimen and the load-applying or support blocks is greater or less than each of the gages over a length of 1 in. (25 mm) or more. Grind, cap, or use leather shims on the specimen contact surface to eliminate any gap in excess of 0.004 in. (0.10 mm) in width. Leather shims shall be of uniform ¼ in. (6.4 mm) thickness, 1 to 2 in. (25 to 50 mm) width, and shall extend across the full width of the specimen. Gaps in excess of 0.015 in. (0.38 mm) shall be eliminated only by capping or grinding. Grinding of lateral surfaces should be minimized inasmuch as grinding may change the physical characteristics of the specimens. Capping shall be in accordance with the applicable sections of Practice C 617.

6.3 Load the specimen continuously and without shock. The load shall be applied at a constant rate to the breaking point. Apply the load at a rate that constantly increases the maximum stress on the tension face between 125 and 175 psi/min (0.86 and 1.21 MPa/min) until rupture occurs. The loading rate is calculated using the following equation:

$$r = Sbd^2/L \quad (1)$$

where:

r = loading rate, lb/min (N/min),
S = rate of increase in maximum stress on the tension face, psi/min (MPa/min),
b = average width of the specimen as oriented for testing, in. (mm),
d = average depth of the specimen as oriented for testing, in. (mm), and

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L = span length, in (mm).

7. Measurement of Specimens After Test

7.1 To determine the dimensions of the specimen cross section for use in calculating modulus of rupture, take measurements across one of the fractured faces after testing. The width and depth are measured with the specimen as oriented for testing. For each dimension, take one measurement at each edge and one at the center of the cross section. Use the three measurements for each direction to determine the average width and the average depth. Take all measurements to the nearest 0.05 in. (1 mm). If the fracture occurs at a capped section, include the cap thickness in the measurement.

8. Calculation

8.1 If the fracture initiates in the tension surface within the middle third of the span length, calculate the modulus of rupture as follows:

$$R = PL/bd^2 \quad (2)$$

where:

R = modulus of rupture, psi, or MPa,
P = maximum applied load indicated by the testing machine, lbf, or N,
L = span length, in., or mm,
b = average width of specimen, in., or mm, at the fracture, and
d = average depth of specimen, in., or mm, at the fracture.

NOTE 2—The weight of the beam is not included in the above calculation.

8.2 If the fracture occurs in the tension surface outside of the middle third of the span length by not more than 5 % of the span length, calculate the modulus of rupture as follows:

$$R = 3Pa/bd^2 \quad (3)$$

where:

a = average distance between line of fracture and the nearest support measured on the tension surface of the beam, in., (or mm).

NOTE 3—The weight of the beam is not included in the above calculation.

8.3 If the fracture occurs in the tension surface outside of the middle third of the span length by more than 5 % of the span length, discard the results of the test.

9. Report

9.1 Report the following information:
9.1.1 Identification number,
9.1.2 Average width to the nearest 0.05 in. (1 mm),
9.1.3 Average depth to the nearest 0.05 in. (1 mm),
9.1.4 Span length in inches (or millimeters),
9.1.5 Maximum applied load in pound-force (or newtons),
9.1.6 Modulus of rupture calculated to the nearest 5 psi (0.05 MPa),
9.1.7 Curing history and apparent moisture condition of the specimens at the time of test,
9.1.8 If specimens were capped, ground, or if leather shims were used,
9.1.9 Whether sawed or molded and defects in specimens, and
9.1.10 Age of specimens.

10. Precision and Bias

10.1 *Precision*—The coefficient of variation of test results has been observed to be dependent on the strength level of the beams.[3] The single operator coefficient of variation has been found to be 5.7 %. Therefore, results of two properly conducted tests by the same operator on beams made from the same batch sample should not differ from each other by more than 16 %. The multilaboratory coefficient of variation has been found to be 7.0 %. Therefore, results of two different laboratories on beams made from the same batch sample should not differ from each other by more than 19 %.

10.2 *Bias*—Since there is no accepted standard for determining bias in this test method, no statement on bias is made.

11. Keywords

11.1 beams; concrete; flexural strength testing; modulus of rupture

[3] See "Improved Concrete Quality Control Procedures Using Third Point Loading" by P. M. Carrasquillo and R. L. Carrasquillo, Research Report 119-1F, Project 3-9-87-1119, Center For Transportation Research, The University of Texas at Austin, November 1987, for possible guidance as to the relationship of strength and variability.

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SUMMARY OF CHANGES

Committee C09 has identified the location of selected changes to this test method since the last issue, C 78 – 08, that may impact the use of this test method. (Approved July 1, 2009)

(*1*) Added new Note 1.

Committee C09 has identified the location of selected changes to this test method since the last issue, C 78 – 07, that may impact the use of this test method. (Approved February 1, 2008)

(*1*) Revised 5.2 and deleted Note 1.

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Designation: C 87 – 05

Standard Test Method for Effect of Organic Impurities in Fine Aggregate on Strength of Mortar[1]

This standard is issued under the fixed designation C 87; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

This standard has been approved for use by agencies of the Department of Defense.

1. Scope*

1.1 This test method covers the determination of the effect on mortar strength of the organic impurities in fine aggregate, whose presence is indicated using Test Method C 40. Comparison is made between compressive strengths of mortar made with washed and unwashed fine aggregate.

1.2 The SI values shown are to be regarded as the standard. The inch-pound values shown in parentheses are provided for information purposes only.

1.3 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*(**Warning—**Fresh hydraulic cementitous mixtures are caustic and may cause chemical burns to exposed skin and tissue upon prolonged exposure.)[2]

2. Referenced Documents

2.1 *ASTM Standards:* [3]

C 33 Specification for Concrete Aggregates

C 40 Test Method for Organic Impurities in Fine Aggregates for Concrete

C 109/C 109M Test Method for Compressive Strength of Hydraulic Cement Mortars (Using 2-in. or [50-mm] Cube Specimens)

C 128 Test Method for Density, Relative Density, (Specific Gravity), and Absorption of Fine Aggregate

C 150 Specification for Portland Cement

C 230 Specification for Flow Table for Use in Tests of Hydraulic Cement

C 305 Practice for Mechanical Mixing of Hydraulic Cement Pastes and Mortars of Plastic Consistency

C 511 Specification for Mixing Rooms, Moist Cabinets, Moist Rooms, and Water Storage Tanks Used in the Testing of Hydraulic Cements and Concretes

C 670 Practice for Preparing Precision and Bias Statements for Test Methods for Construction Materials

C 702 Practice for Reducing Samples of Aggregate to Testing Size

D 75 Practice for Sampling Aggregates

D 3665 Practice for Random Sampling of Construction Materials

3. Summary of Test Method

3.1 A portion of the fine aggregate that produced a color darker than the standard in Test Method C 40 is used to prepare mortar cube specimens. A separate portion of the same fine aggregate is washed in sodium hydroxide solution to remove the organic impurities that caused the failing result when tested in accordance with Test Method C 40, and that washed fine aggregate is used to prepare another set of mortar cube specimens.

3.2 After curing for a stated period, the compressive strengths of the two sets of cube specimens are determined and compared.

4. Significance and Use

4.1 This test method is of significance in making a final determination of the acceptability of fine aggregates with respect to the requirements of Specification C 33 concerning organic impurities.

4.2 This test method is applicable to those samples which, when tested in accordance with Test Method C 40, have produced a supernatant liquid with a color darker than standard color plate No. 3 or color solution.

4.3 Many specifications provide for the acceptance of fine aggregate producing a darker color in the Test Method C 40 test, when testing by this test method indicates the strength of the mortar cubes prepared with the unwashed fine aggregate is comparable to the strength of mortar cubes made with the washed fine aggregate.

[1] This test method is under the jurisdiction of ASTM Committee C09 on Concrete and Concrete Aggregates and is the direct responsibility of Subcommittee C09.20 on Normal Weight Aggregates.

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[2] See section on Safety Precautions, *Manual of Aggregate and Concrete Testing, Annual Book of ASTM Standards,* Vol 04.02.

[3] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

***A Summary of Changes section appears at the end of this standard.**

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5. Apparatus

5.1 *Flow Table, Flow Mold, and Caliper*, as described in Specification C 230.

5.2 *Tamper, Trowel, Cube Molds, and Testing Machine*, as described in Test Method C 109/C 109M.

5.3 *Mixer, Bowl, and Paddle*, as described in Practice C 305.

5.4 *Curing Apparatus*, as described in Specification C 511.

5.5 *pH Paper*, 0–14.

5.6 *pH Meter*, capable of reading to 0.1 pH units or better.

6. Reagents and Materials

6.1 Portland cement shall be Type I or Type II, meeting the requirements of Specification C 150.

6.2 *Sodium Hydroxide Solution (3 %)*—Dissolve 3 parts by mass of sodium hydroxide (NaOH) in 97 parts water.

6.3 *Phenolphthalein*—Dissolve 1 g of reagent grade phenolphthalein in 1 L of 95 % reagent grade ethyl alcohol.

7. Sampling and Sample Preparation

7.1 If sufficient material remains from the sample used for testing in accordance with Test Method C 40, use this material for the tests described in this test method. If there is insufficient material remaining, obtain another field sample from the same source in accordance with Practice D 75 and Practice D 3665.

NOTE 1—At least 20 kg of fine aggregate should be available for the testing described herein.

7.2 If the fine aggregate contains particles coarser than the 4.75-mm (No.4) sieve, remove the coarser particles by sieving on the 4.75-mm (No.4) sieve, so that when the particles are mixed in the designated mixer, there will be no damage to the mixer or crushing of the fine aggregate particles. Determine the percentage of the sample removed. (**Warning**—The clearances between the paddle and the bowl specified in Practice C 305 are suitable when using the mortar made with graded standard sand. To permit the mixer to operate freely and to avoid serious damage to the paddle and bowl when coarser aggregates are used, it may be necessary to set the clearance adjustment bracket to provide greater clearances than specified. A clearance of approximately 4.0 mm is required in Practice C 305; a clearance of approximately 5.0 mm has been found to be satisfactory for this method when used with fine aggregate from which the material retained on the 4.75-mm (No. 4) sieve has been removed.)

7.3 Split the fine aggregate to be used for these tests into two approximately equal portions, using the procedure described in Practice C 702. Set one portion aside to be used in the unwashed condition. The second portion is to be washed before use.

7.4 *Preparing Washed Fine Aggregate*:

7.4.1 Perform the washing and rinsing of the fine aggregate with care to minimize the loss of fines, so that the aggregate after washing and rinsing has a fineness modulus within 0.10 of that of the unwashed aggregate.

7.4.2 *Establishing a Standard for Thoroughness of Rinsing*—Place a small amount of the water to be used for washing and rinsing in a clean, clear container, and determine the pH of the water by use of pH paper, pH meter, or add a drop of phenolphthalein to the wash water and retain for later comparison.

7.4.3 *Washing the Aggregate*—Place sufficient quantity of fine aggregate for three batches in a suitable container, flood with the sodium hydroxide solution, and agitate thoroughly with a spoon or trowel. At the end of the washing and after allowing to stand for fines to settle, siphon off as much of the sodium hydroxide solution as possible, without removing any of the aggregate fines.

7.4.4 *Rinsing the Aggregate* —Add a large quantity of water to the washed aggregate, agitate, allow to stand for fines to settle, and then siphon off the rinse water. Repeat this operation several times, until the water used for rinsing has a pH equal to or lower than the pH of the water prior to contact with the fine aggregate. If phenolphthalein was used as an indicator, the color of the wash water is to be equal or lighter in color than the solution prepared in 7.4.2.

7.4.5 *Verifying Removal of Organic Impurities*—Repeat the Test Method C 40 procedure to determine if the washing has removed sufficient organic impurities to produce a satisfactory result (color lighter than the standard). If the fine aggregate continues to produce an unsatisfactory result (color darker than the standard), repeat the washing and rinsing procedure (described in 7.4.3 and 7.4.4) as many times as necessary until a satisfactory result is obtained by Test Method C 40.

8. Procedure

8.1 *Number of Test Batches*—Prepare three batches of mortar using the washed aggregate and three batches of mortar using the unwashed aggregate, on the same day. Mix the batches, alternating between the washed and unwashed aggregate.

8.2 *Fine Aggregate*—For both the washed and the unwashed fine aggregates, bring the portions of fine aggregate to the saturated surface dry condition as described in Test Method C 128. Prepare a quantity of aggregate of known mass (*the aggregate specimen*) that is slightly more than needed to produce a single batch of the desired consistency.

8.2.1 *Optionally*, if the absorption has been determined in accordance with Test Method C 128, prepare the aggregate for test by adding to a known mass of dry aggregate the amount of water it will absorb, mixing thoroughly, and permitting the aggregate to stand in a covered pan for 30 min before use.

8.3 *Preparation of Mortar*—Prepare the mortar in a mechanical mixer in accordance with the procedure for mixing mortars described in Practice C 305, as modified below.

8.3.1 Use water and cement in quantities that will yield a water-cement ratio of 0.6 by mass (See Note 2). The mixing water shall be at a temperature of 23.0 ± 2.0 °C (73.5 ± 3.5 °F). The mortar shall be proportioned to produce a consistency of 100 ± 5 % as determined by the Section on Flow Test (see 8.4.1).

NOTE 2—It has been found that 600 g of cement and 360 mL of water will usually be adequate for a 6-cube batch. The flow is adjusted by the quantity of fine aggregate added to the mixture.

8.3.2 After placing all the mixing water in the bowl, add the cement to the water. Start the mixer and mix at the slow speed

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(140 ±5 r/min) for 30 s. While still mixing at slow speed over a 30-s period, add a measured quantity of aggregate estimated to provide the proper consistency.

NOTE 3—The quantity of aggregate used may be determined by subtracting from a known quantity of prepared aggregate the mass of the portion remaining after mixing.

8.3.3 Stop the mixer, change to medium speed (285 ± 10 r/min), and mix for 30 s.

8.3.4 Stop the mixer and let the mortar stand for 1.5 min. During the first 15 s of this interval, quickly scrape down into the batch any mortar that may have collected on the side of the bowl, then for the remainder of this interval, cover the bowl with the lid.

8.3.5 Finish by mixing for 1 min at medium speed. If the flow appears to be too high during the first 30 s of this period, stop the mixer briefly, add additional fine aggregate, and then complete the final 30 s of mixing.

8.3.6 In any case requiring a remixing interval, any mortar adhering to the side of the bowl shall be quickly scraped down into the batch with the scraper prior to remixing.

8.3.7 Make a determination of the flow.

8.4 *Flow Test*:

8.4.1 Carefully wipe the flow table clean. Dry the surface and place the flow mold at the center. Immediately after completing the mixing operation, place a layer of mortar approximately 25 mm (1 in.) in thickness in the mold and tamp 20 times with the tamper. The tamping pressure shall be just sufficient to ensure uniform filling of the mold. Slightly overfill the mold with mortar and tamp as specified for the first layer. Cut off the mortar to a plane surface, flush with the top of the mold, by drawing the straight edge of the trowel (held nearly perpendicular to the mold) with a sawing motion across the top of the mold. Wipe the table top clean and dry, being especially careful to remove any water from around the edge of the flow mold. Lift the mold away from the mortar 1 min after completing the mixing operation. Immediately drop the table through a height of 12.7 mm (0.5 in.) ten times in 6 s. The flow is the resulting increase in average diameter of the mortar specimen, measured on at least four diameters at approximately equal angles, expressed as a percentage of the original diameter.

8.4.2 Should the flow be too great, return the mortar to the mixing vessel, add additional fine aggregate, mix for 30 s at medium speed, and make another determination of the flow. If more than two trials must be made to obtain a flow of 100 ± 5 %, consider the mortar as a trial mortar, and prepare a new batch.

8.4.3 If the mortar is too dry, discard the batch and prepare a new batch starting with a smaller quantity of fine aggregate.

8.4.4 Determine the quantity of fine aggregate used by subtracting the mass of the portion remaining from the original mass of the aggregate specimen.

8.5 *Molding Mortar Cubes*—Immediately following completion of a flow test that indicates acceptable consistency, return the mortar from the flow table to the mixing bowl, scrape down the bowl, and then remix the entire batch for 15 s at medium speed. Upon completion of mixing, shake the excess mortar from the paddle into the bowl. Mold one set (three cubes) from each batch, in accordance with Test Method C 109/C 109M.

8.6 *Curing and Testing Mortar Cubes*—Store the test specimens in a moist cabinet or moist room maintained at a temperature of 23.0 ± 2.0 °C (73.5 ± 3.5 °F) and relative humidity not less than 95 % for 24 ± ½ h. Additional curing shall be by immersion in saturated lime water maintained at a temperature of 23.0 ± 2.0 °C (73.5 ± 3.5 °F). Determine the compressive strength of the cubes at 7 days in accordance with Test Method C 109/C 109M.

9. Calculation and Report

9.1 Calculate the compressive strength of each specimen by dividing the maximum load it carried during the test by the cross-sectional area. Average the strengths of the three specimens from each batch. Calculate three strength ratios by dividing the average strength for a batch containing unwashed fine aggregate by the average strength for the corresponding (in respective order of mixing) batch containing washed fine aggregate.

9.2 Report the average of the three ratios, expressed as a percentage (to the nearest 1 %), as the relative strength for the fine aggregate under test.

9.3 If the fine aggregate was sieved to remove particles coarser than the 4.75 mm (No. 4) sieve (as described in 7.2), so state in the report and indicate the quantity of material removed as a percentage of the original sample mass.

10. Precision and Bias

10.1 The following precision statement is applicable when a test result is the average ratio, as defined by this test method, of three pairs of mortar batch strength tests with all the batches mixed on the same day and tested at the same age.

10.2 The single laboratory coefficient of variation has been determined to be 5.4 % (See Note 4). Therefore, strength ratios of two properly conducted tests in the same laboratory are not expected to differ from each other by more than 15.3 % (See Note 4) of their average. The maximum range (difference between highest and lowest) of the three individual ratios used in calculating the average are not expected to exceed 17 % (See Note 4).

NOTE 4—These numbers represent respectively the (1s %) and (d2s %) limits as described in Practice C 670, calculated as described in the section on *Form of Statement for Which a Test Result is Defined as the Average of a Specified Number of Measurements* in Practice C 670.

11. Keywords

11.1 aggregate; fine aggregate; organic impurities; mortar strength

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SUMMARY OF CHANGES

Committee C09 has identified the location of selected changes to this test method since the last issue, C 87 – 04, that may impact the use of this test method. (Approved July 1, 2005)

(*1*) Moved old Note 3 into 8.2.1 and revised 8.3.1.

Committee C09 has identified the location of selected changes to this test method since the last issue, C 87 – 03, that may impact the use of this test method. (Approved August 1, 2004)

(*1*) Revised Sections 4-10.

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Designation: C 88 – 05

Standard Test Method for Soundness of Aggregates by Use of Sodium Sulfate or Magnesium Sulfate[1]

This standard is issued under the fixed designation C 88; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

This standard has been approved for use by agencies of the Department of Defense.

1. Scope

1.1 This test method covers the testing of aggregates to estimate their soundness when subjected to weathering action in concrete or other applications. This is accomplished by repeated immersion in saturated solutions of sodium or magnesium sulfate followed by oven drying to partially or completely dehydrate the salt precipitated in permeable pore spaces. The internal expansive force, derived from the rehydration of the salt upon re-immersion, simulates the expansion of water on freezing. This test method furnishes information helpful in judging the soundness of aggregates when adequate information is not available from service records of the material exposed to actual weathering conditions.

1.2 The values given in parentheses are provided for information purposes only.

1.3 *This standard does not purport to address the safety problems associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

2. Referenced Documents

2.1 *ASTM Standards:* [2]

C 33 Specification for Concrete Aggregates

C 136 Test Method for Sieve Analysis of Fine and Coarse Aggregates

C 670 Practice for Preparing Precision and Bias Statements for Test Methods for Construction Materials

C 702 Practice for Reducing Samples of Aggregate to Testing Size

D 75 Practice for Sampling Aggregates

E 11 Specification for Wire Cloth Sieves for Testing Purposes

E 100 Specification for ASTM Hydrometers

E 323 Specification for Perforated-Plate Sieves for Testing Purposes

3. Significance and Use

3.1 This test method provides a procedure for making a preliminary estimate of the soundness of aggregates for use in concrete and other purposes. The values obtained may be compared with specifications, for example Specification C 33, that are designed to indicate the suitability of aggregate proposed for use. Since the precision of this test method is poor (Section 12), it may not be suitable for outright rejection of aggregates without confirmation from other tests more closely related to the specific service intended.

3.2 Values for the permitted-loss percentage by this test method are usually different for fine and coarse aggregates, and attention is called to the fact that test results by use of the two salts differ considerably and care must be exercised in fixing proper limits in any specifications that include requirements for these tests. The test is usually more severe when magnesium sulfate is used; accordingly, limits for percent loss allowed when magnesium sulfate is used are normally higher than limits when sodium sulfate is used.

NOTE 1—Refer to the appropriate sections in Specification C 33 establishing conditions for acceptance of coarse and fine aggregates which fail to meet requirements based on this test.

4. Apparatus

4.1 *Sieves*—With square openings of the following sizes conforming to Specifications E 11 or E 323, for sieving the samples in accordance with Sections 6, 7, and 9:

[1] This test method is under the jurisdiction of ASTM Committee C09 on Concrete and Concrete Aggregates and is the direct responsibility of Subcommittee C09.20 on Normal Weight Aggregates.

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[2] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

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150 µm (No. 100)	8.0 mm (5⁄16 in.)
	9.5 mm (3⁄8 in.)
300 µm (No. 50)	12.5 mm (1⁄2 in.)
	16.0 mm (5⁄8 in.)
600 µm (No. 30)	19.0 mm (3⁄4 in.)
	25.0 mm (1 in.)
1.18 mm (No. 16)	31.5 mm (1 1⁄4 in.)
2.36 mm (No. 8)	37.5 mm (1 1⁄2 in.)
	50 mm (2 in.)
4.00 mm (No. 5)	63 mm (2 1⁄2 in.)
	larger sizes by
4.75 mm (No. 4)	12.5-mm (1⁄2-in.)
	spread

4.2 *Containers*—Containers for immersing the samples of aggregate in the solution, in accordance with the procedure described in this test method, shall be perforated in such a manner as to permit free access of the solution to the sample and drainage of the solution from the sample without loss of aggregate.

NOTE 2—Baskets made of suitable wire mesh or sieves with suitable openings are satisfactory containers for the samples.

4.3 *Temperature Regulation*—Suitable means for regulating the temperature of the samples during immersion in the sodium sulfate or magnesium sulfate solution shall be provided.

4.4 *Balances*—For fine aggregate, a balance or scale accurate within 0.1 g over the range required for this test; for coarse aggregate, a balance or scale accurate within 0.1 % or 1 g, whichever is greater, over the range required for this test.

4.5 *Drying Oven*—The oven shall be capable of being heated continuously at 230 ± 9 °F (110 ± 5 °C) and the rate of evaporation, at this range of temperature, shall be at least 25 g/h for 4 h, during which period the doors of the oven shall be kept closed. This rate shall be determined by the loss of water from 1-L Griffin low-form beakers, each initially containing 500 g of water at a temperature of 70 ± 3 °F (21 ± 2 °C), placed at each corner and the center of each shelf of the oven. The evaporation requirement is to apply to all test locations when the oven is empty except for the beakers of water.

4.6 *Specific Gravity Measurement*—Hydrometers conforming to the requirements of Specification E 100, or a suitable combination of graduated glassware and balance, capable of measuring the solution specific gravity within ±0.001.

5. Special Solutions Required

5.1 Prepare the solution for immersion of test samples from either sodium or magnesium sulfate in accordance with 5.1.1 or 5.1.2 (Note 3). The volume of the solution shall be at least five times the solid volume of all samples immersed at any one time.

NOTE 3—Some aggregates containing carbonates of calcium or magnesium are attacked chemically by fresh sulfate solution, resulting in erroneously high measured losses. If this condition is encountered or is suspected, repeat the test using a filtered solution that has been used previously to test the same type of carbonate rock, provided that the solution meets the requirements of 5.1.1 and 5.1.2 for specific gravity.

5.1.1 *Sodium Sulfate Solution*—Prepare a saturated solution of sodium sulfate by dissolving a USP or equal grade of the salt in water at a temperature of 77 to 86 °F (25 to 30 °C). Add sufficient salt (Note 4), of either the anhydrous (Na_2SO_4) or the crystalline ($Na_2SO_4·10H_2O$) form,[3] to ensure not only saturation but also the presence of excess crystals when the solution is ready for use in the tests. Thoroughly stir the mixture during the addition of the salt and stir the solution at frequent intervals until used. To reduce evaporation and prevent contamination, keep the solution covered at all times when access is not needed. Allow the solution to cool to 70 ± 2 °F (21 ± 1 °C). Again stir, and allow the solution to remain at the designated temperature for at least 48 h before use. Prior to each use, break up the salt cake, if any, in the container, stir the solution thoroughly, and determine the specific gravity of the solution. When used, the solution shall have a specific gravity not less than 1.151 nor more than 1.174. Discard a discolored solution, or filter it and check for specific gravity.

NOTE 4—For the solution, 215 g of anhydrous salt or 700 g of the decahydrate per litre of water are sufficient for saturation at 71.6 °F (22 °C). However, since these salts are not completely stable and since it is desirable that an excess of crystals be present, the use of not less than 350 g of the anhydrous salt or 750 g of the decahydrate salt per litre of water is recommended.

5.1.2 *Magnesium Sulfate Solution*—Prepare a saturated solution of magnesium sulfate by dissolving a USP or equal grade of the salt in water at a temperature of 77 to 86 °F (25 to 30 °C). Add sufficient salt (Note 5), of either the anhydrous ($MgSO_4$) or the crystalline ($MgSO_4·7H_2O$) (Epsom salt) form, to ensure saturation and the presence of excess crystals when the solution is ready for use in the tests. Thoroughly stir the mixture during the addition of the salt and stir the solution at frequent intervals until used. To reduce evaporation and prevent contamination, keep the solution covered at all times when access is not needed. Allow the solution to cool to 70 ± 2 °F (21 ± 1 °C). Again stir, and allow the solution to remain at the designated temperature for at least 48 h before use. Prior to each use, break up the salt cake, if any, in the container, stir the solution thoroughly, and determine the specific gravity of the solution. When used, the solution shall have a specific gravity not less than 1.295 nor more than 1.308. Discard a discolored solution, or filter it and check for specific gravity.

NOTE 5—For the solution, 350 g of anhydrous salt or 1230 g of the heptahydrate per litre of water are sufficient for saturation at 73.4 °F (23 °C). However, since these salts are not completely stable, with the hydrous salt being the more stable of the two, and since it is desirable that an excess of crystals be present, it is recommended that the heptahydrate salt be used and in an amount of not less than 1400 g/litre of water.

5.1.3 *Barium Chloride Solution*—Prepare 100 mL of 5 % barium chloride solution by dissolving 5 g of $BaCl_2$ in 100 mL of distilled water.

6. Samples

6.1 The sample shall be obtained in general accordance with Practice D 75 and reduced to test portion size in accordance with Practice C 702.

[3] Experience with the test method indicates that a grade of sodium sulfate designated by the trade as dried powder, which may be considered as approximately anhydrous, is the most practical for use. That grade is more economically available than the anhydrous form. The decahydrate sodium sulfate presents difficulties in compounding the required solution on account of its cooling effect on the solution.

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6.2 *Fine Aggregate*—Fine aggregate for the test shall be passed through a 9.5-mm (⅜-in.) sieve. The sample shall be of such size that it will yield not less than 100 g of each of the following sizes, which shall be available in amounts of 5 % or more, expressed in terms of the following sieves:

Passing Sieve	Retained on Sieve
600 µm (No. 30)	300 µm (No. 50)
1.18 mm (No. 16)	600 µm (No. 30)
2.36 mm (No. 8)	1.18 mm (No. 16)
4.75 mm (No. 4)	2.36 mm (No. 8)
9.5 mm (⅜ in.)	4.75 mm (No. 4)

6.3 *Coarse Aggregate*—Coarse aggregate for the test shall consist of material from which the sizes finer than the No. 4 sieve have been removed. The sample shall be of such a size that it will yield the following amounts of the indicated sizes that are available in amounts of 5 % or more:

Size (Square-Opening Sieves)	Mass, g
9.5 mm (⅜ in.) to 4.75 mm (No. 4)	300 ± 5
19.0 mm (¾ in.) to 9.5 mm (⅜ in.)	1000 ± 10
Consisting of:	
12.5-mm (½-in.) to 9.5-mm (⅜-in.) material	330 ± 5
19.0-mm (¾-in.) to 12.5-mm (½-in.) material	670 ± 10
37.5-mm (1 ½-in.) to 19.0-mm (¾ in.)	1500 ± 50
Consisting of:	
25.0-mm (1-in.) to 19.0-mm (¾-in.) material	500 ± 30
37.5-mm (1 ½-in.) to 25.0-mm (1-in.) material	1000 ± 50
63-mm (2 ½ in.) to 37.5-mm (1 ½ in.)	5000 ± 300
Consisting of:	
50-mm (2 in.) to 37.5-mm (1 ½-in.) material	2000 ± 200
63-mm (2 ½-in.) to 50-mm (2-in.) material	3000 ± 300
Larger sizes by nominal 12.5-mm (½-in.) spread in sieve size, each fraction	
Consisting of:	
75-mm (3-in.) to 63-mm (2 ½-in.) material	7000 ± 1000
90-mm (3 ½-in.) to 75-mm (3-in.) material	7000 ± 1000
100-mm (4-in.) to 90-mm (3 ½-in.) material	7000 ± 1000

6.4 When an aggregate to be tested contains appreciable amounts of both fine and coarse material, having a grading with more than 10 weight % coarser than the 9.5-mm (⅜-in.) sieve and, also, more than 10 weight % finer than the 4.75-mm (No. 4) sieve, test separate samples of the minus No. 4 fraction and the plus No. 4 fraction in accordance with the procedures for fine aggregate and coarse aggregate, respectively. Report the results separately for the fine-aggregate fraction and the coarse-aggregate fraction, giving the percentages of the coarse- and fine-size fractions in the initial grading.

7. Preparation of Test Sample

7.1 *Fine Aggregate*—Thoroughly wash the sample of fine aggregate on a 300-µm (No. 50) sieve, dry to constant weight at 230 ± 9 °F (110 ± 5 °C), and separate into the different sizes by sieving, as follows: Make a rough separation of the graded sample by means of a nest of the standard sieves specified in 6.2. From the fractions obtained in this manner, select samples of sufficient size to yield 100 g after sieving to refusal. (In general, a 110-g sample will be sufficient.) Do not use fine aggregate sticking in the meshes of the sieves in preparing the samples. Weigh samples consisting of 100 ± 0.1 g out of each of the separated fractions after final sieving and place in separate containers for the test.

7.2 *Coarse Aggregate*—Thoroughly wash and dry the sample of coarse aggregate to constant weight at 230 ± 9 °F (110 ± 5 °C) and separate it into the different sizes shown in 6.3 by sieving to refusal. Weigh out quantities of the different sizes within the tolerances of 6.3 and, where the test portion consists of two sizes, combine them to the designated total weight. Record the weights of the test samples and their fractional components. In the case of sizes larger than 19.0 mm (¾ in.), record the number of particles in the test samples.

8. Procedure

8.1 *Storage of Samples in Solution*—Immerse the samples in the prepared solution of sodium sulfate or magnesium sulfate for not less than 16 h nor more than 18 h in such a manner that the solution covers them to a depth of at least ½ in. (Note 6). Cover the containers to reduce evaporation and prevent the accidental addition of extraneous substances. Maintain the samples immersed in the solution at a temperature of 70 ± 2 °F (21 ± 1 °C) for the immersion period.

NOTE 6—Suitably weighted wire grids placed over the sample in the containers will permit this coverage to be achieved with very lightweight aggregates.

8.2 *Drying Samples After Immersion*—After the immersion period, remove the aggregate sample from the solution, permit it to drain for 15 ± 5 min, and place in the drying oven. The temperature of the oven shall have been brought previously to 230 ± 9 °F (110 ± 5 °C). Dry the samples at the specified temperature until constant weight has been achieved. Establish the time required to attain constant weight as follows: with the oven containing the maximum sample load expected, check the weight losses of test samples by removing and weighing them, without cooling, at intervals of 2 to 4 h; make enough checks to establish required drying time for the least favorable oven location (see 4.5) and sample condition (Note 7). Constant weight will be considered to have been achieved when weight loss is less than 0.1 % of sample weight in 4 h of drying. After constant weight has been achieved, allow the samples to cool to room temperature, when they shall again be immersed in the prepared solution as described in 8.1.

NOTE 7—Drying time required to reach constant weight may vary considerably for several reasons. Efficiency of drying will be reduced as cycles accumulate because of salt adhering to particles and, in some cases, because of increase in surface area due to breakdown. The different size fractions of aggregate will have differing drying rates. The smaller sizes will tend to dry more slowly because of their larger surface area and restricted interparticle voids, but this tendency may be altered by the effects of container size and shape.

8.3 *Number of Cycles*—Repeat the process of alternate immersion and drying until the required number of cycles is obtained.

8.4 After the completion of the final cycle and after the sample has cooled, wash the sample free from the sodium sulfate or magnesium sulfate as determined by the reaction of the wash water with barium chloride ($BaCl_2$). Wash by circulating water at 110 ± 10 °F (43 ± 6 °C) through the samples in their containers. This may be done by placing them in a tank into which the hot water can be introduced near the bottom and allowed to overflow. In the washing operation, the samples shall not be subjected to impact or abrasion that may tend to break up particles.

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NOTE 8—Tap water containing sulfates when used for the wash water will cloud when tested with the barium chloride solution. The cloudiness of a solution of tap water and the barium chloride solution should be judged so that tested wash water with the same degree of cloudiness can be assumed to be free of sulfates from the test.

9. Quantitative Examination

9.1 Make the quantitative examination as follows:

9.1.1 After the sodium sulfate or magnesium sulfate has been removed, dry each fraction of the sample to constant weight at 230 ± 9 °F (110 ± 5 °C). Sieve the fine aggregate over the same sieve on which it was retained before the test, and sieve the coarse aggregate over the sieve shown below for the appropriate size of particle. For fine aggregate, the method and duration of sieving shall be the same as were used in preparing the test samples. For coarse aggregate, sieving shall be by hand, with agitation sufficient only to assure that all undersize material passes the designated sieve. No extra manipulation shall be employed to break up particles or cause them to pass the sieves. Weigh the material retained on each sieve and record each amount. The difference between each of these amounts and the initial weight of the fraction of the sample tested is the loss in the test and is to be expressed as a percentage of the initial weight for use in Table 1.

Size of Aggregate	Sieve Used to Determine Loss
100 mm (4 in.) to 90 mm (3 ½ in.)	75 mm (3 in.)
90 mm (3 ½ in.) to 75 mm (3 in.)	63 mm (2 ½ in.)
75 mm (3 in.) to 63 mm (2 ½ in.)	50 mm (2 in.)
63 mm (2 ½ in.) to 37.5 mm (1 ½ in.)	31.5 mm (1 ¼ in.)
37.5 mm (1 ½ in.) to 19.0 mm (¾ in.)	16.0 mm (⅝ in.)
19 mm (¾ in.) to 9.5 mm (⅜ in.)	8.0 mm (5⁄16 in.)
9.5 mm (⅜ in.) to 4.75 mm (No. 4)	4.0 mm (No. 5)

10. Qualitative Examination

10.1 Make a qualitative examination of test samples coarser than 19.0 mm (¾ in.) as follows (Note 9):

10.1.1 Separate the particles of each test sample into groups according to the action produced by the test (Note 9).

10.1.2 Record the number of particles showing each type of distress.

NOTE 9—Many types of action may be expected. In general, they may be classified as disintegration, splitting, crumbling, cracking, flaking, etc. While only particles larger than ¾ in. in size are required to be examined qualitatively, it is recommended that examination of the smaller sizes be made in order to determine whether there is any evidence of excessive splitting.

11. Report

11.1 Report the following data (Note 10):

11.1.1 Weight of each fraction of each sample before test,

11.1.2 Material from each fraction of the sample finer than the sieve designated in 9.1.1 for sieving after test, expressed as a percentage of the original weight of the fraction,

11.1.3 Weighted average calculated in accordance with Test Method C 136 from the percentage of loss for each fraction, based on the grading of the sample as received for examination or, preferably, on the average grading of the material from that portion of the supply of which the sample is representative except that:

11.1.3.1 For fine aggregates (with less than 10 % coarser than the 9.5-mm (⅜-in.) sieve), assume sizes finer than the 300-µm (No. 50) sieve to have 0 % loss and sizes coarser than the 9.5-mm (⅜-in.) sieve to have the same loss as the next smaller size for which test data are available.

TABLE 1 Suggested Form for Recording Test Data (with Illustrative Test Values)

Sieve Size			Grading of Original Sample, %	Weight of Test Fractions Before Test, g	Percentage Passing Designated Sieve After Test	Weighted Percentage Loss
Soundness Test of Fine Aggregate						
Minus 150 µm (No. 100)			6	...	...	...
300 µm (No. 50) to No. 100			11	...	...	...
600 µm (No. 30) to No. 50			26	100	4.2	1.1
1.18 mm (No. 16) to No. 30			25	100	4.8	1.2
2.36 mm (No. 8) to No. 16			17	100	8.0	1.4
4.75 mm (No. 4) to No. 8			11	100	11.2	1.2
9.5 mm (⅜ in.) to No. 4			4	...	11.2[A]	0.4
Totals			100.0	...	...	5
Soundness Test of Coarse Aggregate						
63 mm (2 ½ in.) to 50 mm (2 in.) 50 mm (2 in.) to 37.5 mm (1 ½ in.)	2825 *g* 1958 *g*	2 ½ to 1 ½ in.	20	4783	4.8	1.0
37.5 mm (1 ½ in.) to 25.0 mm (1 in.) 25 mm (1 in.) to 19.0 mm (¾ in.)	1012 *g* 513 *g*	1 ½ to ¾ in.	45	1525	8.0	3.6
19.0 mm (¾ in.) to 12.5 mm (½ in.) 12.5 mm (in.) to 9.5 mm (in.)	675 *g* 333 *g*	¾ to ⅜ in.	23	1008	9.6	2.2
9.5 mm (⅜ in.) to 4.75 mm (No. 4)	298 *g*		12	298	11.2	1.3
Totals			100	...	...	8

[A] The percentage loss (11.2 %) of the next smaller size is used as the percentage loss for this size, since this size contains less than 5 % of the original sample as received. See 11.1.3.4.

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TABLE 2 Suggested Form for Qualitative Examination (with Illustrative Test Values)

Sieve Size	Qualitative Examination of Coarse Sizes								
	Particles Exhibiting Distress								
	Splitting		Crumbling		Cracking		Flaking		Total No. of Particles Before Test
	No.	%	No.	%	No.	%	No.	%	
63 mm (2 ½ in.) to 37.5 mm (1 ½ in.)	2	7	...	...	2	7	...	...	29
37.5 mm (1 ½ in.) to 19.0 mm (¾ in.)	5	10	1	2	4	8	...	...	50

11.1.3.2 For coarse aggregate (with less than 10 % finer than the 4.75-mm (No. 4) sieve), assume sizes finer than the 4.75-mm (No. 4) sieve to have the same loss as the next larger size for which test data are available.

11.1.3.3 For an aggregate containing appreciable amounts of both fine and coarse material tested as two separate samples as required in 6.4, compute the weighted average losses separately for the minus No. 4 and plus No. 4 fractions based on recomputed gradings considering the fine fraction as 100 % and the coarse fraction as 100 %. Report the results separately giving the percentage of the minus No. 4 and plus No. 4 material in the initial grading.

11.1.3.4 For the purpose of calculating the weighted average, consider any sizes in 6.2 or 6.3 that contain less than 5 % of the sample to have the same loss as the average of the next smaller and the next larger size, or if one of these sizes is absent, to have the same loss as the next larger or next smaller size, whichever is present.

11.1.4 Report the weighted percentage loss to the nearest whole number,

11.1.5 In the case of particles coarser than 19.0 mm (¾ in.) before test: (*1*) The number of particles in each fraction before test, and (*2*) the number of particles affected, classified as to number disintegrating, splitting, crumbling, cracking, flaking, etc., as shown in Table 2, and

11.1.6 Kind of solution (sodium or magnesium sulfate) and whether the solution was freshly prepared or previously used.

NOTE 10—Table 1, shown with test values inserted for purpose of illustration, is a suggested form for recording test data. The test values shown might be appropriate for either salt, depending on the quality of the aggregate.

12. Precision

12.1 *Precision*—For coarse aggregate with weighted average sulfate soundness losses in the ranges of 6 to 16 % for sodium and 9 to 20 % for magnesium, the precision indexes are as follows:

	Coefficient of Variation (1S %), %[A]	Difference Between Two Tests (D2S %), % of Average[A]
Multilaboratory:		
Sodium sulfate	41	116
Magnesium sulfate	25	71
Single-Operator:		
Sodium sulfate	24	68
Magnesium sulfate	11	31

[A] These numbers represent, respectively, the (1S %) and (D2S %) limits as described in Practice C 670.

12.2 *Bias*—Since there is no accepted reference material suitable for determining the bias for this procedure, no statement on bias is being made.

13. Keywords

13.1 aggregates; magnesium sulfate; sodium sulfate; soundness; weathering

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Designation: C 91 – 05

Standard Specification for Masonry Cement[1]

This standard is issued under the fixed designation C 91; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

This standard has been approved for use by agencies of the Department of Defense.

1. Scope

1.1 This specification covers three types of masonry cement for use where mortar for masonry is required.

1.2 The values stated in SI units are to be regarded as the standard. Values in SI units shall be obtained by measurement in SI units or by appropriate conversion of measurements made in other units, using the Rules for Conversion and Rounding given in IEEE/ASTM SI 10.

1.3 The text of this standard refers to notes and footnotes which provide explanatory material. These notes and footnotes (excluding those in tables and figures) shall not be considered as requirements of the standard.

1.4 The following safety hazards caveat pertains only to Sections 16 and 17 of this specification. *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.* (**Warning—**Fresh hydraulic cementitious mixtures are caustic and may cause chemical burns to skin and tissue upon prolonged exposure.)[2]

2. Referenced Documents

2.1 *ASTM Standards:* [3]

C 109/C 109M Test Method for Compressive Strength of Hydraulic Cement Mortars (Using 2-in. or [50-mm] Cube Specimens)

C 151 Test Method for Autoclave Expansion of Hydraulic Cement

C 183 Practice for Sampling and the Amount of Testing of Hydraulic Cement

C 185 Test Method for Air Content of Hydraulic Cement Mortar

C 187 Test Method for Normal Consistency of Hydraulic Cement

C 188 Test Method for Density of Hydraulic Cement

C 219 Terminology Relating to Hydraulic Cement

C 266 Test Method for Time of Setting of Hydraulic Cement Paste by Gillmore Needles

C 270 Specification for Mortar for Unit Masonry

C 305 Practice for Mechanical Mixing of Hydraulic Cement Pastes and Mortars of Plastic Consistency

C 430 Test Method for Fineness of Hydraulic Cement by the 45-μm (No. 325) Sieve

C 511 Specification for Mixing Rooms, Moist Cabinets, Moist Rooms, and Water Storage Tanks Used in the Testing of Hydraulic Cements and Concretes

C 778 Specification for Standard Sand

C 1506 Test Method for Water Retention of Hydraulic Cement-Based Mortars and Plasters

IEEE/ASTM SI 10 Standard for Use of the International System of Units (SI): The Modern Metric System

3. Terminology

3.1 *Definitions:*

3.1.1 *masonry cement*—a hydraulic cement, primarily used in masonry and plastering construction, consisting of a mixture of portland or blended hydraulic cement and plasticizing materials (such as limestone, hydrated or hydraulic lime) together with other materials introduced to enhance one or more properties such as setting time, workability, water retention, and durability.

3.1.2 Other terms used in this specification are defined in Terminology C 219.

4. Classification

4.1 *Type N*—For use in preparation of Specification C 270 Type N mortar without further addition of cements or hydrated lime, and for use in preparation of Specification C 270 Type S

[1] This specification is under the jurisdiction of ASTM Committee C01 on Cement and is the direct responsibility of Subcommittee C01.11 on Masonry Cement.

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[2] *Annual Book of ASTM Standards*, Vol 04.01. See the section on Safety Precautions in the Manual of Cement Testing.

[3] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

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or Type M mortar when cement is added in accordance with the requirements of C 270.

4.2 *Type S*—For use in preparation of Specification C 270 Type S mortar without further addition of cements or hydrated lime.

4.3 *Type M*—For use in preparation of Specification C 270 Type M mortar without further addition of cements or hydrated lime.

5. Physical Properties

5.1 Masonry cement shall conform to the applicable requirements prescribed in Table 1 for its classification.

6. Sampling

6.1 The masonry cement shall be sampled in accordance with Practice C 183.

7. Temperature and Humidity

7.1 The temperature and relative humidity of the air in the vicinity of the mixing slab and dry materials, molds, base plates, and mixing bowl shall conform to the requirements of Test Method C 109/C 109M.

7.2 The moist cabinet or moist room shall conform to the requirements of Specification C 511.

8. Fineness

8.1 Determine the residue on the 45-μm (No. 325) sieve in accordance with Test Method C 430.

9. Normal Consistency

9.1 Determine normal consistency by the Vicat apparatus in accordance with Test Method C 187.

10. Autoclave Expansion

10.1 Determine autoclave expansion in accordance with Test Method C 151. After molding, store the bars in the moist cabinet or room for 48 h ± 30 min before removal from the molds for measurement and testing in the autoclave. Calculate the difference in length of the test specimen before and after autoclaving to the nearest 0.01 % of the effective gauge length and report as the autoclave expansion of the masonry cement.

11. Time of Setting

11.1 Determine the time of setting by the Gillmore needle method in accordance with Test Method C 266.

12. Density

12.1 Determine the density of the masonry cement in accordance with Test Method C 188, using kerosine as the liquid. Use the density so determined in the calculation of the air content of the mortars.

13. Blended Sand

13.1 The sand shall be a blend of equal parts by weight of graded standard sand and standard 20–30 sand conforming to Specification C 778.

14. Preparation of Mortar

14.1 *Proportions for Mortar*—Mortar for air entrainment, compressive strength, and water retention tests shall be proportioned to contain 1620 g of sand and a mass of cement, in grams, in accordance with Table 2. The sand shall consist of 810 g of graded standard sand and 810 g of 20–30 standard sand (Note 1). The quantity of water, measured in millilitres shall be such as to produce a flow of 110 ± 5 as determined by Test Method C 109/C 109M.

NOTE 1—Historically, field-mixed mortar has been proportioned by volume measured in increments or fractions of ft^3. The comparable whole SI-unit volume to 1 ft^3 is 28 L. The specified mortar proportions approximate the 1:3 nominal proportions by volume, commonly specified for construction, on the basis of the following assumed mass and volume relationships:

The mass of dry sand in 28 L of loose damp sand is 36 kg.
28 L Type N masonry cement has a mass of 32 kg.
28 L Type S masonry cement has a mass of 34 kg.
28 L Type M masonry cement has a mass of 36 kg.

For example, the amount of cement needed to provide a 1:3 volume proportion of cement to sand using a Type N masonry cement is as follows:

$$A = 1620 \times (C/B) = 1620 \times (32/108) = 480 \quad (1)$$

TABLE 1 Physical Requirements

Masonry Cement Type	N	S	M
Fineness, residue on a 45-μm (No. 325) sieve, max, %	24	24	24
Autoclave expansion, max, %	1.0	1.0	1.0
Time of setting, Gillmore method:			
Initial set, minutes, not less than	120	90	90
Initial set, minutes, not more than	1000	1000	1000
Compressive strength (average of 3 cubes): The compressive strength of mortar cubes, composed of 1 part cement and 3 parts blended sand (half graded standard sand, and half standard 20–30 sand) by volume, prepared and tested in accordance with this specification shall be equal to or higher than the values specified for the ages indicated below:			
7 days, MPa (psi)	3.4 (500)	9.0 (1300)	12.4 (1800)
28 days, MPa (psi)	6.2 (900)	14.5 (2100)	20.0 (2900)
Air content of mortar, prepared and tested in accordance with requirements of this specification:			
Min, volume %	8	8	8
Max, volume %	21	19	19
Water retention value, min, % of original flow	70	70	70

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TABLE 2 Cement in Laboratory Batch of Mortar

Masonry Cement Type	Mass of Cement, g
N	480
S	510
M	540

where:

A = number of grams of cement to be used in the mortar with 1620 g of sand,

B = 3 × 36 = 108 kg, the mass of dry sand in 84 (or 3 × 28) L of loose damp sand, and

C = mass of Type N masonry cement per 28 L.

14.2 *Mixing of Mortars*—Mix the mortar in accordance with Practice C 305.

15. Air Entrainment

15.1 *Procedure*—If the mortar has the correct flow, use a separate portion of the mortar for the determination of entrained air. Determine the mass of 400 mL of mortar in accordance with Test Method C 185.

15.2 *Calculation*—Calculate the air content of the mortar and report it to the nearest 1 % as follows:

$$D = (W_1 + W_2 + V_w)/[(W_1/S_1) + (W_2/S_2) + V_w] \quad (2)$$

$$A = 100 - (W_m/4D)$$

where:

D = density of air-free mortar, g/cm^3,

W_1 = mass of cement, g,

W_2 = mass of sand, g,

V_w = millilitres-grams of water used,

S_1 = density of cement, g/cm^3

S_2 = density of standard sand, 2.65 g/cm^3,

A = volume percent of entrained air, and

W_m = mass of 400 mL of mortar, g.

16. Compressive Strength

16.1 *Test Specimens*:

16.1.1 *Molding*—Immediately after determining the flow and mass of 400 mL of mortar, return all of the mortar to the mixing bowl and remix for 15 s at the medium speed. Then mold the test specimens in accordance with Test Method C 109/C 109M, except that the elapsed time for mixing mortar, determining flow, determining air entrainment, and starting the molding of cubes shall be within 8 min.

16.1.2 *Storage*—Immediately after molding, store all test specimens in the molds on plane plates in a moist cabinet or moist room for 48 to 52 h in such a manner that the upper surfaces shall be exposed to the moist air. Then remove the cubes from the molds, and place them in the moist cabinet or moist room for 5 days in such a manner as to allow free circulation of air around at least five faces of the specimens. At the age of 7 days, immerse the cubes for the 28-day tests in saturated lime water in storage tanks of noncorrodible materials.

16.2 *Procedure*:

16.2.1 Test the cube specimens immediately after their removal from the moist cabinet or moist room for 7-day specimens, and immediately after their removal from storage water for all other specimens. If more than one specimen at a time is removed from the moist cabinet or moist room for 7-day tests, cover these cubes with a damp cloth until the time of testing.

16.2.2 The remainder of the testing procedure shall conform to Test Method C 109/C 109M.

17. Water Retention

17.1 Water retention shall be determined in accordance with the procedures in Test Method C 1506.

18. Storage

18.1 The cement shall be stored in such a manner as to permit easy access for the proper inspection and identification of each shipment, and in a suitable weathertight building that will protect the cement from dampness and minimize warehouse set.

19. Inspection

19.1 Every facility shall be provided to the purchaser for the necessary inspection and sampling.

19.2 All packages shall be in good condition at the time of inspection.

20. Rejection

20.1 At the option of the purchaser, the cement shall be rejected if it fails to meet any of the requirements of this specification.

20.2 At the option of the purchaser, packages more than 2 % below the mass marked thereon shall be rejected. At the option of the purchaser, the entire shipment represented shall be rejected if the average mass of packages in any shipment as shown by weighing fifty packages taken at random is less than that marked on the packages.

20.3 At the option of the purchaser, cement remaining in storage prior to shipment for a period greater than six months after testing shall be retested and, at the option of the purchaser shall be rejected if it fails to meet any of the requirements of this specification.

21. Manufacturer's Certification

21.1 Upon request of the purchaser in the contract or order, a manufacturer's report shall be furnished at the time of shipment stating the results of the tests made on samples of the material taken during production or transfer and certifying that the applicable requirements of this specification have been met.

22. Packaging and Package Marking

22.1 When masonry cement is delivered in packages, the brand, name of the manufacturer, type of masonry cement, and net mass of the package in kilograms (see Note 2) shall be indicated plainly thereon. Similar information shall be provided in the shipping documents accompanying the shipment of masonry cement in bulk.

NOTE 2—To facilitate the change to SI units, a standard SI package size of 32 kg for Type N, 34 kg for Type S, and 36 kg for Type M will provide convenient mass increments reasonably similar to the traditional 70-, 75-, and 80-lb packages.

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23. Keywords

23.1 masonry; masonry cement; mortar

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Designation: C94/C94M – 09a

Standard Specification for Ready-Mixed Concrete[1]

This standard is issued under the fixed designation C94/C94M; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

This standard has been approved for use by agencies of the Department of Defense.

1. Scope*

1.1 This specification covers ready-mixed concrete as defined in 3.2.2. Requirements for quality of concrete shall be either as hereinafter specified or as specified by the purchaser. In any case where the requirements of the purchaser differ from these in this specification, the purchaser's specification shall govern. This specification does not cover the placement, consolidation, curing, or protection of the concrete after delivery to the purchaser.

1.2 The values stated in either SI units, shown in brackets, or inch-pound units are to be regarded separately as standard. The values stated in each system may not be exact equivalents; therefore, each system shall be used independently of the other. Combining values from the two systems may result in nonconformance with the standard.

1.3 As used throughout this specification the manufacturer produces ready-mixed concrete. The purchaser buys ready-mixed concrete.

1.4 The text of this standard references notes and footnotes which provide explanatory material. These notes and footnotes (excluding those in tables and figures) shall not be considered as requirements of the standard.

1.5 *This standard does not purport to address all the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.* (**Warning**—Fresh hydraulic cementitious mixtures are caustic and may cause chemical burns to skin and tissue upon prolonged use.[2])

2. Referenced Documents

2.1 *ASTM Standards:*[3]

C31/C31M Practice for Making and Curing Concrete Test Specimens in the Field
C33 Specification for Concrete Aggregates
C39/C39M Test Method for Compressive Strength of Cylindrical Concrete Specimens
C125 Terminology Relating to Concrete and Concrete Aggregates
C138/C138M Test Method for Density (Unit Weight), Yield, and Air Content (Gravimetric) of Concrete
C143/C143M Test Method for Slump of Hydraulic-Cement Concrete
C150 Specification for Portland Cement
C172 Practice for Sampling Freshly Mixed Concrete
C173/C173M Test Method for Air Content of Freshly Mixed Concrete by the Volumetric Method
C231 Test Method for Air Content of Freshly Mixed Concrete by the Pressure Method
C260 Specification for Air-Entraining Admixtures for Concrete
C330 Specification for Lightweight Aggregates for Structural Concrete
C494/C494M Specification for Chemical Admixtures for Concrete
C567 Test Method for Determining Density of Structural Lightweight Concrete
C595 Specification for Blended Hydraulic Cements
C618 Specification for Coal Fly Ash and Raw or Calcined Natural Pozzolan for Use in Concrete
C637 Specification for Aggregates for Radiation-Shielding Concrete
C989 Specification for Slag Cement for Use in Concrete and Mortars
C1017/C1017M Specification for Chemical Admixtures for Use in Producing Flowing Concrete
C1064/C1064M Test Method for Temperature of Freshly Mixed Hydraulic-Cement Concrete
C1077 Practice for Laboratories Testing Concrete and Concrete Aggregates for Use in Construction and Criteria for Laboratory Evaluation
C1157 Performance Specification for Hydraulic Cement
C1240 Specification for Silica Fume Used in Cementitious Mixtures

[1] This specification is under the jurisdiction of ASTM Committee C09 on Concrete and Concrete Aggregates and is the direct responsibility of Subcommittee C09.40 on Ready-Mixed Concrete.

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[2] See Section on Safety Precautions, Manual of Aggregate and Concrete Testing, *Annual Book of ASTM Standards*, Vol. 04.02.

[3] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

***A Summary of Changes section appears at the end of this standard.**

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C1602/C1602M Specification for Mixing Water Used in the Production of Hydraulic Cement Concrete

C1611/C1611M Test Method for Slump Flow of Self-Consolidating Concrete

2.2 *ACI Documents:*[4]

CP-1 Technician Workbook for ACI Certification of Concrete Field Testing Technician–Grade I

211.1 Standard Practice for Selecting Proportions for Normal, Heavyweight, and Mass Concrete

211.2 Standard Practice for Selecting Proportions for Structural Lightweight Concrete

301 Standard Specifications for Structural Concrete

305R Hot Weather Concreting

306R Cold Weather Concreting

318 Building Code Requirements for Structural Concrete and Commentary

2.3 *Other Documents:*

Bureau of Reclamation Concrete Manual [5]

3. Terminology

3.1 *Definitions*:

The terms used in this specification are defined in Terminology C125.

3.2 Definitions of Terms Specific to This Standard:

3.2.1 *concrete, central-mixed*, *n*—concrete mixed completely in a stationary mixer.

3.2.2 *concrete, ready-mixed*, *n*—concrete manufactured and delivered to a purchaser in a fresh state.

3.2.3 *concrete, shrink-mixed*, *n*—concrete partially mixed in a stationary mixer with mixing completed in a truck mixer.

3.2.4 *concrete, truck-mixed*, *n*—concrete completely mixed in a truck mixer.

4. Basis of Purchase

4.1 The basis of purchase shall be a cubic yard or cubic metre of fresh concrete as discharged from the transportation unit.

4.2 The volume of fresh concrete in a given batch shall be determined from the total mass of the batch divided by the density of the concrete. The total mass of the batch shall be determined as the net mass of the concrete in the batch as delivered, including the total mixing water as defined in 9.3. The density shall be determined in accordance with Test Method C138/C138M. The yield shall be determined as the average of at least three measurements, one from each of three different transportation units sampled in accordance with Practice C172.

NOTE 1—It should be understood that the volume of hardened concrete may be, or appear to be, less than expected due to waste and spillage, over-excavation, spreading forms, some loss of entrained air, or settlement of wet mixtures, none of which are the responsibility of the producer.

[4] Available from American Concrete Institute (ACI), P.O. Box 9094, Farmington Hills, MI 48333-9094, http://www.concrete.org.

[5] Available from Superintendent of Documents, U. S. Government Printing Office, Washington, DC 20402.

5. Materials

5.1 In the absence of designated applicable materials specifications, the following materials specifications shall be used:

5.2 *Cementitious Materials*

5.2.1 *Hydraulic Cement*—Hydraulic cement shall conform to Specification C150, Specification C595, or Specification C1157.

5.2.2 *Supplementary Cementitious Materials*—Coal fly ash or natural pozzolans shall conform to Specification C618. Ground granulated blast furnace slag shall conform to Specification C989. Silica fume shall conform to Specification C1240.

5.2.3 *Cementitious concrete mixtures*—Cementitious concrete mixtures shall contain the kind(s) and class(es) of hydraulic cement(s) and the kind(s) and class(es) of supplementary cementitious material(s) as specified by the purchaser. If hydraulic cement specification or type is not provided then the requirements of portland cement Type I or Type II conforming to Specification C150 shall apply or other cementitious materials that have a demonstrated ability to satisfy the intended use.

5.3 *Aggregates*—Normal weight aggregates shall conform to Specification C33. Lightweight aggregates shall conform to Specification C330 and heavyweight aggregates shall conform to Specification C637.

5.4 *Water*—Water shall conform to Specification C1602/C1602M.

5.5 *Air-Entraining Admixtures*—Air-entraining admixtures shall conform to Specification C260 (Note 2).

5.6 *Chemical Admixtures*—Chemical admixtures shall conform to either Specification C494/C494M or C1017/C1017M as applicable (Note 2).

NOTE 2—In any given instance, the required dosage of air-entraining, accelerating, and retarding admixtures may vary. Therefore, a range of dosages should be allowed which will permit obtaining the desired effect.

NOTE 3—Interchanging kinds, characteristics, types, classes, or grades of the materials permitted in ready-mixed concrete may produce concrete of different properties.

6. Ordering Information

6.1 In the absence of designated applicable general specifications, the purchaser shall specify the following:

6.1.1 Designated size, or sizes, of coarse aggregate,

6.1.2 Slump, or slumps, desired at the point of delivery (see Section 7 for acceptable tolerances),

6.1.3 Slump flow, or flows, desired at the point of delivery (see Section 7 for acceptable tolerances),

6.1.4 When air-entrained concrete is specified, the air content of the samples taken at the point of discharge from the transportation unit (see Section 8 and Table 1 for the total air content and tolerances) (Note 4),

6.1.5 Which of Options A, B, or C shall be used as a basis for determining the proportions of the concrete to produce the required quality,

6.1.6 When structural lightweight concrete is specified, the mass per unit volume as wet mass, air-dry mass, or oven-dry mass (Note 5), and

6.1.7 If desired, any of the optional requirements of Table 2 in Specification C1602/C1602M.

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TABLE 1 Recommended Total Air Content for Air-Entrained Concrete[A,B]

Exposure Condition[C]	Total Air Content, % — Nominal Maximum Sizes of Aggregate, in. [mm]						
	⅜ [9.5]	½ [12.5]	¾ [19.0]	1 [25.0]	1½ [37.5]	2 [50.0]	3 [75.0]
Mild	4.5	4.0	3.5	3.0	2.5	2.0	1.5
Moderate	6.0	5.5	5.0	4.5	4.5	4.0	3.5
Severe	7.5	7.0	6.0	6.0	5.5	5.0	4.5

[A] For air-entrained concrete, when specified.
[B] Unless exposure conditions dictate otherwise, it is permissible to reduce air contents recommended above by up to 1 % for concretes with specified compressive strength, f'_c, of 5000 psi [35 MPa] or above.
[C] For description of exposure conditions, refer to Standard Practice ACI 211.1, Section 6.3.3, with attention to accompanying footnotes.

NOTE 4—In selecting the specified air content, the purchaser should consider the exposure conditions to which the concrete will be subjected. Air contents less than shown in Table 1 may not give the required resistance to freezing and thawing, which is the primary purpose of air-entrained concrete. Air contents higher than the levels shown may reduce strength without contributing any further improvement of durability.

NOTE 5—The mass per unit volume of fresh concrete, which is the only unit mass determinable at the time of delivery, is always higher than the air-dry or oven-dry mass. Definitions of, and methods for determining or calculating air-dry and oven-dry masses, are covered by Test Method C567.

6.2 *Option A*:

6.2.1 When the purchaser requires the manufacturer to assume full responsibility for the selection of the proportions for the concrete mixture (Note 6), the purchaser shall also specify the following:

6.2.1.1 Requirements for compressive strength as determined on samples taken from the transportation unit at the point of discharge evaluated in accordance with Section 18. The purchaser shall specify the requirements in terms of the compressive strength of standard specimens cured under standard laboratory conditions for moist curing (see Section 18). Unless otherwise specified the age at test shall be 28 days.

NOTE 6—The purchaser, in selecting requirements for which he assumes responsibility should give consideration to requirements for workability, placeability, durability, surface texture, and density, in addition to those for structural design. The purchaser is referred to Standard Practice ACI 211.1 and Standard Practice ACI 211.2 for the selection of proportions that will result in concrete suitable for various types of structures and conditions of exposure. The water-cement ratio of most structural lightweight concretes cannot be determined with sufficient accuracy for use as a specification basis.

6.2.2 At the request of the purchaser, the manufacturer shall, prior to the actual delivery of the concrete, furnish a statement to the purchaser, giving the dry masses of cement and saturated surface-dry-masses of fine and coarse aggregate and quantities, type, and name of admixtures (if any) and of water per cubic yard or cubic metre of concrete that will be used in the manufacture of each class of concrete ordered by the purchaser. He shall also furnish evidence satisfactory to the purchaser that the materials to be used and proportions selected will produce concrete of the quality specified.

6.3 *Option B*:

6.3.1 When the purchaser assumes responsibility for the proportioning of the concrete mixture, he shall also specify the following:

6.3.1.1 Cement content in bags or pounds per cubic yard [kilograms per cubic metre] of concrete,

6.3.1.2 Maximum allowable water content in gallons per cubic yard [litres per cubic metre] of concrete, including surface moisture on the aggregates, but excluding water of absorption (Note 6), and

6.3.1.3 If admixtures are required, the type, name, and dosage to be used. The cement content shall not be reduced when admixtures are used under this option without the written approval of the purchaser.

6.3.2 At the request of the purchaser, the manufacturer shall, prior to the actual delivery of the concrete, furnish a statement to the purchaser giving the sources, densities, and sieve analyses of the aggregates and the dry masses of cement and saturated-surface-dry masses of fine and coarse aggregate and quantities, type and name of admixture (if any) and of water per cubic yard or cubic metre of concrete that will be used in the manufacture of each class of concrete ordered by the purchaser.

6.4 *Option C*:

6.4.1 When the purchaser requires the manufacturer to assume responsibility for the selection of the proportions for the concrete mixture with the minimum allowable cement content specified (Note 7), the purchaser shall also specify the following:

6.4.1.1 Required compressive strength as determined on samples taken from the transportation unit at the point of discharge evaluated in accordance with Section 18. The purchaser shall specify the requirements for strength in terms of tests of standard specimens cured under standard laboratory conditions for moist curing (see Section 18). Unless otherwise specified the age at test shall be 28 days.

6.4.1.2 Minimum cement content in bags or pounds per cubic yard [kilograms per cubic metre] of concrete.

6.4.1.3 If admixtures are required, the type, name, and dosage to be used. The cement content shall not be reduced when admixtures are used.

NOTE 7—Option C can be distinctive and useful only if the designated minimum cement content is at about the same level that would ordinarily be required for the strength, aggregate size, and slump or slump flow specified. At the same time, it must be an amount that will be sufficient to ensure durability under expected service conditions, as well as satisfactory surface texture and density, in the event specified strength is attained with it. For additional information refer to Standard Practice ACI 211.1 and Standard Practice 211.2 referred to in Note 6.

6.4.2 At the request of the purchaser, the manufacturer shall, prior to the actual delivery of the concrete, furnish a statement to the purchaser, giving the dry masses of cement and saturated surface-dry masses of fine and coarse aggregate and quantities,

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type, and name of admixture (if any) and of water per cubic yard or cubic metre of concrete that will be used in the manufacture of each class of concrete ordered by the purchaser. He shall also furnish evidence satisfactory to the purchaser that the materials to be used and proportions selected will produce concrete of the quality specified. Whatever strengths are attained the quantity of cement used shall not be less than the minimum specified.

6.5 The proportions arrived at by Options A, B, or C for each class of concrete and approved for use in a project shall be assigned a designation to facilitate identification of each concrete mixture delivered to the project. This is the designation required in 14.1.7 and supplies information on concrete proportions when they are not given separately on each delivery ticket as outlined in 14.2. A certified copy of all proportions as established in Options A, B, or C shall be on file at the batch plant.

6.6 The purchaser shall ensure that the manufacturer is provided copies of all reports of tests performed on concrete samples taken to determine compliance with specification requirements. Reports shall be provided on a timely basis.

7. Tolerances in Slump or Slump Flow

7.1 Unless other tolerances are included in the project specifications, the following shall apply.

7.1.1 When the project specifications for slump are written as a "maximum" or "not to exceed" requirement:

	Specified slump:	
	If 3 in. [75 mm] or less	If more than 3 in. [75 mm]
Plus tolerance:	0	0
Minus tolerance:	1½ in. [40 mm]	2½ in. [65 mm]

This option is to be used only if one addition of water is permitted on the job provided such addition does not increase the water-cement ratio above the maximum permitted by the specifications.

7.1.2 When the project specifications for slump are *not* written as a "maximum" or "not to exceed" requirement:

Tolerances for Nominal Slumps

For Specified Slump of:	Tolerance
2 in. [50 mm] and less	±½ in. [15 mm]
More than 2 through 4 in. [50 to 100 mm]	±1 in. [25 mm]
More than 4 in. [100 mm]	±1½ in. [40 mm]

7.1.3 When the project specifications indicate a slump flow requirement for self-consolidating concrete:

Tolerances for Slump Flow

For Specified Slump Flow	Tolerance
Less than or equal to 22 in. [550 mm]	± 1 ½ in. [40 mm]
More than 22 in [550 mm]	± 2 ½ in. [65 mm]

7.2 Concrete shall be available within the permissible range of slump or slump flow for a period of 30 min starting either on arrival at the job site or after the initial slump adjustment permitted in 12.7, whichever is later. The first and last ¼ yd^3 or ¼ m^3 discharged are exempt from this requirement. If the user is unprepared for discharge of the concrete from the vehicle, the producer shall not be responsible for the limitation of minimum slump or slump flow after 30 min have elapsed starting either on arrival of the vehicle at the prescribed destination or at the requested delivery time, whichever is later.

8. Air-Entrained Concrete

8.1 When air-entrained concrete is desired the purchaser shall specify the total air content of the concrete. See Table 1 for recommended total air contents (Note 2).

8.2 The air content of air-entrained concrete when sampled from the transportation unit at the point of discharge shall be within a tolerance of ± 1.5 of the specified value.

8.3 When a preliminary sample taken within the time limits of 12.7 and prior to discharge for placement shows an air content below the specified level by more than the allowable tolerance in accordance with 8.2, the manufacturer may use additional air entraining admixture to achieve the desired air content level, followed by a minimum of 30 revolutions at mixing speed, so long as the revolution limit of 12.7 is not exceeded (see Note 8).

NOTE 8—Acceptance sampling and testing in accordance with Practice C172 is not obviated by this provision.

9. Measuring Materials

9.1 Except as otherwise specifically permitted, cementitious materials shall be measured by mass. When supplementary cementitious materials are used in the concrete mixtures, the cumulative mass is permitted to be measured with hydraulic cement, but in a batch hopper and on a scale which is separate and distinct from those used for other materials. The mass of the hydraulic cement shall be measured before supplementary cementitious materials. When the quantity of cementitious material exceeds 30 % of the full capacity of the scale, the measured quantity of the hydraulic cement shall be within ± 1 % of the required mass, and the cumulative measured quantity of hydraulic cement plus supplementary cementitious materials shall also be within ± 1 % of the required cumulative mass at each intermediate weighing. For smaller batches to a minimum of 1 yd^3 [1 m^3], the measured quantity of the hydraulic cement and the measured cumulative quantity of hydraulic cement plus supplementary cementitious materials used shall be not less than the required amount nor more than 4 % in excess. Under special circumstances approved by the purchaser, hydraulic cement is permitted to be measured in bags of standard mass (Note 9). No fraction of a bag of hydraulic cement shall be used unless its mass has been determined.

NOTE 9—In the United States the standard mass of a bag of portland cement is 94 lb [42.6 kg] ± 3 %.

9.2 Aggregate shall be measured by mass. Batch mass measurements shall be based on dry materials and shall be the required masses of dry materials plus the total mass of moisture (both absorbed and surface) contained in the aggregate. The quantity of aggregate used in any batch of concrete as indicated by the scale shall be within ±2 % of the required mass when the mass is measured in individual aggregate weigh batchers. In a cumulative aggregate weigh batcher, the cumulative weight after each successive weighing shall be within ±1 % of the required cumulative amount up to that point when the scale is used in excess of 30 % of its capacity. For cumulative

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weights for less than 30 % of scale capacity, the tolerance shall be ±0.3 % of scale capacity or ±3 % of the required cumulative weight, whichever is less.

9.3 Mixing water shall consist of water added to the batch, ice added to the batch, water occurring as surface moisture on the aggregates, and water introduced in the form of admixtures. The added water shall be measured by weight or volume to an accuracy of 1 % of the required total mixing water. Added ice shall be measured by weight. In the case of truck mixers, any wash water retained in the drum for use in the next batch of concrete shall be accurately measured; if this proves impractical or impossible the wash water shall be discharged prior to loading the next batch of concrete. Total water (including any wash water) shall be measured or weighed to an accuracy of ±3 % of the specified total amount.

9.4 Chemical admixtures in powdered form shall be measured by mass. Liquid chemical admixtures shall be batched by mass or volume. Admixtures measured by either mass or volume, shall be batched with an accuracy of ±3 % of the total amount required or plus or minus the amount or dosage required for 100 lb [50 kg] of hydraulic cement, whichever is greater.

NOTE 10—Admixture dispensers of the mechanical type capable of adjustment for variation of dosage, and of simple calibration, are recommended.

10. Batching Plant

10.1 Bins with adequate separate compartments shall be provided in the batching plant for fine and for each required size of coarse aggregate. Each bin compartment shall be designed and operated so as to discharge efficiently and freely, with minimum segregation, into the weighing hopper. Means of control shall be provided so that, as the quantity desired in the weighing hopper is approached, the material shall be shut off with precision. Weighing hoppers shall be constructed so as to eliminate accumulations of tare materials and to discharge fully.

10.2 Indicating devices shall be in full view and near enough to be read accurately by the operator while charging the hopper. The operator shall have convenient access to all controls.

10.3 Scales shall be considered accurate when at least one static load test within each quarter of the scale capacity can be shown to be within ±0.15 % of the total capacity of the scale or 0.4 % of the net applied load, whichever is greater.

10.4 Adequate standard test weights shall be available for checking accuracy. All exposed fulcrums, clevises, and similar working parts of scales shall be kept clean. Beam scales shall be equipped with a balance indicator sensitive enough to show movement when a weight equal to 0.1 % of the nominal capacity of the scale is placed in the batch hopper. Pointer travel shall be a minimum of 5 % of the net-rated capacity of the largest weigh beam for underweight and 4 % for overweight.

10.5 The device for the measurement of the added water shall be capable of delivering to the batch the quantity required within the accuracy required in 9.3. The device shall be so arranged that the measurements will not be affected by variable pressures in the water supply line. Measuring tanks shall be equipped with outside taps and valves to provide for checking their calibration unless other means are provided for readily and accurately determining the amount of water in the tank.

NOTE 11—The scale accuracy limitations of the National Ready Mixed Concrete Association Plant Certification meet the requirements of this specification.

11. Mixers and Agitators

11.1 Mixers will be stationary mixers or truck mixers. Agitators will be truck mixers or truck agitators.

11.1.1 Stationary mixers shall be equipped with a metal plate or plates on which are plainly marked the mixing speed of the drum or paddles, and the maximum capacity in terms of the volume of mixed concrete. When used for the complete mixing of concrete, stationary mixers shall be equipped with an acceptable timing device that will not permit the batch to be discharged until the specified mixing time has elapsed.

11.1.2 Each truck mixer or agitator shall have attached thereto in a prominent place a metal plate or plates on which are plainly marked the gross volume of the drum, the capacity of the drum or container in terms of the volume of mixed concrete, and the minimum and maximum mixing speeds of rotation of the drum, blades, or paddles. When the concrete is truck mixed as described in 12.5, or shrink mixed as described in 12.4, the volume of mixed concrete shall not exceed 63 % of the total volume of the drum or container. When the concrete is central mixed as described in 12.3, the volume of concrete in the truck mixer or agitator shall not exceed 80 % of the total volume of the drum or container. Truck mixers and agitators shall be equipped with means to readily verify the number of revolutions of the drum, blades, or paddles.

11.2 All stationary and truck mixers shall be capable of combining the ingredients of the concrete within the specified time or the number of revolutions specified in 11.5, into a thoroughly mixed and uniform mass and of discharging the concrete so that not less than five of the six requirements shown in Table A1.1 shall have been met.

NOTE 12—The sequence or method of charging the mixer will have an important effect on the uniformity of the concrete.

11.3 The agitator shall be capable of maintaining the mixed concrete in a thoroughly mixed and uniform mass and of discharging the concrete with a satisfactory degree of uniformity as defined by Annex A1.

11.4 Slump tests of individual samples taken after discharge of approximately 15 % and 85 % of the load will provide a quick check of the probable degree of uniformity (Note 13). These two samples shall be obtained within an elapsed time of not more than 15 min. If these slumps differ more than that specified in Annex A1, the mixer or agitator shall not be used unless the condition is corrected, except as provided in 11.5.

NOTE 13—No samples should be taken before 10 % or after 90 % of the batch has been discharged. Due to the difficulty of determining the actual quantity of concrete discharged, the intent is to provide samples that are representative of widely separated portions, but not the beginning and end of the load.

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11.5 Use of the equipment is permitted when operation with a longer mixing time, a smaller load, or a more efficient charging sequence will permit the requirements of Annex A1 to be met.

11.6 Mixers and agitators shall be examined or their mass determined as frequently as necessary to detect changes in condition due to accumulations of hardened concrete or mortar and examined to detect wear of blades. When such changes are extensive enough to affect the mixer performance, the proof-tests described in Annex A1 shall be performed to show whether the correction of deficiencies is required.

12. Mixing and Delivery

12.1 Ready-mixed concrete shall be mixed and delivered to the point designated by the purchaser by means of one of the following combinations of operations:

12.1.1 *Central-Mixed Concrete*.

12.1.2 *Shrink-Mixed Concrete*.

12.1.3 *Truck-Mixed Concrete*.

12.2 Mixers and agitators shall be operated within the limits of capacity and speed of rotation designated by the manufacturer of the equipment.

12.3 *Central-Mixed Concrete*—Concrete that is mixed completely in a stationary mixer and transported to the point of delivery either in a truck agitator, or a truck mixer operating at agitating speed, or in nonagitating equipment approved by the purchaser and meeting the requirements of Section 13, shall conform to the following: The mixing time shall be counted from the time all the solid materials are in the drum. The batch shall be so charged into the mixer that some water will enter in advance of the cement and aggregate, and all water shall be in the drum by the end of the first one fourth of the specified mixing time.

12.3.1 Where no mixer performance tests are made, the acceptable mixing time for mixers having capacities of 1 yd^3 [0.76 m^3] or less shall be not less than 1 min. For mixers of greater capacity, this minimum shall be increased 15 s for each cubic yard [cubic metre] or fraction thereof of additional capacity (See Note 14).

NOTE 14—Stationary mixers of similar design bearing a Performance Rated plate of the Concrete Plant Manufacturers Bureau have been tested to produce uniformly mixed concrete in accordance with Annex A1 for low slump (< 2 in. [50 mm]) and normal slump (4–6 in. [100–150 mm]) concrete in a mixing time between 30 and 90 sec.

12.3.2 Where mixer performance tests have been made on given concrete mixtures in accordance with the testing program set forth in the following paragraphs, and the mixers have been charged to their rated capacity, the acceptable mixing time is permitted to be reduced for those particular circumstances to a point at which satisfactory mixing defined in 12.3.3 shall have been accomplished. When the mixing time is so reduced the maximum time of mixing shall not exceed this reduced time by more than 60 s for air-entrained concrete.

12.3.3 *Sampling for Uniformity Tests of Stationary Mixers*—Samples of concrete for comparative purposes shall be obtained immediately after arbitrarily designated mixing times, in accordance with one of the following procedures:

12.3.3.1 *Alternative Procedure 1*—The mixer shall be stopped, and the required samples removed by any suitable means from the concrete at approximately equal distances from the front and back of the drum, or

12.3.3.2 *Alternative Procedure 2*—As the mixer is being emptied, individual samples shall be taken after discharge of approximately 15 % and 85 % of the load. The method of sampling shall provide that the samples are representative of widely separated portions, but not from the very ends of the batch (Note 13).

12.3.3.3 The samples of concrete shall be tested in accordance with Section 18, and differences in test results for the two samples shall not exceed those given in Annex A1. Mixer performance tests shall be repeated whenever the appearance of the concrete or the coarse aggregate content of samples selected as outlined in this section indicates that adequate mixing has not been accomplished.

12.4 *Shrink-Mixed Concrete*—Concrete that is first partially mixed in a stationary mixer, and then mixed completely in a truck mixer, shall conform to the following: The time of partial mixing shall be minimum required to intermingle the ingredients. After transfer to a truck mixer the amount of mixing at the designated mixing speed will be that necessary to meet the requirements for uniformity of concrete as indicated in Annex A1. Tests to confirm such performance shall be made in accordance with 12.3.3 and 12.3.3.3. Additional turning of the mixer, if any, shall be at a designated agitating speed.

12.5 *Truck-Mixed Concrete*—Concrete that is completely mixed in a truck mixer, 70 to 100 revolutions at the mixing speed designated by the manufacturer to produce the uniformity of concrete indicated in Annex A1 (see Note 15). Concrete uniformity tests shall be made in accordance with 12.5.1 and if requirements for uniformity of concrete indicated in Annex A1 are not met with 100 revolutions of mixing, after all ingredients including water, are in the drum, that mixer shall not be used until the condition is corrected, except as provided in 11.5. When satisfactory performance is found in one truck mixer, the performance of mixers of substantially the same design and condition of blades are permitted to be regarded as satisfactory. Additional revolutions of the mixer beyond the number found to produce the required uniformity of concrete shall be at a designated agitating speed.

NOTE 15—Truck mixers of similar design bearing a Performance Rated plate of the Truck Mixer Manufacturers Bureau have been tested to produce uniformly mixed concrete in accordance with Annex A1.

12.5.1 *Sampling for Uniformity of Concrete Produced in Truck Mixers*—The concrete shall be discharged at the normal operating rate for the mixer being tested, with care being exercised not to obstruct or retard the discharge by an incompletely opened gate or seal. Separate samples, each consisting of approximately 2 ft^3 [0.1 m^3 approximately] shall be taken after discharge of approximately 15 % and 85 % of the load (Note 13). These samples shall be obtained within an elapsed time of not more than 15 min. The samples shall be secured in accordance with Practice C172, but shall be kept separate to represent specific points in the batch rather than combined to form a composite sample. Between samples, where necessary to maintain slump, the mixer shall be turned in mixing

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direction at agitating speed. During sampling the receptacle shall receive the full discharge of the chute. Sufficient personnel must be available to perform the required tests promptly. Segregation during sampling and handling must be avoided. Each sample shall be remixed the minimum amount to ensure uniformity before specimens are molded for a particular test.

12.6 When a truck mixer or truck agitator is used for transporting concrete that has been completely mixed in a stationary mixer, any turning during transportation shall be at the speed designated by the manufacturer of the equipment as agitating speed.

12.7 For truck mixers satisfying the requirements of 11.5 for mixing concrete, no water from the truck water system or elsewhere shall be added after the initial introduction of mixing water for the batch except when on arrival at the job site the slump or slump flow of the concrete is less than that specified. If the desired slump or slump flow is less than specified, and unless otherwise stated, obtain the desired slump or slump flow within the tolerances stated in 7.1.1, 7.1.2, or 7.1.3 with a one-time addition of water. Do not exceed the maximum water content for the batch as established by the designed mixture proportion. A one-time addition of water is not prohibited from being several distinct additions of water provided that no concrete has been discharged except for slump or slump flow testing. All water additions shall be completed within 15 min from the start of the first water addition. Such additional water shall be injected into the mixer under such pressure and direction of flow to allow for proper distribution within the mixer. The drum shall be turned an additional 30 revolutions, or more if necessary, at mixing speed to ensure that a homogenous mixture is attained. Water shall not be added to the batch at any later time. Discharge of the concrete shall be completed within 1½ h, or before the drum has revolved 300 revolutions, whichever comes first, after the introduction of the mixing water to the cement and aggregates or the introduction of the cement to the aggregates. These limitations are permitted to be waived by the purchaser if the concrete is of such slump or slump flow after the 1½-h time or 300-revolution limit has been reached that it can be placed, without the addition of water, to the batch. In hot weather, or under conditions contributing to quick stiffening of the concrete, a time less than 1½ h is permitted to be specified by the purchaser.

12.8 Concrete delivered in cold weather shall have the applicable minimum temperature indicated in the following table. (The purchaser shall inform the producer as to the type of construction for which the concrete is intended.)

Minimum Concrete Temperature as Placed

Section Size, in. [mm]	Temperature, min, °F [°C]
<12 [<300]	55 [13]
12–36 [300–900]	50 [10]
36–72 [900–1800]	45 [7]
>72 [>1800]	40 [5]

The maximum temperature of concrete produced with heated aggregates, heated water, or both, shall at no time during its production or transportation exceed 90 °F [32 °C].

NOTE 16—When hot water is used rapid stiffening may occur if hot water is brought in direct contact with the cement. Additional information on cold weather concreting is contained in ACI 306R.

12.9 The producer shall deliver the ready mixed concrete during hot weather at concrete temperatures as low as practicable, subject to the approval of the purchaser.

NOTE 17—In some situations difficulty may be encountered when concrete temperatures approach 90 °F [32 °C]. Additional information may be found in the Bureau of Reclamation Concrete Manual and in ACI 305R.

13. Use of Nonagitating Equipment

13.1 When the use of non-agitating transportation equipment is approved by the purchaser, the concrete shall be manufactured in a central mix plant. The proportions of the concrete shall be approved by the purchaser and the following limitations shall apply:

13.2 Bodies of nonagitating equipment shall be smooth, watertight, metal containers equipped with gates that will permit control of the discharge of the concrete. Covers shall be provided for protection against the weather when required by the purchaser.

13.3 The concrete shall be delivered to the site of the work in a thoroughly mixed and uniform mass and discharged with a satisfactory degree of uniformity as prescribed in Annex A1.

13.4 Slump tests of individual samples taken after discharge of approximately 15 % and 85 % of the load will provide for a quick check of the probable degree of uniformity (Note 13). These two samples shall be obtained within an elapsed time of not more than 15 min. If these slumps differ more than that specified in Table A1.1, the nonagitating equipment shall not be used unless the conditions are corrected as provided in 13.5.

13.5 If the requirements of Annex A1 are not met when the nonagitating equipment is operated for the maximum time of haul, and with the concrete mixed the minimum time, the equipment shall only be used when operated using shorter hauls, or longer mixing times, or combinations thereof that will result in the requirements of Annex A1 being met.

14. Batch Ticket Information

14.1 The manufacturer of the concrete shall furnish to the purchaser with each batch of concrete before unloading at the site, a delivery ticket on which is printed, stamped, or written, information concerning said concrete as follows:

14.1.1 Name of ready-mix company and batch plant, or batch plant number,

14.1.2 Serial number of ticket,

14.1.3 Date,

14.1.4 Truck number,

14.1.5 Name of purchaser,

14.1.6 Specific designation of job (name and location),

14.1.7 Specific class or designation of the concrete in conformance with that employed in job specifications,

14.1.8 Amount of concrete in cubic yards (or cubic metres),

14.1.9 Time loaded or of first mixing of cement and aggregates, and

14.1.10 Water added by receiver of concrete and his initials.

14.2 Additional information for certification purposes as designated by the purchaser and required by the job specifications shall be furnished when requested; such information as:

14.2.1 Reading of revolution counter at the first addition of water,

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14.2.2 Type, brand, and amount of cement,

14.2.3 Class, brand, and amount of coal fly ash, or raw or calcined natural pozzolans,

14.2.4 Grade, brand, and amount of ground granulated blast-furnace slag,

14.2.5 Type, brand, and amount of silica fume,

14.2.6 Type, brand, and amount of admixtures

14.2.7 Type, brand, and amount of fiber reinforcement,

14.2.8 Source and amount of each metered or weighed water or recycled slurry,

14.2.9 Information necessary to calculate the total mixing water. Total mixing water includes free water on aggregates, batch water (metered or weighed) including ice batched at the plant, wash water retained in the mixing drum, and water added by the truck operator from the mixer tank,

14.2.10 Maximum size of aggregate,

14.2.11 Mass (amount) of fine and coarse aggregate,

14.2.12 Ingredients certified as being previously approved, and

14.2.13 Signature or initials of producer's representative.

15. Plant Inspection

15.1 The manufacturer shall afford the inspector all reasonable access, without charge, for making necessary checks of the production facilities and for securing necessary samples to determine if the concrete is being produced in accordance with this specification. All tests and inspection shall be so conducted as not to interfere unnecessarily with the manufacture and delivery of concrete.

16. Practices, Test Methods, and Reporting

16.1 Test ready-mixed concrete in accordance with the following methods:

16.1.1 *Compression Test Specimens*—Practice C31/C31M, using standard moist curing in accordance with the applicable provisions of Practice C31/C31M.

16.1.2 *Compression Tests*—Test Method C39/C39M.

16.1.3 *Yield, Mass per Cubic Foot*—Test Method C138/C138M.

16.1.4 *Air Content*—Test Method C138/C138M; Test Method C173/C173M or Test Method C231.

16.1.5 *Slump*—Test Method C143/C143M.

16.1.6 *Slump Flow*—Test Method C1611/C1611M.

16.1.7 *Sampling Fresh Concrete*—Practice C172.

16.1.8 *Temperature*—Test Method C1064/C1064M.

16.2 The testing laboratory performing acceptance tests of concrete shall meet the requirements of Practice C1077.

16.3 Laboratory reports of concrete test results used to determine compliance with this specification shall include a statement that all tests performed by the laboratory or its agents were in accordance with the applicable test methods or shall note all known deviations from the prescribed procedures (Note 18). The reports shall also list any part of the test methods not performed by the laboratory.

NOTE 18—Deviation from standard test methods may adversely affect test results.

NOTE 19—Deviation from standard moisture and temperature curing conditions is often a reason for low strength test results. Such deviations may invalidate the use of such test results as a basis for rejection of the concrete.

17. Sampling and Testing Fresh Concrete

17.1 The contractor shall afford the inspector all reasonable access and assistance, without charge, for the procurement of samples of fresh concrete at time of placement to determine conformance of it to this specification.

17.2 Tests of concrete required to determine compliance with this specification shall be made by a certified ACI Concrete Field Testing Technician, Grade I or equivalent. Equivalent personnel certification programs shall include both written and performance examinations as outlined in ACI CP-1.

17.3 Samples of concrete shall be obtained in accordance with Practice C172, except when taken to determine uniformity of slump within any one batch or load of concrete (11.4, 12.3.3, 12.5.1, and 13.4).

17.4 Slump or slump flow, air-content, density, and temperature tests shall be made at the time of placement at the option of the inspector as often as is necessary for control checks. In addition, these tests shall be made when specified and always when strength specimens are made.

17.5 Strength tests as well as slump or slump flow, temperature, density, and air content tests shall generally be made with a frequency of not less than one test for each 150 yd^3 (115 m^3). Each test shall be made from a separate batch. On each day concrete is delivered, at least one strength test shall be made for each class of concrete.

17.6 If preliminary checks of slump, slump flow, or air content are made, a single sample shall be taken after the discharge of not less than ¼ yd^3 or ¼ m^3. All other requirements of Practice C172 shall be retained. If the preliminary measurement of slump (12.7) or air content (8.3) falls outside the specified limits, address as indicated in section 17.6.1 or 17.6.2 as appropriate.

17.6.1 If the measured slump or slump flow, or air content, or both is greater than the specified upper limit, a check test shall be made immediately on a new test sample. In the event the check test fails, the concrete shall be considered to have failed the requirements of the specification.

17.6.2 If the measured slump or slump flow, or air content, or both is less than the lower limit, permit adjustments in accordance with 12.7 or 8.3 or both, as appropriate, and obtain a new sample. If the sample of the adjusted concrete fails, a check test shall be made immediately on a new sample of the adjusted concrete. In the event the check test fails, the concrete shall be considered to have failed the requirements of the specification.

18. Strength

18.1 When strength is used as a basis for acceptance of concrete, standard specimens shall be made in accordance to Practice C31/C31M. The specimens shall be cured under standard moisture and temperature conditions in accordance with the applicable provisions of Practice C31/C31M. The technician performing the strength test shall be certified as an

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ACI Concrete Strength Testing Technician, Concrete Laboratory Testing Technician—Grade II or by an equivalent written and performance test program covering the relevant test methods. If acceptance is based upon compressive strength test results, the certification requirement is satisfied by certification as an ACI Concrete Laboratory Testing Technician—Grade I or by an equivalent written and performance test program.

18.2 For a strength test, at least two standard test specimens shall be made from a composite sample secured as required in Section 17. A test shall be the average of the strengths of the specimens tested at the age specified in 6.2.1.1 or 6.4.1.1 (Note 20). If a specimen shows definite evidence other than low strength, of improper sampling, molding, handling, curing, or testing, it shall be discarded and the strength of the remaining cylinder shall then be considered the test result.

NOTE 20—Additional tests may be made at other ages to obtain information for determining form removal time or when a structure may be put in service. Specimens for such tests are cured according to the section on Field Curing in Practice C31/C31M.

18.3 The representative of the purchaser shall ascertain and record the delivery-ticket number for the concrete and the exact location in the work at which each load represented by a strength test is deposited.

18.4 To conform to the requirements of this specification, strength tests representing each class of concrete must meet the following two requirements (Note 21):

18.4.1 The average of any three consecutive strength tests shall be equal to, or greater than, the specified strength, f'_c, and

18.4.2 When the specified strength is 5000 psi [35 MPa] or less, no individual strength test (average of two cylinder tests) shall be more than 500 psi [3.5 MPa] below the specified strength, f'_c.

NOTE 21—Due to variations in materials, operations, and testing, the average strength necessary to meet these requirements will be substantially higher than the specified strength. The amount higher depends upon the standard deviation of the test results and the accuracy with which that value can be estimated from prior data as explained in ACI 318 and ACI 301. Pertinent data are given in Appendix X1.

18.4.3 When the specified strength is greater than 5000 psi [35 MPa], no individual strength test (average of two cylinder tests) shall be less than 0.90 f'_c.

19. Failure to Meet Strength Requirements

19.1 In the event that concrete tested in accordance with the requirements of Section 18 fails to meet the strength requirements of this specification, the manufacturer of the ready-mixed concrete and the purchaser shall confer to determine whether agreement can be reached as to what adjustment, if any, shall be made. If an agreement on a mutually satisfactory adjustment cannot be reached by the manufacturer and the purchaser, a decision shall be made by a panel of three qualified engineers, one of whom shall be designated by the purchaser, one by the manufacturer, and the third chosen by these two members of the panel. The question of responsibility for the cost of such arbitration shall be determined by the panel. Its decision shall be binding, except as modified by a court decision.

20. Keywords

20.1 accuracy; blended hydraulic cement; certification; ready-mixed concrete; scales; testing

ANNEX

(Mandatory Information)

A1. CONCRETE UNIFORMITY REQUIREMENTS

A1.1 The variation within a batch as provided in Table A1.1 shall be determined for each property listed as the difference between the highest value and the lowest value obtained from the different portions of the same batch. For this specification the comparison will be between two samples, representing the first and last portions of the batch being tested. Test results

TABLE A1.1 Requirements for Uniformity of Concrete

Test	Requirement, Expressed as Maximum Permissible Difference in Results of Tests of Samples Taken from Two Locations in the Concrete Batch
Mass per cubic foot [mass per cubic meter] calculated to an air-free basis, lb/ft^3[kg/m^3]	1.0 [16]
Air content, volume % of concrete	1.0
Slump:	
If average slump is 4 in. [100 mm] or less, in. [mm]	1.0 [25]
If average slump is 4 to 6 in. [100 to 150 mm], in. [mm]	1.5 [40]
Coarse aggregate content, portion by mass of each sample retained on No. 4 [4.75-mm] sieve, %	6.0
Mass per unit volume of air-free mortar[A] based on average for all comparative samples tested, %.	1.6
Average compressive strength at 7 days for each sample,[B] based on average strength of all comparative test specimens, %	7.5[C]

[A] "Test for Variability of Constituents in Concrete," Designation 26, *Bureau of Reclamation Concrete Manual,* 7th Edition.[5]
[B] Not less than 3 cylinders will be molded and tested from each of the samples.
[C] Approval of the mixer shall be tentative, pending results of the 7-day compressive strength tests.

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conforming to the limits of five of the six tests listed in Table A1.1 shall indicate uniform concrete within the limits of this specification.

A1.2 *Coarse Aggregate Content,* using the washout test, shall be computed from the following relations:

$$P = (c/b) \times 100 \quad \text{(A1.1)}$$

where:

P = mass % of coarse aggregate in concrete,
c = saturated-surface-dry mass in lb [kg] of aggregate retained on the No. 4 [4.75-mm] sieve, resulting from washing all material finer than this sieve from the fresh concrete, and
b = mass of sample of fresh concrete in mass per unit volume container, lb [kg].

A1.3 *Mass per Unit Volume of Air Free Mortar* shall be calculated as follows:

Inch-pound units:

$$M = \frac{b - c}{V - \left(\frac{V \times A}{100} + \frac{c}{G}\right)} \quad \text{(A1.2)}$$

SI units:

$$M = \frac{b - c}{V - \left(\frac{V \times A}{100} + \frac{c}{G}\right)} \quad \text{(A1.3)}$$

where:

M = mass per unit volume of air-free mortar, lb/ft^3 [kg/m^3],
b = mass of concrete sample in mass container, lb [kg],
c = saturated-surface-dry mass of aggregate retained on No. 4 [4.75-mm] sieve, lb [kg],
V = volume of mass per unit volume container, ft^3 [m^3],
A = air content of concrete, %, measured in accordance with 16.1.4 on the sample being tested, and
G = density of coarse aggregate (SSD).

APPENDIX

(Nonmandatory Information)

X1. Calculation of the Average Compressive Strength (f'_{cr}), Necessary to Meet the Strength Requirements of Sections 18.4.1, 18.4.2, and 18.4.3

X1.1 Section 18.4 of this specification contains the same strength requirements as those contained in ACI 318 and ACI 301, except it does not require the submittal of the data and calculation of the average strength, f'_{cr} necessary to meet those ACI Code and Specifications. This Appendix does not include all of the detailed requirements of the ACI Code and Specification that will govern a submittal for their respective purposes. The following material is intended to guide users of this specification when no formal submittal is required.

X1.1.1 Table X1.1 provides the statistical formulas that can be used to calculate the required average strength f'_{cr} when historical statistical data are available. The formula to achieve a satisfactory average of three consecutive strength tests as

TABLE X1.1 Required Average Compressive Strength when Data are Available to Establish a Standard Deviation

Inch-pound System			SI System		
Specified Strength f'_c, psi	Required Average Strength f'_{cr}, psi		Specified Strength f'_c, MPa	Required Average Strength f'_{cr}, MPa	
f'_c equal to or less than 5000	Use the larger from Eq X1.1 and X1.2		f'_c equal to or less than 35	Use the larger from Eq X1.1 and X1.2m	
	$f'_{cr} = f'_c + 1.34s$	(X1.1)		$f'_{cr} = f'_c + 1.34s$	(X1.1)
	$f'_{cr} = f'_c + 2.33s - 500$	(X1.2)		$f'_{cr} = f'_c + 2.33s - 3.45$	(X1.2m)
greater than 5000	Use the larger from Eq X1.1 and X1.3		greater than 35	Use the larger from Eq X1.1 and X1.3	
	$f'_{cr} = f'_c + 1.34s$	(X1.1)		$f'_{cr} = f'_c + 1.34s$	(X1.1)
	$f'_{cr} = 0.90f'_c + 2.33s$	(X1.3)		$f'_{cr} = 0.90f'_c + 2.33s$	(X1.3)

where:

f'_c = the specified compressive strength
f'_{cr} = the required average compressive strength
s = the standard deviation

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required in 18.4.1 is (Eq. X1.1) of Table X1.1. The formulas for the minimum strength of an individual strength test result as required in 18.4.2 and 18.4.3 are (Eq. X1.2) and (Eq. X1.3) in Table X1.1. Since the average strength, f'_{cr}, must be high enough to conform to both averages of three consecutive tests and the requirements on minimum strength of a test, the one which requires highest average strength (f'_{cr}) governs.

X1.1.2 The first step in the process of calculating the over-design above f'_c or the required average strength is to determine if a record of 30 consecutive tests is available for the proposed mixture or similar mixture with a design strength within 1000 psi [6.6 MPa] of the specified compressive strength proposed for use. If it is a new mixture or strength level and no standard deviation data is available then Table X1.2 provides default levels of over-design equal to 1000, 1200 or ($1.10f'_c$ +700) psi.

X1.1.3 Table X1.3 provides calculated values of over-design and required average strength for selected standard deviations and specified strength levels. Because of the large ranges of strength and standard deviations, the gray shaded areas are considered unusual or not likely to be encountered.

TABLE X1.2 Required Average Compressive Strength When Data Are Not Available to Establish a Standard Deviation

Inch-pound System		SI System	
Specified Strength f'_c, psi	Required Average Strength f'_{cr}, psi	Specified Strength f'_c, MPa	Required Average Strength f'_{cr}, MPa
Less than 3000	f'_c + 1000	Less than 21	f'_c + 7.0
3000 to 5000	f'_c + 1200	21 to 35	f'_c + 8.5
greater than 5000	$1.10f'_c$ + 700	greater than 35	$1.10f'_c$ + 5.0

where:
f'_c = the specified compressive strength
f'_{cr} = the required average compressive strength
s = the standard deviation

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TABLE X1.3 Overdesign Necessary to Conform to Specified Compressive Strength

Inch - Pound units — Required Overdesign

f'c, psi		Standard Deviation from field data				no SD data
Specified	300	500	700	900	1,100	unknown
Strength	Overdesign above f'c					
less than 3000						f'c+1000
3,000	402	670	1,131	1,597	2,063	1,200
5,000	402	670	1,131	1,597	2,063	1,200
7,000	402	670	938	1,397	1,863	1,400
9,000	402	670	938	1,206	1,663	1,600
11,000	402	670	938	1,206	1,474	1,800
13,000	402	670	938	1,206	1,474	2,000
15,000	402	670	938	1,206	1,474	2,200
17,000	402	670	938	1,206	1,474	2,400

SI metric units — Required Overdesign

f'c, MPa		Standard Deviation from field data				no SD data
Specified	2.0	3.5	5.0	6.0	7.5	unknown
Strength	Overdesign above f'c					
less than 21						f'c+7.0
21	3.0	5.0	8.5	10.8	14.3	8.5
35	2.7	4.7	8.2	10.5	14.0	8.5
50	2.7	4.7	6.7	9.0	12.5	10.0
60	2.7	4.7	6.7	8.0	11.5	11.0
75	2.7	4.7	6.7	8.0	10.1	12.5
90	2.7	4.7	6.7	8.0	10.1	14.0
100	2.7	4.7	6.7	8.0	10.1	15.0
120	2.7	4.7	6.7	8.0	10.1	17.0

Required Average Strength

f'c, psi		Standard Deviation from field data, psi				no SD data
Specified	300	500	700	900	1,100	unknown
Strength	f'cr, required Average Strength, psi					
less than 3000						f'c+1000
3,000	3,402	3,670	4,131	4,597	5,063	4,200
5,000	5,402	5,670	6,131	6,597	7,063	6,200
7,000	7,402	7,670	7,938	8,397	8,863	8,400
9,000	9,402	9,670	9,938	10,206	10,663	10,600
11,000	11,402	11,670	11,938	12,206	12,474	12,800
13,000	13,402	13,670	13,938	14,206	14,474	15,000
15,000	15,402	15,670	15,938	16,206	16,474	17,200
17,000	17,402	17,670	17,938	18,206	18,474	19,400

SI metric units — Required Average Strength

f'c, MPa		Standard Deviation, Mpa from field data				No data
Specified	2.0	3.5	5.0	6.0	7.5	unknown
Strength	f'cr, required Average Strength, MPa					
less than 21						f'c+7.0
21.0	24	26	29	32	35	29.5
35.0	38	40	43	46	49	43.5
50.0	53	55	57	59	62	60.0
60.0	63	65	67	68	71	71.0
75.0	78	80	82	83	85	87.5
90.0	93	95	97	98	100	104.0
100.0	103	105	107	108	110	115.0
120.0	123	125	127	128	130	137.0

Shaded Areas identify levels of specified strength where the standard deviations should be considered unusual or inappropiate.

SUMMARY OF CHANGES

Committee C09 has identified the location of selected changes to this specification since the last issue, C94/C94M – 09, that may impact the use of this specification. (Approved November 1, 2009)

(*1*) Revised the standard throughout to add slump flow. Added new 6.1.3, 7.1.3, and 16.1.6 and renumbered subsequent paragraphs.

Committee C09 has identified the location of selected changes to this specification since the last issue, C94/C94M – 07, that may impact the use of this specification. (Approved January 1, 2009)

(*1*) Revised 1.1, 4.1, 4.2, 9.1, and 9.4.
(*2*) Added new definitions in Section 3.
(*3*) Added new Note 14 and Note 15.

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Designation: C 109/C 109M – 08

Standard Test Method for Compressive Strength of Hydraulic Cement Mortars (Using 2-in. or [50-mm] Cube Specimens)[1]

This standard is issued under the fixed designation C 109/C 109M; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

This standard has been approved for use by agencies of the Department of Defense.

1. Scope*

1.1 This test method covers determination of the compressive strength of hydraulic cement mortars, using 2-in. or [50-mm] cube specimens.

NOTE 1—Test Method C 349 provides an alternative procedure for this determination (not to be used for acceptance tests).

1.2 This test method covers the application of the test using either inch-pound or SI units. The values stated in either SI units or inch-pound units are to be regarded separately as standard. Within the text, the SI units are shown in brackets. The values stated in each system may not be exact equivalents; therefore, each system shall be used independently of the other. Combining values from the two systems may result in nonconformance with the standard.

1.3 Values in SI units shall be obtained by measurement in SI units or by appropriate conversion, using the Rules for Conversion and Rounding given in Standard IEEE/ASTM SI 10, of measurements made in other units.

1.4 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use. (***Warning—**Fresh hydraulic cementitious mixtures are caustic and may cause chemical burns to skin and tissue upon prolonged exposure.[2])

2. Referenced Documents

2.1 *ASTM Standards:*[3]

C 91 Specification for Masonry Cement

C 114 Test Methods for Chemical Analysis of Hydraulic Cement

C 150 Specification for Portland Cement

C 230/C 230M Specification for Flow Table for Use in Tests of Hydraulic Cement

C 305 Practice for Mechanical Mixing of Hydraulic Cement Pastes and Mortars of Plastic Consistency

C 349 Test Method for Compressive Strength of Hydraulic-Cement Mortars (Using Portions of Prisms Broken in Flexure)

C 511 Specification for Mixing Rooms, Moist Cabinets, Moist Rooms, and Water Storage Tanks Used in the Testing of Hydraulic Cements and Concretes

C 595 Specification for Blended Hydraulic Cements

C 618 Specification for Coal Fly Ash and Raw or Calcined Natural Pozzolan for Use in Concrete

C 670 Practice for Preparing Precision and Bias Statements for Test Methods for Construction Materials

C 778 Specification for Standard Sand

C 989 Specification for Ground Granulated Blast-Furnace Slag for Use in Concrete and Mortars

C 1005 Specification for Reference Masses and Devices for Determining Mass and Volume for Use in the Physical Testing of Hydraulic Cements

C 1157 Performance Specification for Hydraulic Cement

C 1328 Specification for Plastic (Stucco) Cement

C 1329 Specification for Mortar Cement

C 1437 Test Method for Flow of Hydraulic Cement Mortar

IEEE/ASTM SI 10 Standard for Use of the International System of Units (SI): The Modern Metric System

3. Summary of Test Method

3.1 The mortar used consists of 1 part cement and 2.75 parts of sand proportioned by mass. Portland or air-entraining portland cements are mixed at specified water/cement ratios. Water content for other cements is that sufficient to obtain a flow of 110 ± 5 in 25 drops of the flow table. Two-inch or [50-mm] test cubes are compacted by tamping in two layers.

[1] This test method is under the jurisdiction of ASTM Committee C01 on Cement and is the direct responsibility of Subcommittee C01.27 on Strength.

Current edition approved Dec. 1, 2008. Published January 2009. Originally approved in 1934. Last previous edition approved in 2007 as C 109/C 109M – 07$^{\varepsilon 1}$.

[2] See the section on Safety, Manual of Cement Testing, *Annual Book of ASTM Standards*, Vol 04.01.

[3] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

***A Summary of Changes section appears at the end of this standard.**

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The cubes are cured one day in the molds and stripped and immersed in lime water until tested.

4. Significance and Use

4.1 This test method provides a means of determining the compressive strength of hydraulic cement and other mortars and results may be used to determine compliance with specifications. Further, this test method is referenced by numerous other specifications and test methods. Caution must be exercised in using the results of this test method to predict the strength of concretes.

5. Apparatus

5.1 *Weights and Weighing Devices*, shall conform to the requirements of Specification C 1005. The weighing device shall be evaluated for precision and accuracy at a total load of 2000 g.

5.2 *Glass Graduates*, of suitable capacities (preferably large enough to measure the mixing water in a single operation) to deliver the indicated volume at 20 °C. The permissible variation shall be ±2 mL. These graduates shall be subdivided to at least 5 mL, except that the graduation lines may be omitted for the lowest 10 mL for a 250-mL graduate and for the lowest 25 mL of a 500-mL graduate. The main graduation lines shall be circles and shall be numbered. The least graduations shall extend at least one seventh of the way around, and intermediate graduations shall extend at least one fifth of the way around.

5.3 *Specimen Molds*, for the 2-in. or [50-mm] cube specimens shall be tight fitting. The molds shall have not more than three cube compartments and shall be separable into not more than two parts. The parts of the molds when assembled shall be positively held together. The molds shall be made of hard metal not attacked by the cement mortar. For new molds the Rockwell hardness number of the metal shall be not less than 55 HRB. The sides of the molds shall be sufficiently rigid to prevent spreading or warping. The interior faces of the molds shall be plane surfaces and shall conform to the tolerances of Table 1.

5.4 *Mixer, Bowl and Paddle*, an electrically driven mechanical mixer of the type equipped with paddle and mixing bowl, as specified in Practice C 305.

5.5 *Flow Table and Flow Mold*, conforming to the requirements of Specification C 230/C 230M.

5.6 *Tamper*, a nonabsorptive, nonabrasive, nonbrittle material such as a rubber compound having a Shore A durometer hardness of 80 ± 10 or seasoned oak wood rendered nonabsorptive by immersion for 15 min in paraffin at approximately 392 °F or [200 °C], shall have a cross section of about ½ by 1 in. or [13 by 25 mm] and a convenient length of about 5 to 6 in. or [120 to 150 mm]. The tamping face shall be flat and at right angles to the length of the tamper.

5.7 *Trowel*, having a steel blade 4 to 6 in. [100 to 150 mm] in length, with straight edges.

5.8 *Moist Cabinet or Room,* conforming to the requirements of Specification C 511.

5.9 *Testing Machine*, either the hydraulic or the screw type, with sufficient opening between the upper bearing surface and the lower bearing surface of the machine to permit the use of verifying apparatus. The load applied to the test specimen shall be indicated with an accuracy of ±1.0 %. If the load applied by the compression machine is registered on a dial, the dial shall be provided with a graduated scale that can be read to at least the nearest 0.1 % of the full scale load (Note 2). The dial shall be readable within 1 % of the indicated load at any given load level within the loading range. In no case shall the loading range of a dial be considered to include loads below the value that is 100 times the smallest change of load that can be read on the scale. The scale shall be provided with a graduation line equal to zero and so numbered. The dial pointer shall be of sufficient length to reach the graduation marks; the width of the end of the pointer shall not exceed the clear distance between the smallest graduations. Each dial shall be equipped with a zero adjustment that is easily accessible from the outside of the dial case, and with a suitable device that at all times until reset, will indicate to within 1 % accuracy the maximum load applied to the specimen.

5.9.1 If the testing machine load is indicated in digital form, the numerical display must be large enough to be easily read. The numerical increment must be equal to or less than 0.10 % of the full scale load of a given loading range. In no case shall the verified loading range include loads less than the minimum numerical increment multiplied by 100. The accuracy of the indicated load must be within 1.0 % for any value displayed within the verified loading range. Provision must be made for adjusting to indicate true zero at zero load. There shall be provided a maximum load indicator that at all times until reset will indicate within 1 % system accuracy the maximum load applied to the specimen.

NOTE 2—As close as can be read is considered 1/50 in. or [0.5 mm] along the arc described by the end of the pointer. Also, one half of the scale interval is about as close as can reasonably be read when the spacing on the load indicating mechanism is between 1/25 in. or [1 mm] and 1/16 in. or [1.6 mm]. When the spacing is between 1/16 in. or [1.6 mm] and 1/8 in. or [3.2 mm], one third of the scale interval can be read with reasonable certainty. When the spacing is 1/8 in. or [3.2 mm] or more, one fourth of the scale interval can be read with reasonable certainty.

TABLE 1 Permissible Variations of Specimen Molds

	2-in. Cube Molds		[50-mm] Cube Molds	
Parameter	New	In Use	New	In Use
Planeness of sides	<0.001 in.	<0.002 in.	[<0.025 mm]	[<0.05 mm]
Distance between opposite sides	2 in. ± 0.005	2 in. ± 0.02	[50 mm ± 0.13 mm]	[50 mm ± 0.50 mm]
Height of each compartment	2 in. + 0.01 in. to – 0.005 in.	2 in. + 0.01 in. to – 0.015 in.	[50 mm + 0.25 mm to – 0.13 mm]	[50 mm + 0.25 mm to – 0.38 mm]
Angle between adjacent faces[A]	90 ± 0.5°	90 ± 0.5°	90 ± 0.5°	90 ± 0.5°

[A] Measured at points slightly removed from the intersection. Measured separately for each compartment between all the interior faces and the adjacent face and between interior faces and top and bottom planes of the mold.

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5.9.2 The upper bearing shall be a spherically seated, hardened metal block firmly attached at the center of the upper head of the machine. The center of the sphere shall lie at the center of the surface of the block in contact with the specimen. The block shall be closely held in its spherical seat, but shall be free to tilt in any direction. A hardened metal bearing block shall be used beneath the specimen to minimize wear of the lower platen of the machine. To facilitate accurate centering of the test specimen in the compression machine, one of the two surfaces of the bearing blocks shall have a diameter or diagonal of between 2.83 in. [70.7 mm] (See Note 3) and 2.9 in. [73.7 mm]. When the upper block bearing surface meets this requirement, the lower block bearing surface shall be greater than 2.83 in. [70.7 mm]. When the lower block bearing surface meets this requirement, the diameter or diagonal of upper block bearing surface shall be between 2.83 and 3⅛ in. [70.7 and 79.4 mm]. When the lower block is the only block with a diameter or diagonal between 2.83 and 2.9 in. [70.7 and 73.7 mm], the lower block shall be used to center the test specimen. In that case, the lower block shall be centered with respect to the upper bearing block and held in position by suitable means. The bearing block surfaces intended for contact with the specimen shall have a Rockwell harness number not less than 60 HRC. These surfaces shall not depart from plane surfaces by more than 0.0005 in. [0.013 mm] when the blocks are new and shall be maintained within a permissible variation of 0.001 in. or [0.025 mm].

NOTE 3—The diagonal of a 2 in. [50 mm] cube is 2.83 in. [70.7 mm].

6. Materials

6.1 *Graded Standard Sand*:

6.1.1 The sand (Note 4) used for making test specimens shall be natural silica sand conforming to the requirements for graded standard sand in Specification C 778.

NOTE 4—*Segregation of Graded Sand*—The graded standard sand should be handled in such a manner as to prevent segregation, since variations in the grading of the sand cause variations in the consistency of the mortar. In emptying bins or sacks, care should be exercised to prevent the formation of mounds of sand or craters in the sand, down the slopes of which the coarser particles will roll. Bins should be of sufficient size to permit these precautions. Devices for drawing the sand from bins by gravity should not be used.

7. Temperature and Humidity

7.1 *Temperature*—The temperature of the air in the vicinity of the mixing slab, the dry materials, molds, base plates, and mixing bowl, shall be maintained between 73.5 ± 5.5 °F or [23.0 ± 3.0 °C]. The temperature of the mixing water, moist closet or moist room, and water in the storage tank shall be set at 73.5 ± 3.5 °F or [23 ± 2 °C].

7.2 *Humidity*—The relative humidity of the laboratory shall be not less than 50 %. The moist closet or moist room shall conform to the requirements of Specification C 511.

8. Test Specimens

8.1 Make two or three specimens from a batch of mortar for each period of test or test age.

9. Preparation of Specimen Molds

9.1 Apply a thin coating of release agent to the interior faces of the mold and non-absorptive base plates. Apply oils and greases using an impregnated cloth or other suitable means. Wipe the mold faces and the base plate with a cloth as necessary to remove any excess release agent and to achieve a thin, even coating on the interior surfaces. When using an aerosol lubricant, spray the release agent directly onto the mold faces and base plate from a distance of 6 to 8 in. or [150 to 200 mm] to achieve complete coverage. After spraying, wipe the surface with a cloth as necessary to remove any excess aerosol lubricant. The residue coating should be just sufficient to allow a distinct finger print to remain following light finger pressure (Note 5).

9.2 Seal the surfaces where the halves of the mold join by applying a coating of light cup grease such as petrolatum. The amount should be sufficient to extrude slightly when the two halves are tightened together. Remove any excess grease with a cloth.

9.3 Seal molds to their base plates with a watertight sealant. Use microcrystalline wax or a mixture of three parts paraffin to five parts rosin by mass. Paraffin wax is permitted as a sealant with molds that clamp to the base plate. Liquefy the wax by heating it to a temperature of between 230 and 248 °F or [110 and 120 °C]. Effect a watertight seal by applying the liquefied sealant at the outside contact lines between the mold and its base plate (Note 6).

9.4 Optionally, a watertight sealant of petroleum jelly is permitted for clamped molds. Apply a small amount of petroleum jelly to the entire surface of the face of the mold that will be contacting the base plate. Clamp the mold to the base plate and wipe any excess sealant from the interior of the mold and base plate.

NOTE 5—Because aerosol lubricants evaporate, molds should be checked for a sufficient coating of lubricant immediately prior to use. If an extended period of time has elapsed since treatment, retreatment may be necessary.

NOTE 6—*Watertight Molds*—The mixture of paraffin and rosin specified for sealing the joints between molds and base plates may be found difficult to remove when molds are being cleaned. Use of straight paraffin is permissible if a watertight joint is secured, but due to the low strength of paraffin it should be used only when the mold is not held to the base plate by the paraffin alone. When securing clamped molds with paraffin, an improved seal can be obtained by slightly warming the mold and base plate prior to applying the wax. Molds so treated should be allowed to return to room temperature before use.

10. Procedure

10.1 *Composition of Mortars*:

10.1.1 The proportions of materials for the standard mortar shall be one part of cement to 2.75 parts of graded standard sand by weight. Use a water-cement ratio of 0.485 for all portland cements and 0.460 for all air-entraining portland cements. The amount of mixing water for other than portland and air-entraining portland cements shall be such as to produce a flow of 110 ± 5 as determined in accordance with 10.3 and shall be expressed as weight percent of cement.

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10.1.2 The quantities of materials to be mixed at one time in the batch of mortar for making six and nine test specimens shall be as follows:

	Number of Specimens	
	6	9
Cement, g	500	740
Sand, g	1375	2035
Water, mL		
Portland (0.485)	242	359
Air-entraining portland (0.460)	230	340
Other (to flow of 110 ± 5)	...	...

10.2 *Preparation of Mortar*:

10.2.1 Mechanically mix in accordance with the procedure given in Practice C 305.

10.3 *Determination of Flow*:

10.3.1 Determine flow in accordance with procedure given in Test Method C 1437.

10.3.2 For portland and air-entraining portland cements, merely record the flow.

10.3.3 In the case of cements other than portland or air-entraining portland cements, make trial mortars with varying percentages of water until the specified flow is obtained. Make each trial with fresh mortar.

10.3.4 Immediately following completion of the flow test, return the mortar from the flow table to the mixing bowl. Quickly scrape the bowl sides and transfer into the batch the mortar that may have collected on the side of the bowl and then remix the entire batch 15 s at medium speed. Upon completion of mixing, the mixing paddle shall be shaken to remove excess mortar into the mixing bowl.

10.3.5 When a duplicate batch is to be made immediately for additional specimens, the flow test may be omitted and the mortar allowed to stand in the mixing bowl 90 s without covering. During the last 15 s of this interval, quickly scrape the bowl sides and transfer into the batch the mortar that may have collected on the side of the bowl. Then remix for 15 s at medium speed.

10.4 *Molding Test Specimens*:

10.4.1 Complete the consolidation of the mortar in the molds either by hand tamping or by a qualified alternative method. Alternative methods include but are not limited to the use of a vibrating table or mechanical devices.

10.4.2 *Hand Tamping*—Start molding the specimens within a total elapsed time of not more than 2 min and 30 s after completion of the original mixing of the mortar batch. Place a layer of mortar about 1 in. or [25 mm] (approximately one half of the depth of the mold) in all of the cube compartments. Tamp the mortar in each cube compartment 32 times in about 10 s in 4 rounds, each round to be at right angles to the other and consisting of eight adjoining strokes over the surface of the specimen, as illustrated in Fig. 1. The tamping pressure shall be just sufficient to ensure uniform filling of the molds. The 4 rounds of tamping (32 strokes) of the mortar shall be completed in one cube before going to the next. When the tamping of the first layer in all of the cube compartments is completed, fill the compartments with the remaining mortar and then tamp as specified for the first layer. During tamping of the second layer, bring in the mortar forced out onto the tops of the molds after each round of tamping by means of the gloved fingers and the tamper upon completion of each round and before starting the next round of tamping. On completion of the tamping, the tops of all cubes should extend slightly above the tops of the molds. Bring in the mortar that has been forced out onto the tops of the molds with a trowel and smooth off the cubes by drawing the flat side of the trowel (with the leading edge slightly raised) once across the top of each cube at right angles to the length of the mold. Then, for the purpose of leveling the mortar and making the mortar that protrudes above the top of the mold of more uniform thickness, draw the flat side of the trowel (with the leading edge slightly raised) lightly once along the length of the mold. Cut off the mortar to a plane surface flush with the top of the mold by drawing the straight edge of the trowel (held nearly perpendicular to the mold) with a sawing motion over the length of the mold.

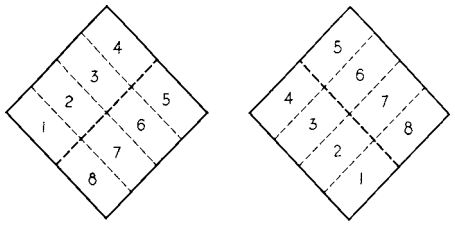

FIG. 1 Order of Tamping in Molding of Test Specimens

10.4.3 *Alternative Methods*—Any consolidation method may be used that meets the qualification requirements of this section. The consolidation method consists of a specific procedure, equipment and consolidation device, as selected and used in a consistent manner by a specific laboratory. The mortar batch size of the method may be modified to accommodate the apparatus, provided the proportions maintain the same ratios as given in 10.1.2.

10.4.3.1 Separate qualifications are required for the following classifications:

Class A, *Non-air entrained cements*—for use in concrete, such as sold under Specifications C 150, C 595, and C 1157.

Class B, *Air-entrained cements*—for use in concrete, such as sold under Specifications C 150, C 595, and C 1157.

Class C, *Masonry, Mortar and Stucco Cements*—such as sold under Specifications C 91, C 1328, and C 1329.

10.4.3.2 An alternative method may only be used to test the cement types as given in 10.4.3.1 above, for which it has been qualified.

10.4.3.3 It can also be used for Strength Activity Index determinations for fly ash and slag, such as sold under Specifications C 618 and C 989, provided the alternative method has qualified for both Class A and Class C cements.

10.4.4 *Qualification Procedure*—Contact CCRL to purchase cement samples that have been used in the Proficiency Sample Program (PSP). Four samples (5 Kg each) of the class to be qualified will be required to complete a single qualification (See Note 7).

10.4.4.1 In one day, prepare replicate 6-cube or 9-cube batches using one of the cements and cast a minimum of 36 cubes. Complete one round of tests on each cement on different days. Store and test all specimens as prescribed in the sections below. Test all cubes at the age of 7-days.

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10.4.4.2 Tabulate the compressive strength data and complete the mathematical analyses as instructed in Annex A1.

10.4.5 *Requalification of the Alternate Compaction Method*:

10.4.5.1 Requalification of the method shall be required if any of the following occur:

(1) Evidence that the method may not be providing data in accordance with the requirements of Table 2.

(2) Results that differ from the reported final average of a CCRL-PSP sample with a rating of 3 or less.

(3) Results that differ from the accepted value of a known reference sample with established strength values by more than twice the multi-laboratory 1s % values of Table 2.

Before starting the requalification procedure, evaluate all aspects of cube fabrication and testing process to determine if the offending result is due to some systematic error or just an occasional random event.

10.4.5.2 If the compaction equipment is replaced, significantly modified, repaired, or has been recalibrated, requalify the equipment in accordance with 10.4.4.

NOTE 7—It is recommended that a large homogenous sample of cement be prepared at the time of qualification for use as a secondary standard and for method evaluation. Frequent testing of this sample will give early warning of any changes in the performance of the apparatus.

10.5 *Storage of Test Specimens*—Immediately upon completion of molding, place the test specimens in the moist closet or moist room. Keep all test specimens, immediately after molding, in the molds on the base plates in the moist closet or moist room from 20 to 72 h with their upper surfaces exposed to the moist air but protected from dripping water. If the specimens are removed from the molds before 24 h, keep them on the shelves of the moist closet or moist room until they are 24-h old, and then immerse the specimens, except those for the 24-h test, in saturated lime water in storage tanks constructed of noncorroding materials. Keep the storage water clean by changing as required.

TABLE 2 Precision

		Test Age, Days	Coefficient of Variation 1s %[A]	Acceptable Range of Test Results d2s %[A]
Portland Cements				
Constant water-cement ratio:				
Single-lab		3	4.0	11.3
		7	3.6	10.2
	Av		3.8	10.7
Multi-lab		3	6.8	19.2
		7	6.4	18.1
	Av		6.6	18.7
Blended Cements				
Constant flow mortar:				
Single-lab		3	4.0	11.3
		7	3.8	10.7
		28	3.4	9.6
	Av		3.8	10.7
Multi-lab		3	7.8	22.1
		7	7.6	21.5
		28	7.4	20.9
	Av		7.6	21.5
Masonry Cements				
Constant flow mortar:				
Single-lab		7	7.9	22.3
		28	7.5	21.2
	Av		7.7	21.8
Multi-lab		7	11.8	33.4
		28	12.0	33.9
	Av		11.9	33.7

[A] These numbers represent, respectively, the (1s %) and (d2s %) limits as described in Practice C 670.

10.6 *Determination of Compressive Strength*:

10.6.1 Test the specimens immediately after their removal from the moist closet in the case of 24-h specimens, and from storage water in the case of all other specimens. All test specimens for a given test age shall be broken within the permissible tolerance prescribed as follows:

Test Age	Permissible Tolerance
24 h	±½ h
3 days	±1 h
7 days	±3 h
28 days	±12 h

If more than one specimen at a time is removed from the moist closet for the 24-h tests, keep these specimens covered with a damp cloth until time of testing. If more than one specimen at a time is removed from the storage water for testing, keep these specimens in water at a temperature of 73.5 ± 3.5 °F or [23 ± 2 °C] and of sufficient depth to completely immerse each specimen until time of testing.

10.6.2 Wipe each specimen to a surface-dry condition, and remove any loose sand grains or incrustations from the faces that will be in contact with the bearing blocks of the testing machine. Check these faces by applying a straightedge (Note 8). If there is appreciable curvature, grind the face or faces to plane surfaces or discard the specimen. A periodic check of the cross-sectional area of the specimens should be made.

NOTE 8—*Specimen Faces*—Results much lower than the true strength will be obtained by loading faces of the cube specimen that are not truly plane surfaces. Therefore, it is essential that specimen molds be kept scrupulously clean, as otherwise, large irregularities in the surfaces will occur. Instruments for cleaning molds should always be softer than the metal in the molds to prevent wear. In case grinding specimen faces is necessary, it can be accomplished best by rubbing the specimen on a sheet of fine emery paper or cloth glued to a plane surface, using only a moderate pressure. Such grinding is tedious for more than a few thousandths of an inch (hundredths of a millimetre); where more than this is found necessary, it is recommended that the specimen be discarded.

10.6.3 Apply the load to specimen faces that were in contact with the true plane surfaces of the mold. Carefully place the specimen in the testing machine below the center of the upper bearing block. Prior to the testing of each cube, it shall be ascertained that the spherically seated block is free to tilt. Use no cushioning or bedding materials. Bring the spherically seated block into uniform contact with the surface of the specimen. Apply the load rate at a relative rate of movement between the upper and lower platens corresponding to a loading on the specimen with the range of 200 to 400 lbs/s [900 to 1800 N/s]. Obtain this designated rate of movement of the platen during the first half of the anticipated maximum load and make no adjustment in the rate of movement of the platen in the latter half of the loading especially while the cube is yielding before failure.

NOTE 9—It is advisable to apply only a very light coating of a good quality, light mineral oil to the spherical seat of the upper platen.

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11. Calculation

11.1 Record the total maximum load indicated by the testing machine, and calculate the compressive strength as follows:

$$fm = P/A \quad (1)$$

where:

fm = compressive strength in psi or [MPa],
P = total maximum load in lbf or [N], and
A = area of loaded surface in^2 or [mm^2].

Either 2-in. or [50-mm] cube specimens may be used for the determination of compressive strength, whether inch-pound or SI units are used. However, consistent units for load and area must be used to calculate strength in the units selected. If the cross-sectional area of a specimen varies more than 1.5 % from the nominal, use the actual area for the calculation of the compressive strength. The compressive strength of all acceptable test specimens (see Section 12) made from the same sample and tested at the same period shall be averaged and reported to the nearest 10 psi [0.1 MPa].

12. Report

12.1 Report the flow to the nearest 1 % and the water used to the nearest 0.1 %. Average compressive strength of all specimens from the same sample shall be reported to the nearest 10 psi [0.1 MPa].

13. Faulty Specimens and Retests

13.1 In determining the compressive strength, do not consider specimens that are manifestly faulty.

13.2 The maximum permissible range between specimens from the same mortar batch, at the same test age is 8.7 % of the average when three cubes represent a test age and 7.6 % when two cubes represent a test age (Note 10).

NOTE 10—The probability of exceeding these ranges is 1 in 100 when the within-batch coefficient of variation is 2.1 %. The 2.1 % is an average for laboratories participating in the portland cement and masonry cement reference sample programs of the Cement and Concrete Reference Laboratory.

13.3 If the range of three specimens exceeds the maximum in 13.2, discard the result which differs most from the average and check the range of the remaining two specimens. Make a retest of the sample if less than two specimens remain after disgarding faulty specimens or disgarding tests that fail to comply with the maximum permissible range of two specimens.

NOTE 11—Reliable strength results depend upon careful observance of all of the specified requirements and procedures. Erratic results at a given test period indicate that some of the requirements and procedures have not been carefully observed; for example, those covering the testing of the specimens as prescribed in 10.6.2 and 10.6.3. Improper centering of specimens resulting in oblique fractures or lateral movement of one of the heads of the testing machine during loading will cause lower strength results.

14. Precision and Bias

14.1 *Precision*—The precision statements for this test method are listed in Table 2 and are based on results from the Cement and Concrete Reference Laboratory Reference Sample Program. They are developed from data where a test result is the average of compressive strength tests of three cubes molded from a single batch of mortar and tested at the same age. A significant change in precision will not be noted when a test result is the average of two cubes rather than three.

14.2 These precision statements are applicable to mortars made with cements mixed, and tested at the ages as noted. The appropriate limits are likely, somewhat larger for tests at younger ages and slightly smaller for tests at older ages.

14.3 *Bias*—The procedure in this test method has no bias because the value of compressive strength is defined in terms of the test method.

15. Keywords

15.1 compressive strength; hydraulic cement mortar; hydraulic cement strength; mortar strength; strength

ANNEX

(Mandatory Information)

A1. ANALYSES OF TEST RESULTS FOR QUALIFICATION OF ALTERNATE COMPACTION METHODS

A1.1 *Calculation of Average Within-Batch Standard Deviation and Elimination of Outliers*—Tabulate the results for each cement sample (or round) in separate spreadsheets. In the spreadsheet, list results of each batch in columns and complete the calculations as shown in Table A1.1.

A1.1.1 Eliminate any outliers from the test data and repeat the calculations until none of the values lie outside the normal range.

A1.1.2 Tabulate the cube strengths with all the outliers eliminated and complete the calculations as shown in Table A1.2.

A1.2 *Summary of Results*—Compile the results of the four rounds and complete the calculations as shown in Table A1.3. The number of outliers shall not exceed 5 % of the total number of tests when rounded to the nearest whole number (for example, 4 rounds × 4 batches × 9 cubes = 144 tests × (5%/100) = 7.2 or 7).

A1.3 *Precision Qualification*—Calculate the relative within batch error (RWBE %) as shown in Table A1.3. This value must be less than 2.1 % to comply with the limit established in Note 10 of this specification.

A1.4 *Bias Qualification*—The test results compiled in Table A1.3 are evaluated against three limits to demonstrate an acceptable qualification. The limits have been established

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TABLE A1.1 Example Using 9 Cube Batch

Round – 2
CCRL Sample # 140 Industry Average Strength, X_i = 32.923
Cast Date – 00/00/00

7-Day Strengths, MPa				
A	B	C	D	E
Batch No.	1	2	3	4
Cube 1	33.0	34.3	34.4	33.2
Cube 2	33.9	32.5	34.0	34.0
Cube 3	33.4	34.0	34.1	33.8
Cube 4	33.1	33.8	34.0	33.8
Cube 5	33.0	33.4	34.2	34.0
Cube 6	32.8	33.7	31.8	33.1
Cube 7	33.6	32.6	33.9	32.8
Cube 8	31.5	32.1	33.0	33.3
Cube 9	33.6	34.3	33.4	34.4
Average, X_b	33.10	33.42	33.65	33.60
SD_b	0.70	0.82	0.81	0.52
N_b	9	9	9	9
$(N_b–1)SD_b^2$	3.936	5.432	5.265	2.145
			N_r	36
			X_r	33.44
			SD_r	0.692
			MND	1.703
Normal Range				
Max	34.81	35.12	35.35	35.30
Min	31.40	31.71	32.95	31.89
Outliers	None	None	Cube 6	None

where:

X_i = industry average strength (CCRL),
X_b = average of tests values in a single batch,
SD_b = standard deviation of a single batch = $\sqrt{\frac{\sum_{Cube}(X - X_b)^2}{N_b - 1}}$
N_b = number of tests per batch,
$(N_b–1)SD_b^2$ = an intermediate calculation,
N_r = total number of tests per round,
X_r = grand average of tests values obtained per round, MPa,
SD_r = mean standard deviation of round = $\sqrt{\frac{\sum_{Batch}[(N_b - 1)SD_b^2]}{N_r - 1}}$
MND = maximum normal deviation: use Excel® function "=norminv(1–0.25/N_r,0,SD_r)" or equivalent, or use statistical tables to find the inverse integrated normal distribution for an integral value of (1–0.25/n_r) in a normal distribution with $\sigma = SD_r$.

Normal Range:
Maximum = (X_b + MND).
Minimum = (X_b – MND).
Outlier = any test value falling outside the calculated normal range.

statistically from analyses of historical CCRL data and are given in Table A1.4.

A1.5 *Rationale for the Limits Given in* A1.4:

A1.5.1 The multi-laboratory precision (1s%) for the average of *n* batches is given by:

$$s\%_{ML,n} = \sqrt{s\%_{ML}^2 - \left(1 - \frac{1}{n}\right)s\%_{SO}^2}$$

A1.5.2 The limit for deviation of the individual rounds (no failures being allowed when 4 rounds are performed) is 1.2 $s\%_{ML,n}$, as used in Test Methods C 114.

A1.5.3 The multi-laboratory precision (1s%) for the mean of 4 rounds is 0.5 $s\%_{ML,n}$.

TABLE A1.2 Test Data After the Elimination of Outliers (Example Using 9 Cube Batch)

Round – 2
CCRL Sample # 140 Industry Average Strength, X_i = 32.923
Cast Date – 00/00/00 Raw Cube Data:

7-Day Strengths, MPa				
A	B	C	D	E
Batch No.	1	2	3	4
Cube 1	33.0	34.3	34.4	33.2
Cube 2	33.9	32.5	34.0	34.0
Cube 3	33.4	34.0	34.1	33.8
Cube 4	33.1	33.8	34.0	33.8
Cube 5	33.0	33.4	34.2	34.0
Cube 6	32.8	33.7		33.1
Cube 7	33.6	32.6	33.9	32.8
Cube 8		32.1	33.0	33.3
Cube 9	33.6	34.3	33.4	34.4
Average, X_{bv}	33.29	33.42	33.89	33.60
SD_{bv}	0.39	0.82	0.46	0.52
N_{bv}	8	9	8	9
$(N_{bv}–1)SD_{bv}^2$	1.092	5.348	1.462	2.159
			N_{rv}	34
			X_{rv}	33.55
			X_i	32.92
			SD_{rv}	0.55
			E_r, MPa	0.63
			RE_r, %	1.91

where:

X_{bv} = average of valid test values obtained per batch, MPa,
X_i = industry average strength (CCRL), MPa,
SD_{bv} = $\sqrt{\frac{\sum_{ValidCube}(X - X_{bv})^2}{N_{bv} - 1}}$
N_{bv} = number of valid tests per batch,
$(N_{bv}\text{-}1)SD_{bv}^2$ = an intermediate calculation,
N_{rv} = total number of valid tests of the round,
X_{rv} = grand average of valid tests for the round, MPa,
SD_{rv} = mean standard deviation of the round = $\sqrt{\frac{\sum_{Batch}[(N_{bv} - 1)SD_{bv}^2]}{N_{rv} - 1}}$
E_r = error = (X_i – X_{rv}), MPa, and
RE_r = relative error for the round, % = 100(E_r/X_{rv}).

A1.5.4 The limit for deviation of the mean of 4 rounds (95 % confidence) is 1.96 times this, or 0.98 $s\%_{ML,n}$.

A1.5.5 The values for $s\%_{ML}$ and $s\%_{SO}$ for Cement Classes A and C (non-air-entrained cements for concrete and cements for mortar respectively) are the 7-day values in the current precision statement of Test Method C 109/C 109M. There appears to be no data for Cement Class B (air-entrained cements for concrete). Working on the assumption that the value of this quantity is related to the air content, the values adopted for Class B are the mean of the A- and C-values.

A1.5.6 For the applicable conditions, the equations above give the following:

Derivation of Limits for Table A1.4						
Cement Class	A	B	C	A	B	C
Batches per Round (n)	6	6	6	4	4	4
Single Operator s% (single batch)	3.6	5.75	7.9	3.6	5.75	7.9
Multi-Laboratory s% (single batch)	6.4	9.1	11.8	6.4	9.1	11.8
Multi-Laboratory s% (n batches)	5.5	7.4	9.3	5.6	7.6	9.6
Limit for deviation of a single round %	6.6	8.9	11.2	6.7	9.1	11.5
Limit for deviation of mean of four rounds %	5.4	7.3	9.2	5.5	7.5	9.4

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TABLE A1.3 Summary of Results

A	B CCRL #	C Day	D X_i, MPa	E X_{rv}, MPa	F RE_r, %	G N_{rv}	H SD_{rv}	I $(N_r-1)SD_r^2$
Round 1	139	1	28.47	30.42	6.85	36	0.97	32.93
Round 2	140	2	32.92	33.55	1.91	34	0.55	9.98
Round 3	141	3	32.64	33.14	1.53	34	0.47	7.29
Round 4	142	4	32.24	33.01	2.39	36	0.51	9.10
						Max, RE_r, %		6.85
						Mean, RE_r, %		3.17
						GMWBE, MPa		0.65
						RWBE, %		2.01
						Max RWBE, %[A]		2.1
						Precision Test		Pass

where:

X_r = industry average strength, MPa,
X_{rv} = grand mean value of the valid tests of a round,
RE_{rv}, % = relative error = $100(X_i - X_{rv})$,
N_{rv} = total number of valid tests of the round,
SD_{rv} = mean standard deviation of a round =

$$\sqrt{\frac{\sum_{Batch}[(N_{bv}-1)SD_{rv}^2]}{N_{rv}-1}}$$

$(N_r-1)SD_r^2$ = intermediate calculation,
X_g = grand mean value of all valid tests (4 rounds),
N_g = total number of valid tests in 4 rounds,
$GMWBE$ = grand mean within-batch error, MPa =

$$\sqrt{\frac{\sum_{Round}[(N_{rv}-1)SD_{rv}^2]}{N_g-1}}$$

$RWBE$ = relative within batch error, % = $100(GMWBE / X_g)$, and
$Max\ RWBE$ = maximum allowed RWBE = 2.10 % (See Note 10).

[A] See Note 9.

TABLE A1.4 Bias Qualification Requirements

	6 Cube Batches (Min 6 Batches per Round)			9 Cube Batches (Min 4 Batches per Round)		
Cement Classification (see 10.4.3.1)	A	B	C	A	B	C
Max allowable relative error any 4 or 6 batches, MAREr %	6.6	8.9	11.2	6.7	9.1	11.5
Max allowable relative error mean of 4 rounds of 4 or 6 batches <5 % failures, GRE%	5.4	7.3	9.2	5.5	7.5	9.4
Minimum allowable confidence limit, % MACL %	95	95	95	95	95	95

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TABLE A1.5 Bias Tests
(Example Using 9-Cube Batches, Class A Cement)

MREr %, the maximum relative error value of the four rounds	6.85
MAREr %, max allowable MREr from Table A1.4	6.7
	Fails
GRE %, the average REr % of the four rounds	3.13
Maximum limit of MGREg % from Table A1.4	5.5
	Pass
Bias confidence limit, CL %	96.99
Minimum allowable confidence limit, MACL % (from Table A1.4)	95
	Pass
The above results indicate the data fails to show compliance.	

where:

MREr, % = the maximum relative error, % obtained for any round (from values in column F, Table A1.3),

MAREr, % = the maximum allowable relative error, % of any Round (Table A1.4),

GRE, % = the grand average of the REr, % values of the four rounds,

MAREg, % = maximum allowed GRE, % value (average of column F, Table A1.3), and

CL, % = bias confidence limit, %, the confidence with which it can be stated that the error of the mean of 4 rounds is non-zero. Calculate this by use of Excel® function "=ttest(<range of industry means>,<range of values obtained>,1,1)" or equivalent, or use statistical tables to find the confidence in a one-tailed, paired-value t-test on the set of round errors.

NOTE—The qualification method fails for bias if *(1)* the MREr exceeds the MAREr, % limit; or if *(2)* the GRE, % exceeds the MGREg limit and the CL, % exceeds 95 %.

SUMMARY OF CHANGES

Committee C01 has identified the location of selected changes to this test method since the last issue, C 109/C 109M – 07$^{\varepsilon 1}$, that may impact the use of this test method. (Approved December 1, 2008).

(*1*) Revised 5.1.

(*2*) Revised 9.3, added new 9.4, and revised Note 6.

Committee C01 has identified the location of selected changes to this test method since the last issue, C 109/C 109M – 05, that may impact the use of this test method. (Approved August 15, 2007).

(*1*) Revised 5.9.2.

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Designation: C 110 – 09a

Standard Test Methods for Physical Testing of Quicklime, Hydrated Lime, and Limestone[1]

This standard is issued under the fixed designation C 110; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

This standard has been approved for use by agencies of the Department of Defense.

1. Scope*

1.1 These test methods cover physical testing of quicklime and hydrated lime, and of limestone not otherwise covered in ASTM standards.[2]

NOTE 1—Quicklime and hydrated lime have a high affinity for moisture and carbon dioxide. Caution should be taken to protect both hydrated and quicklime during sampling, storage, and testing (see Practice C 50).

1.2 The test procedures appear in the following order:

	Section
Air Entrainment	8
Apparent Loose Density of Hydrated Lime, Pulverized Quicklime, and Limestone	20
Apparent Packed Density of Hydrated Lime, Pulverized Quicklime, and Limestone	21
Autoclave Expansion of Hydrated Lime	9
Dry Brightness of Pulverized Limestone	12
Dry Screening by Air Jet Sieve	18
Fineness of Pulverized Quicklime and Hydrated Lime by Air Permeability	16
Limestone Grindability	13
Particle Size of Pulverized Limestone	17
Plasticity of Lime Putty	6
Popping and Pitting of Hydrated Lime	10
Residue and Sieve Analysis	15
Settling Rate of Hydrated Lime	14
Slaking Rate of Quicklime	11
Specific Gravity of Hydrated Lime Products	22
Standard Consistency of Lime Putty	5
Water Retention of Hydrated Lime	7
Wet Sieve Analysis of Agricultural Liming Materials	19

1.3 The values stated in SI units are to be regarded as standard. The values given in parentheses are mathematical conversions to inch-pound units that are provided for information only and are not considered standard.

1.4 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

2. Referenced Documents

2.1 *ASTM Standards:*[3]

C 28/C 28M Specification for Gypsum Plasters
C 50 Practice for Sampling, Sample Preparation, Packaging, and Marking of Lime and Limestone Products
C 51 Terminology Relating to Lime and Limestone (as used by the Industry)
C 91 Specification for Masonry Cement
C 109/C 109M Test Method for Compressive Strength of Hydraulic Cement Mortars (Using 2-in. or [50-mm] Cube Specimens)
C 136 Test Method for Sieve Analysis of Fine and Coarse Aggregates
C 150 Specification for Portland Cement
C 185 Test Method for Air Content of Hydraulic Cement Mortar
C 188 Test Method for Density of Hydraulic Cement
C 192/C 192M Practice for Making and Curing Concrete Test Specimens in the Laboratory
C 204 Test Methods for Fineness of Hydraulic Cement by Air-Permeability Apparatus
C 207 Specification for Hydrated Lime for Masonry Purposes
C 230/C 230M Specification for Flow Table for Use in Tests of Hydraulic Cement
C 231 Test Method for Air Content of Freshly Mixed Concrete by the Pressure Method
C 305 Practice for Mechanical Mixing of Hydraulic Cement Pastes and Mortars of Plastic Consistency
C 430 Test Method for Fineness of Hydraulic Cement by the 45-μm (No. 325) Sieve
C 472 Test Methods for Physical Testing of Gypsum, Gypsum Plasters and Gypsum Concrete

[1] These test methods are under the jurisdiction of ASTM Committee C07 on Lime and are the direct responsibility of Subcommittee C07.06 on Physical Tests.

Current edition approved June 15, 2009. Published July 2009. Originally approved in 1934. Last previous edition approved in 2008 as C 110–09.

[2] For tests on limestone as aggregate, see Vol 04.02 of the *Annual Book of ASTM Standards*. For tests on limestone as building stone, see Vol 04.05 of the *Annual Book of ASTM Standards*.

[3] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

***A Summary of Changes section appears at the end of this standard.**

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C 595 Specification for Blended Hydraulic Cements
C 670 Practice for Preparing Precision and Bias Statements for Test Methods for Construction Materials
C 702 Practice for Reducing Samples of Aggregate to Testing Size
C 778 Specification for Standard Sand
C 1005 Specification for Reference Masses and Devices for Determining Mass and Volume for Use in the Physical Testing of Hydraulic Cements
C 1107 Specification for Packaged Dry, Hydraulic-Cement Grout (Nonshrink)
D 75 Practice for Sampling Aggregates
E 11 Specification for Woven Wire Test Sieve Cloth and Test Sieves
E 29 Practice for Using Significant Digits in Test Data to Determine Conformance with Specifications
E 177 Practice for Use of the Terms Precision and Bias in ASTM Test Methods
E 691 Practice for Conducting an Interlaboratory Study to Determine the Precision of a Test Method

3. Terminology

3.1 *Definitions*—Unless otherwise specified, for definitions of terms used in this standard see Terminology C 51.

4. General Procedures

4.1 *Sampling*—Samples of lime and limestone for physical analysis shall be taken and prepared in accordance with the requirements of Practice C 50 applicable to the material to be tested.

4.2 *Calculation*:

4.2.1 The calculations included in the individual procedures sometimes assume that the exact weight specified has been used. Accurately weighed samples which are approximately but not exactly equal to the weight specified may be used provided appropriate corrections are made in the calculation. Unless otherwise stated, weights of all samples and residues should be recorded to the nearest 0.0001 g.

4.2.2 In all mathematical operations on a set of observed values, the equivalent of two more places of figures than in the single observed values shall be retained. For example, if observed values are read or determined to the nearest 0.1 mg, carry numbers to the nearest 0.001 mg in calculation.

4.3 *Rounding Figures*—Rounding of figures to the nearest significant place required in the report should be done after the calculations are completed, in order to keep the final results free from calculation errors. The rounding procedure should follow the principle outlined in Practice E 29.

PLASTIC PROPERTY TESTING

5. Standard Consistency of Lime Putty

5.1 *Significance and Use*:

5.1.1 In order to measure certain physical properties of a lime putty, such as plasticity, it is necessary to have a uniform or standard consistency (viscosity), since the property measurement is affected by the consistency level.

5.2 *Apparatus*:

5.2.1 *Modified Vicat Apparatus*—The apparatus, constructed as shown in Fig. 1, shall consist of a bracket, *A*, bearing a movable brass rod, *B*, 6.3 mm in diameter and of suitable length to fit the Vicat bracket. A plunger, *C*, 12.5 mm in diameter, made of aluminum tubing, shall be attached to the lower end of the rod. The total weight of the rod with plunger shall be 30 g. The lower end of the plunger shall be closed without shoulders or curvature and the tube may be loaded with shot to the specified weight. The total weight required may also be obtained by means of a weight, *D*, screwed into the rod. The rod can be held in any position by means of a screw, *E*, and has a mark midway between the ends which moves under a scale, *F*, graduated in millimetres, attached to the bracket, *A*.

5.2.2 *Mold*—The conical ring mold shall be made of a noncorroding, nonabsorbent material, and shall have an inside diameter of 70 mm at the base and 60 mm at the top, and a height of 40 mm.

5.2.3 *Base Plate*—The base plate for supporting the ring mold shall be of plate glass and about 100 mm square.

5.2.4 *Mechanical Mixers*.

5.3 *Standard Consistency Determination*:

5.3.1 *Mechanical Mixing Procedure Using the Vac-U-Mixer*—To a measured amount of water contained in an 800-cm^3 Vac-U-Mix bowl, add 300 g of hydrated lime and hand mix for 10 s with a stiff spatula (Note 2). Cover putty to prevent evaporation of water. After the applicable soaking period, 30 min maximum for Type S, special hydrated lime, and not less than 16 h nor more than 24 h for Type N, normal hydrated lime, insert the paddle assembly and mix the putty for 30 s with the mechanical mixer. Remove the paddle assembly and scrape down any putty adhering to it and to the sides of the

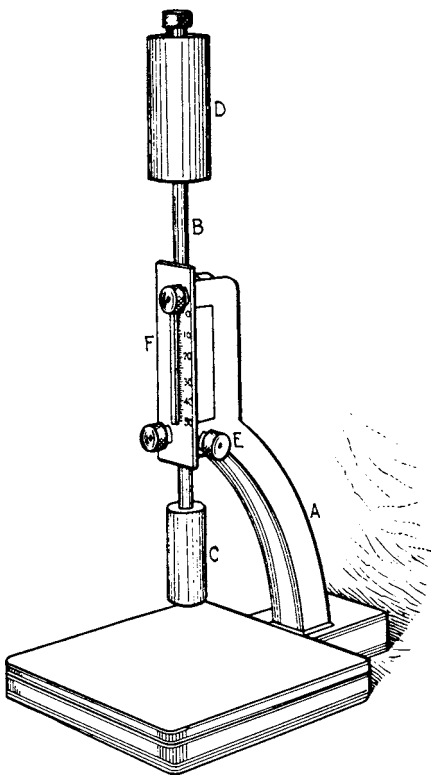

FIG. 1 Modified Vicat Apparatus

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mixing bowl. Remix for 30 s and determine the consistency as prescribed in 5.3. If the penetration is less than 15 mm, return all of the material to the mixer bowl, add additional water, and remix for 15 s. If the penetration is greater than 25 mm, repeat the test.

NOTE 2—Most lime hydrates will require 250 to 300 mL of water to produce a putty of proper consistency for this test if 300 g of lime are used.

5.3.2 *Mechanical Mixing Procedure Using the Hobart N-50 Mixer*—To a measured amount of water contained in the N-50 mixing bowl, add 600 g of hydrated lime and hand mix for 10 s with a stiff spatula (Note 3). Cover putty to prevent evaporation of water. After the applicable soaking period, 30 min maximum for Type S, special hydrated lime, and not less than 16 h nor more than 24 h for Type N, normal hydrated lime, insert the paddle assembly and mix the putty for 1 min at a slow speed. Stop the mixer and scrape down the paddle and the sides of the mixing bowl. Remix for 4 min at a slow speed. Determine the consistency as prescribed in 5.3.3. If the penetration is less than 15 mm, return all of the material to the mixing bowl, add additional water, and remix for 15 s. If the penetration is more than 25 mm, repeat the test.

NOTE 3—Most lime hydrates will require 500 to 600 mL of water to produce a putty of proper consistency for this test if 600 g of lime are used.

5.3.3 *Consistency Determination*—To determine consistency, place the mold with its larger end resting on the glass base plate and fill with the lime putty. Then strike off the putty flush with the top of the mold. Center the lime putty, confined in the ring mold resting on the plate, under the rod of the modified Vicat apparatus (Fig. 1). Bring the plunger end, *C*, in contact with the surface of the lime putty and take an initial reading. Release the rod and take the final reading 30 s after the plunger is released. The lime putty is of standard consistency when a penetration of 20 ± 5 mm is obtained. Record both the total amount of water required to bring the putty to standard consistency and the actual penetration. Proceed with the plasticity determination in accordance with 6.3.

5.4 *Precision and Bias*:

5.4.1 The precision and bias of this test method has not been determined.

6. Plasticity of Lime Putty

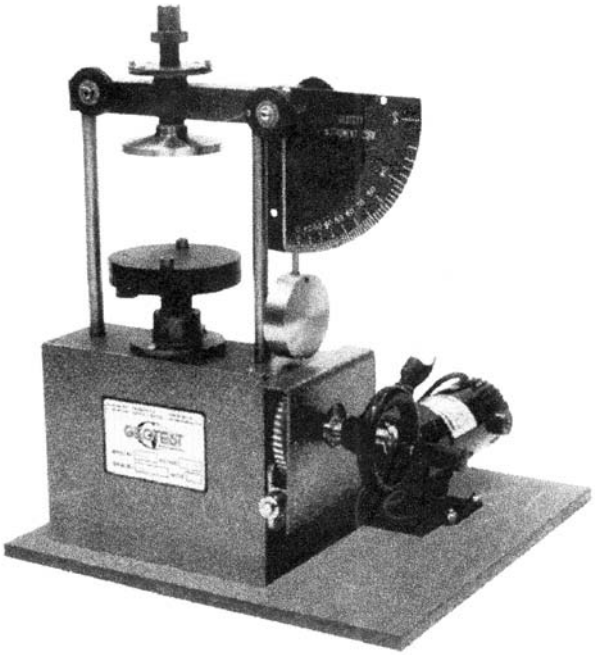
6.1 *Significance and Use*:

6.1.1 This test method provides a measure of the degree of stiffening of lime putty of standard consistency as water is withdrawn from it by a standard suction base plate.

6.1.2 Plasticity is an important property when applying mixtures containing lime putty to porous or absorptive surfaces such as in plastering, stuccoing, and masonry construction.

6.2 *Apparatus*:

6.2.1 Determine the plasticity of lime putty using the plasticimeter shown in Fig. 2.[4]



Constants of the Machine:

Absorption of Porcelain and Plaster Base Plate—minimum of 40 g in 24 h. For rate of absorption of base plates see 6.2.3.2.

Dimension of Base Plate—25 mm (1 in.) in thickness by 100 mm (4 in.) in diameter.

Dimensions of Disk—0.8 to 12.7 mm (1⁄32 to ½ in.) in thickness by 76 mm (3 in.) in diameter.

Speed of Vertical Shaft—1 revolution in 6 min, 40 s.

Torque on Disk when Bob Reading is 100—1.41 N·m.

FIG. 2 Emley Plasticimeter

6.2.2 *Cleaning and Care of Base Plates*—Base plates may be made of porcelain or plaster. In making the plasticity determinations, much of the success attainable depends upon the condition of the base plates. In the case of porcelain plates which are reused, improper cleaning results in clogging of the pores with reduction in the rate of absorption. After a porcelain plate has been used, wipe the excess lime off and immerse the plate in clear water for not less than 2 h, after which transfer it without drying to a dilute solution of hydrochloric acid (HCl, 1 + 9) where it shall be kept immersed for another 2 h. Then transfer to a receptacle containing running water for at least 1 h. The plate is then free of acid. After the removal of excess water, place the plate in an oven overnight at a temperature of between 100 and 110 °C (212 and 230 °F) for drying. Before using, cool the plate to room temperature. In the case of plaster base plates, dry the base plates prior to use in plasticity or absorption testing in an oven at a temperature between 37.8 and 48.9 °C (100 and 120 °F) until they achieve a constant weight. Before using, cool the plaster plate to room temperature in a dessicator charged with a drying agent. If the plate is not to be used immediately after reaching room temperature, continue to store the plate in the dessicator until such time that it is to be used. Plaster base plates shall not be reused after plasticity, total absorption or rate of absorption testing (see 6.2.3).

6.2.3 *Absorption of Plasticimeter Base Plates*:

[4] The sole source of supply of the Emley Plasticimeter known to the committee at this time is Geotest Instrument Corporation, 910 University Place, Evanston, IL 60201, USA. If you are aware of alternative suppliers, please provide this information to ASTM International Headquarters. Your comments will receive careful consideration at a meeting of the responsible technical committee [1], which you may attend.

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6.2.3.1 *Total Absorption*—Plasticimeter base plates when immersed in water at room temperature for a period of 24 h shall absorb not less than 40 g of water. Before making the determination, dry the porcelain plates overnight in an oven at a temperature between 100 and 110 °C (212 and 230 °F) and permit to cool to room temperature. Dry the plaster plates in an oven at a temperature between 37.8 and 48.9 °C (100 and 120 °F) until they achieve a constant weight and permit to cool to room temperature in a dessicator charged with a drying agent. After immersion and before weighing either porcelain or plaster plates, wipe off the excess water with a damp cloth.

6.2.3.2 *Rate of Absorption (Note 4)*—When tested over an area 70 mm (2¾ in.) in diameter, the water absorbed by either porcelain or plaster base plates shall be in accordance with the following:

Time, min	Water Absorbed, mL
1	8 to 14
2	5 to 7½
3	4 to 6½
4	4 to 6
5	3½ to 5½

(1) Plaster plates designated for rate of absorption testing shall be statistically representative of all plates manufactured for that purpose and made from one manufacturing batch run. Plaster plates selected for rate of absorption testing may not be re-dried and used for plasticity testing. Porcelain plates designated for rate of absorption testing shall be individually tested and may be re-dried and used for plasticity testing (see 6.2.2).

NOTE 4—A convenient apparatus for determining the rate of absorption consists of a buret sealed onto an inverted glass funnel from which the stem has been removed. The diameter of the larger end of the funnel shall be ground so as to be 70 mm (2¾ in.) in internal diameter. The funnel may be attached to the plate on which the measurement is being made by melted paraffin. The paraffin should not be too hot. A little experience will indicate when it is of the proper consistency. Alternative apparati manufactured of polycarbonate, metal and other materials are acceptable.[5]

6.3 *Plasticity Determination*:

6.3.1 Lubricate a ring mold such as is described in 5.2.2 with a thin film of water, place on a porcelain base plate (see 6.2.2 and 6.2.3) or a disposable plaster base plate (see 6.2.3), fill with the paste which has been adjusted to standard consistency as described in 5.3.3, and strike off level. Remove the mold by raising it vertically without distorting the paste. Center the base plate and paste in the instrument and turn the carriage up by hand until the surface of the paste is in contact with the disk and the distance between the disk and the top of the base plate is 32 mm (1¼ in.). Throw the carriage into gear and start the motor. It is essential that the motor be started exactly 120 s after the first portion of the paste has been placed in the mold. Record the time when the first portion of paste is placed in the mold as zero time; the motor is therefore started at 2 min. Take care to protect the specimen from drafts during the test.

6.3.2 Record the scale reading at 1-min intervals until the test is completed. Consider the test complete when: *(1)* the scale reading reaches 100, *(2)* any reading is less than the one before, or *(3)* the scale reading remains constant for three consecutive readings (2 min) and the specimen has visibly ruptured or broken loose from the base plate. Note the time and the scale reading at the end of the test.

6.4 *Calculation*:

6.4.1 Calculate the plasticity figure as follows:

$$P = \sqrt{F^2 + (10T)^2} \quad (1)$$

where

P = plasticity figure,
F = scale reading at the end of the test, and
T = time in minutes from the time when the first portion of paste was put in the mold to the end of the test.

6.5 *Precision and Bias*:

6.5.1 The precision of this test method is based on interlaboratory studies conducted in March and October of 2007. To determine interlaboratory and intralaboratory precision, one operator from each of ten different laboratories tested three different dolomitic Type S hydrated lime samples and one dolomitic Type N hydrated lime sample made into lime putty of standard consistency for Final Vicat Penetration (mm) and Calculated Plasticity Figure (Emley Units). Each laboratory obtained three replicate test results for each of the supplied materials.[6] Statistical summaries of the testing results are shown in Tables 1 and 2.

6.5.1.1 *Repeatability*—Two test results obtained within one laboratory shall be judged not equivalent if they differ by more than the "r" value for that material; "r" is the interval representing the critical difference between two test results for

[5] Godbey, Richard J. and Thomson, Margaret L., "Standardized Laboratory Apparatus for Measuring Emley Baseplate Rate of Absorption," Rochell Jaffe, Ed., Proceedings: 2005--International Building Lime Symposium, Michael Tate, Chairperson, National Lime Association, Arlington, VA, ISBN 0-9767621-0-2.

[6] Supporting data have been filed at ASTM International Headquarters and may be obtained by requesting Research Report RR: C07–1005.

TABLE 1 Final Vicat Penetration (mm)

MATERIAL	Average	Repeatability Standard Deviation	Reproducibility Standard Deviation	Repeatability Limit	Reproducibility Limit
	$\bar{\chi}$	s_r	s_R	r	R
Type S Hydrated Lime Samples A, C, F	19.7	2.76	2.81	7.7	7.9
Type S Hydrated Lime Samples B, E, G	18.4	2.13	2.53	5.9	7.1
Type S Hydrated Lime Samples D H I	18.4	2.83	2.83	7.9	7.9
Type N Hydrated Lime	17.8	2.59	2.59	7.3	7.3

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TABLE 2 Calculated Plasticity Figure (Emley Units)

MATERIAL	Average	Repeatability Standard Deviation	Reproducibility Standard Deviation	Repeatability Limit	Reproducibility Limit
	$\bar{\chi}$	s_r	s_R	r	R
Type S Hydrated Lime Samples A, C, F	502	22.70	41.62	64	117
Type S Hydrated Lime Samples B, E, G	480	42.93	66.77	120	187
Type S Hydrated Lime Samples D H I	381	40.52	49.11	114	138
Type N Hydrated Lime	438	25.06	53.51	70	150

the same material, obtained by the same operator using the same equipment on the same day in the same laboratory.

6.5.1.2 *Reproducibility*—Two test results should be judged not equivalent if they differ by more than the "R" value for that material; "R" is the interval representing the difference between two test results for the same material, obtained by different operators using different equipment in different laboratories.

6.5.1.3 Any judgment in accordance with statements 6.5.1.1 or 6.5.1.2 would have an approximate 95 % probability of being correct. To judge the equivalency of two test results, it is recommended to choose the material closest in characteristics to the test material (Type S or Type N hydrated lime).

6.5.2 *Bias*—At the time of the studies, there was no accepted reference material suitable for determining the bias for this test method, therefore no statement on bias can be made. To judge the equivalency of two test results, it is recommended to choose the material closest in characteristics to the test material (Type S or Type N hydrated lime).

7. Water Retention of Hydrated Lime

7.1 *Significance and Use*:

7.1.1 This test method measures the ability of the hydrated lime in a plastic mix with sand to retain water, and hence retain consistency of the mix, when subjected to an applied suction. This ability, measured as a percent of the original consistency, is indicative of the workability to be expected in a masonry mortar containing the lime.

7.2 *Proportioning and Mixing*:

7.2.1 *Apparatus*—The apparatus used shall conform to Practice C 305.

7.2.2 *Proportions*—The mortar tested shall be composed of 500 g of lime and 1500 g of standard sand conforming to 8.2.3. If hydrated lime putty is used, use that weight of putty that is equivalent to 500 g of dry hydrated lime.

7.2.3 *Mechanical Mixing*:

7.2.3.1 Place the dry paddle and the dry bowl in the mixing position in the mixer.

7.2.3.2 Place a measured quantity of water in the bowl.

7.2.3.3 Add the lime to the water, then start the mixer and mix at slow speed (140 ± 5 r/min) for 30 s.

7.2.4 Add the entire quantity of sand slowly over a 30-s period while mixing at slow speed.

7.2.5 Stop the mixer, change to medium speed (285 ± 10 rpm) and mix for 30 s.

7.2.6 Stop the mixer and let the mortar stand for 1½ min. (During the first 15 s of this interval, quickly scrape down into the batch any mortar that may have collected on the side of the bowl, then for the remainder of this interval cover the bowl with the lid.)

7.2.7 Finish the mixing for 1 min at medium speed.

7.2.8 In any case requiring a remixing interval, any mortar adhering to the side of the bowl shall be quickly scraped down into the batch prior to remixing.

7.3 *Consistency*:

7.3.1 *Apparatus*—The flow table and mold used for the measurement of consistency of the mortar shall conform to Specification C 230/C 230M.

7.3.2 *Procedure*—Carefully wipe dry the flow table top and place the flow mold at the center. Immediately after completing the mixing operation, fill the mold with mortar gently pressed into place by the finger tips to ensure uniform filling free of voids. Smooth off the mortar level with the top of the mold by aid of a trowel, and remove the mold. Immediately drop the table through a height of 13 mm (½ in.), 25 times in 15 s. The flow is the resulting increase in diameter of the mortar mass, expressed as the percentage of the original diameter. The mortar may be adjusted, if the flow is below 100 %, by additions of water until the flow is within the range from 100 to 115 %. Make each adjustment by returning the mortar to the original mixing bowl, add water, and then mix at medium speed (285 ± 10 r/min) for 30 s. If the flow of the original mortar is greater than 115 %, prepare a new batch.

7.4 *Water Retention Test*:

7.4.1 *Apparatus*—The equipment shall conform to the apparatus used for the water retention test in Specification C 91 (see Fig. 3).

7.4.2 *Procedure*:

7.4.2.1 Adjust the vacuum regulator to maintain a vacuum of 51 ± 3 mm as measured on the vacuum gauge. Seat the perforated dish on the greased gasket of the funnel. Place a wetted filter paper in the bottom of the dish. Turn the stopcock to apply the vacuum to the funnel and check the apparatus for leaks and to determine that the required vacuum is obtained. Then turn the stopcock to shut off the vacuum from the funnel.

7.4.2.2 Immediately after the final consistency test (7.3.2), return all of the mortar to the bowl and remix the entire batch for 15 s at medium speed. Immediately after remixing the mortar, fill the perforated dish with the mortar to slightly above the rim. Tamp the mortar 15 times with the tamper. Apply ten of the tamping strokes at approximately uniform spacing adjacent to the rim of the dish and with the long axis of the tamping face held at right angles, to the radius of the dish.

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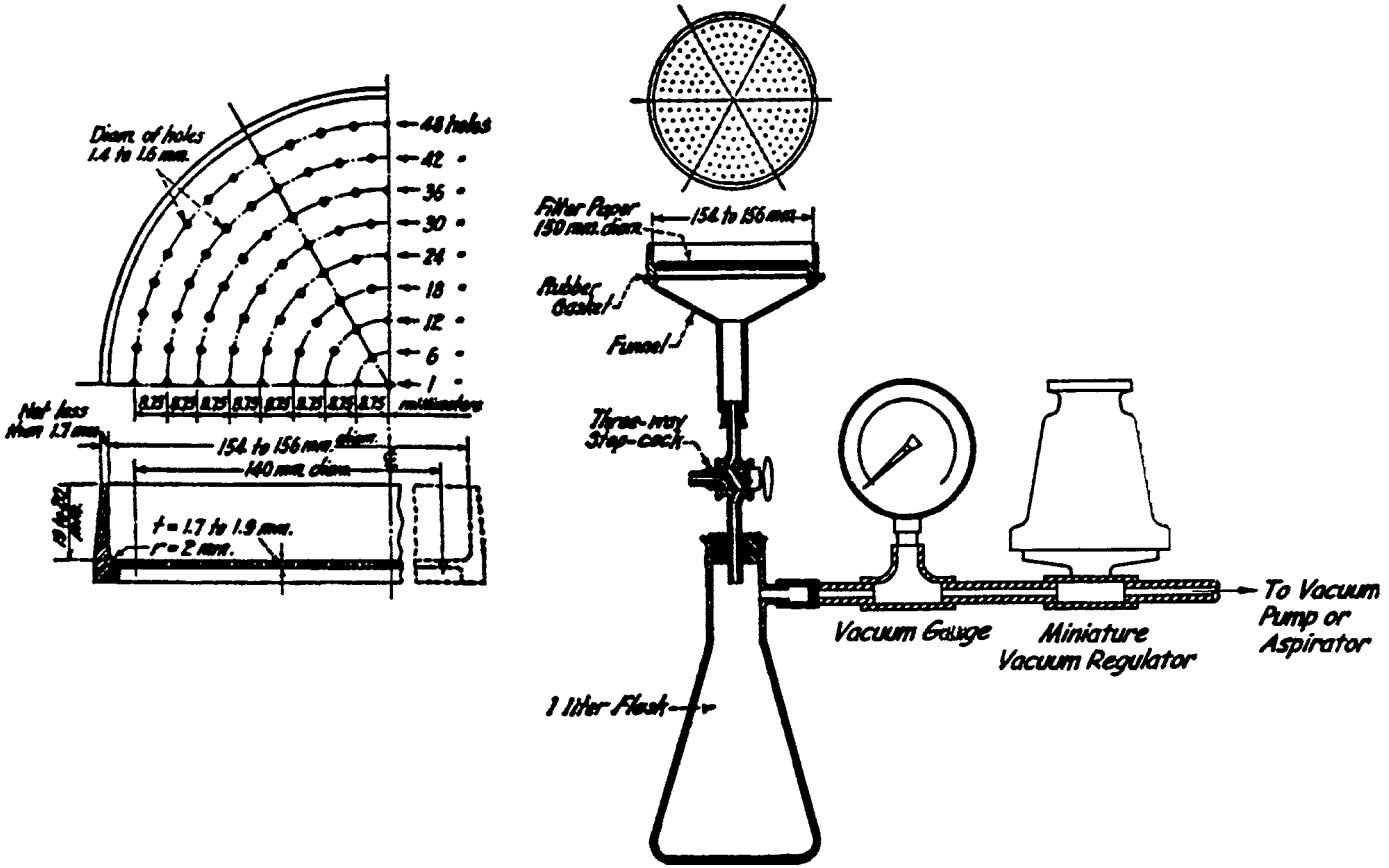

FIG. 3 Vacuum Gauge Apparatus Assembly for the Water Retention Test

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Apply the remaining five tamping strokes at random points distributed over the central area of the dish. The tamping pressure shall be just sufficient to ensure filling of the dish. On completion of the tamping, the top of the mortar should extend slightly above the rim of the dish. Smooth off the mortar by drawing the flat side of the straightedge (with the leading edge slightly raised) across the top of the dish. Then cut off the mortar to a plane surface flush with the rim of the dish by drawing the straightedge with a sawing motion across the top of the dish in two cutting strokes, starting each cut near the center of the dish. If the mortar is pulled away from the side of the dish during the process of cutting off the excess mortar, gently press the mortar back into contact with the side of the dish using the tamper.

7.4.2.3 Turn the stopcock to apply vacuum to the funnel. After suction for 60 s, quickly turn the stopcock to expose the funnel to atmospheric pressure. Immediately slide the perforated dish off the funnel, touch it momentarily on a damp cloth to remove droplets of water, and set the dish on the table. Then using the bowl scraper (rubber scraper as specified in Practice C 305), plow and mix the mortar in the dish for 15 s. Upon completion of mixing, place the mortar in the flow mold and determine the flow. Carry out the entire operation without interruption and as quickly as possible. Not more than 30 min should be required for completion, starting from the completion of the mixing of the mortar for the first flow determination.

7.4.3 *Calculation*:

7.4.3.1 Calculate the water retention value for the mortar as follows:

$$\textit{Water}\ \text{retention value} = (A/B) \times 100 \qquad (2)$$

where:

A = flow after suction, and

B = flow immediately after mixing.

7.5 *Precision and Bias*:

7.5.1 No precision data are available due to the limited use of this test method. Therefore, users are advised to develop their own laboratory precision.

8. Air Entrainment

8.1 *Significance and Use*:

8.1.1 Hydrated lime, particularly that containing an air-entraining additive, used in masonry mortar may contribute to the air content of the mortar. Certain specifications and applications of mortar place a limit on this air content.

8.2 *Apparatus*:

8.2.1 *Flow Table*, conforming to the requirements prescribed in Specification C 230/C 230M.

8.2.2 *Mixing Apparatus*, conforming to the requirements as prescribed in Practice C 305.

8.2.3 The sand shall be a blend of equal parts by weight of graded Ottawa sand and standard 20-30 Ottawa sand. The fineness of graded Ottawa sand and standard 20-30 sand may be checked by using the methods described in Specification C 778.

8.3 *Preparation of Mortar*:

8.3.1 *Proportions for Mortar*—Lime-based mortars for measurement of air entrainment shall be proportioned to conform, in batch size, to the unit weights by volume of cementitious material and aggregate as shown in Table 3. The cement shall conform to Specifications C 150, C 595, or C 1107, and the hydrated lime to Specification C 207. The quantity of water, measured in millilitres, shall be such as to produce a flow of 110 ± 5 % as determined by the flow table. Proportions for the generally used batch sizes based on Table 4 material unit weight shall contain the weights as prescribed in Table 5.

8.3.2 *Mixing of Mortars*—Mix the mortar in accordance with the procedure for mixing pastes in Practice C 305.

8.3.3 *Determination of Flow*—Determine the flow in accordance with the Procedure section of Test Method C 109/C 109M.

8.4 *Procedure*:

8.4.1 If the mortar has the correct flow, use a separate portion of the mortar for the determination of entrained air. The amount of air entrainment shall be determined by one of two methods. The density method determines air content from the measured density of the mortar, the known density of constituents, and the mixture properties. The air pail method measures air content using Test Method C 231.

8.4.2 Density Method:

8.4.2.1 *Apparatus*:

Scales, Sieves, Glass Graduates, Tamper, Measure, Straightedge, Spatula, Tapping Stick, and Spoon, conforming to the requirements given in Test Method C 185.

8.4.2.2 *Procedure*:

(1) Fill a 400 ml measure with the mortar sample in accordance with Test Method C 185.

(2) Determine the weight of mortar in the measure.

8.4.2.3 *Calculation*:

Calculate the air content of the mortar and report it to the nearest 0.1 % as follows:

$$D = (W_1 + W_2 + W_3 + V_w)/[(W_1/S_1) + (W_2/S_2) + (W_3/S_3) + V_w]A = 100 - (W_m/4D) \qquad (3)$$

where:

D = density of air-free mortar,

W_1 = weight of cement, g,

W_2 = weight of lime, g,

W_3 = weight of blended Ottawa sand, g,

V_w = water used, mL,

S_1 = specific gravity of portland cement,

S_2 = specific gravity of hydrated lime,

S_3 = specific gravity of blended Ottawa sand,

A = volume % of entrained air, and

W_m = weight of 400 mL of mortar, g.

TABLE 3 Unit Weights and Apparent Specific Gravities

Materials	Unit weight, kg/m³(lb/ft³)[A]	Specific Gravity
Portland Cement	1,504 (94)	3.15
Blended Cement	obtain from purchaser	
Hydraulic Cement	obtain from purchaser	
Hydrated Lime	640 (40)	2.30
Blended Ottawa Silica Sand	1,280 (80)	2.65

[A] The unit weight values listed for cementitious materials are assumed values commonly used in construction practice.

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TABLE 4 Precision Data

Material	Labs	Results in °C Rise		*r*	*R*
		Time	Range Tested		
High Calcium	12	30 s	12.3–44.4	1.56	4.21
High Calcium	11	3 min	32.1–56.1	1.72	4.72
Dolomitic	10	30 s	3.6–12.0	1.38	2.84
Dolomitic	9	3 min	21.2–36.4	1.62	3.72

TABLE 5 Weight of Materials for Mortar Batch

Mortar Type	Proportions by Volume	Portland Cement (g)	Hydrated Lime (g)	Blended Ottawa Silica Sand (g)
M	1:¼ :3¾	470.0	62.5	1,500
S	1:½ :4½	376.0	100.0	1,440
N	1:1:6	282.0	150.0	1,440
O	1:2:9	188.0	200.0	1,440
Lime/Sand	1:3		300.0	1,440

NOTE 5—For lime/sand mortars, W_1 and S_1 should be dropped from the calculation.

8.4.2.4 *Precision and Bias*:

(1) The single operator within laboratory standard deviation has been found to be 0.56 % air content throughout the range of 8 % to 19 % air content. Therefore results of two properly conducted tests by the same operator on similar batches of mortar should not differ by more than 1.6 % air content.

(2) The multilaboratory standard deviation has been found to be 1.0 % air content throughout the range of 8 % to 19 % air content. Therefore, results of two different laboratories on similar batches of mortar should not differ from each other by more than 2.8 % air content (see Test Method C 185).

8.4.3 Air Pail Method

8.4.3.1 *Apparatus*:

(1) Air Meters—There are two basic operational designs employing the principle of Boyle's law. Both types of units are detailed in Test Method C 231.

(2) Calibration Vessel, Spray Tube, Tamping Rod, Mallet, Strike-Off Bar, Funnel, and Water Measure, conforming to the requirements given in Test Method C 231.

8.4.3.2 *Procedure*:

(1) Calibrate the air meter using procedures described in Test Method C 231 Section 5.

(2) Fill the air meter and determine air content by using the method detailed in Test Method C 231 Section 8, except that for Type B meters with a volume of 1 L or less, there shall be no use of an internal vibrator as required in Test Method C 231 and described in Practice C 192.

(3) When using Type B meters with a volume of 1 L or less, compact the mortar into the bowl by tamping the mortar 15 times with a tamper meeting the requirements of Test Method C 185 Section 5. Apply 10 of the tamping strokes near the outside circumference of the mortar bowl evenly spaced at right angles to the radius of the bowl and five of the tamping strokes at random points distributed in the center of the bowl. Apply the tamping strokes in such a manner as to only settle and consolidate the mortar into the bowl without the addition of voids left by the insertion and removal of the tamper at each stroke.

8.4.3.3 *Precision and Bias*:

Although precision for the test method for air content of freshly mixed concrete has been reported in Test Method C 231, the precision of this test method has not been determined for lime-based mortars. When sufficient data has been obtained and analyzed, a statement of precision will be provided. In the meantime users of the test method are advised to develop their own.

SOUNDNESS TESTING

9. Autoclave Expansion of Hydrated Lime

9.1 *Significance and Use*:

9.1.1 Expansion of pressed tablets of hydrated lime generally indicates the presence of unhydrated oxides of magnesium and calcium. The relation of the degree of expansion in this test method to field performance has not been determined.

9.2 *Apparatus*:

9.2.1 *Mold and Press*—A steel mold capable of producing a press tablet at least 0.032 m (1.25 in.) in diameter and 0.006 m (0.25 in.) thick, and able to sustain at least 88.9 kN (20 000 lbf) pressure from a suitable press. It should be provided with a release jig also.

9.2.2 *Autoclave*, capable of holding 1034 kPa (150 psi) for 2 h.

9.2.3 *Micrometer*, dial-type, capable of measuring 2.54 µm (0.0001 in.).

9.2.4 *Microscope*, with graduated lens for measuring 0.10 mm.

9.3 *Procedure*:

9.3.1 Weigh out 15 g of hydrated sample, place in the mold, and press into a tablet. Press to 33.4 kN (7500 lbf) for 10 s, then increase pressure to 88.9 kN (20 000 lbf) or more. Hold for 10 s before releasing. Press tablet from mold with jig and draw three diameter lines across the surface of the tablet using a lead pencil. Draw two diameter lines normal to each other and draw the third bisecting the 90° angles of the other two. Measure the diameters with a dial micrometer and place the tablet on the autoclave rack. Use aluminum foil to protect the tablets from water dripping. Autoclave at 862 to 1034 kPa (125 to 150 psi) for 2 h. Begin timing when the pressure reaches 345 kPa (50 psi). After the autoclaving interval, allow the autoclave to cool, remove the tablet, and remeasure the diameters. Calculate the average percent expansion of the tablet from the before and after measurements.

9.4 *Expansion of Hydrated Lime-Portland Cement-Aggregate*:

9.4.1 *Materials*:

9.4.1.1 *Standard Cement*—Type I or Type II portland cement.

9.4.1.2 *Standard Aggregate*—Pulverized limestone, minus 212-µm (No. 70) sieve, having less than 0.5 % silicon dioxide (SiO_2).

9.4.2 *Procedure*:

9.4.2.1 *Test Tablet*—Make up a pressed tablet in accordance with the procedure outlined in 9.3.1 using the following mixture for the sample:

Standard portland cement	14 g
Hydrated lime	8 g

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Standard aggregate (pulverized limestone)	72 g

Blend the mix until homogeneous.

9.4.2.2 *Standard Tablet*—Make up a pressed tablet in accordance with the procedure outlined in 9.3.1 using the following mixture for the sample:

Standard portland cement	7 g
Standard aggregate (pulverized limestone)	16 g

Blend the mix until homogeneous.

9.4.2.3 Autoclave and calculate expansions of the test tablet and the standard tablet in accordance with 9.3.1.

9.4.2.4 Determine the autoclave expansion of hydrated lime for masonry purposes by subtracting the average percent expansion of the standard tablet from the sample tablet.

9.5 *Precision and Bias*:

9.5.1 No precision data are available due to the limited use of this test method. Therefore, users are advised to develop their own laboratory precision. No statement is being made about the bias of this test method.

10. Popping and Pitting of Hydrated Lime

10.1 *Significance and Use*:

10.1.1 Pops and pits are caused by the hydration and expansion of coarse particles of unhydrated lime or lime-impurity reaction products present in the hydrated lime. The level of popping and pitting in the sample is indicative of the potential for the appearance of surface defects in plastering applications.

10.2 *Gauging Plaster*:

10.2.1 The gauging plaster used for the popping and pitting test shall conform to the Test Methods section of Specification C 28/C 28M and shall have a setting time of not more than 1 h when tested in accordance with Test Methods C 472. Test the gauging plaster without lime in the manner described in 10.3 to ensure its freedom from pops and pits. If any pops or pits are found, provide another lot of gauging plaster that is free of pops and pits when subjected to this test.

10.3 *Procedure*:

10.3.1 Mix 100 g of hydrated lime with sufficient water to bring to such a consistency as to give a penetration of 20 ± 5 mm when tested in accordance with 5.3.3. Mix into this putty, 25 g of gauging plaster (10.2.1), adding more water as required to maintain workable consistency. Spread on a glass plate to make a pat at least 150 by 200 mm (6 by 8 in.) by approximately 3 mm (⅛ in.) in thickness. Trowel to a smooth finish. Allow to stand overnight.

10.3.2 Place the specimen and plate on a rack in the steam bath so that water is not in contact with the specimen to be tested. Provide a sloping cover above the specimen to prevent condensed steam from dripping onto the surface of the specimen. Raise the temperature of the water in the steam bath to boiling and maintain at boiling for 5 h. Remove the specimens from the bath and examine for pops and pits.

10.3.3 The pitting potential of hydrated lime can be determined in conjunction with autoclave expansion as in 9.3.1. However, it is not necessary to measure diameter, if only the pitting potential is to be determined. After following the procedure for expansion in 9.3.1, examine the pressed tablet under the measuring microscope, and count and measure the pits in millimetres.

APPLICATION TESTING

11. Slaking Rate of Quicklime

11.1 Significance and Use:

11.1.1 The temperature rise in 30 s is a measure of the reactivity of the softer-burned portion of the quicklime. Total slaking time provides a measure of the overall degree of reactivity of the material. Total temperature rise is largely dependent on the available lime content of the sample.

11.1.2 These slaking parameters provide an indication of the performance of the quicklime to be expected in industrial slaking systems. Slaking characteristics have an effect on lime slurry properties such as settling characteristics, viscosity, particle size, and reaction rate.

11.2 *Apparatus*:

11.2.1 *Mechanical Stirrer*, speed 400 ± 50 r/min, fitted with a special stirring rod.

11.2.2 *Modified Dewar Flask*, 665-mL, fitted with special rubber gasket covers.

11.2.3 *Thermometer*, dial-type, 0 to 100 °C range in 1 °C increments or thermocouple with a response time equivalent to or faster than the dial thermometer.

11.2.4 *Torsion Balance*.

11.2.5 *Sieve*, 203-mm (8-in.), 3.35-mm (No. 6), conforming to Specification E 11.

11.2.6 An apparatus essentially the same as that illustrated in Fig. 4 and Fig. 5 shall be used. The apparatus consists of a covered reaction container fitted with a mechanical stirrer and thermometer. The quicklime charge shall be stirred with a mechanical stirrer fitted with a stainless steel rod, the end of which is formed into a loop to follow the contour of the reaction container. The vacuum reaction flask shall be provided with a cover consisting of two circular pieces of gasket rubber sheet, approximately 3 mm (⅛ in.) thick. The first piece is provided with a single radial slot that slides over the stirring rod and the thermometer. The second piece (top) has a similar slot plus a hole to provide for the dial thermometer. When the two cover pieces are in place, the slot on the lower piece is at right angles to the slot on the upper piece with the thermometer stem extending through the lower slot. The apparatus may be assembled by any convenient supporting equipment.

11.3 *Procedure*:

11.3.1 Prepare the sample of quicklime (as rapidly as possible to prevent sample deterioration) so that a majority of the material passes a 3.35 mm (No. 6) sieve. Place the sample in an airtight container and allow to come to room temperature before testing. The slaking rate of lime is significantly affected by the particle size of the sample and must be as close to a 3.35 mm (No. 6) sieve as possible. It is not necessary that 100 % of the sample pass a 3.35 mm (No. 6) sieve, but all of the sample, including the plus 3.35 mm (plus No. 6) fraction, must be used in the test.

11.3.2 *Slaking Rate*—Adjust the temperature of about 500 mL of distilled water in accordance with the schedule given in Table 6, and add the specified amount to the Dewar flask. Set

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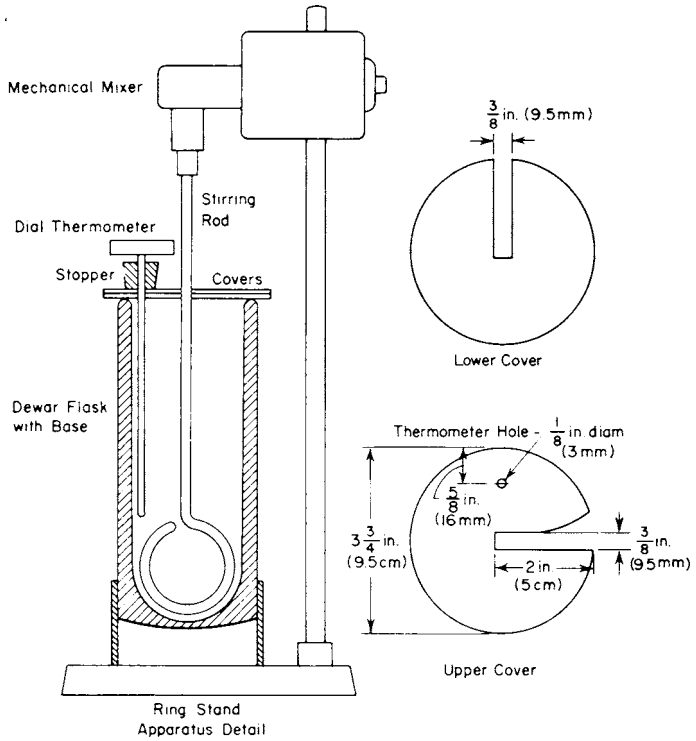

FIG. 4 Slaking Reactivity Apparatus

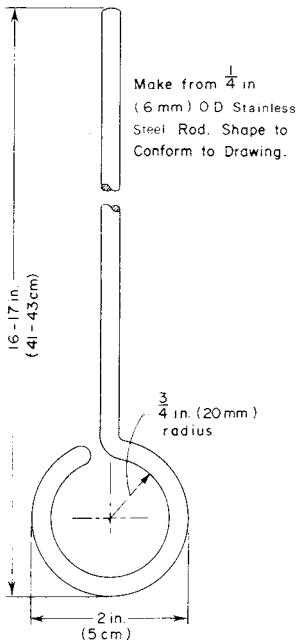

FIG. 5 Stirring Rod Detail

the agitator revolving at 400 ± 50 r/min. The temperature of the water in the flask must be ±0.5 °C of the desired temperature. Quarter and weigh out the required amount of the prepared quicklime sample. Add the quicklime to the water without delay and simultaneously begin timing. Put the covers in place immediately. Take a reading at each 30 s interval.

11.3.3 Continue readings until less than 0.5 °C temperature change is noted in each of three consecutive readings. The total active slaking time will then be the time at which the first of the three consecutive readings was taken. The temperature at this time will be considered the final reaction temperature. Subtract the initial temperature from the final temperature to obtain the total temperature rise. Subtract the initial temperature from the temperature at 30 s for the temperature rise in 30 s. Subtract the initial temperature from the temperature at 3 min for the temperature rise in 3 min.

TABLE 6 Schedule for Slaking Rate

	Material to Be Tested	
	Dolomitic	High Calcium
Temperature of water, °C	40	25[A]
Quantity of water, mL	400	400
Quantity of quicklime, g	120	100

[A] Initial temperature of 40 °C may be used, provided the report of results states the initial temperature.

11.3.4 *Residue of Quicklime*—Allow slurry from the slaking/reactivity test to continue slaking for a minimum of 15 min. Stop the stirrer and remove the Dewar flask, washing the slurry residue from the stirring rod into the flask. Carefully and slowly pour the residue through a No. 30 (600-µm) sieve (Note 6). Wash the slurry through the screen with a spray of tap water, being careful not to lose any residue over the top of the sieve. Continue washing until all slurry is through the sieve and all that remains are residue particles. Blot dry the bottom of the sieve with a paper towel and then place in a drying oven for 1 h at 105 ± 5 °C. Remove from the oven, cool, collect the dried residue, and weigh.

$$\textit{Calculation: } \frac{\textit{Grams of Residue}}{\textit{Weight of Sample}} \times 100 = \%\ \textit{Residue}$$

NOTE 6—The quicklime being slaked is very hot and highly basic. Caution must be taken not to let this material contact the eyes or skin as this may cause severe thermal and/or chemical burns.

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11.4 *Report*:

11.4.1 Record the actual temperature rise and plot a suitable curve showing temperature rise as the ordinate and time as the abscissa. The results may also be reported as:

11.4.1.1 Temperature rise in 30 s (or at any other designated time) in degrees Celsius,

11.4.1.2 Total temperature rise in degrees Celsius, and

11.4.1.3 Total active slaking time in minutes.

11.5 *Precision and Bias*:

11.5.1 Twelve laboratories cooperated in the testing of five high calcium quicklimes and four dolomitic quicklimes thereby obtaining the repeatability (*r*) and reproducibility (*R*) (Practice E 691) data contained in Table 4.[7]

11.5.2 Due to the lack of a recognized industry standard, the bias of this test method has not been determined. The variety of reporting options also complicates obtaining a suitable bias statement.

12. Dry Brightness of Pulverized Limestone

12.1 *Summary of Test Method*:

12.1.1 A sample of the dry material is compressed and its reflectance measured on a reflectometer that has previously been standardized.

12.2 *Significance and Use*:

12.2.1 This test method provides a measure of the reflectance, or whiteness, or both of ground calcium carbonate products by comparison with a standard, using green and blue filters.

12.3 *Apparatus*:

12.3.1 *Reflectometer*:

12.3.2 *Dry Powder Press (See Fig. 6)*—Instructions, as supplied by the manufacturer, for preparation of the sample and use of the powder press shall be explicitly followed.

12.3.3 *White Porcelain Standard Plaque*, to be used as secondary standard.

12.4 *Reagent*:

12.4.1 *Barium Sulfate ($BaSO_4$)*—Use Eastman Kodak[8] Chemical No. 6091[9], white reflectance standard only.

12.5 *Calibration and Standardization*:

12.5.1 *Zero Scale Calibration (bottom of scale standardization)*:

12.5.1.1 Place the black glass provided with the instrument over the specimen port, so that the shiny side is towards the opening. The glass should be positioned so that no light escapes from the black glass-opening interface.

12.5.1.2 The processor is then adjusted to read *zero reflectance.*

12.5.2 *Standardizing of the White Standard (standardization of the upper part of the scale)*:

12.5.2.1 A primary standard pellet (barium sulfate) which is free from surface flaws should be positioned over the specimen port so that no light can escape at the pellet-opening interface.

12.5.2.2 The Eastman Kodak barium sulfate reflectance standard is provided with reflectance values at various wavelengths. Since some variation is possible between lots of $BaSO_4$, the values used to standardize the reflectometer must be calculated. A normal *Y* value will be between 99.0 and 98.5, depending on the lot number.

12.5.2.3 After this has been accomplished, a reading of the white standard plaque can be taken and the values of *X*, *Y*, and *Z* recorded. This plaque can then be used as a secondary standard for future standardizations. This reduces the necessity of making a barium sulfate pellet for every test series.

12.6 *Procedure*:

12.6.1 The reflectometer must be given ample warm-up time prior to the sample readings.

12.6.2 The reflectometer must first be standardized; this consists of standardization of the bottom of the scale and standardization of the upper part of the scale.

12.6.3 Sample pellets should then be pressed (Note 7) following manufacturer instructions explicitly (Note 8).

NOTE 7—Ground products with more than 0.5 % residue on a 45-μm (No. 325) screen will require special care in preparing the sample cup. The coarser the product, the harder to obtain a compact, smooth surface.

NOTE 8—Some reflectometers and spectrophotometers can measure reflectance with the powder sample in a horizontal position, thus eliminating the necessity to prepare a sample pellet. Also, coated ground limestones are difficult to pelletize. Loose powder samples should be smoothed in a convenient sized container until the surface is level and free from cracks and other surface defects.

12.6.4 After the reflectometer has been standardized, the sample pellets are centered beneath the opening and positioned so that no light escapes from the pellet-opening interface.

12.6.5 The samples are then read for *X*, *Y*, *Z*, *L*, *a*, and *b* values. These values are recorded.

12.6.6 To determine if the values of the reflectometer have drifted, the white standard (either the barium sulfate pellet or the porcelain plaque) is placed over the specimen port and read. Values should be the same as those placed in the processor during the standardization procedure.

12.7 *Report*:

12.7.1 The *Y* value is recorded as the dry brightness of that specific limestone.

12.8 *Precision and Bias*:

12.8.1 The same instrument, operator, and standard should reproduce ±0.2 %. Different instrument (Note 9), operators, and standard should agree ±1.0 %.

NOTE 9—It is recognized that there are various manufacturers of reflectometers, and testing has been undertaken to relate *X*, *Y*, and *Z* tristimulus color values from one instrument to another. If results of this comparison testing are desired, please contact the Pulverized Limestone Association.

13. Limestone Grindability Determination by the Laboratory Ball Mill Method

13.1 *Scope*:

[7] Supporting data have been filed at ASTM International Headquarters and may be obtained by requesting Research Report RR: C07–1003.

[8] Registered trademark.

[9] The sole source of supply of the apparatus known to the committee at this time is Eastman Kodak Co., 343 State St., Rochester, NY 14650. If you are aware of alternative suppliers, please provide this information to ASTM International Headquarters. Your comments will receive careful consideration at a meeting of the responsible technical committee,[1] which you may attend.

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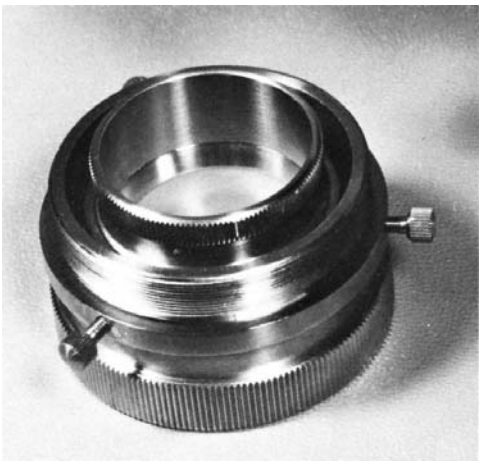

FIG. 6 Dry-Powder Press

13.1.1 This test method is used to determine the relative grindability or ease of pulverization of limestones of differing hardness and to report this as a grindability index.

13.1.2 This test method is applicable to all types of limestone.

13.2 *Summary of Test Method*:

13.2.1 Limestone of a specified size range is wet ground in a ball mill therein receiving a specified amount of grinding energy. The amount of minus 75-µm (200-mesh) limestone produced is measured by wet sieving and reported as the percent passing 75-µm (200-mesh) after 5000 revolutions. This is the grindability index.

13.3 *Significance and Use*:

13.3.1 This test method is useful for comparison and acceptance testing of limestone for applications where fine ground limestone is desired.

13.4 *Apparatus*:

13.4.1 *Jar Mill*, operated at 110 ± 10 r/min.

13.4.2 *Mill Jar*, ceramic 14 cm (5½ in.) diameter by 20.2 cm (6¾ in.) high.

13.4.3 *Grinding Media*, 160 ± 1 g total, consisting of seven ceramic 21 by 21 mm (13⁄16 by 13⁄16 in.) cylindrical grinding media (about 23 g each).

13.4.4 The sieves used shall conform to the requirements of Specification E 11.

13.4.5 Weights and weighing devices, shall conform to the requirements of Specification C 1005.

13.4.6 *Drying Oven*, capable of maintaining 100 °C.

13.4.7 *A Chipmunk Crusher*, capable of breaking large rocks to less than 6.35 mm (¼ in.).

13.4.8 *Riffle Sample Splitter*, open pan, 12.7 mm (½ in.) chute width.

13.4.9 *Stopwatch*.

13.5 *Reagents and Materials*:

13.5.1 *Milling Solution*, a 0.1 % solution of acrylate based dispersant. The dispersant chosen should not increase the solubility of limestone in water.[10]

13.6 *Sampling*:

13.6.1 Sample in accordance with Practice D 75.

13.6.2 Reduce the sample in accordance with Practice C 702 and prepare by sieving out the material that passes a 850-µm (No. 20) sieve[11] and is retained on a 425-µm (No. 40) sieve.[11]

13.7 *Procedure*:

13.7.1 Weigh seven grinding media, make adjustments (by substitutions or filing) to bring total weight to 160 g ± 1 g.

13.7.2 If the jar mill has provision for automatic shut-off, set it for 5000 revolutions, otherwise determine the mill r/min by counting the revolutions in an accurately timed period (using stopwatch) and then calculate the exact time required for 5000 revolutions.

13.7.3 Weigh out 20 ± 0.01 g of dried 20 by 40 mesh limestone. Record actual weight as *W*1.

13.7.4 Add 180 mL of milling solution to clean and empty mill jar.

13.7.5 Add the seven grinding media and quantitatively transfer the limestone sample to the mill jar and secure the top.

13.7.6 Place the mill jar on the mill rollers and operate the mill for the exact time required to make 5000 revolutions.

13.7.7 Quantitatively transfer the limestone slurry from the jar mill by rinsing the entire contents onto a coarse sieve (for example, 3.35 mm (No. 6)) and an underlying 75-µm (No. 200) sieve. Rinse the media and coarse sieve and separate the sieves.

13.7.8 Wet sieve the sample remaining on the 75-µm (No. 200) sieve to remove the finer material.

13.7.9 Dry and weigh the residue from the 75-µm (No. 200) sieve and record as *W*2 (to the nearest 0.01 g).

13.8 *Calculation*:

13.8.1 Calculate the grindability index (*GI*) as follows:

$$GI = (W1 - W2)/W1 \times 100 \quad (4)$$

13.9 *Precision and Bias*:

13.9.1 The precision and bias of this test method has not been determined at this time.

14. Settling Rate of Hydrated Lime

14.1 *Significance and Use*:

14.1.1 This test method provides a measure of the rate of settling of a hydrated lime slurry, a form in which this material is frequently used. In some applications a slow settling slurry is desirable; in others, fast settling is preferred.

14.2 *Procedure*:

14.2.1 Place 10.0 g of lime hydrate in a 100-mL glass-stoppered graduated cylinder (internal diameter about 24 mm). Wet with 50 mL of carbon dioxide (CO_2) free distilled water at 23 ± 1.7 °C (73.4± 3 °F) and mix thoroughly by alternately inverting and righting the cylinder slowly for a period of 2 min. Allow the graduate and contents to stand at 23 ± 1.7 °C for 30 min and then dilute to the 100-mL mark with CO_2-free distilled water at 23 ± 1.7 °C. Mix contents again thoroughly as before and allow to stand undisturbed at 23 ± 1.7 °C for 24 h.

14.3 *Report*:

[10] Distilled or deionized water should be used for milling solution or solubility tests.

[11] U.S. Standard Sieves 6, 20, 40 and 200 mesh sizes; 20.3 cm (8 in.) diameter by 5 cm (2 in.) depth with stainless steel wire cloth.

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14.3.1 Report the sedimentation height in millilitres after ¼ , ½ , ¾ , 1, 2, 4, and 24 h, reading the bottom of the meniscus.

NOTE 10—Slight variations in results of this test method on a sample run in different laboratories or by different operators are permissible. The test is not an absolute one, but is designed to distinguish between fast and slow settling hydrates.

14.4 *Precision and Bias*:

14.4.1 No precision data are available due to the limited use of this test method. Therefore, users are advised to develop their own laboratory precision.

PARTICLE SIZE ANALYSIS

15. Residue and Sieve Analysis

15.1 *Significance and Use*:

15.1.1 This test method determines the residue obtained from slaking quicklime. Residue, in this case, is largely unreacted material such as uncalcined limestone or dolomite, overburned quicklime, or gross impurities, or a combination of these.

15.2 *Apparatus*:

15.2.1 The sieves used shall conform to the requirements of Specification E 11. Preferably the sieves should have a 4-in. depth.

15.2.2 If sieve calibrations are required, follow the method as outlined in Test Method C 430.

15.2.3 *Spray Nozzle*, conforming to the requirements of Test Method C 430.

15.2.4 *Pressure Gage* shall be 3-in. (75-mm) minimum diameter, and shall be graduated in 1-psi (6.9 kPa) increments, and shall have a maximum capacity of 30-psi (207 kPa). The accuracy at 10 psi (69 kPa) shall be ±0.25 psi (±1.7 kPa).

15.2.5 Attach a pressure gage to the water faucet and a rubber tubing to the output side of the pressure gage. On the other end of the rubber tubing attach the spray nozzle (see 15.2.3).

15.3 *Residue of Quicklime*:

15.3.1 Select a representative 2.5-kg (5-lb) sample of the quicklime. Break lime selected for this test so as to entirely pass a 25.0-mm (1-in.) square mesh screen. Test the pulverized lime as received. Place the sample in a box of wood or of some material of similarly low thermal conductivity, and an experienced operator should slake it with sufficient water at 21 to 27 °C (70 to 80 °F) to produce the maximum quantity of lime putty, carefully avoiding "burning" or "drowning" the lime. Allow it to stand for 1 h and then wash through an 850-µm (No. 20) sieve by a stream of water having a moderate pressure. Do not rub any material through the sieve. Continue the washing until the residue on the screen appears to consist entirely of coarse particles, but in no case continue the washing for more than 30 min. Dry the residue to constant weight at a temperature of 100 to 107 °C (212 to 225 °F) and calculate the percentage residue, based on the original weight of the sample.

15.4 *Sieve Analysis of Hydrated Lime*:

15.4.1 Select a 100-g sample of the hydrated lime as received and place on a 600-µm (No. 30) sieve, which is nested above a 75-µm (No. 200) sieve. Wash the material through the sieves by means of a stream of water from the nozzle attached to a rubber tubing (see 15.2.5) after adjusting the water pressure to 10 psi (69 kPa) ±0.25 psi (±1.7 kPa). Carefully wash the sample through the sieves without allowing any splashing over the sides of the sieve. After the sample is washed through the top sieve, separate the two sieves and continue washing through the 75-µm (No. 200) sieve until the water coming through the sieve is clear, that is, no particles can be seen in a beaker of the rinse water, but in no case continue the washing longer than 30 min. Take care not to let water accumulate on the 75-µm (No. 200) sieve, because the openings will become clogged and the operation cannot be completed in 30 min.

15.4.2 Calculate the percentage residue retained on each sieve, based on the original weight of the sample. The weight of the material retained on the 600-µm (No. 30) sieve shall be added to the weight of the material retained on the 75-µm sieve to obtain the correct weight of the material retained on the 75-µm sieve.

15.5 *Sieve Analysis of Limestone and Dry Quicklime*:

15.5.1 Select the desired sieves and nest them with the coarsest sieves on top. Weigh a 100-g sample of the material to be tested and place it on the top sieve. Conduct the sieving operation by means of a lateral and vertical motion of the sieve accompanied by a jarring action to keep the sample moving continuously over the surface of the sieve. Continue sieving until not more than 1 % of the residue passes any sieve during 1 min. If mechanical sieving is used, the device shall be such as to impart the type of agitation described in the hand sieving operation. Continue the shaking for a period of 15 min.

15.5.2 Weigh the residue retained on each sieve to the nearest 0.1 g. Report the results of the sieve analysis as follows: (*1*) total percentages passing each sieve, (*2*) total percentages retained on each sieve, or (*3*) percentages retained between consecutive sieves, depending upon the form of the specification for the use of the material under test.

15.6 *Precision and Bias*:

15.6.1 No precision data are available due to the limited use of these test methods. Therefore, users are advised to develop their own laboratory precision. No statement is being made about the bias of these test methods.

16. Fineness of Pulverized Quicklime and Hydrated Lime by Air Permeability

16.1 *Significance and Use*:

16.1.1 This test method covers the determination of fineness of pulverized quicklime and hydrated lime using the Blaine air permeability apparatus described in Test Method C 204. Fineness in terms of surface area shall be expressed as total surface area in square centimetres per gram, or square metres per kilogram.

16.1.2 This test method provides, in general, relative rather than absolute fineness values. For the complete description of the apparatus and the procedures for use, refer to Test Method C 204.

16.2 *Precision and Bias*:

16.2.1 Although precision for the test method for fineness of portland cement by air permeability apparatus has been reported in Test Method C 204, the precision of this test method has not been determined for pulverized lime and hydrated lime.

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When sufficient data has been obtained and analyzed, a statement of precision will be provided. In the meantime users of this test method are advised to develop their own.

17. Particle Size of Pulverized Limestone

17.1 *Significance and Use*:

17.1.1 Particle size of pulverized limestone, as the word is used in these methods, is the percent distribution of the equivalent spherical diameter of the individual particles expressed in micrometres, using the principle of sedimentation and Stokes' law for particle size determination. It is intended for use with pulverized limestones with not more than 0.5 % residue on a 45-μm (No. 325) sieve.

17.2 *Apparatus*:

17.2.1 *Soil Hydrometer*, ASTM 152H.

17.2.2 *Sedimentation Cylinder*, ASTM, 1000-mL capacity.

17.2.3 *Rubber Stopper*, Size 12.

17.2.4 *Thermometer*, 0 to 105 °C.

17.2.5 *Stop Watch*.

17.2.6 *Regular Clock or Watch*.

17.2.7 *Mixer*.

17.2.8 *Water Bath*.

17.2.9 *Balance*.

17.2.10 *Watch Glass*.

17.2.11 *Graph Paper*, 3 cycles × 70 divisions.

17.2.12 *Sieve*, 45-μm (No. 325), stainless steel cloth, brass frame, 8-in. diameter.

17.2.13 *Sieve*, 500-mesh, stainless steel cloth, brass frame, 4-in. diameter, 5-in. tall frame.

17.3 *Reagents*:

17.3.1 *Particle-Dispersing Agent*, (30 mL of 25 % solution is diluted up to 400 mL with distilled water).

17.4 *Procedure*:

17.4.1 Determine meniscus correction by inserting the hydrometer in the sedimentation cylinder filled to mark with distilled water. Record the reading at the top of the meniscus and at the bottom of the meniscus. The difference between the two readings is the meniscus correction. For example, in Fig. 7, the correction for the hydrometer used is 1.2. This reading is *added* to each R to obtain R_r.

17.4.2 Calibrate the hydrometer by adding 30 mL of the particle-dispersing solution to the sedimentation cylinder, then bringing up to the mark with distilled water at 27 °C. Mix thoroughly and take a hydrometer reading (read at the top of the meniscus). Repeat after cooling the cylinder to 17 °C and adjusting the meniscus so it is on the mark. Assume a straight-line relationship and draw a line that gives the *composite correction factor.* This factor is the difference between the reading and zero. These are the corrections entered in Table 7 and should be determined for each hydrometer. Four factors are compensated for in the correction factor: (*1*) *Temperature:* Hydrometers and cylinders are calibrated at 20 °C; variations from this temperature produce inaccuracy in the hydrometer reading; (*2*) *Specific gravity:* Addition of dispersant changes the specific gravity of the solution; (*3*) *Meniscus correction:* Hydrometers are graduated to read at the bottom of the meniscus but opaque calcium carbonate solutions require readings at the top of the meniscus; and (*4*) *Hydrometers:* In spite of the supposed similarity in volume of the hydrometers (ASTM 152H), variations of as much as 1.0-scale divisions between two similar hydrometers have been noted. The correction factor brings all four into line with one another. It is not necessary to repeat this calibration unless changing to a different hydrometer.

17.4.3 Weigh 40 g of sample.

17.4.4 Add approximately 300 mL of distilled water to the mixer, 30 mL of the particle-dispersing solution, followed by 40 g of unknown sample. Cover. Agitate for exactly 2 min at high speed.

17.4.5 Transfer the slurry quantitatively to the 1000-mL sedimentation cylinder. Make up to approximately 3.2 mm (⅛ in.) above the mark since it must be read from the top (as the bottom of the meniscus is not visible) and this will approximate the 1000-mL calibration of the cylinder. Cylinder temperature can be adjusted to 20 °C by running cool water on the outside of the cylinder and stirring with a thermometer until 20 °C is reached. Cap with the rubber stopper. Mix well by inverting the cylinder 15 or more times. Remove the stopper and put the cylinder in a water bath that has been previously adjusted to as close to 20 °C as is possible. Start the stop watch and note the time on the clock. At exactly 4½ min after start, carefully insert the hydrometer to the approximate point where the reading is to be made. Take the reading at exactly 5 min. Record the reading and temperature (Note 11). Remove the hydrometer and wash clean of any slurry. Cover the cylinder with the watch glass.

NOTE 11—Temperature must be taken inside the cylinder and not in the water bath.

17.4.6 Take additional readings at 15, 30, 60, 120, *or* 180 min; 300 *or* 360 min; and 1200 *or* 1440 min after the start.

17.4.7 Take a 25-g sample and run a 500-mesh wet-sieve test. The opening of the 500-mesh sieve is approximately 25 μm. From this result calculate the percent finer than 25 μm. Do not discard the plus 500-mesh but use this with the 45-μm (No. 325) sieve to obtain the percent finer than 44 μm. The opening of the 45-μm sieve is 44 μm.

17.5 *Calculation*:

17.5.1 Arrange the data on a sample sheet.

17.5.2 Record the date and clock readings as readings are taken.

17.5.3 Readings are usually taken at 5, 15, 30, 60, 180, 360, and 1440 min. The 25-μm point is obtained from the 500-mesh sieve result and the 44-μm point is obtained from the 45-μm sieve result.

17.5.4 Record the temperature, T, and the hydrometer reading, R, for each reading.

17.5.5 Obtain R_r by *adding* the meniscus correction to each R value.

17.5.6 Obtain R_c, the corrected hydrometer reading, from Fig. 7. This value can be different for each hydrometer and must be individually determined.

17.5.7 Obtain L from Table 8 using R_r values.

17.5.8 $\sqrt{L/T}$ is found from Fig. 8 and the values for L and T (time). For times not in Fig. 8, calculate the $\sqrt{L/T}$ since the values for L and T (in minutes) are known.

17.5.9 Find D at 20 °C in terms of $\sqrt{L/T}$ using Table 9.

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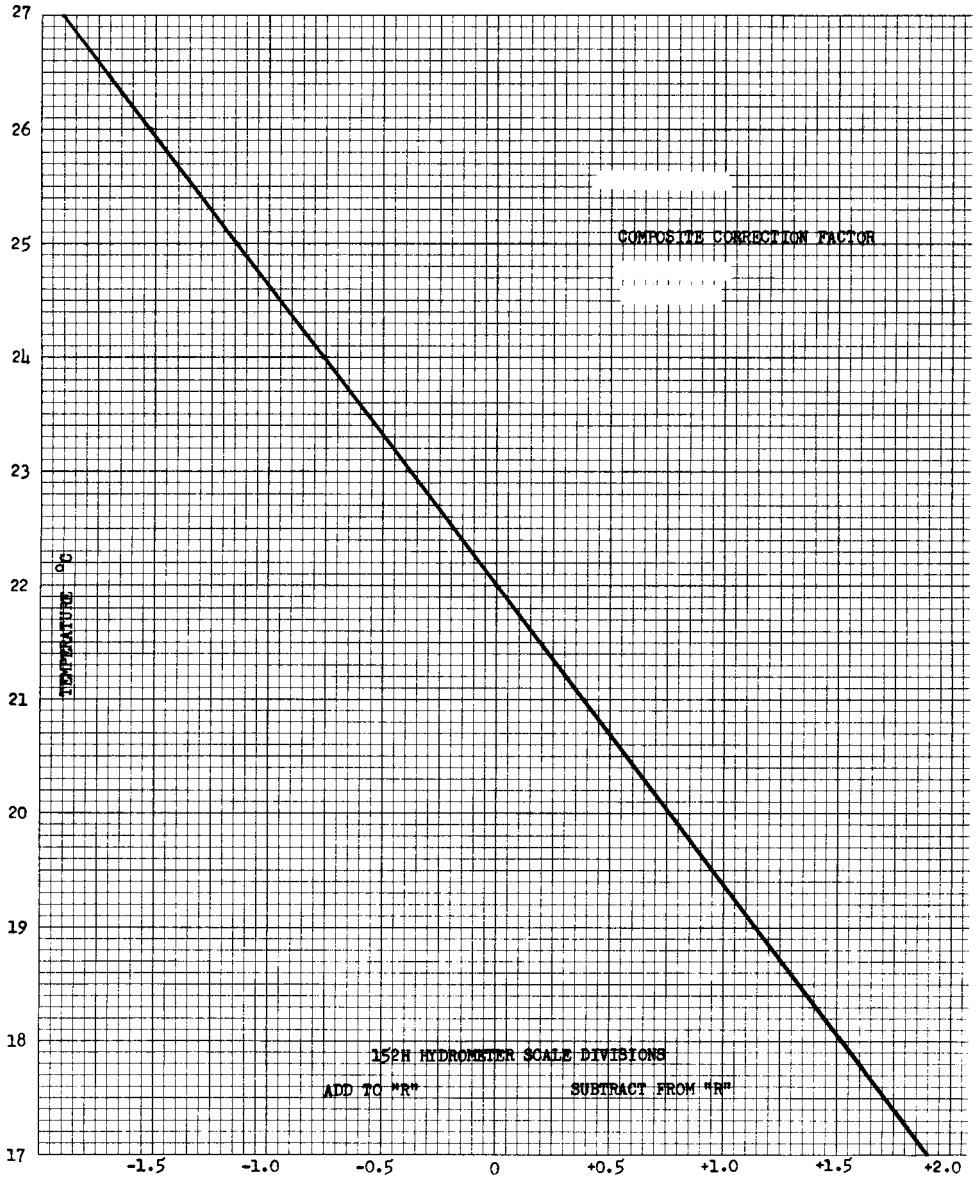

FIG. 7 Composite Correction Factor for Hydrometer

TABLE 7 Hydrometer Composite Correction Factor

Temperature, °C	Correction Factor
17	+1.90
18	+1.52
19	+1.14
20	+0.76
21	+0.39
22	0.00
23	−0.38
24	−0.76
25	−1.14
26	−1.52
27	−1.90

17.5.10 . To correct D for temperature, use Table 10 and find ΔD in terms of $\sqrt{L/T}$. Multiply by ΔT (ΔT is the difference in temperature between 20 °C and the actual temperature of the test). This will give a value to be subtracted from the D found in 17.5.9 if the temperature is above 20 °C. If the temperature is below 20 °C, this correction should be added.

17.5.11 Find P by using Table 10 and the value for R_c.

17.5.12 The values of D_c are now plotted against the values of P.

17.6 *Precision and Bias*:

17.6.1 The precision and bias of this test method has not been determined.

18. Dry Screening of Hydrated Lime, Pulverized Quicklime, and Limestone by Air Jet Sieving

18.1 *Significance and Use*:

18.1.1 This test method uses a rotating slit nozzle to supply a stream of air directed at the backside of a test sieve, keeping the screen from “blinding.” The aerated material is then pulled back through the sieve by a vacuum source.

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TABLE 8 Effective Depth, *L*, for Hydrometer 152H

R_r	L, cm	R_r	L, cm
0	16.3	31	11.2
1	16.1	32	11.1
2	16.0	33	10.9
3	15.8	34	10.7
4	15.6	35	10.6
5	15.5	36	10.4
6	15.3	37	10.2
7	15.2	38	10.1
8	15.0	39	9.9
9	14.8	40	9.7
10	14.7	41	9.6
11	14.5	42	9.4
12	14.3	43	9.2
13	14.2	44	9.1
14	14.0	45	8.9
15	13.8	46	8.8
16	13.7	47	8.6
17	13.5	48	8.4
18	13.3	49	8.3
19	13.2	50	8.1
20	13.0	51	7.9
21	12.9	52	7.8
22	12.7	53	7.6
23	12.5	54	7.4
24	12.4	55	7.3
25	12.2	56	7.1
26	12.0	57	7.0
27	11.9	58	6.8
28	11.7	59	6.6
29	11.5	60	6.5
30	11.4		

18.1.2 The advantages of dry screening by air jet sieving are twofold. The material being tested is less likely to "blind" the screen because of the recurring counterflow of an air stream to the back of the sieve. Also, dry screening avoids the error introduced by the interaction of the test material with soluble liquid media.

18.1.3 This test method is suitable for screening material from a nominal 300 µm (50 mesh) in size to 20 µm (635 mesh).

NOTE 12—Blinding of the sieves can occur at various sizes depending on the materials being sieved. Experience has shown 45 µm (325 mesh) to be the lower limit with some hydrates. Other hydrates and pulverized quicklime may be sieved to 32 µm (450 mesh). Limestone can be sieved to 20 µm (635 mesh).

18.2 *Apparatus*:

18.2.1 *An Enclosed Device*, capable of creating a vacuum on the backside of a sieve causing a rotating slit nozzle to supply an air stream perpendicular to the bottom of the sieve. The purpose is to suspend all material on the sieve by the air stream on a rotating basis.[12]

18.2.2 *Balance*, suitable for weighing accurately to 0.01 g.

NOTE 13—Selection of balance with regard to accuracy is dependent on the sample size chosen and residue retained and must be consistent with the accuracy required. Therefore, a balance weighing accurately to 0.001 g may be desired.

18.2.3 *Brush*, soft bristle.

18.2.4 *Sieve Cover*—A hard plastic transparent cover used to create a vacuum on the sieve.

18.2.5 *Test Sieves*—The sieves should be constructed using a woven wire, either brass or stainless steel, mounted on a substantial frame. Electroformed sieves are not recommended because of increased blinding and cleaning problems, making them impractical to use under most conditions. The sieves shall be approximately 8 in. in diameter and conform to Specification E 11. A flexible collar must be used to ensure an air tight fit between the sieve and the device.

18.3 *Procedure*:

18.3.1 After placing the appropriate sieve into position, weigh (to the nearest 0.01 g) a sample of the test material and place it on the sieve.

NOTE 14— The accuracy of sieve analysis with products with fine particle size distributions such as Type S hydrated lime can be improved by adding graphite powder (nominal 20 µm (625 mesh)) to the sample. For every 20 g of sample, 0.5 g of graphite should be added.

NOTE 15—The amount of sample and duration of sieving are dependent upon the type of material and gradation and therefore should be adapted to individual conditions. Generally, the larger the sample size, the more representative of the material tested and the less significant are errors of technique, therefore, the results are the more exact. Sample weights can vary from 20 g for material finer than 40 µm up to 50 g for larger, heavier materials.

18.3.2 Place cover on sieve, set timer to 6 min and start vacuum (maintain vacuum according to manufacturer's recommendation). Any material clinging to the cover or edge of the sieve can be removed by light tapping with a mallet or similar device (see Note 15). If agglomerations form, they can be broken apart with a soft bristle brush.

NOTE 16—Static electrical charges can often develop on the cover (if it is made of plastic) causing it to hold a heavy film of the material being sieved. If tapping will not loosen the material, a static face sheet[13] may be used to wipe the cover surface before starting the test.

18.3.3 After screening, clean the sieve with a fine bristle brush being careful not to damage the mesh and then weigh the residue to the nearest 0.01 g.

18.4 *Calculation*:

18.4.1 Calculate percent passing as follows:

$$[(S - R)/S] \times 100 = \text{percent passing} \quad (5)$$

where:

S = sample weight, g, and

R = weight of sieve residue, g.

18.5 *Precision and Bias*:

18.5.1 There are as yet insufficient analyzed data to permit preparation of a precision and bias statement for this test method.

19. Wet Sieve Analysis of Agricultural Liming Materials

19.1 *Scope*:

19.1.1 This test method covers the determination of gradation of an Agricultural Liming material by wash. Material finer

[12] The apparatus describes commercially available units sold by the Alpine American Corporation of Natick, Massachusetts. Although the description of the apparatus is directed toward this commercially available equipment, it does not restrict the use of other equivalent equipment which may be available or may be constructed, as long as it follows the general principles outlined under the summary of this test method.

[13] Commercially available.

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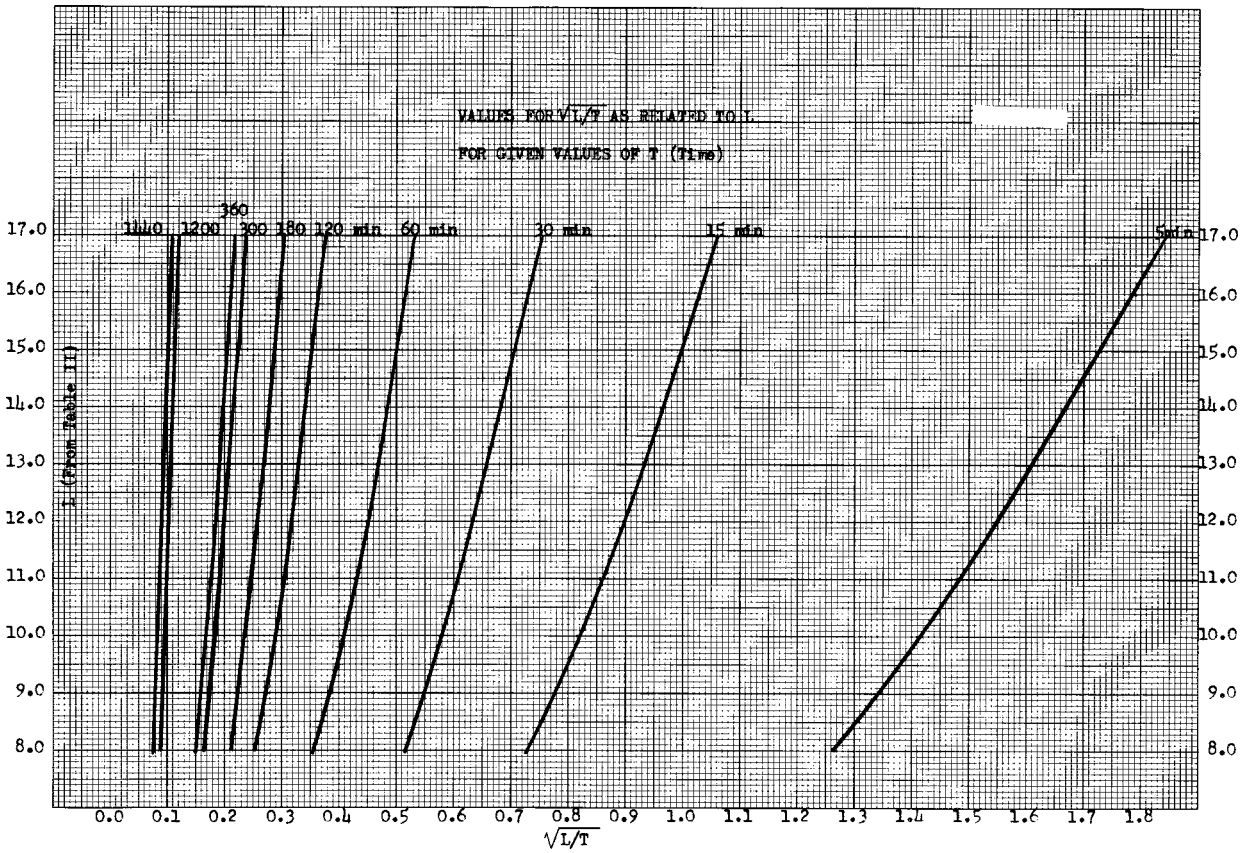

FIG. 8 Values for $\sqrt{L/T}$ as Related to *L* for Given Values of *T* (Time)

TABLE 9 *D* as Related to $\sqrt{L/T}$ at 20 °C

$\sqrt{L/T}$	*D*, μm	$\sqrt{L/T}$	*D*, μm
0.05	0.7	1.05	14.0
0.10	1.4	1.10	14.7
0.15	2.0	1.15	15.4
0.20	2.7	1.20	16.0
0.25	3.4	1.25	16.7
0.30	4.0	1.30	17.4
0.35	4.7	1.35	18.0
0.40	5.4	1.40	18.7
0.45	6.0	1.45	19.4
0.50	6.7	1.50	20.1
0.55	7.4	1.55	20.8
0.60	8.0	1.60	21.4
0.65	8.7	1.65	22.1
0.70	9.4	1.70	22.8
0.75	10.0	1.75	23.4
0.80	10.7	1.80	24.1
0.85	11.4	1.85	24.8
0.90	12.0		
0.95	12.7		
1.00	13.4		

TABLE 10 ΔD from $\sqrt{L/T}$

$\sqrt{L/T}$	ΔD
2.0	0.32
1.9	0.31
1.8	0.29
1.7	0.27
1.6	0.26
1.5	0.24
1.4	0.23
1.3	0.21
1.2	0.19
1.1	0.18
1.0	0.16
0.9	0.15
0.8	0.13
0.7	0.11
0.6	0.10
0.5	0.08
0.4	0.07
0.3	0.05
0.2	0.03
0.1	0.02

than 75 micrometres (No. 200) sieve will be removed from the aggregate during the test, prior to dry sieving of the coarser fraction.

19.1.2 The results of this procedure can be used to determine compliance to a particle size distribution relative to applicable specifications for agricultural liming materials.

19.1.3 This method can **not** be used for the sieve analysis of quicklime or materials containing quicklime, because of the exothermic reaction with water.

19.2 *Significance and Use*:

19.2.1 Material finer than the 75 micrometres (No. 200) sieve can be separated from larger particles more efficiently

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TABLE 11 Values for P as Related to R_c, Using $a = 0.988$ and $W = 40$

NOTE 1—Calculate to nearest 0.1 of R_c. For a reading of 24.7, take reading of 24.5 which is 60.0 and add 2 × 0.4 or 60.8%.

R_c	P	R_c	P	R_c	P	R_c	P
0.0	0.0	11.5	28.5	23.0	57.0	34.5	85.0
0.5	1.5	12.0	30.0	23.5	58.0	35.0	86.5
1.0	2.5	12.5	31.0	24.0	59.0	35.5	87.5
1.5	3.5	13.0	32.0	24.5	60.0	36.0	89.0
2.0	5.0	13.5	33.5	25.0	62.0	36.5	90.0
2.5	6.0	14.0	35.0	25.5	63.0	37.0	91.5
3.0	7.5	14.5	36.0	26.0	64.0	37.5	92.5
3.5	8.5	15.0	37.5	26.5	65.0	38.0	94.0
4.0	10.0	15.5	38.5	27.0	66.5	38.5	95.0
4.5	11.0	16.0	39.5	27.5	67.5	39.0	96.5
5.0	12.5	16.5	40.5	28.0	69.0	39.5	97.5
5.5	13.5	17.0	42.0	28.5	70.0	40.0	99.0
6.0	15.0	17.5	43.0	29.0	71.5	40.5	100.0
6.5	16.0	18.0	44.5	29.5	72.5		
7.0	17.5	18.5	45.5	30.0	74.0		
7.5	18.5	19.0	47.0	30.5	75.0		
8.0	20.0	19.5	48.0	31.0	76.5		
8.5	21.0	20.0	49.5	31.5	77.5		
9.0	22.5	20.5	50.5	32.0	79.0		
9.5	23.5	21.0	52.0	32.5	80.0		
10.0	25.0	21.5	53.0	33.0	81.5		
10.5	26.0	22.0	54.5	33.5	82.5		
11.0	27.5	22.5	56.5	34.0	84.0		

and completely by wet sieving than through the use of dry sieving. In sieving fine aggregate, the finer fractions can adhere to the coarser fractions through a normal dry sieving operation. Further, due to electrostatic charges, fine material can also adhere to the coarser sieves. By removing the finer fractions through the wash test, these problems are avoided. Therefore, when an accurate determination of an agricultural liming material is desired, this test method should be used.

19.2.2 The results of this test method are included in the calculation of gradation, and the total amount of material finer than 75 micrometres by washing, plus that obtained by dry sieving the same sample, is reported with the results. Usually the additional amount of material finer than 75 micrometres obtained in the subsequent dry sieving process is a small amount. If it is large, the efficiency of the washing operation should be checked. It could, also, be an indication of degradation of the material.

19.3 *Apparatus and Materials*:

19.3.1 *Balance*—A balance or scale readable and accurate to 0.1 g or 0.1 % of the test load, whichever is greater, at any point within the range of use.

19.3.2 *Sieves*—The sieves shall be mounted on substantial frames, either full height or extended, and constructed in a manner that will prevent loss of material during sieving. The sieves shall be of equal diameter and shape to allow for nesting. The sieves shall conform to Specification E 11.

19.3.3 *Sieve Pan*—A pan of the same diameter as the sieves.

19.3.4 *Container*—A pan or vessel of a size sufficient to contain the sample covered with water and to permit vigorous agitation without loss of any part of the sample or water.

19.3.5 *Oven*—An oven of sufficient size, capable of maintaining a uniform temperature of 110 ± 5 °C.

NOTE 17—The use of a mechanical apparatus to perform the washing operation is not precluded, provided the results are consistent with those obtained using manual operations. The use of some mechanical washing equipment with some samples may cause degradation of the sample.

19.4 *Sampling*:

19.4.1 Since sampling is equally as important as testing, it is critical that samples be obtained that are representative of the materials being investigated. Therefore, sampling must be conducted in as conscientious a manner as possible. Incremental sampling should be employed, combining the increments into one bulk sample.

19.4.2 Use the procedures described in Practice C 50, or Practice D 75.

19.4.3 To reduce the bulk sample to the amount needed for testing, the use of mechanical splitters or the process of quartering must be used. At no time can a random lot be drawn from the bulk sample for testing.

19.5 *Procedure*:

19.5.1 Dry the test sample to constant mass at a temperature of 110 ± 5 °C. Determine the mass to the nearest 0.1 % of the mass of the test sample. The amount of sample required for this test shall be between 200 to 400 g. The test sample shall be the end result of the reduction. Reduction to an exact predetermined mass shall not be permitted.

19.5.2 After drying and determining the mass, place the test sample in the container and add sufficient water to cover it. Agitate the sample with sufficient vigor to result in complete separation from the coarser particles of all particles finer than the 75 micrometre sieve from the coarser particles, and to bring the fine material into suspension. Immediately pour the wash water containing the suspended and dissolved solids over the nested sieves (see Note 18), arranged with the coarser sieve on top. Take care to avoid, as much as feasible, the decantation of coarser particles of the sample.

NOTE 18—It is recommended that a #16 mesh sieve or one of approximate size be used to nest on top of the # 200 mesh sieve for protection from the sample.

19.5.3 Add a second charge of water to the sample in the container, agitate, and decant as before. Repeat this operation until the wash water is clear (see Note 19).

NOTE 19—If mechanical washing equipment is used, the charging of water, agitating, and decanting may be a continuous operation.

19.5.4 Return all material retained on the nested sieves by flushing to the washed sample. Dry the washed material to constant mass at a temperature of 110 ± 5 °C and determine the mass to the nearest 0.1 g. Calculate the amount of material passing a 75 micrometre sieve by washing according to 19.6.1.

19.5.5 Select the sieves of a suitable size as desired or required by specification and those sieves necessary to regulate the amount of material between the various screens. Nest the screens in order of decreasing size of opening, from top to bottom, on a sieve pan. Be sure to nest the 75 micrometre sieve just above the pan. Place the dried sample on the top sieve. Shake the nested sieves briskly or by use of a mechanical device for a sufficient period to assure that the sample has been adequately screened (see Note 20).

NOTE 20—To be adequately screened, no more than 1 % of the residue on any individual sieve will pass that sieve during 1 min. of continuous

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sieving. For a more detailed explanation refer to C 136-84a, paragraph 7.4.

19.5.6 The amount of material on an eight inch sieve after shaking is limited to approximately 200 g, so that all particles during a test have access to the screen medium (see Note 21). If the amount remaining on a sieve is greater than 200 g, the sieve analysis must be repeated. Place an intermediate sieve between the overloaded sieve and the one nested above.

NOTE 21—A twelve inch screen can be used, but the amount of material retained on a sieve is limited to 6 kg/m^2.

19.5.7 Record the weight of material from each size increment and the sieve pan by weighing on a balance to the nearest 0.1 g (see Note 22). Total the retained masses of all the size increments and the sieve pan from the dry sieve test. If this amount differs from the dry mass of the sample after washing by more than 0.3 %, the results should not be used for acceptance purposes.

NOTE 22—A soft bristle can be used to help remove material from sieves, but at no time can material be forced through a sieve.

19.6 *Calculation*:

19.6.1 Calculate the amount of a material passing a 75 micrometre sieve by washing as follows:

$$A = [(B - C) / B] \times 100 \quad (6)$$

where:

A = percentage of material finer than a 75 micrometre sieve by washing,
B = original dry mass of sample, g, and
C = dry mass of sample after washing, g.

19.6.2 Calculation of amount of material passing individual sieves follows:

19.6.2.1 Add weight of material finer than a 75 micrometre sieve by washing (B – C, in 19.6.1) to the weight of material finer than a 75 micrometre sieve obtained in the dry screening, if washed.

19.6.2.2 Calculate the percent retained on each sieve and the pan as follows:

$$A = (B / C) \times 100 \quad (7)$$

where:

A = percentage of material retained on each sieve (pan),
B = dry mass of sample, g, retained on each sieve (pan), and
C = original dry mass of sample, g.

19.6.2.3 Calculate the cumulative percent retained for each screen by adding the percentage retained on that sieve and all sieves of larger diameter opening.

19.6.2.4 For each screen, subtract the cumulative percent retained from 100 to obtain the percent passing.

19.7 *Precision and Bias*:

19.7.1 The precision of this test method is based on an interlaboratory study of C 110 – 01 conducted in 2005. Each of the twelve laboratories tested five different materials. Each "test result" was an individual determination of the percent of material passing a particular mesh sieve. Participating laboratories obtained three replicate test results for each material and sieve combination.[14] See Tables 12-16.

19.7.1.1 *Repeatability*—Two test results obtained within one laboratory shall be judged not equivalent if they differ by more than the "*r*" value for that material; "*r*" is the interval representing the critical difference between two test results for the same material, obtained by the same operator using the same equipment on the same day in the same laboratory.

19.7.1.2 *Reproducibility*—Two test results should be judged not equivalent if they differ by more than the "*R*" value for that material; "*R*" is the interval representing the difference between two test results for the same material, obtained by different operators using different equipment in different laboratories.

19.7.1.3 Any judgment in accordance with these two statements would have an approximate 95 % probability of being correct.

19.7.2 *Bias*—At the time of the study, there was no accepted reference material suitable for determining the bias for this test method, therefore no statement on bias is being made.

19.7.3 The precision and bias statements were determined through statistical examination of 1440 test results, from a total of twelve laboratories, analyzing five materials.

DENSITY MEASUREMENT

20. Apparent Loose Density of Hydrated Lime, Pulverized Quicklime, and Limestone

20.1 *Significance and Use*:

20.1.1 This test method determines the loose or unsettled density of hydrated lime, pulverized quicklime, and limestone. It provides for an approximate measure of the maximum volume occupied by a given weight of hydrated lime, pulverized quicklime, or limestone.

20.2 *Apparatus*:

20.2.1 *Flour Sifter*—A 114 to 127 mm (4½ to 5 in.) kitchen-type flour sifter of either the squeeze handle type or the hand crank type. It shall be able to hold at least 300 g of hydrated lime or 500 g of limestone or quicklime. The wire mesh openings should be between 0.8 and 1.5 mm.

20.2.2 *Density Cup*, 400 mL cylindrical cup as described in the Apparatus Section of Test Method C 185.

[14] Supporting data pending being filed at ASTM International Headquarters.

TABLE 12 Screenings

Sieve Size	Average	Repeatability Standard Deviation	Reproducibility Standard Deviation	Repeatability Limit	Reproducibility Limit
	$\bar{\chi}$	s_r	s_R	r	R
#200	19.60	0.44	2.26	1.23	6.33
#100	26.66	0.52	2.05	1.46	5.74
#60	32.67	0.26	1.68	0.73	4.70
#36	44.41	0.37	1.28	1.04	3.58
#16	58.60	0.60	1.09	1.68	3.05
#8	78.62	0.71	1.22	1.99	3.42
#4	97.99	0.38	0.47	1.06	1.32
⅜ "	100.00	0.00	0.00	0.00	0.00

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TABLE 13 Superfine

Sieve Size	Average	Repeatability Standard Deviation	Reproducibility Standard Deviation	Repeatability Limit	Reproducibility Limit
	$\bar{x}$	s_r	s_R	r	R
#200	99.94	0.12	0.13	0.34	0.36
#100	99.97	0.07	0.08	0.20	0.22
#60	99.99	0.06	0.05	0.17	0.14
#36	99.99	0.04	0.04	0.11	0.11
#16	99.99	0.03	0.03	0.08	0.08
#8	100.00	0.00	0.00	0.00	0.00
#4	100.00	0.00	0.00	0.00	0.00
⅜ ”	100.00	0.00	0.00	0.00	0.00

TABLE 14 Ground

Sieve Size	Average	Repeatability Standard Deviation	Reproducibility Standard Deviation	Repeatability Limit	Reproducibility Limit
	$\bar{x}$	s_r	s_R	r	R
#200	73.75	4.39	4.56	12.29	12.77
#100	92.67	4.69	4.67	13.13	13.08
#60	98.19	0.76	0.83	2.13	2.32
#36	99.33	0.13	0.19	0.36	0.53
#16	99.72	0.10	0.15	0.28	0.42
#8	99.91	0.09	0.09	0.25	0.25
#4	99.99	0.02	0.02	0.06	0.06
⅜ ”	100.0	0.00	0.00	0.00	0.00

TABLE 15 Meal

Sieve Size	Average	Repeatability Standard Deviation	Reproducibility Standard Deviation	Repeatability Limit	Reproducibility Limit
	$\bar{x}$	s_r	s_R	r	R
#200	30.16	1.16	2.27	3.25	6.36
#100	37.00	1.04	1.72	2.91	4.82
#60	42.24	0.84	1.22	2.35	3.42
#36	53.86	0.70	0.99	1.96	2.77
#16	67.00	0.70	1.05	1.96	2.94
#8	86.48	0.75	1.79	2.10	5.01
#4	98.67	0.66	0.63	1.85	1.76
⅜ ”	99.91	0.30	0.29	0.84	0.81

TABLE 16 Pulverized

Sieve Size	Average	Repeatability Standard Deviation	Reproducibility Standard Deviation	Repeatability Limit	Reproducibility Limit
	$\bar{x}$	s_r	s_R	r	R
#200	87.97	0.88	1.23	2.46	3.44
#100	97.96	0.42	2.98	1.18	8.34
#60	99.77	0.19	0.27	0.53	0.76
#36	99.98	0.05	0.07	0.14	0.20
#16	100.00	0.00	0.00	0.00	0.00
#8	100.00	0.00	0.00	0.00	0.00
#4	100.00	0.00	0.00	0.00	0.00
⅜ ”	100.00	0.00	0.00	0.00	0.00

20.2.3 *Balance*, suitable for weighing at least 800 g accurately to 0.1 g.

20.2.4 *Clock or Watch*.

20.2.5 *Straight Edge*.

20.3 *Procedure*:

20.3.1 Weigh the empty density cup to the nearest 0.1 g on a balance. Place the tared cup on a solid table with a suitable mat inserted underneath the cup to collect excess sample spilling over the cup. Fill the flour sifter with more than enough material to fill the density cup. Start the clock and the sifting device to facilitate the flow of powder into the cup. Overflow the cup until there is a cone of excess material.

20.3.2 After 3 min, carefully remove the excess powder by passing the edge of a spatula blade parallel with, and in contact with, the top of the cup. Move the spatula smoothly and keep it level at all times to prevent packing or pulling the sample out of the cup.

20.3.3 After the cup is level, lightly tap it with the edge of the spatula to settle the powder. Wipe the outside of the cup with a lintless cloth or paper towel. Avoid spilling the sample while transferring the cup to the balance for weighing.

20.3.4 Weigh the cup and sample to the nearest 0.1 g and determine the weight of the sample by difference.

20.3.5 The loose density of the material is calculated and reported as grams per cubic centimetre, or as pounds per cubic foot.

20.4 *Calculation*:

20.4.1 Calculate the loose density as follows:

$$D = W/V \tag{8}$$

where:

D = loose density,
W = weight of sample, g, and
V = volume of cup, cm^3.

20.4.2 For reporting as pounds per cubic foot, multiply grams per cubic centimetre by 62.43.

20.5 *Precision and Bias*:

20.5.1 *Single Operator Precision*—The single operator standard deviation has been found to be 0.4 lb/ft^3(Note 9). Therefore, results of two properly conducted tests by the same operator on the same material should not differ by more than 1.13 lb/ft^3.

20.5.2 *Multilaboratory Precision*—The multilaboratory standard deviation has been found to be 1.26 lb/ft^3(Note 23). Therefore, results of two properly conducted tests from two different laboratories on samples of the same material should not differ by more than 3.6 lb/ft^3.

NOTE 23—These numbers represent, respectively, the (1s) and (d2s) limits as described in Practice C 670.

20.5.3 The above precision statements are based on a multilaboratory testing program for determination of the loose bulk density of hydrated lime. No statement is made regarding the precision of this method as it relates to other materials. Due to a lack of a recognized industry standard, the bias of this test method has not been determined.

21. Apparent Packed Density of Hydrated Lime, Pulverized Quicklime, and Limestone

21.1 Significance and Use:

21.1.1 This test method determines the packed or settled density of hydrated lime, pulverized quicklime, and limestone. It provides for determining the minimum volume occupied by a given weight of hydrated lime, pulverized quicklime or limestone.

21.2 *Apparatus*:

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21.2.1 *Graduated Cylinder*, 100 mL capacity.

21.2.2 *Balance*, accurate to 0.1 g.

21.3 *Procedure*:

21.3.1 Weigh to within 0.1 g a 25 g sample of powdered material and transfer it to the graduated cylinder.

21.3.2 Allow powder to settle by gently tapping the cylinder on a desk top cushioned with a thick magazine or writing tablet so that compaction occurs without fluffing.

21.3.3 Record the volume of the lime after each 100 taps and continue tapping until compaction volume change is less than 0.5 mL/100 taps.

21.3.4 Calculate the density in grams per cubic centimetre or in pounds per cubic foot to the nearest pound.

21.4 *Calculation*:

21.4.1 Calculate the packed density as follows:

$$D = W/V \tag{9}$$

where:

D = packed density,
W = weight of sample, g, and
V = final volume of sample, cm^3.

21.4.2 For reporting as pounds per cubic foot, multiply grams per cubic centimetre by 62.43.

21.5 *Precision and Bias*:

21.5.1 *Single Operator Precision*—The single operator standard deviation has been found to be 0.5 lb/ft^3(Note 23). Therefore, results of two properly conducted tests by the same operator on the same material should not differ by more than 1.4 lb/ft^3.

21.5.2 *Multilaboratory Precision*—The multilaboratory standard deviation has been found to be 1.7 lb/ft^3(Note 23). Therefore, results of two properly conducted tests from two different laboratories on samples of the same material should not differ by more than 4.8 lb/ft^3.

21.5.3 The above precision statements are based on a multilaboratory testing program for determination of the packed bulk density of hydrated lime. No statement is made regarding the precision of this method as it relates to other materials. Due to a lack of a recognized industry standard, the bias of this test method has not been determined.

22. Relative Density (Specific Gravity) of Hydrated Lime Products

22.1 *Significance and Use*:

22.1.1 This test method covers two methods for the determination of the relative density (specific gravity) of hydrated lime.

22.1.2 Relative density (specific gravity) of hydrated lime is defined as the ratio of the density of the material to the density of water at a stated temperature; the values are dimensionless.

22.2 *Le Chatelier Flask Method*:

22.2.1 The standard flask, which is circular in cross section with shape and dimensions conforming essentially to Fig. 1 of Test Method C 188 (Note 24). The requirements in regard to tolerance, inscription and length, spacing, and uniformity of graduation shall be rigidly observed. There shall be a space of at least 10 mm between the highest graduation mark and the lowest point of grinding for the glass stopper.

22.2.1.1 The material of construction shall be best quality glass, transparent and free of striae. The glass shall be chemically resistant and shall have small thermal hysteresis. The flasks shall be thoroughly annealed before being graduated. They shall be of sufficient thickness to ensure reasonable resistance to breakage.

22.2.1.2 The neck shall be graduated from 0 to 1 mL and from 18 to 24 mL in 0.1 mL graduations. The error of any indicated capacity shall not be greater than 0.05 mL.

22.2.1.3 Each flask shall bear a permanent identification number and the stopper, if not interchangeable ground, shall bear the same number. Interchangeable ground-glass parts shall be marked on both members with the standard-taper symbol followed by the size designation. The standard temperature shall be indicated, and the unit of capacity shall be shown by the letters "mL" placed above the highest graduation mark.

NOTE 24—The design is intended to ensure complete drainage of the flask when emptied, and stability of standing on a level surface, as well as accuracy and precision of reading.

22.3 *Reagents*:

22.3.1 *Ethyl Alcohol (Absolute)*, free of water, shall be used in the density determination. The ethanol used should not have been denatured with methanol.

22.4 *Procedure*:

22.4.1 Determine the specific gravity of hydrated lime on the material as received, unless otherwise specified.

22.4.2 Fill the flask (Note 25) with denatured ethyl alcohol to a point on the stem between the 0 and 1-mL mark. Dry the inside of the flask above the level of the liquid, if necessary, after pouring. Record the first reading after the flask has been immersed in the water bath (Note 26) in accordance with 19.3.4.

NOTE 25—It is advisable to use a rubber pad on the table top when filling or rolling the flask.

NOTE 26—Before the hydrated lime has been added to the flask, a loose fitting lead-ring weight around the stem of the flask will be helpful in holding the flask in an upright position in the water bath, or the flask may be held in the water bath by a buret clamp.

22.4.3 Introduce a quantity of hydrated lime, weighed to the nearest 0.05 g, (about 50 g for hydrated lime) in small increments at the same temperature as the liquid (Note 25). Take care to avoid splashing and see that the hydrated lime does not adhere to the inside of the flask above the liquid. A vibrating apparatus may be used to accelerate the introduction of the hydrated lime into the flask and to prevent the lime from sticking to the neck. After all the hydrated lime has been introduced, place the stopper in the flask and roll the flask in an inclined position (Note 25), or gently whirl it in a horizontal circle as to free the lime from air until no further air bubbles rise to the surface of the liquid. If a proper amount of hydrated lime has been added, the level of the liquid will be in its final position at some point of the upper series of graduations. Take the final reading after the flask has been immersed in the water bath in accordance with 22.3.4.

22.4.4 Immerse the flask in a constant-temperature water bath for sufficient periods of time in order to avoid flask temperature variations greater than 0.2 °C between the initial and final readings.

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22.5 *Calculation:*

22.5.1 The difference between the first and the final readings represents the volume of liquid displaced by the mass of hydrated lime used in the test.

22.5.2 Calculate the hydrated lime density, *p*, as follows:

$$p(\mathrm{Mg/m^3}) = p(\mathrm{g/cm^3}) = \frac{\text{mass of hydrated lime (g)}}{\text{displaced volume (cm}^3\text{)}} \quad (10)$$

NOTE 27—The displaced volume in milliliters is numerically equal to the displaced volume in cubic centimeters.

22.6 *Precision and Bias*:

22.6.1 *Round Robin*—An interlaboratory study, consistent with the guidelines of Practice E 691, was conducted in June 2000. The test for specific gravity was conducted in accordance with these test methods, Section 22. Four hydrated lime products, two dolomitic "S" samples and two Type "N" (one high calcium and one dolomitic) samples were tested by seven laboratories. Each laboratory performed three determinations, thus meeting the requirements of Practice E 691. The research report is on file with ASTM International.[15]

22.6.2 *Precision*—The relative precision of this test method, characterized by repeatability (s_r and r) and reproducibility (s_R and R) has been determined for the materials to be the following:

Hydrate Type	Average	s_r	s_R	r	R
High Calcium "N"	2.217	0.007	0.030	0.020	0.083
Dolomitic "S"	2.306	0.023	0.059	0.065	0.164
Dolomitic "N"	2.466	0.016	0.035	0.045	0.097

22.6.3 *Repeatability*—Examine the data in 22.6.2 as to hydrate type to determine the expected differences in absolute value of replicate determinations, carried out in the same laboratory, by the same operator using the same apparatus at a 95 % confidence level. The critical value for repeatability is r.

22.6.4 *Reproducibility*—Examine the data in 22.6.2 as to hydrate type to determine the expected differences in absolute value of replicate determinations, carried out in different laboratories using samples taken at random from the same bulk sample. The critical value, R, may be expected to occur at a 95 % confidence level, for reproducibility.

22.6.5 *Bias*—No bias is expected for the method.

22.7 *Helium Gas Pycnometry Method*:

22.7.1 Apparatus and Instrument Requirements:

22.7.1.1 Helium gas pychnometers are commercially available.

22.7.1.2 Laboratory air temperature 25 ± 10 °C (50 – 96 °F).

22.7.1.3 Laboratory relative humidity 50 ± 30 %, non-condensing.

22.7.1.4 Pychnometer must be located free from draft and direct sunlight.

22.7.1.5 Power cords and voltage/amperage requirements must meet the requirements of the manufacturer's requirements.

22.7.1.6 Prior to analysis, calibration following manufacturer's instructions.

22.7.1.7 Purge fill and run fill pressure to be maintained at the manufacturer's requirements.

22.7.1.8 Sample purging to be completed as required by manufacturer.

22.7.1.9 Chamber cap to remain in place at all times, except when inserting or removing sample.

22.7.1.10 Sample holder or cup to be clean and dry. Use only cups provided by the manufacturer. Clean only with lint-free cloth. Handle only gloved hand.

22.7.1.11 Enable run precision or deviation requested at the mid-range of the manufacturer's offering.

22.7.1.12 Run equilibration rate at the manufacturer's requirements.

22.7.1.13 Percent of Nominal Cell Volume is entered at manufacturer's recommended value.

22.7.1.14 Precision reproducibility to be within ± 0.03 % of full scale cell chambers sample capacity; accuracy to within ± 0.02 of nominal full scale cell chamber volume sample capacity.

22.7.1.15 Mass balance shall be calibrated and capable of recording mass in grams to 4 decimal places with a tolerance of ± 0.01 mg.

22.7.2 *Reagents*:

22.7.2.1 Helium gas of research grade (99.995 % pure) or helium gas with dewpoint of –67 °C or less.

22.7.3 *Procedure*:

22.7.3.1 Warm up pycnometer for a least two hours prior to testing.

22.7.3.2 Ensure cell chamber, cap, and sample cup are clean and dry; wear gloves when handling; helium gas tank pressure within manufacturer's parameters; complete cell purges prior to analysis.

22.7.3.3 Weigh cup with lid (four decimal places), fill sample cup to ¾ full, and weigh cup-lid + sample. Record data.

22.7.3.4 Remove cell cap and insert cup, lid, and sample into the pycnometer cell chamber, replace cap and perform analysis following manufacturer's recommendations. Record results.

22.7.4 *Precision and Bias*:

22.7.4.1 The precision of this test method is based on an interlaboratory study of Test Methods C 110 conducted in 2007. Seven laboratories tested three different types of hydrated lime. Every "test result" represents an individual determination. Each laboratory was asked to report triplicate test results in order to permit the estimation of Intralaboratory precision. Practice E 691 was followed for the design and analysis of the data.[16]

22.7.4.2 *Repeatability limit (r)*—Two test results obtained within one laboratory shall be judged not equivalent if they differ by more than the "r" value for that material; "r" is the interval representing the critical difference between two test results for the same material, obtained by the same operator using the same equipment on the same day in the same laboratory.

[15] Supporting data have been filed at ASTM International Headquarters and may be obtained by requesting Research Report RR: C07-1004.

[16] Supporting data have been filed at ASTM International Headquarters and may be obtained by requesting Research Report RR: C07–ILS0238..

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Repeatability limits are listed in Table 17.

22.7.4.3 *Reproducibility limit (R)*—Two test results shall be judged not equivalent if they differ by more than the "R" value for that material; "R" is the interval representing the critical difference between two test results for the same material, obtained by different operators using different equipment in different laboratories.

Reproducibility limits are listed in Table 17.

22.7.4.4 The above terms (repeatability limit and reproducibility limit) are used as specified in Practice E 177.

TABLE 17 Relative Density (Specific Gravity)

Material	Average[A]	Repeatability Standard Deviation	Reproducibility Standard Deviation	Repeatability Limit	Reproducibility Limit
	$\bar{X}$	s_r	s_R	r	R
1	2.3186	0.0076	0.0141	0.0212	0.0395
2	2.2978	0.0103	0.0236	0.0288	0.0660
3	2.5267	0.0088	0.0144	0.0246	0.0402

[A]The average of the laboratories' calculated averages.

22.7.4.5 Any judgment in accordance with statements 22.7.4.2 and 22.7.4.3 would have an approximate 95% probability of being correct.

22.8 *Bias*—At the time of the study, there was no accepted reference material suitable for determining the bias for this test method, therefore no statement on bias is being made.

22.9 The precision statement was determined through statistical examination of 63 results, from seven laboratories, on three materials. The materials were described as the following:

Material 1: Type S (Dolomitic) Hydrated Lime

Material 2: High Calcium Hydrated Lime

Material 3: Type N (Dolomitic) Hydrated Lime

23. Keywords

23.1 accepted reference value; accuracy; apparent density; bias; dry brightness; dry screening; fineness; interlaboratory study; lime putty; limestone grindability; particle size; precision; precision conditions; repeatability; reproducibility; slaking rate; standard deviation

SUMMARY OF CHANGES

Committee C07 has identified the location of selected changes to these test methods since the last issue, C 110 – 09, that may impact the use of these test methods. (Approved June 15, 2009)

(*1*) Heavily revised Section 22, including the addition of Table 17.

Committee C07 has identified the location of selected changes to these test methods since the last issue, C 110 – 08a, that may impact the use of these test methods. (Approved March 1, 2009)

(*1*) Revised Table 3.

(*2*) Revised Note 14.

Committee C07 has identified the location of selected changes to these test methods since the last issue, C 110 – 08, that may impact the use of these test methods. (Approved December 1, 2008)

(*1*) Revised 7.4.1 and 7.4.2.1.

(*2*) Moved old Section 22 Wet Sieve Analysis of Agricultural Liming Materials to Section 19 and renumbered subsequent sections. Added a precision and bias statement to Section 19.

Committee C07 has identified the location of selected changes to these test methods since the last issue, C 110 – 06, that may impact the use of these test methods. (Approved June 1, 2008)

(*1*) Revised the precision and bias statement in 6.5. Added new Tables 1 and 2 and renumbered subsequent tables. Added new Footnote 6 and renumbered subsequent footnotes.

(*2*) Revised 7.1.1.

(*3*) Added new Footnote 7 and renumbered subsequent footnotes.

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Designation: C114 – 09b

Standard Test Methods for Chemical Analysis of Hydraulic Cement[1]

This standard is issued under the fixed designation C114; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope*

1.1 These test methods cover the chemical analyses of hydraulic cements. Any test methods of demonstrated acceptable precision and bias may be used for analysis of hydraulic cements, including analyses for referee and certification purposes, as explained in Section 3. Specific chemical test methods are provided for ease of reference for those desiring to use them. They are grouped as Reference Test Methods and Alternative Test Methods. The reference test methods are long accepted classical chemical test methods which provide a reasonably well-integrated basic scheme of analysis for hydraulic cements. The alternative test methods generally provide individual determination of specific components and may be used alone or as alternates and determinations within the basic scheme at the option of the analyst and as indicated in the individual method.

1.2 *Contents:*

Section	Subject
2	Referenced Documents
3	Description of Referee Analyses
3.1	Referee Analyses
4	Qualification for Different Analyses
4.1	Certified Reference Materials
4.2	Requirements for Qualification Testing
4.3	Alternative Analyses
4.4	Performance Requirements for Rapid Test Methods
5	General
5.1	Interferences and Limitations
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5.6	Recommended Order for Reporting Analyses
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7.2	Cements with Insoluble Residue Less Than 1 %
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22	Calcium Oxide
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25.1	Portland Blast-Furnace Slag Cement and Slag Cement
26	Titanium Dioxide
27	Phosphorus Pentoxide
28	Manganic Oxide
29	Free Calcium Oxide
Appendices	Title
Appendix X1	Example of Determination of Equivalence Point for the Chloride Determination
Appendix X2	CO_2 Determinations in Hydraulic Cements

1.3 The values stated in SI units are to be regarded as standard. No other units of measurement are included in this standard.

1.4 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.* See 7.3.2.1 and 15.4.1 for specific caution statements.

2. Referenced Documents

2.1 *ASTM Standards:*[2]

C25 Test Methods for Chemical Analysis of Limestone, Quicklime, and Hydrated Lime

D1193 Specification for Reagent Water

E29 Practice for Using Significant Digits in Test Data to Determine Conformance with Specifications

[1] These test methods are under the jurisdiction of ASTM Committee C01 on Cement and are the direct responsibility of Subcommittee C01.23 on Compositional Analysis.

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[2] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

***A Summary of Changes section appears at the end of this standard.**

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E275 Practice for Describing and Measuring Performance of Ultraviolet and Visible Spectrophotometers
E350 Test Methods for Chemical Analysis of Carbon Steel, Low-Alloy Steel, Silicon Electrical Steel, Ingot Iron, and Wrought Iron
E617 Specification for Laboratory Weights and Precision Mass Standards
E832 Specification for Laboratory Filter Papers

3. Description of Referee Analyses

3.1 *Referee Analyses*—When conformance to chemical specification requirements is questioned, perform referee analyses as described in 3.1.1. The reference test methods that follow in Sections 6-21, or other test methods qualified according to 4.4, the *Performance Requirements for Rapid Test Methods* Section, are required for referee analysis. A cement shall not be rejected for failure to conform to chemical requirements unless all determinations of constituents involved and all necessary separations prior to the determination of any one constituent are made entirely by these methods. When reporting the results of referee analyses, specify which test methods were used.

3.1.1 Referee analyses shall be made in duplicate and the analyses shall be made on different days. If the two results do not agree within the permissible variation given in Table 1, the determination shall be repeated until two or three results agree within the permissible variation. When two or three results do agree within the permissible variation, their average shall be accepted as the correct value. When an average of either two or three results can be calculated, the calculation shall be based on the three results. For the purpose of comparing analyses and calculating the average of acceptable results, the percentages shall be calculated to the nearest 0.01 (or 0.001 in the case of chloroform-soluble organic substances), although some of the average values are reported to 0.1 as indicated in the test methods. When a blank determination (See Note 1) is specified, one shall be made with each individual analysis or with each group of two or more samples analyzed on the same day for a given component.

NOTE 1—A blank determination is a procedure which follows all steps of analysis but in the absence of a sample. It is used for detection and compensation of systematic bias.

4. Qualification for Different Analyses

4.1 *Certified Reference Materials*—A Certified Reference Material (CRM) must be used in the qualification of test methods and analysts. Acceptable reference cements are NIST CRMs, or other reference cements traceable to the NIST CRMs. The reference cement must have an assigned value for the analyte being determined. Traceability consists of documentary evidence that the assigned values of the reference cement are compatible with the certified values of NIST CRMs. To demonstrate traceability for a given analyte, perform a referee analysis (as defined in 3.1) on the proposed reference cement, using a NIST CRM for demonstration of precision and accuracy. The reference cement is acceptable if its assigned value agrees with the average referee value within the limits given in column 3 of Table 1. If the reference cement, as supplied, has no documented guarantee of homogeneity, establish its homogeneity by analyzing at least six randomly selected samples. No result shall deviate from the assigned value by more than the limits given in column 2 of Table 1. An acceptable reference cement must be accompanied by a document showing the data produced in demonstrating traceability and homogeneity.

4.2 *Requirements for Qualification Testing*—Referee analyses or analyses intended for use as a basis for acceptance or rejection of a cement or for manufacturer's certification shall be made only after demonstration of precise and accurate analyses by the test methods in use by meeting the requirements of 4.2.1, except when demonstrated under 4.4, the *Performance Requirements for Rapid Test Methods* Section. Such demonstration may be made concurrently with analysis of the cement being tested and must have been made within the preceding two years. The requirements for verification of equipment and personnel are summarized in Table 2. The demonstration is required only for those constituents being used as a basis for acceptance, rejection, or certification of a cement, but may be made for any constituent of cement for which a standard exists.

4.2.1 Initial qualification of the analyst shall be demonstrated by analysis of each constituent of concern in at least one CRM cement no matter what test method is used (for example, gravimetric or instrumental). Duplicate samples shall be run on different days. The same test methods to be used for analysis of cement being tested shall be used for analysis of the CRM cement. If the duplicate results do not agree within the permissible variation given in Table 1, the determinations shall be repeated, following identification and correction of problems or errors, until a set of duplicate results do agree within the permissible variation.

4.2.2 The average of the results of acceptable duplicate determinations for each constituent may differ from the CRM assigned value by no more than the value shown in column 2 of Table 1 after correction for minor components when needed.

4.2.3 Qualification data demonstrating that the same operator or analyst making the acceptance determination obtained precise and accurate results with CRM cements as per 4.2.1 shall be made available on request to all parties concerned when there is a question of acceptance of a cement. If the CRM used is not a NIST cement, the traceability documentation of the CRM used shall also be made available on request.

4.3 *Alternative Analyses*—The alternative test methods provide, in some cases, procedures that are shorter or more convenient to use for routine determination of certain constituents than are the reference test methods (Note 2). Longer, more complex procedures, in some instances, have been retained as

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TABLE 1 Maximum Permissible Variations in Results[A]

(Column 1) Component	(Column 2) Maximum Difference Between Duplicates[B]	(Column 3) Maximum Difference of the Average of Duplicates from SRM Certificate Values[C,D,B]
SiO_2(silicon dioxide)	0.16	±0.2
Al_2O_3(aluminum oxide)	0.20	±0.2
Fe_2O_3(ferric oxide)	0.10	±0.10
CaO (calcium oxide)	0.20	±0.3
MgO (magnesium oxide)	0.16	±0.2
SO_3(sulfur trioxide)	0.10	±0.1
LOI (loss on ignition)	0.10	±0.10
Na_2O (sodium oxide)	0.03	±0.05
K_2O (potassium oxide)	0.03	±0.05
TiO_2(titanium dioxide)	0.02	±0.03
P_2O_5(phosphorus pentoxide)	0.03	±0.03
ZnO (zinc oxide)	0.03	±0.03
Mn_2O_3(manganic oxide)	0.03	±0.03
S (sulfide sulfur)	0.01	*E*
Cl (chloride)	0.003	*E*
IR (insoluble residue)	0.10	*E*
Cx (free calcium oxide)	0.20	*E*
CO_2(carbon dioxide)	0.12	*E,F*
Alk_{sol}(water-soluble alkali)[G]	0.75/*w*	*E*
Chl_{sol}(chloroform-soluble organic substances)	0.004	*E*

[A] When seven CRM cements are required, as for demonstrating the performance of rapid test methods, at least six of the seven shall be within the prescribed limits and the seventh shall differ by no more than twice that value. When more than seven CRMs are used, as for demonstrating the performance of rapid test methods, at least 77 % shall be within the prescribed limits, and the remainder by no more than twice the value. When a lesser number of CRM cements are required, all of the values shall be within the prescribed limits.

[B] Where no value appears in Column 3, CRM certificate values do not exist. In such cases, only the requirement for differences between duplicates shall apply.

[C] Interelement corrections may be used for any oxide standardization provided improved accuracy can be demonstrated when the correction is applied to all seven CRM cements.

[D] Where an CRM certificate value includes a subscript number, that subscript number shall be treated as a valid significant figure.

[E] Not applicable. No certificate value given.

[F] Demonstrate performance by analysis, in duplicate, of at least one Portland cement. Prepare three standards, each in duplicate: Standard A shall be selected Portland cement; Standard B shall be Standard A containing 2.00 % Certified $CaCO_3$ (such as NIST 915a); Standard C shall be Standard A containing 5.00 % Certified $CaCO_3$. Weigh and prepare two separate specimens of each standard. Assign the CO_2 content of Standard A as the average of the two values determined, provided they agree within the required limit of Column 2. Assign CO_2 values to Standards B and C as follows: Multiply the Certified $CaCO_3$ value (Y) for CO_2 (from the certificate value) by the mass fraction of Certified $CaCO_3$ added to that standard (percentage added divided by 100); multiply the value determined for Standard A by the mass fraction of Standard A in each of the other standards (that is, 0.98 and 0.95 for Standards B and C, respectively); add the two values for Standard A and for Standard B, respectively; call these values B and C.

Example:

B = 0.98A + 0.02Y.

C = 0.95A + 0.05Y.

Where for Certified $CaCO_3$, if Y = 39.9 %

B = 0.98A + 0.80 % by mass.

C = 0.95A + 2.00 % by mass.

Maximum difference between the duplicate CO_2 values for Standards B and C, respectively, shall be 0.17 and 0.24 % by mass. Averages of the duplicate values for Standards B and C shall differ from their assigned values (B and C) by no more than 10 % of those respective assigned values.

[G] *w* = weight, in grams, of samples used for the test.

alternative test methods to permit comparison of results by different procedures or for use when unusual materials are being examined, where unusual interferences may be suspected, or when unusual preparation for analysis is required. Test results from alternative test methods may be used as a basis for acceptance or rejection when it is clear that a cement does or does not meet the specification requirement. Any change in test method procedures from those procedures listed in Sections 6-29 requires method qualification in accordance with 4.4, the *Performance Requirements for Rapid Test Methods* Section.

TABLE 2 Minimum Number of CRMs Required for Qualification of Chemical Testing

	Method Type	
	Reference[A]	Other[B]
Equipment Qualification	None	7
Analyst Qualification[C]	1	1

[A] Reference Methods are those outlined in Sections 6-21.

[B] These may be any test method as described in 4.3, the *Alternative Analyses* Section, or any instrumental or rapid test method, which must be qualified in accordance with 4.4, the *Performance Requirements for Rapid Test Methods* Section.

[C] Each analyst performing acceptance or reference analyses must be qualified in accordance with 4.2.1, the *Performance Requirements for Rapid Test Methods* Section, at a frequency of two years. If qualification of the instrument is completed by a single analyst, the analyst has demonstrated individual qualifications per 4.2.1.

NOTE 2—It is not intended that the use of reference test methods be confined to referee analysis. A reference test method may be used in preference to an alternative test method when so desired. A reference test method must be used where an alternative test method is not provided.

4.3.1 Duplicate analyses and blank determinations are not required when using the alternative test methods. If, however, a blank determination is desired for an alternative test method, one may be used and it need not have been obtained concurrently with the analysis. The final results, when corrected for blank values, should, in either case, be so designated.

4.4 *Performance Requirements for Rapid Test Methods:*[3]

4.4.1 *Definition and Scope*—Where analytical data obtained in accordance with this test method are required, any test method may be used that meets the requirements of 4.4.2, the *Qualification of a Test Method Section*. A test method is considered to consist of the specific procedures, reagents, supplies, equipment, instrument, etc. selected and used in a consistent manner by a specific laboratory. See Note 3 for examples of procedures.

NOTE 3—Examples of test methods used successfully by their authors for analysis of hydraulic cement are given in the list of references. Included are test methods using atomic absorption X-ray spectrometry, and spectrophotometry-EDTA.

4.4.1.1 If more than one instrument, even though substantially identical, is used in a specific laboratory for the same analyses, use of each instrument shall constitute a separate test method and each must be qualified separately.

4.4.2 *Qualification of a Test Method*—Prior to use for analysis of hydraulic cement, each test method (see 4.4.1) must be qualified individually for such analysis. Qualification data, or if applicable, requalification data, shall be made available pursuant to the Manufacturer's Certification Section of the appropriate hydraulic cement specification.

4.4.2.1 Using the test method chosen, make single determinations for each oxide under consideration on at least seven

[3] Gebhardt, R. F., "Rapid Methods for Chemical Analysis of Hydraulic Cement," ASTM STP 985, 1988.

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CRM samples. Requirements for a CRM are listed in 4.1, the *Certified Reference Material* Section. Complete two rounds of tests on different days repeating all steps of sample preparations. Calculate the differences between values and averages of the values from the two rounds of tests.

4.4.2.2 When seven CRMs are used in the qualification procedure, at least six of the seven differences between duplicates obtained of any single component shall not exceed the limits shown in Column 2 of Table 1 and the remaining differences by no more than twice that value. When more than seven CRMs are used, the values for at least 77 % of the samples shall be within the prescribed limits, while the values for the remainder shall differ by no more than twice that value.

4.4.2.3 For each component and each CRM, the average obtained shall be compared to the certified concentrations. Where a certificate value includes a subscript number, that subscript shall be assumed to be a significant number. When seven CRMs are used in the qualification procedure, at least six of the seven averages for each component (oxide) shall not differ from the certified concentrations by more than the value shown in Column 3 of Table 1, and the remaining average by more than twice that value. When more than seven CRMs are used in the qualification procedure, at least 77 % of the averages for each component (oxide) shall not differ from the certified concentrations by more than the value shown in Column 3 of Table 1, and the remaining average(s) by more than twice that value.

4.4.2.4 The standardization, if needed, used for qualification and for analysis of each constituent shall be determined by valid curve-fitting procedures. A point-to-point, saw-tooth curve that is artificially made to fit a set of data points does not constitute a valid curve-fitting procedure. A complex polynomial drawn through the points is similarly not valid. For the same reason, empirical inter-element corrections may be used, only if $\leq (N - 3)/2$ are employed, where N is the number of different standards used. The qualification testing shall be conducted with specimens newly prepared from scratch, including all the preparation stages applicable for analysis of an unknown sample, and employing the reagents currently in use for unknown analyses.

4.4.3 *Partial Results*—Test Methods that provide acceptable results for some components but not for others may be used only for those components for which acceptable results are obtained.

4.4.4 *Report of Results*—When performing chemical analysis and reporting results for Manufacturer's Certification, the type of method (Reference or Rapid) and the test method used along with any supporting qualification testing shall be available on request.

4.4.5 *Rejection of Material*—See 3.1, the *Referee Analyses* Section, and 4.3, the *Alternative Analyses* Section.

4.4.6 *Requalification of a Test Method*:

4.4.6.1 Requalification of a test method shall be required upon receipt of substantial evidence that the test method may not be providing data in accordance with Table 1 for one or more constituents. Such requalification may be limited to those constituents indicated to be in error and shall be carried out prior to further use of the method for analysis of those constituents.

4.4.6.2 Substantial evidence that a test method may not be providing data in accordance with Table 1 shall be considered to have been received when a laboratory is informed that analysis of the same material by Reference Test Methods run in accordance with 3.1.1, the final average of a CCRL sample, a certificate value of an NIST CRM, the assigned value of an alternate CRM, or an accepted value of a known secondary standard differs from the value obtained by the test method in question by more than twice the value shown in Column 2 of Table 1 for one or more constituents. When indirect test methods are involved, as when a value is obtained by difference, corrections shall be made for minor constituents in order to put analyses on a comparable basis prior to determining the differences. For any constituents affected, a test method also shall be requalified after any substantial repair or replacement of one or more critical components of an instrument essential to the test method.

4.4.6.3 If an instrument or piece of equipment is replaced, even if by one of identical make or model, or is significantly modified, a previously qualified test method using such new or modified instrument or equipment shall be considered a new method and must be qualified in accordance with 4.4.2.

4.4.7 *Precision and Bias*—Different analytical test methods are subject to individual limits of precision and bias. It is the responsibility of the user to demonstrate that the test methods used at least meet the limits of precision and bias shown in Table 1.

5. General

5.1 *Interferences and Limitations*:

5.1.1 These test methods were developed primarily for the analysis of portland cements. However, except for limitations noted in the procedure for specific constituents, the reference test methods provide for accurate analyses of other hydraulic cements that are completely decomposed by hydrochloric acid, or where a preliminary sodium carbonate fusion is made to ensure complete solubility. Some of the alternative test methods may not always provide accurate results because of interferences from elements which are not removed during the procedure.

5.1.2 When using a test method that determines total sulfur, such as most instrumental test methods, sulfide sulfur will be determined with sulfate and included as such. In most hydraulic cements, the difference resulting from such inclusion will be insignificant, less than 0.05 weight %. In some cases, notably slags and slag-containing cements but sometimes other cements as well, significant levels of sulfide may be present. In such cases, especially if there is a question of meeting or not meeting a specification limit or when the most accurate results are desired, analytical test methods shall be chosen so that sulfate and sulfide can be reported separately.

5.2 *Apparatus and Materials*:

5.2.1 *Balance*—The analytical balance used in the chemical determinations shall conform to the following requirements:

5.2.1.1 The balance shall be capable of reproducing results within 0.0002 g with an accuracy of ±0.0002 g. Direct-reading

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balances shall have a sensitivity not exceeding 0.0001 g (Note 4). Conventional two-pan balances shall have a maximum sensibility reciprocal of 0.0003 g. Any rapid weighing device that may be provided, such as a chain, damped motion, or heavy riders, shall not increase the basic inaccuracy by more than 0.0001 g at any reading and with any load within the rated capacity of the balance.

NOTE 4—The sensitivity of a direct-reading balance is the weight required to change the reading one graduation. The sensibility reciprocal for a conventional balance is defined as the change in weight required on either pan to change the position of equilibrium one division on the pointer scale at capacity or at any lesser load.

5.2.2 *Weights*—Weights used for analysis shall conform to Types I or II, Grades S or O, Classes 1, 2, or 3 as described in Specification E617. They shall be checked at least once a year, or when questioned, and adjusted at least to within allowable tolerances for Class 3 weights (Note 5). For this purpose each laboratory shall also maintain, or have available for use, a reference set of standard weights from 50 g to 10 mg, which shall conform at least to Class 3 requirements and be calibrated at intervals not exceeding five years by the National Institute of Standards and Technology (NIST). After initial calibration, recalibration by the NIST may be waived provided it can be shown by documented data obtained within the time interval specified that a weight comparison between summations of smaller weights and a single larger weight nominally equal to that summation, establishes that the allowable tolerances have not been exceeded. All new sets of weights purchased shall have the weights of 1 g and larger made of stainless steel or other corrosion-resisting alloy not requiring protective coating, and shall meet the density requirements for Grades S or O.

NOTE 5—The scientific supply houses do not presently list weights as meeting Specification E617. They list weights as meeting NIST or OIML standards. The situation with regard to weights is in a state of flux because of the trend toward internationalization. Hopefully this will soon be resolved.

NIST Classes S and S-1 and OIML Class F_1 weights meet the requirements of this standard.

5.2.3 *Glassware and Laboratory Containers*—Standard volumetric flasks, burets, and pipets should be of precision grade or better. Standard-taper, interchangeable, ground-glass joints are recommended for all volumetric glassware and distilling apparatus, when available. Wherever applicable, the use of special types of glassware, such as colored glass for the protection of solutions against light, alkali-resistant glass, and high-silica glass having exceptional resistance to thermal shock is recommended. Polyethylene containers are recommended for all aqueous solutions of alkalies and for standard solutions where the presence of dissolved silica or alkali from the glass would be objectionable. Such containers shall be made of high-density polyethylene having a wall thickness of at least 1 mm.

5.2.4 *Desiccators*— Desiccators shall be provided with a good desiccant, such as magnesium perchlorate, activated alumina, or sulfuric acid. Anhydrous calcium sulfate may also be used provided it has been treated with a color-change indicator to show when it has lost its effectiveness. Calcium chloride is not a satisfactory desiccant for this type of analysis.

5.2.5 *Filter Paper*— Filter paper shall conform to the requirements of Specification E832, Type II, Quantitative. When coarse-textured paper is required, Class E paper shall be used, when medium-textured paper is required, Class F paper shall be used, and when retentive paper is required, Class G shall be used.

5.2.6 *Crucibles*—Platinum crucibles for ordinary chemical analysis should preferably be made of pure unalloyed platinum and be of 15 to 30-mL capacity. Where alloyed platinum is used for greater stiffness or to obviate sticking of crucible and lid, the alloyed platinum should not decrease in weight by more than 0.2 mg when heated at 1200 °C for 1 h.

5.2.7 *Muffle Furnace*— The muffle furnace shall be capable of operation at the temperatures required and shall have an indicating pyrometer accurate within ±25 °C, as corrected, if necessary, by calibration. More than one furnace may be used provided each is used within its proper operating temperature range.

5.3 *Reagents*:

5.3.1 *Purity of Reagents*—Reagent grade chemicals shall be used in all tests. Unless otherwise indicated, it is intended that all reagents shall conform to the specifications of the Committee on Analytical Reagents of the American Chemical Society, where such specifications are available.[4] Other grades may be used, provided it is first ascertained that the reagent is of sufficiently high purity to permit its use without lessening the accuracy of the determination.

5.3.2 Unless otherwise indicated, references to water shall mean water conforming to the numerical limits for Type II reagent water described in Specification D1193.

5.3.3 *Concentration of Reagents*:

5.3.3.1 *Prepackaged Reagents*—Commercial prepackaged standard solutions or diluted prepackaged concentrations of a reagent may be used whenever that reagent is called for in the procedures provided that the purity and concentrations are as specified. Verify purity and concentration of such reagents by suitable tests.

5.3.3.2 *Concentrated Acids and Ammonium Hydroxide*—When acids and ammonium hydroxide are specified by name or chemical formula only, it shall be understood that concentrated reagents of the following specific gravities or concentrations by weight are intended:

Acetic acid ($HC_2H_3O_2$)	99.5 %
Hydrochloric acid (HCl)	sp gr 1.19
Hydrofluoric acid (HF)	48 %
Nitric acid (HNO_3)	sp gr 1.42
Phosphoric acid (H_3PO_4)	85 %
Sulfuric acid (H_2SO_4)	sp gr 1.84
Ammonium hydroxide (NH_4OH)	sp gr 0.90

5.3.3.3 The desired specific gravities or concentrations of all other concentrated acids shall be stated whenever they are specified.

[4] *Reagent Chemicals, American Chemical Society Specifications,* American Chemical Society, Washington, DC. For suggestions on the testing of reagents not listed by the American Chemical Society, see *Analar Standards for Laboratory Chemicals,* BDH Ltd., Poole, Dorset, U.K., and the *United States Pharmacopeia and National Formulary,* U.S. Pharmacopeia Convention, Inc. (USPC), Rockville, MD.

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5.3.4 *Diluted Acids and Ammonium Hydroxide*—Concentrations of diluted acids and ammonium hydroxide, except when standardized, are specified as a ratio stating the number of volumes of the concentrated reagent to be added to a given number of volumes of water, for example: HCl (1+99) means 1 volume of concentrated HCl (sp gr 1.19) added to 99 volumes of water.

5.3.5 *Standard Solutions*—Concentrations of standard solutions shall be expressed as normalities (*N*) or as equivalents in grams per millilitre of the component to be determined, for example: 0.1 *N* $Na_2S_2O_3$ solution or $K_2Cr_2O_7$(1 mL = 0.004 g Fe_2O_3). The average of at least three determinations shall be used for all standardizations. When a material is used as a primary standard, reference has generally been made to the standard furnished by NIST. However, when primary standard grade materials are otherwise available they may be used or the purity of a salt may be determined by suitable tests.

5.3.6 *Nonstandardized Solutions*—Concentrations of nonstandardized solutions prepared by dissolving a given weight of the solid reagent in a solvent shall be specified in grams of the reagent per litre of solution, and it shall be understood that water is the solvent unless otherwise specified, for example: NaOH solution (10 g/L) means 10 g of NaOH dissolved in water and diluted with water to 1 L. Other nonstandardized solutions may be specified by name only, and the concentration of such solutions will be governed by the instructions for their preparation.

5.3.7 *Indicator Solutions*:

5.3.7.1 *Methyl Red*—Prepare the solution on the basis of 2 g of methyl red/L of 95 % ethyl alcohol.

5.3.7.2 *Phenolphthalein*— Prepare the solution on the basis of 1 g of phenolphthalein/L of 95 % ethyl alcohol.

5.4 *Sample Preparation*:

5.4.1 Before testing, pass representative portions of each sample through a No. 20 (850-µm) sieve, or any other sieve having approximately 20 openings/1 in., in order to mix the sample, break up lumps, and remove foreign materials. Discard the foreign materials and hardened lumps that do not break up on sieving or brushing.

TABLE 3 Rounding of Reported Results

Component	Decimal Places
SiO_2 (silicon dioxide)	1
Al_2O_3 (aluminum oxide)	1
Fe_2O_3 (ferric oxide)	2
CaO (calcium oxide)	1
MgO (magnesium oxide)	1
SO_3 (sulfur trioxide)	2
LoI (loss on ignition)	1
Na_2O (sodium oxide)	2
K_2O (potassium oxide)	2
SrO (strontium oxide)	2
TiO_2 (titanium dioxide)	2
P_2O_5 (phosphorous pentoxide)	2
ZnO (zinc oxide)	2
Mn_2O_3 (manganic oxide)	3
S (sulfide sulfur)	2
Cl (chloride)	3
IR (insoluble residue	2
FL (free calcium oxide)	1
CO_2 (carbon dioxide)	1
Water-soluble Alkali	2
Chloroform-soluble Organic Substances	3

5.4.2 By means of a sample splitter or by quartering, the representative sample shall be reduced to a laboratory sample of at least 50 g. Where larger quantities are required for additional determinations such as water-soluble alkali, chloride, duplicate testing, etc., prepare a sample of at least 100 g.

5.4.3 Pass the laboratory sample through a U.S. No. 100 sieve (sieve opening of 150 µm). Further grind the sieve residue so that it also passes the No. 100 sieve. Homogenize the entire sample by again passing it through the sieve.

5.4.4 Transfer the sample to a clean, dry, glass container with an airtight lid and further mix the sample thoroughly.

5.4.5 Expedite the above procedure so that the sample is exposed to the atmosphere for a minimum time.

5.5 *General Procedures*:

5.5.1 *Weighing*—The calculations included in the individual test methods assume that the exact weight specified has been used. Accurately weighed samples, that are approximately but not exactly equal to the weight specified, may be used provided appropriate corrections are made in the calculations. Unless otherwise stated, weights of all samples and residues should be recorded to the nearest 0.0001 g.

5.5.2 *Tared or Weighed Crucibles*—The tare weight of crucibles shall be determined by preheating the empty crucible to constant weight at the same temperature and under the same conditions as shall be used for the final ignition of a residue and cooling in a desiccator for the same period of time used for the crucible containing the residue.

5.5.3 *Constancy of Weight of Ignited Residues*—To definitely establish the constancy of weight of an ignited residue for referee purposes, the residue shall be ignited at the specified temperature and for the specified time, cooled to room temperature in a desiccator, and weighed. The residue shall then be reheated for at least 30 min, cooled to room temperature in a desiccator, and reweighed. If the two weights do not differ by more than 0.2 mg, constant weight is considered to have been attained. If the difference in weights is greater than 0.2 mg, additional ignition periods are required until two consecutive weights agree within the specified limits. For ignition loss, each reheating period shall be 5 min.

5.5.4 *Volatilization of Platinum*—The possibility of volatilization of platinum or alloying constituents from the crucibles must be considered. On reheating, if the crucible and residue lose the same weight (within 0.2 mg) as the crucible containing the blank, constant weight can be assumed. Crucibles of the same size, composition, and history shall be used for both the sample and the blank.

5.5.5 *Calculation*— In all operations on a set of observed values such as manual multiplication or division, retain the equivalent of at least two more places of figures than in the single observed values. For example, if observed values are read or determined to the nearest 0.1 mg, carry numbers to the nearest 0.001 mg in calculation. When using electronic calculators or computers for calculations, perform no rounding, except in the final reported value.

5.5.6 *Rounding Figures*— Rounding of figures to the number of significant places required in the report should be done after calculations are completed, in order to keep the final results substantially free of calculation errors. The rounding

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procedure should follow the principle outlined in Practice E29.[5] In assessing analyst- and method-qualification in accordance with Section 3, the individual duplicate results, the difference between them, the average of duplicates on CRMs, and the difference of this average from the certificate value shall be left un-rounded for comparison with the required limits. Round results for reporting as shown in Table 3.

NOTE 6—The rounding procedure referred to in 5.5.6, in effect, drops all digits beyond the number of places to be retained if the next figure is less than 5. If it is more than 5, or equal to 5 and subsequent places contain a digit other than 0, then the last retained digit is increased by one. When the next digit is equal to 5 and all other subsequent digits are 0, the last digit to be retained is unchanged when it is even and increased by one when it is odd. For example 3.96 (50) remains 3.96 but 3.95 (50) becomes 3.96.

5.6 *Recommended Order for Reporting Analyses*—The following order is recommended for reporting the results of chemical analysis of portland cement:

Major Components:
SiO_2(silicon dioxide)
Al_2O_3(aluminum oxide)
Fe_2O_3(ferric oxide)
CaO (calcium oxide)
MgO (magnesium oxide)
SO_3(sulfur trioxide)
Loss on ignition
Minor Components:
Na_2O (sodium oxide)
K_2O (potassium oxide)
TiO_2(titanium dioxide)
P_2O_5(phosphorus pentoxide)
ZnO (zinc oxide)
Mn_2O_3(manganic oxide)
Sulfide sulfur
Separate Determinations:
Insoluble residue
Free calcium oxide
CO_2(Carbon Dioxide)
Water-soluble alkali
Chloroform—soluble organic substances

REFERENCE TEST METHODS

6. Insoluble Residue (*Reference Test Method*)

6.1 *Summary of Test Method*:

6.1.1 In this test method, insoluble residue of a cement is determined by digestion of the sample in hydrochloric acid followed, after filtration, by further digestion in sodium hydroxide. The resulting residue is ignited and weighed (Note 7).

NOTE 7—This test method, or any other test method designed for the estimation of an acid-insoluble substance in any type of cement, is empirical because the amount obtained depends on the reagents and the time and temperature of digestion. If the amount is large, there may be a little variation in duplicate determinations. The procedure should be followed closely in order to reduce the variation to a minimum.

6.1.2 When this test method is used on blended cement, the decomposition in acid is considered to be complete when the portland-cement clinker is decomposed completely. An ammonium nitrate solution is used in the final washing to prevent finely-ground insoluble material from passing through the filter paper.

6.2 *Reagents*:

6.2.1 *Ammonium Nitrate Solution* (20 g NH_4NO_3/L).

6.2.2 *Sodium Hydroxide Solution* (10 g NaOH/L).

6.3 *Procedure*:

6.3.1 To 1 g of the sample (Note 8) add 25 mL of cold water. Disperse the cement in the water and while swirling the mixture, quickly add 5 mL of HCl. If necessary, warm the solution gently, and grind the material with the flattened end of a glass rod for a few minutes until it is evident that decomposition of the cement is complete (Note 9). Dilute the solution to 50 mL with hot water (nearly boiling) and heat the covered mixture rapidly to near boiling by means of a high-temperature hot plate. Then digest the covered mixture for 15 min at a temperature just below boiling (Note 10). Filter the solution through a medium-textured paper into a 400-mL beaker, wash the beaker, paper, and residue thoroughly with hot water, and reserve the filtrate for the sulfur trioxide determination, if desired (Note 11). Transfer the filter paper and contents to the original beaker, add 100 mL of hot (near boiling) NaOH solution (10 g/L), and digest at a temperature just below boiling for 15 min. During the digestion, occasionally stir the mixture and macerate the filter paper. Acidify the solution with HCl using methyl red as the indicator and add an excess of 4 or 5 drops of HCl. Filter through medium-textured paper and wash the residue at least 14 times with hot NH_4 NO_3 solution (20 g/L) making certain to wash the entire filter paper and contents during each washing. Ignite the residue in a weighed platinum crucible at 900 to 1000 °C, cool in a desiccator, and weigh.

NOTE 8—If sulfur trioxide is to be determined by turbidimetry it is permissible to determine the insoluble residue on a 0.5-g sample. In this event, the percentage of insoluble residue should be calculated to the nearest 0.01 by multiplying the weight of residue obtained by 200. However, the cement should not be rejected for failure to meet the insoluble residue requirement unless a 1-g sample has been used.

NOTE 9—If a sample of portland cement contains an appreciable amount of manganic oxide, there may be brown compounds of manganese which dissolve slowly in cold diluted HCl but rapidly in hot HCl in the specified strength. In all cases, dilute the solution as soon as decomposition is complete.

NOTE 10—In order to keep the solutions closer to the boiling temperature, it is recommended that these digestions be carried out on an electric hot plate rather than in a steam bath.

NOTE 11—Continue with the sulfur trioxide determination (16.1.2.1-16.1.3) by diluting to 250 or 200 mL as required by the appropriate section.

6.3.2 *Blank*—Make a blank determination, following the same procedure and using the same amounts of reagents, and correct the results obtained in the analysis accordingly.

6.4 *Calculation*— Calculate the percentage of the insoluble residue to the nearest 0.01 by multiplying the weight in grams of the residue (corrected for the blank) by 100.

7. Silicon Dioxide (*Reference Test Method*)

7.1 *Selection of Test Method*—For cements other than portland and for which the insoluble residue is unknown, determine the insoluble residue in accordance with Section 6 of

[5] See also the *ASTM Manual on Presentation of Data and Control Chart Analysis, STP 15D,* 1976.

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these test methods. For portland cements and other cements having an insoluble residue less than 1 %, proceed in accordance with 7.2. For cements having an insoluble residue greater than 1 % proceed in accordance with 7.3.

7.2 *Silicon Dioxide in Portland Cements and Cements with Low Insoluble Residue*:

7.2.1 *Summary of Test Method*—In this test method silicon dioxide (SiO_2) is determined gravimetrically. Ammonium chloride is added and the solution is not evaporated to dryness. This test method was developed primarily for hydraulic cements that are almost completely decomposed by hydrochloric acid and should not be used for hydraulic cements that contain large amounts of acid-insoluble material and require a preliminary sodium carbonate fusion. For such cements, or if prescribed in the standard specification for the cement being analyzed, the more lengthy procedure in 7.3 shall be used.

7.2.2 *Reagent*—Ammonium chloride (NH_4Cl).

7.2.3 *Procedure*:

7.2.3.1 Mix thoroughly 0.5 g of the sample and about 0.5 g of NH_4Cl in a 50-mL beaker, cover the beaker with a watch glass, and add cautiously 5 mL of HCl, allowing the acid to run down the lip of the covered beaker. After the chemical action has subsided, lift the cover, add 1 or 2 drops of HNO_3, stir the mixture with a glass rod, replace the cover, and set the beaker on a steam bath for 30 min (Note 12). During this time of digestion, stir the contents occasionally and break up any remaining lumps to facilitate the complete decomposition of the cement. Fit a medium-textured filter paper to a funnel, transfer the jelly-like mass of silicic acid to the filter as completely as possible without dilution, and allow the solution to drain through. Scrub the beaker with a policeman and rinse the beaker and policeman with hot HCl (1+99). Wash the filter two or three times with hot HCl (1+99) and then with ten or twelve small portions of hot water, allowing each portion to drain through completely. Reserve the filtrate and washings for the determination of the ammonium hydroxide group (Note 13).

NOTE 12—A hot plate may be used instead of a steam bath if the heat is so regulated as to approximate that of a steam bath.

Under conditions where water boils at a lower temperature than at sea level: such as at higher elevations, 30 min may not be sufficient to recover all of the silica. In such cases, increase the time of digestion as necessary to get complete recovery of the silica. In no case should this time exceed 60 min.

NOTE 13—Determine the ammonium hydroxide group in accordance with the procedure described in 8.1-8.3.

7.2.3.2 Transfer the filter paper and residue to a weighed platinum crucible, dry, and ignite, at first slowly until the carbon of the paper is completely consumed without inflaming, and finally at 1100 to 1200 °C for 1 h. Cool in a desiccator and weigh. Reignite to constant weight. Treat the SiO_2 thus obtained, which will contain small amounts of impurities, in the crucible with 1 or 2 mL of water, 2 drops of H_2SO_4 (1+1), and about 10 mL of HF, and evaporate cautiously to dryness. Finally, heat the small residue at 1050 to 1100 °C for 5 min, cool in a desiccator, and weigh. The difference between this weight and the weight previously obtained represents the weight of SiO_2. Consider the weighed residue remaining after the volatilization of SiO_2 as combined aluminum and ferric oxides and add it to the result obtained in the determination of the ammonium hydroxide group.

7.2.3.3 If the HF residue exceeds 0.0020 g, the silica determination shall be repeated, steps should be taken to ensure complete decomposition of the sample before a silica separation is attempted, and the balance of the analysis (ammonium hydroxide group, CaO, and MgO) determined on the new silica filtrate provided the new silica determination has a HF residue of 0.0020 g or less except as provided in 7.2.3.4 and 7.2.3.5.

7.2.3.4 If two or three repeated determinations of a sample of portland cement consistently show HF residues higher than 0.0020 g, this is evidence that contamination has occurred in sampling or the cement has not been burned properly during manufacture. In such a case, do not fuse the large HF residue with pyrosulfate for subsequent addition to the filtrate from the silica separation. Instead, report the value obtained for the HF residue. Do not ignite the ammonium hydroxide group in the crucible containing this abnormally large HF residue.

7.2.3.5 In the analysis of cements other than portland, it may not always be possible to obtain HF residues under 0.0020 g. In such cases, add 0.5 g of sodium or potassium pyrosulfate ($Na_2S_2O_7$ or $K_2S_2O_7$) to the crucible and heat below red heat until the small residue of impurities is dissolved in the melt (Note 14). Cool, dissolve the fused mass in water, and add it to the filtrate and washings reserved for the determination of the ammonium hydroxide group.

NOTE 14—A supply of nonspattering pyrosulfate may be prepared by heating some pyrosulfate in a platinum vessel below red heat until the foaming and spattering cease, cooling, and crushing the fused mass.

7.2.3.6 *Blank*—Make a blank determination, following the same procedure and using the same amounts of reagents, and correct the results obtained in the analysis accordingly.

7.2.4 *Calculation*— Calculate the percentage of SiO_2 by multiplying the mass in grams of SiO_2 by 200 (100 divided by the mass (see 7.2.3.1) or equivalent mass (see 7.3.2.1) of the sample used (0.5 g)). Round in accordance with Table 3.

7.3 *Silicon Dioxide in Cements with Insoluble Residue Greater Than 1 %*:

7.3.1 *Summary of Test Method*—This test method is based on the sodium carbonate fusion followed by double evaporation to dryness of the hydrochloric acid solution of the fusion product to convert silicon dioxide (SiO_2) to the insoluble form. The solution is filtered and the insoluble siliceous residue is ignited and weighed. Silicon dioxide is volatilized by hydrofluoric acid and the loss of weight is reported as pure SiO_2.

7.3.2 *Procedure*:

7.3.2.1 Weigh a quantity of the ignited sample equivalent to 0.5 g of the as-received sample calculated as follows:

$$W = [(0.5\ (100.00 - I)]/100 \quad (1)$$

where:

W = weight of ignited sample, g, and
I = loss of ignition, %.

The ignited material from the loss on ignition determination may be used for the sample. Thoroughly mix the sample with 4 to 6 g of Na_2CO_3 by grinding in an agate mortar. Place a thin layer of Na_2CO_3 on the bottom of a platinum crucible of 20 to 30-mL capacity, add the cement-Na_2CO_3 mixture, and cover

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the mixture with a thin layer of Na_2CO_3. Place the covered crucible over a moderately low flame and increase the flame gradually to a maximum (approximately 1100 °C) and maintain this temperature until the mass is quiescent (about 45 min). Remove the burner, lay aside the cover of the crucible, grasp the crucible with tongs, and slowly rotate the crucible so that the molten contents spread over the sides and solidify as a thin shell on the interior. Set the crucible and cover aside to cool. Rinse off the outside of the crucible and place the crucible on its side in a 300-mL casserole about one third full of water. Warm the casserole and stir until the cake in the crucible disintegrates and can be removed easily. By means of a glass rod, lift the crucible out of the liquid, rinsing it thoroughly with water. Rinse the cover and crucible with HCl (1+3); then add the rinse to the casserole. Very slowly and cautiously add 20 mL of HCl (sp gr 1.19) to the covered casserole. Remove the cover and rinse. If any gritty particles are present, the fusion is incomplete and the test must be repeated, using a new sample. **Warning**—Subsequent steps of the test method must be followed exactly for accurate results.

7.3.2.2 Evaporate the solution to dryness on a steam bath (there is no longer a gelatinous appearance). Without heating the residue any further, treat it with 5 to 10 mL of HCl, wait at least 2 min, and then add an equal amount of water. Cover the dish and digest for 10 min on the steam bath or a hot plate. Dilute the solution with an equal volume of hot water, immediately filter through medium-textured paper and wash the separated SiO_2 thoroughly with hot HCl (1+99), then with hot water. Reserve the residue.

7.3.2.3 Again evaporate the filtrate to dryness, and bake the residue in an oven for 1 h at 105 to 110 °C. Cool, add 10 to 15 mL of HCl (1+1), and digest on the steam bath or hot plate for 10 min. Dilute with an equal volume of water, filter immediately on a fresh filter paper, and wash the small SiO_2 residue thoroughly as described in 7.3.2.2. Stir the filtrate and washings and reserve for the determination of the ammonium hydroxide group in accordance with 8.1-8.3.

7.3.2.4 Continue the determination of silicon dioxide in accordance with 7.2.3.2.

8. Ammonium Hydroxide Group (*Reference Test Method*)

8.1 *Summary of Test Method*—In this test method aluminum, iron, titanium, and phosphorus are precipitated from the filtrate, after SiO_2 removal, by means of ammonium hydroxide. With care, little if any manganese will be precipitated. The precipitate is ignited and weighed as the oxides.

8.2 *Procedure*:

8.2.1 To the filtrate reserved in accordance with 7.2.3.1 (Note 15) which should have a volume of about 200 mL, add HCl if necessary to ensure a total of 10 to 15 mL of the acid. Add a few drops of methyl red indicator and heat to boiling. Then treat with NH_4OH (1+1) (Note 16), dropwise until the color of the solution becomes distinctly yellow, and add one drop in excess (Note 17). Heat the solution containing the precipitate to boiling and boil for 50 to 60 s. In the event difficulty from bumping is experienced while boiling the ammoniacal solution, a digestion period of 10 min on a steam bath, or on a hot plate having the approximate temperature of a steam bath, may be substituted for the 50 to 60-s boiling period. Allow the precipitate to settle (not more than 5 min) and filter using medium-textured paper (Note 18). Wash, with hot ammonium nitrate (NH_4NO_3, 20 g/L) (Note 19), twice for a small precipitate to about four times for a large one.

NOTE 15—If a platinum evaporating dish has been used for the dehydration of SiO_2, iron may have been partially reduced. At this stage, add about 3 mL of saturated bromine water to the filtrate and boil the filtrate to eliminate the excess bromine before adding the methyl red indicator. If difficulty from bumping is experienced during the boiling, the following alternate techniques may be helpful: (*1*) a piece of filter paper, approximately 1 cm^2 in area, positioned where the bottom and side of the beaker merge and held down by the end of a stirring rod may solve the difficulty, and (*2*) use of 400-mL beakers supported inside a cast aluminum cup has also been found effective.

NOTE 16—The NH_4OH used to precipitate the hydroxides must be free of contamination with carbon dioxide (CO_2).

NOTE 17—It usually takes 1 drop of NH_4OH (1+1) to change the color of the solution from red to orange and another drop to change the color from orange to yellow. If desired, the addition of the indicator may be delayed until ferric hydroxide ($Fe(OH)_3$) is precipitated without aluminum hydroxide ($Al(OH)_3$) being completely precipitated. In such a case, the color changes may be better observed. However, if the content of Fe_2O_3 is unusually great, it may be necessary to occasionally let the precipitate settle slightly so that the color of the supernatant liquid can be observed. If the color fades during the precipitation, add more of the indicator. Observation of the color where a drop of the indicator strikes the solution may be an aid in the control of the acidity. The boiling should not be prolonged as the color may reverse and the precipitate may be difficult to retain on the filter. The solution should be distinctly yellow when it is ready to filter. If it is not, restore the yellow color with more NH_4OH (1+1) or repeat the precipitation.

NOTE 18—To avoid drying of the precipitate with resultant slow filtration, channeling, or poor washing, the filter paper should be kept nearly full during the filtration and should be washed without delay.

NOTE 19—Two drops of methyl red indicator solution should be added to the NH_4NO_3 solution in the wash bottle, followed by NH_4OH (1+1) added dropwise until the color just changes to yellow. If the color reverts to red at any time due to heating, it should be brought back to yellow by the addition of a drop of NH_4OH (1+1).

8.2.2 Set aside the filtrate and transfer the precipitate and filter paper to the same beaker in which the first precipitation was effected. Dissolve the precipitate with hot HCl (1+2). Stir to thoroughly macerate the paper and then dilute the solution to about 100 mL. Reprecipitate the hydroxides as described in 8.2.1. If difficulty from bumping is experienced while boiling the acid solution containing the filter paper, it may be obviated by diluting the hot 1+2 solution of the mixed oxides with 100 mL of boiling water and thus eliminate the need for boiling. Filter the solution and wash the precipitate with about four 10-mL portions of hot NH_4NO_3 solution (20 g/L) (Note 19). Combine the filtrate and washings with the filtrate set aside and reserve for the determination of CaO in accordance with 14.3.1.

8.2.3 Place the precipitate in a weighed platinum crucible, heat slowly until the papers are charred, and finally ignite to constant weight at 1050 to 1100 °C taking care to prevent reduction, and weigh as the ammonium hydroxide group.

8.2.4 *Blank*—Make a blank determination, following the same procedure and using the same amounts of reagents, and correct the results obtained in the analysis accordingly.

8.3 *Calculation*— Calculate the percentage of ammonium hydroxide group by multiplying the weight in grams of

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ammonium hydroxide group by 200 (100 divided by the weight of sample used (0.5 g)).

9. Ferric Oxide (*Reference Test Method*)

9.1 *Summary of Test Method*—In this test method, the Fe_2O_3 content of the cement is determined on a separate portion of the cement by reducing the iron to the ferrous state with stannous chloride ($SnCl_2$) and titrating with a standard solution of potassium dichromate ($K_2Cr_2O_7$). This determination is not affected by any titanium or vanadium that may be present in the cement.

9.2 *Reagents*:

9.2.1 *Barium Diphenylamine Sulfonate Indicator Solution*—Dissolve 0.3 g of barium diphenylamine sulfonate in 100 mL of water.

9.2.2 *Potassium Dichromate, Standard Solution* (1 mL = 0.004 g Fe_2O_3)—Pulverize and dry primary standard potassium dichromate ($K_2Cr_2O_7$) reagent, the current lot of NIST 136, at 180 to 200 °C to constant weight. Weigh accurately an amount of dried reagent equal to 2.45700 g times the number of litres of solution to be prepared. Dissolve in water and dilute to exactly the required volume in a single volumetric flask of the proper size. This solution is a primary standard and requires no further standardization.

NOTE 20—Where large quantities of standard solution are required, it may be desirable for certain laboratories to use commercially-produced primary standard potassium dichromate for most determinations. Such a material may be used provided that the first solution made from the container is checked, as follows: Using a standard solution of NIST 136, prepared as described in 9.2.2, analyze, in duplicate, samples of a NIST CRM cement, by the procedure given in 8.3.1.3 and 8.3.1.4. Repeat using a similar solution prepared from the commercial primary standard dichromate. The average percentages of Fe_2O_3 found by each method should not differ by more than 0.06 %.

9.2.3 *Stannous Chloride Solution*—Dissolve 5 g of stannous chloride ($SnCl_2 \cdot 2H_2O$) in 10 mL of HCl and dilute to 100 mL. Add scraps of iron-free granulated tin and boil until the solution is clear. Keep the solution in a closed dropping bottle containing metallic tin.

9.3 *Procedure*—For cements other than portland and for which the insoluble residue is unknown, determine the insoluble residue in accordance with the appropriate sections of these test methods. When insoluble residue is known, proceed in accordance with 9.3.1 or 9.3.2 as is appropriate for the cement being analyzed.

9.3.1 For portland cements and cements having insoluble residue lower than 1 %, weigh 1 g of the sample into a 500-mL Phillips beaker or other suitable container. Add 40 mL of cold water and, while the beaker is being swirled, add 10 mL of HCl. If necessary, heat the solution and grind the cement with the flattened end of a glass rod until it is evident that the cement is completely decomposed. Continue the analysis in accordance with 9.3.3.

9.3.2 For cements with insoluble residue greater than 1 %, weigh a 0.500 g sample, blend with 1 g $LiBO_2$ using a mortar and pestle, and transfer to a previously fired 8-mL carbon crucible that has 0.1 g $LiBO_2$ sprinkled in the bottom (Note 21). Cover with 0.1 g $LiBO_2$ that was used to chemically wash the mortar and pestle (Note 22). Place the uncovered crucible in a furnace set at 1100 °C for 15 min. Remove the crucible from the furnace and check for complete fusion (Note 23). If the fusion is incomplete, return the crucible to the furnace for another 30 min. Again, check for complete fusion. If the fusion is still incomplete, discard the sample and repeat the fusion procedure using 0.250 g sample or a smaller quantity with the same amount of $LiBO_2$. When the fusion is complete, gently swirl the melt and pour into a 150-mL glass beaker containing 10 mL concentrated HCl and 50 mL water. Stir continuously until the fusion product is dissolved, usually 10 min or less (Note 24). If a stirring bar is used, remove and rinse the bar. Continue the analysis in accordance with 9.3.3.

NOTE 21—The firing loosens the carbon on the surface, reducing the possibility of the fusion product sticking to the crucible.

NOTE 22—A chemical wash is a dry rinse of the equipment in which the blending was done so that any sample adhering to this equipment will be loosened and transferred to the crucible.

NOTE 23—When fusion is incomplete, the sample may not be completely melted or there may be particles on top of the bead. Usually, if the bead forms a small smooth spherical ball when taken from the furnace and before it is swirled, the sample is completely fused.

NOTE 24—There are usually some carbon particles that are in suspension, undissolved in the solution, but they will not interfere with the completion of the analysis.

9.3.3 Heat the solution to boiling and treat it with the $SnCl_2$ solution, added dropwise while stirring and boiling, until the solution is decolorized. Add 1 drop in excess and cool the solution to room temperature by placing the beaker in a pan of cool water. After cooling and without delay, rinse the inside of the vessel with water, and add all at once 10 mL of a cool, saturated mercuric chloride ($HgCl_2$) solution. Stir the solution vigorously for 1 min by swirling the beaker and add 10 mL of H_3PO_4 (1+1) and 2 drops of barium diphenylamine sulfonate indicator. Add sufficient water so that the volume after titration will be between 75 and 100 mL. Titrate with the standard $K_2Cr_2O_7$ solution. The end point shall be taken as the point at which a single drop causes an intense purple coloration that remains unchanged on further addition of standard $K_2Cr_2O_7$ solution.

9.3.4 *Blank*—Make a blank determination following the same procedure and using the same amounts of reagents. Record the volume of $K_2Cr_2O_7$ solution required to establish the end point as described in 9.3.3. As some iron must be present to obtain the normal end point, if no definite purple color is obtained after the addition of 4 drops of the standard $K_2Cr_2O_7$ solution, record the blank as zero.

9.4 *Calculation*:

9.4.1 Calculate the percentage of Fe_2O_3 as follows:

$$Fe_2O_3, \% = E(V - B) \times 100/W \quad (2)$$

where:

E = Fe_2O_3 equivalent of the $K_2Cr_2O_7$ solution, g/mL,
V = millilitres of $K_2Cr_2O_7$ solution required by the sample determination,
B = millilitres of $K_2Cr_2O_7$ solution required by the blank determination, and
W = mass of sample within 0.1 mg.

Round in accordance with Table 3.

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10. Phosphorus Pentoxide (*Reference Test Method*)

10.1 *Summary of Test Method*—This colorimetric test method is applicable to the determination of P_2O_5 in portland cement. Under the conditions of the test, no constituent normally present in portland cement will interfere.

10.2 *Apparatus*:

10.2.1 *Spectrophotometer* (Note 25):

10.2.1.1 The instrument shall be equipped to measure absorbance of solutions at a spectral wavelength of 725 nm.

10.2.1.2 Wavelength measurements shall be repeatable within ±1 nm or less.

10.2.1.3 In the absorbance range from 0.1 to 1.0, the absorbance measurements shall be repeatable within ±1 % or less.

10.2.1.4 To establish that the spectrophotometer will permit a satisfactory degree of accuracy, qualify the instrument in accordance with 4.4.2 using the procedure in 10.4.1-10.4.9.

NOTE 25—For the measurement of the performance of the spectrophotometer, refer to Practice E275.

10.3 *Reagents*:

10.3.1 *Ammonium Molybdate Solution*—Into a 1-L volumetric flask introduce 500.0 mL of 10.6 *N* H_2SO_4 (10.3.7). Dissolve 25.0 g of ammonium molybdate ($(NH_4)_6MO_7O_{24} \cdot 4H_2O$) in about 250 mL of warm water and transfer to the flask containing the H_2SO_4, while swirling the flask. Cool, dilute to 1 L with water, and store in a plastic bottle.

10.3.2 *Ascorbic Acid Powder*—For ease in dissolving, the finest mesh available should be used.

10.3.3 *Hydrochloric Acid, Standard* (6.5 ± 0.1 *N*)—Dilute 540 mL of concentrated HCl (sp gr 1.19) to 1 L with water. Standardize against standard NaOH solution (10.3.6) using phenolphthalein as indicator. Determine the exact normality and adjust to 6.5 ± 0.1 *N* by dilution with water. Restandardize to ensure that the proper normality has been achieved.

10.3.4 *Phosphate, Standard Solution A*—Dissolve 0.1917 g of oven-dried potassium dihydrogen phosphate (KH_2PO_4) in water and dilute to 1 L in a volumetric flask.

10.3.5 *Phosphate, Standard Solution B*—Dilute 50.0 mL of phosphate solution A to 500 mL with water.

10.3.6 *Sodium Hydroxide, Standard Solution* (1 *N*)—Dissolve 40.0 g of sodium hydroxide (NaOH) in water, add 10 mL of a freshly filtered saturated solution of barium hydroxide ($Ba(OH)_2$), and dilute to 1 L with water that has been recently boiled and cooled. Shake the solution from time to time during a several-hour period, and filter into a plastic bottle. Keep the bottle tightly closed to protect the solution from CO_2 in the air. Standardize against acid potassium phthalate or benzoic acid acidimetric standards furnished by NIST (standard samples 84f and 350), using the test methods in the certificates accompanying the standard samples. Determine the exact normality of the solution.

10.3.7 *Sulfuric Acid, Standard* (10.6 ± 0.1 *N*)—To a 1-L volumetric flask cooled in water add about 600 mL of water and then, slowly, with *caution,* 300 mL of concentrated H_2SO_4 (sp gr 1.84). After cooling to room temperature, dilute to 1 L with water. Standardize against the standard NaOH solution (10.3.6) using phenolphthalein as indicator. Determine the normality and adjust to 10.6 ± 0.1 *N* by dilution with water. Restandardize to ensure that the proper normality has been achieved.

10.4 *Procedure*:

10.4.1 Prepare a series of phosphate solutions to cover the range from 0 to 0.5 % P_2O_5. Prepare each solution by adding a suitable volume of standard phosphate solution B and 25.0 mL of the 6.5 *N* hydrochloric acid to a 250-mL volumetric flask (Note 26). Dilute to the mark with water.

NOTE 26—One millilitre of standard phosphate solution B/250 mL of solution is equivalent to 0.004 % P_2O_5 for a 0.25-g cement sample. Aliquots of 0, 12.5, 25, 50, 74, 100, and 125 mL are equivalent to P_2O_5 contents in the sample of 0, 0.05, 0.10, 0.20, 0.30, 0.40, and 0.50 %.

10.4.2 Prepare a blank by adding 25.0 mL of the standard HCl to a 250-mL volumetric flask and diluting to 250 mL with water.

10.4.3 Develop colors in the series of phosphate solutions, and in the blank, in accordance with 10.4.6-10.4.8.

10.4.4 Plot the net absorbance (absorbance of standard minus that of the blank) values obtained as ordinates and the corresponding P_2O_5 concentrations as abscissas. Draw a smooth curve through the points.

NOTE 27—A suitable paper for plotting the calibration curve is a 10 by 15-in. (254 by 381-mm) linear cross section paper having 20 by 20 divisions to the inch. The percentage of P_2O_5 can then be plotted on the long dimension using five divisions equal to 0.01 % P_2O_5. A scale of one division equal to 0.005 absorbance units is suitable as the ordinate (short dimension of the paper). Scales other than this may be used but under no circumstances should a scale division less than 1/20 in. (1.3 mm) be used for 0.005 units of absorbance or for 0.005 % P_2O_5. A separate calibration curve should be made for each spectrophotometer used, and the calibration curve checked against standard phosphate solution whenever a new batch of ammonium molybdate reagent is used.

10.4.5 Transfer 0.250 g of the sample to a 250-mL beaker and moisten with 10 mL of cold water to prevent lumping. Add 25.0 mL of the standard HCl and digest with the aid of gentle heat and agitation until solution is complete. Filter into a 250-mL volumetric flask and wash the paper and the separated silica thoroughly with hot water. Allow the solution to cool and then dilute with water to 250 mL.

10.4.6 Transfer a 50.0-mL aliquot (Note 28) of the sample solution to a 250-mL beaker, add 5.0 mL of ammonium molybdate solution and 0.1 g of ascorbic acid powder. Mix the contents of the beaker by swirling until the ascorbic acid has dissolved completely. Heat the solution to vigorous boiling and then boil, uncovered, for 1.5 ± 0.5 min. Cool to room temperature and transfer to a 50-mL volumetric flask. Rinse the beaker with one small portion of water and add the rinse water to the flask. Dilute to 50 mL with water.

NOTE 28—The range of the test can be extended by taking a smaller aliquot of the sample solution. In such instances the decrease in the aliquot volume must be made up by the blank solution (10.4.5) to maintain the proper acidity of the final solution. Thus, if a 25-mL aliquot of the sample solution is taken (instead of the usual 50 mL), a 25-mL aliquot of the blank solution should be added before proceeding with the test. The result of the test must then be calculated accordingly.

10.4.7 Measure the absorbance of the solution against water as the reference at 725.0 nm.

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10.4.8 Develop on a 50.0-mL aliquot of the blank solution prepared in 10.4.2 in the same manner as was used in 10.4.6 for the sample solution. Measure the absorbance in accordance with 10.4.7 and subtract this absorbance value from that obtained for the sample solution in 10.4.6 in order to obtain the net absorbance for the sample solution.

10.4.9 Using the net absorbance value found in 10.4.8, record the percentage of P_2O_5 in the cement sample as indicated by the calibration curve. Report the percentage of P_2O_5 rounded in accordance with Table 3

11. Titanium Dioxide (*Reference Test Method*)

11.1 *Summary of Test Method*—In this test method titanium dioxide (TiO_2) in portland cement is determined colorimetrically using Tiron reagent. Under the conditions of the test iron is the only constituent of portland cement causing a very slight interference equivalent to 0.01 % for each 1 % of Fe_2O_3 present in the sample.

11.2 *Apparatus*:

11.2.1 *Spectrophotometer* (Note 29):

11.2.1.1 The instrument shall be equipped to measure absorbance of solutions at a spectral wavelength of 410 nm.

11.2.1.2 Wavelength measurements shall be repeatable within ±1 nm or less.

11.2.1.3 In the absorbance range from 0.1 to 1.0, the absorbance measurements shall be repeatable within ±1 % or less.

11.2.1.4 To establish that the spectrophotometer will permit a satisfactory degree of accuracy, qualify the instrument in accordance with 4.4.2 using the procedure in 11.4.1-11.4.6 of this test method.

NOTE 29—For the measurement of the performance of the spectrophotometer, refer to Practice E275.

11.3 *Reagents*:

11.3.1 *Buffer* (pH 4.7)—68 g of $NaC_2H_3O_2 \cdot 3H_2O$, plus 380 mL of water, plus 100 mL of 5.0 *N* CH_3COOH.

11.3.2 *Ethylenedinitrilo Tetraacetic Acid Disodium Salt, Dihydrate* (0.2 *M* EDTA)—Dissolve 37.5 g of EDTA in 350 mL of warm water, and filter. Add 0.25 g of $FeCl_3 \cdot 6H_2O$ and dilute to 500 mL.

11.3.3 *Hydrochloric Acid* (1+6).

11.3.4 *Hydrochloric Acid, Standard* (6.5 *N*)—Dilute 540 mL of concentrated HCl (sp gr 1.19) to 1 L with water.

11.3.5 *Ammonium Hydroxide* (NH_4OH, 1+1).

11.3.6 *Potassium Pyrosulfate* ($K_2S_2O_7$).

11.3.7 *Titanium Dioxide, Stock Solution A*—Fuse slowly in a platinum crucible over a very small flame 0.0314 g of NIST SRM 154b (TiO_2 = 99.74 %) or its replacements with about 2 or 3 g of $K_2S_2O_7$. Allow to cool, and place the crucible in a beaker containing 125 mL of H_2SO_4 (1+1). Heat and stir until the melt is completely dissolved. Cool, transfer to a 250-mL volumetric flask, and dilute the solution to volume.

11.3.7.1 *Titanium Dioxide, Dilute Standard Solution B* (1 mL = 0.0125 mg TiO_2)—Pipet 50 mL of stock TiO_2 solution into a 500-mL volumetric flask, and dilute to volume. One millilitre of this solution is equal to 0.0125 mg of TiO_2, which is equivalent to 0.05 % TiO_2 when used as outlined in 11.4.4-11.4.6.

11.3.8 *Sulfuric Acid* (1+1).

11.3.9 *Tiron* (disodium-1,2-dihydroxybenzene-3,5 disulfonate).

11.4 *Procedure*:

11.4.1 Prepare a series of TiO_2 solutions to cover the range from 0 to 1.0 % TiO_2. Prepare each solution in a 50-mL volumetric flask.

NOTE 30—One millilitre of dilute TiO_2 standard solution B per 50 mL (11.3.7.1) is equivalent to 0.05 % TiO_2 for a 0.2500-g cement sample. Aliquots of 0, 5, 10, 15, and 20 mL of dilute TiO_2 standard solution are equivalent to TiO_2 contents in the sample of 0, 0.25, 0.50, 0.75, and 1.0 %. Dilute each to 25 mL with water.

11.4.2 Develop color in accordance with 11.4.4 starting with second sentence. Measure absorbance in accordance with 11.4.5.

11.4.3 Plot absorbance values obtained as ordinates and the corresponding TiO_2 concentrations as abscissas. Draw a smooth curve through the points.

NOTE 31—A suitable paper for plotting the calibration curve is a linear cross section paper having 10 × 10 divisions to 1 cm. A scale division equivalent to 0.002 absorbance and 0.002 % TiO_2 should be used. A separate calibration curve should be made for each spectrophotometer used.

11.4.4 Transfer a 25.0-mL aliquot of the sample solution prepared in 10.4.5 into a 50-mL volumetric flask (Note 32). Add 5 mL tiron and 5 mL EDTA, mix, and then add NH_4OH (1+1) dropwise, mixing thoroughly after each drop, until the color changes through yellow to green, blue, or ruby red. Then, just restore the yellow color with HCl (1+6) added dropwise and mixing after each drop. Add 5 mL buffer, dilute to volume and mix.

11.4.5 Measure the absorbance of the solution against water as the reference at 410 nm.

NOTE 32—The range of the test can be extended by taking a smaller aliquot. The results of the test must then be calculated accordingly.

11.4.6 Using the absorbance value determined in 11.4.5, record the percentage of TiO_2 in the cement sample as indicated by the calibration curve. Correct for the iron present in the sample to obtain the true TiO_2 as follows: True TiO_2 = measured % TiO_2 – (0.01 × % Fe_2O_3). Report the percent of TiO_2 rounded in accordance with Table 3.

12. Zinc Oxide (*Reference Test Method*)[6]

12.1 Any test method may be used that meets the requirements of Section 4.4 and Table 1.

12.2 Report the result rounded in accordance with Table 3.

13. Aluminum Oxide (*Reference Test Method*)

NOTE 33—In the reference test method, Al_2O_3 is calculated from the ammonium hydroxide group by subtracting the separately determined constituents that usually are present in significant amounts in the ammonium hydroxide precipitate. These are Fe_2O_3, TiO_2 and P_2O_5. Most instrumental test methods for Al_2O_3 analysis give Al_2O_3 alone if standardized and calibrated properly.

[6] The 1988 revision of these test methods deleted the colorimetric method for determination of ZnO using an extraction with CCl_4. Those interested in this test method should refer to the *1987 Annual Book of ASTM Standards,* Volume 04.01.

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13.1 *Calculation*:

13.1.1 Calculate the percentage of Al_2O_3 by deducting the percentage of the sum of the Fe_2O_3, TiO_2, and P_2O_5 from the percentage of ammonium hydroxide group, using un-rounded values of all four quantities. All determinations shall be by referee test methods described in the appropriate sections herein. Report the Al_2O_3 rounded in accordance with Table 3. For nonreferee analyses, the percentages of Fe_2O_3, TiO_2, and P_2O_5 can be determined by any procedure for which qualification has been shown.

14. Calcium Oxide (*Reference Test Method*)

14.1 *Summary of Test Method*:

14.1.1 In this test method, manganese is removed from the filtrate after the determination of SiO_2 and the ammonium hydroxide group. Calcium is then precipitated as the oxalate. After filtering, the oxalate is redissolved and titrated with potassium permanganate ($KMnO_4$).

NOTE 34—For referee analysis or for the most accurate determinations, removal of manganese in accordance with 14.3.2 must be made. For less accurate determinations, and when only insignificant amounts of manganese oxides are believed present, 13.3.2 may be omitted.

14.1.2 Strontium, usually present in portland cement as a minor constituent, is precipitated with calcium as the oxalate and is subsequently titrated and calculated as CaO. If the SrO content is known and correction of CaO for SrO is desired as, for example, for research purposes or to compare results with CRM certificate values, the CaO obtained by this method may be corrected for SrO. In determining conformance of a cement to specifications, the correction of CaO for SrO should not be made.

14.2 *Reagents*:

14.2.1 *Ammonium Oxalate Solution* (50 g/L).

14.2.2 *Potassium Permanganate, Standard Solution* (0.18 *N*)—Prepare a solution of potassium permanganate ($KMnO_4$) containing 5.69 g/L. Let this solution stand at room temperature for at least 1 week, or boil and cool to room temperature. Siphon off the clear solution without disturbing the sediment on the bottom of the bottle; then filter the siphoned solution through a bed of glass wool in a funnel or through a suitable sintered glass filter. Do not filter through materials containing organic matter. Store in a dark bottle, preferably one that has been painted black on the outside. Standardize the solution against 0.7000 to 0.8000 g of primary standard sodium oxalate, according to the directions furnished with the sodium oxalate and record the temperature at which the standardization was made (Note 35).

14.2.2.1 Calculate the CaO equivalent of the solution as follows:

1 mL of 1 *N* $KMnO_4$ solution is equivalent to 0.06701 g of pure sodium oxalate.

$$\text{Normality of } KmnO_4 = \frac{\text{weight of sodium oxalate} \times \text{fraction of its purity}}{\text{mL of } KMnO_4 \text{ solution} \times 0.06701} \quad (3)$$

1 mL of 1 *N* $KMnO_4$ solution is equivalent to 0.02804 g of CaO.

$$F = \frac{\text{normality of } KMnO_4 \text{ solution} \times 0.02804 \times 100}{0.5}$$

where F = CaO equivalent of the $KMnO_4$ solution in % CaO/mL based on a 0.5-g sample of cement.

NOTE 35—Because of the instability of the $KMnO_4$ solution, it is recommended that it be restandardized at least bimonthly.

14.3 *Procedure*:

14.3.1 Acidify the combined filtrates obtained in the precipitations of the ammonium hydroxide group (8.2.2). Neutralize with HCl to the methyl red end point, make just acid, and add 6 drops of HCl in excess.

14.3.2 *Removal of Manganese*—Evaporate to a volume of about 100 mL. Add 40 mL of saturated bromine water to the hot solution and immediately add NH_4OH until the solution is distinctly alkaline. Addition of 10 mL of NH_4OH is generally sufficient. A piece of filter paper, about 1 cm^2 in area, placed in the heel of the beaker and held down by the end of a stirring rod aids in preventing bumping and initiating precipitation of hydrated manganese oxides (MnO). Boil the solution for 5 min or more, making certain that the solution is distinctly alkaline at all times. Allow the precipitate to settle, filter using medium-textured paper, and wash with hot water. If a precipitate does not appear immediately, allow a settling period of up to 1 h before filtration. Discard any manganese dioxide that may have been precipitated. Acidify the filtrate with HCl using litmus paper as an indicator, and boil until all the bromine is expelled (Note 36).

14.3.3 Add 5 mL of HCl, dilute to 200 mL, and add a few drops of methyl red indicator and 30 mL of warm ammonium oxalate solution (50 g/L) (Note 37). Heat the solution to 70 to 80 °C, and add NH_4OH (1+1) dropwise, while stirring until the color changes from red to yellow (Note 38). Allow the solution to stand without further heating for 60 ± 5 min (no longer), with occasional stirring during the first 30 min.

14.3.4 Filter, using retentive paper, and wash the precipitate 8 to 10 times with hot water, the total amount of water used in rinsing the beaker and washing not to exceed 75 mL. During this washing, water from the wash bottle should be directed around the inside of the filter paper to wash the precipitate down, then a jet of water should be gently directed towards the center of the paper in order to agitate and thoroughly wash the precipitate. Acidify the filtrate with HCl and reserve for the determination of MgO.

14.3.5 Place the beaker in which the precipitation was made under the funnel, pierce the apex of the filter paper with the stirring rod, place the rod in the beaker, and wash the precipitate into the beaker by using a jet of hot water. Drop about 10 drops of H_2SO_4 (1+1) around the top edge of the filter paper. Wash the paper five more times with hot water. Dilute to 200 mL, and add 10 mL of H_2SO_4 (1+1). Heat the solution to a temperature just below boiling, and titrate it immediately with the 0.18 *N* $KMnO_4$ solution (Note 39). Continue the titration slowly until the pink color persists for at least 10 s. Add the filter paper that contained the original precipitate and macerate it. If the pink color disappears continue the titration until it again persists for at least 10 s.

NOTE 36—Potassium iodide starch paper may be used to indicate the complete volatilization of the excess bromine. Expose a strip of moistened paper to the fumes from the boiling solution. The paper should remain colorless. If it turns blue bromine is still present.

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NOTE 37—If the ammonium oxalate solution is not perfectly clear, it should be filtered before use.

NOTE 38—This neutralization must be made slowly, otherwise precipitated calcium oxalate may have a tendency to run through the filter paper. When a number of these determinations are being made simultaneously, the following technique will assist in ensuring slow neutralization. Add two or three drops of NH_4OH to the first beaker while stirring, then 2 or 3 drops to the second, and so on, returning to the first beaker to add 2 or 3 more drops, etc., until the indicator color has changed in each beaker.

NOTE 39—The temperature of the 0.18 *N* $KMnO_4$ solution at time of use should not vary from its standardization temperature by more than 10 °F (5.5 °C). Larger deviations could cause serious error in the determination of CaO.

14.3.6 *Blank*—Make a blank determination, following the same procedure and using the same amounts of reagents (Note 40), and record the millilitres of $KMnO_4$ solution required to establish the end point.

NOTE 40—When the amount of calcium oxalate is very small, its oxidation by $KMnO_4$ is slow to start. Before the titration, add a little $MnSO_4$ to the solution to catalyze the reaction.

14.4 *Calculation*:

14.4.1 Calculate the percentage of CaO as follows:

$$\text{CaO, \%} = E(V - B) \quad (4)$$

where:

E = CaO equivalent of the $KMnO_4$ solution in % CaO/mL based on a 0.5-g sample,

V = millilitres of $KMnO_4$ solution required by the sample, and

B = millititres of $KMnO_4$ solution required by the blank.

Report the result rounded in accordance with Table 3.

14.4.2 If desired calculate the percentage of CaO corrected for SrO as follows:

$$\text{CaO}_c\ \% = \text{CaO}_i\ \% - 0.54\ \text{SrO}\ \% \quad (5)$$

where:

CaO_c = CaO corrected for SrO, and

CaO_i = initial CaO as determined in 14.4.1

$0.54 = \frac{56.08}{103.62}$ = molecular weight ratio $\frac{\text{CaO}}{\text{SrO}}$

15. Magnesium Oxide (*Reference Test Method*)

15.1 *Summary of Test Method*—In this test method, magnesium is precipitated as magnesium ammonium phosphate from the filtrate after removal of calcium. The precipitate is ignited and weighed as magnesium pyrophosphate ($Mg_2P_2O_7$). The MgO equivalent is then calculated.

15.2 *Reagent*—Ammonium phosphate, dibasic (100 g/L) $(NH_4)_2HPO_4$.

15.3 *Procedure*:

15.3.1 Acidify the filtrate from the determination of CaO (14.3.4) with HCl and evaporate by boiling to about 250 mL. Cool the solution to room temperature, add 10 mL of ammonium phosphate, dibasic, $(NH_4)_2HPO_4$ (100 g/L), and 30 mL of NH_4OH. Stir the solution vigorously during the addition of NH_4OH and then for 10 to 15 min longer. Let the solution stand for at least 8 h in a cool atmosphere and filter. Wash the residue five or six times with NH_4OH (1+20) and ignite in a weighed platinum or porcelain crucible, at first slowly until the filter paper is charred and then burn off (see 15.4.1), and finally at 1100 °C for 30 to 45 min. Weigh the residue as magnesium pyrophosphate ($Mg_2P_2O_7$).

15.3.2 *Blank*—Make a blank determination following the same procedure and using the same amounts of reagents, and correct the results obtained in the analysis accordingly.

15.4 *Calculation*:

15.4.1 Calculate the percentage of MgO to the nearest 0.1 as follows:

$$\text{MgO, \%} = W \times 72.4 \quad (6)$$

where:

W = grams of $Mg_2P_2O_7$, and

72.4 = molecular ratio of 2MgO to $Mg_2P_2O_7$(0.362) divided by the weight of sample used (0.5 g) and multiplied by 100.

Report the result rounded in accordance with Table 3.

Warning—Extreme caution should be exercised during this ignition. Reduction of the phosphate precipitate can result if carbon is in contact with it at high temperatures. There is also danger of occluding carbon in the precipitate if ignition is too rapid.

16. Sulfur (See Note 41)

16.1 *Sulfur Trioxide: (Reference Test Method)*:

16.1.1 *Summary of Test Method*—In this test method, sulfate is precipitated from an acid solution of the cement with barium chloride ($BaCl_2$). The precipitate is ignited and weighed as barium sulfate ($BaSO_4$) and the SO_3 equivalent is calculated.

16.1.2 *Procedure*:

16.1.2.1 To 1 g of the sample add 25 mL of cold water and, while the mixture is stirred vigorously, add 5 mL of HCl (Note 42). If necessary, heat the solution and grind the material with the flattened end of a glass rod until it is evident that decomposition of the cement is complete (Note 43). Dilute the solution to 50 mL and digest for 15 min at a temperature just below boiling. Filter through a medium-textured paper and wash the residue thoroughly with hot water. Dilute the filtrate to 250 mL and heat to boiling. Add slowly, dropwise, 10 mL of hot $BaCl_2$(100 g/L) and continue the boiling until the precipitate is well formed. Digest the solution for 12 to 24 h at a temperature just below boiling (Note 44). Take care to keep the volume of solution between 225 and 260 mL and add water for this purpose if necessary. Filter through a retentive paper, wash the precipitate thoroughly with hot water, place the paper and contents in a weighed platinum crucible, and slowly char and consume the paper without inflaming. Ignite at 800 to 900 °C, cool in a desiccator, and weigh.

NOTE 41—When an instrumental test method is used for sulfur or when comparing results of classical wet and instrumental test methods, consult 5.1.2 of these test methods.

NOTE 42—The acid filtrate obtained in the determination of the insoluble residue (6.3.1) may be used for the determination of SO_3 instead of using a separate sample.

NOTE 43—A brown residue due to compounds of manganese may be disregarded (see Note 9).

NOTE 44—If a rapid determination is desired, immediately after adding the $BaCl_2$, place the beaker with the solution in an ultrasonic bath for 5 min, and then continue the determination starting with "Filter through a

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retentive paper. . .". Qualify the method in accordance with the Performance Requirements for Rapid Test Methods.

16.1.2.2 *Blank*—Make a blank determination following the same procedure and using the same amounts of reagents, and correct the results obtained in the analysis accordingly.

16.1.3 *Calculation*— Calculate the percentage of SO_3 to the nearest 0.01 as follows:

$$SO_3, \% = W \times 34.3 \quad (7)$$

where:

W = grams of $BaSO_4$, and
34.3 = molecular ratio of SO_3 to $BaSO_4$(0.343) multiplied by 100.

Report the result rounded in accordance with Table 3.

16.2 *Sulfide: (Reference Test Method)*

16.2.1 *Summary of Test Method*—In this test method sulfide sulfur is determined by evolution as hydrogen sulfide (H_2S) from an acid solution of the cement into a solution of ammoniacal zinc sulfate ($ZnSO_4$) or cadmium chloride (CdCl 2). The sulfide sulfur is then titrated with a standard solution of potassium iodate (KIO_3). Sulfites, thiosulfates, and other compounds intermediate between sulfides and sulfates are assumed to be absent. If such compounds are present, they may cause an error in the determination.

16.2.2 *Apparatus*:

16.2.2.1 *Gas-Generating Flask*—Connect a dry 500-mL boiling flask with a long-stem separatory funnel and a small connecting bulb by means of a rubber stopper. Bend the stem of the funnel so that it will not interfere with the connecting bulb, adjust the stem so that the lower end is close to the bottom of the flask, and connect the opening of the funnel with a source of compressed air. Connect the bulb with an L-shaped glass tube and a straight glass tube about 200 mm in length. Insert the straight glass tube in a tall-form, 400-mL beaker. A three-neck distilling flask with a long glass tubing in the middle opening, placed between the source of compressed air and the funnel, is a convenient aid in the regulation of the airflow. Rubber used in the apparatus shall be pure gum grade, low in sulfur, and shall be cleaned with warm HCl.

16.2.3 *Reagents*:

16.2.3.1 *Ammoniacal Cadmium Chloride Solution*—Dissolve 15 g of cadmium chloride ($CdCl_2 \cdot 2H_2O$) in 150 mL of water and 350 mL of NH_4OH. Filter the solution after allowing it to stand at least 24 h.

16.2.3.2 *Ammoniacal Zinc Sulfate Solution*—Dissolve 50 g of zinc sulfate ($ZnSO_4 \cdot 7H_2O$) in 150 mL of water and 350 mL of NH_4OH. Filter the solution after allowing it to stand at least 24 h.

16.2.3.3 *Potassium Iodate, Standard Solution* (0.03 *N*)—Prepare a solution of potassium iodate (KIO_3) and potassium iodide (KI) as follows: Dry KIO_3 at 180 °C to constant weight. Weigh 1.0701 g of the KIO_3 and 12 g of KI. Dissolve and dilute to 1 L in a volumetric flask. This is a primary standard and requires no standardization (Note 45). One millilitre of this solution is equivalent to 0.0004809 g of sulfur.

NOTE 45—The solution is very stable, but may not maintain its titer indefinitely. Whenever such a solution is over 1 year old it should be discarded or its concentration checked by standardization.

16.2.3.4 *Stannous Chloride Solution*—To 10 g of stannous chloride ($SnCl_2 \cdot 2H_2O$) in a small flask, add 7 mL of HCl (1+1), warm the mixture gently until the salt is dissolved, cool the solution, and add 95 mL of water. This solution should be prepared as needed, as the salt tends to hydrolyze.

16.2.3.5 *Starch Solution*— To 100 mL of boiling water, add a cool suspension of 1 g of soluble starch in 5 mL of water and cool. Add a cool solution of 1 g of sodium hydroxide (NaOH) in 10 mL of water, then 3 g of potassium iodide (KI), and mix thoroughly.

16.2.4 *Procedure*:

16.2.4.1 Place 15 mL of the ammoniacal $ZnSO_4$ or $CdCl_2$ solution (Note 46) and 285 mL of water in a beaker. Put 5 g of the sample (Note 47) and 10 mL of water in the flask and shake the flask gently to wet and disperse the cement completely. This step and the addition of $SnCl_2$ should be performed rapidly to prevent the setting of the cement. Connect the flask with the funnel and bulb. Add 25 mL of the $SnCl_2$ solution through the funnel and shake the flask. Add 100 mL of HCl (1+3) through the funnel and shake the flask. During these shakings keep the funnel closed and the delivery tube in the ammoniacal $ZnSO_4$ or $CdCl_2$ solution. Connect the funnel with the source of compressed air, open the funnel, start a slow stream of air, and heat the flask and contents slowly to boiling. Continue the boiling gently for 5 or 6 min. Cut off the heat, and continue the passage of air for 3 or 4 min. Disconnect the delivery tube and leave it in the solution for use as a stirrer. Cool the solution to 20 to 30 °C (Note 48), add 2 mL of the starch solution and 40 mL of HCl (1+1) and titrate immediately with the 0.03 *N* KIO_3 solution until a persistent blue color is obtained (Note 49).

NOTE 46—In general, the $ZnSO_4$ is preferable to the $CdCl_2$ solution because $ZnSO_4$ is more soluble in NH_2OH than is $CdCl_2$. The $CdCl_2$ solution may be used when there is doubt as to the presence of a trace of sulfide sulfur, as the yellow cadmium sulfide (CdS) facilitates the detection of a trace.

NOTE 47—If the content of sulfur exceeds 0.20 or 0.25 %, a smaller sample should be used so that the titration with the KIO_3 solution will not exceed 25 mL.

NOTE 48—The cooling is important as the end point is indistinct in a warm solution.

NOTE 49—If the content of sulfur is appreciable but not approximately known in advance, the result may be low due to the loss of H_2S during a slow titration. In such a case the determination should be repeated with the titration carried out more rapidly.

16.2.4.2 Make a blank determination, following the same procedure and using the same amounts of reagents. Record the volume of KIO 3 solution necessary to establish the end point as described in 16.2.4.1.

16.2.5 *Calculation*— Calculate the percentage of sulfide sulfur (see 16.2.1) as follows:

$$\text{Sulfide}, \% = E(V - B) \times 20 \quad (8)$$

where:

E = sulfide equivalent of the KIO_3 solution, g/mL,
V = millilitres of KIO_3 solution required by the sample,
B = millilitres of KIO_3 solution required by the blank, and
20 = 100 divided by the weight of sample used (5 g).

Report the result rounded in accordance with Table 3.

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17. Loss on Ignition (*Reference Test Methods*)

17.1 *Portland Cement*:

17.1.1 *Summary of Test Method*—In this test method, the cement is ignited in a muffle furnace at a controlled temperature. The loss is assumed to represent the total moisture and CO_2 in the cement. This procedure is not suitable for the determination of the loss on ignition of portland blast-furnace slag cement and of slag cement. A test method suitable for such cements is described in 17.2.1 through 17.2.3.

17.1.2 *Procedure*—Weigh 1 g of the sample in a tared platinum crucible. Cover and ignite the crucible and its contents to constant weight in a muffle furnace at a temperature of 950 ± 50 °C. Allow a minimum of 15 min for the initial heating period and at least 5 min for all subsequent periods.

17.1.3 *Calculation*— Calculate the percentage of loss on ignition to the nearest 0.1 by multiplying the loss of weight in grams by 100. Report the result rounded in accordance with Table 3.

17.2 *Portland Blast-Furnace Slag Cement and Slag Cement*:

17.2.1 *Summary of Test Method*—Since it is desired that the reported loss on ignition represent moisture and CO_2, this test method provides a correction for the gain in weight due to oxidation of sulfides usually present in portland blast-furnace slag cement and slag cement by determining the increase in SO_3 content during ignition. An optional test method providing for a correction based on the decrease in sulfide sulfur during ignition is given in 25.1.1 through 23.1.3.1.

17.2.2 *Procedure*:

17.2.2.1 Weigh 1 g of cement into a tared platinum crucible and ignite in a muffle furnace at a temperature of 950 ± 50 °C for 15 min. Cool to room temperature in a desiccator and weigh. Without checking for constant weight, carefully transfer the ignited material to a 400-mL beaker. Break up any lumps in the ignited cement with the flattened end of a glass rod.

17.2.2.2 Determine the SO_3 content by the test method given in 15.1.1.1 through 15.1.3.1 (Note 50). Also determine the SO_3 content of a portion of the same cement that has not been ignited, using the same procedure.

NOTE 50—Some of the acid used for dissolving the sample may first be warmed in the platinum crucible to dissolve any adhering material.

17.2.3 *Calculation*— Calculate the percentage loss of weight occurring during ignition and add 0.8 times the difference between the percentages of SO_3 in the ignited sample and the original cement (Note 51). Report the corrected percentage, rounded in accordance with Table 3, as loss on ignition.

NOTE 51—If a gain in weight is obtained during ignition, subtract the percentage gain from the correction for SO_3.

18. Sodium and Potassium Oxides (*Reference Test Methods*)

18.1 *Total Alkalies*:

18.1.1 *Summary of Test Method*—This test method[7] covers the determination of sodium oxide (Na_2O) and potassium oxide (K_2O) by flame photometry or atomic absorption.

NOTE 52—This test method is suitable for hydraulic cements that are completely decomposed by hydrochloric acid and should not be used for determination of total alkalies in hydraulic cements that contain large amounts of acid-insoluble material, for example, pozzolan cements. It may be used to determine acid-soluble alkalies for such cements. An alternate test method of sample dissolution for such cements is in preparation.

18.1.2 *Apparatus*:

18.1.2.1 *Instrument*—Any type flame photometer or atomic absorption unit may be used provided it can be demonstrated that the required degree of accuracy and precision is as indicated in 18.1.3.

NOTE 53—After such accuracy is established, for a specific instrument, further tests of instrument accuracy are not required except when it must be demonstrated that the instrument gives results within the prescribed degree of accuracy by a single series of tests using the designated standard samples.

NOTE 54—For normal laboratory testing, it is recommended that the accuracy of the instrument be routinely checked by the use of either a National Institute of Standards and Technology cement or cement of known alkali content.

18.1.2.2 The instrument shall consist at least of an atomizer and burner; suitable pressure-regulating devices and gages for fuel and oxidant gas; an optical system, capable of preventing excessive interference from wavelengths of light other than that being measured; and a photosensitive indicating device.

18.1.3 *Initial Qualification of Instrument*—Qualify the instrument in accordance with 4.4.2 to establish that an instrument provides the desired degree of precision and accuracy.

18.1.4 *Reagents and Materials*:

18.1.4.1 *Laboratory Containers*—All glassware shall be made of borosilicate glass and all polyethylene shall comply with the requirements of 5.2.3.

18.1.4.2 *Calcium Carbonate*—The calcium carbonate ($CaCO_3$) used in the preparation of the calcium chloride stock solution (18.1.5.1) shall contain not more than 0.020 % total alkalies as sulfate.

NOTE 55—Materials sold as a primary standard or ACS "low alkali" grade normally meet this requirement. However, the purchaser should assure himself that the actual material used conforms with this requirement.

18.1.4.3 *Potassium Chloride* (KCl).

18.1.4.4 *Sodium Chloride* (NaCl).

18.1.4.5 Commercially available solutions may be used in place of those specified in 18.1.5.

18.1.5 *Preparation of Solutions*:

[7] The 1963 revision of these test methods deleted the classical (J. L. Smith) gravimetric method for the determination of Na_2O and K_2O in cements. Those interested in this method should refer to the *1961 Book of ASTM Standards,* Part 4. The 1983 revision of these test methods deleted the details of the flame photometric procedure for the determination of Na_2O and K_2O. Those interested in this method should refer to the *1982 Annual Book of ASTM Standards,* Part 13.

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18.1.5.1 *Calcium Chloride Stock Solution*—Add 300 mL of water to 112.5 g of $CaCO_3$ in a 1500-mL beaker. While stirring, slowly add 500 mL of HCl. Cool the solution to room temperature, filter into a 1-L volumetric flask, dilute to 1 L, and mix thoroughly. This solution contains the equivalent of 63 000 ppm (6.30 %) CaO.

18.1.5.2 *Sodium-Potassium Chloride Stock Solution*—Dissolve 1.8858 g of sodium chloride (NaCl) and 1.583 g of potassium chloride (KCl) (both dried at 105 to 110 °C for several hours prior to weighing) in water. Dilute to 1 L in a volumetric flask and mix thoroughly. This solution contains the equivalent of 1000 ppm (0.10 %) each of Na_2O and K_2O. Separate solutions of Na_2O and of K_2O may be used provided that the same concentration solutions are used for calibration for cement analysis as were used for the calibration when qualifying the instrument in accordance with 18.1.3.

18.1.5.3 *Standard Solutions*—Prepare the standard solutions prescribed for the instrument and method used. Measure the required volume of NaCl-KCl stock solutions in calibrated pipets or burets. The calcium chloride stock solutions, if needed, may be measured in appropriate graduated cylinders. If the instrument being used requires an internal standard, measure the internal standard solution with a pipet or buret. Place each solution in a volumetric flask, dilute to the indicated volume, and mix thoroughly.

18.1.5.4 If more dilute solutions are required by the method in use, pipet the required aliquot to the proper sized volumetric flask, add any necessary internal standard, dilute to the mark, and mix thoroughly.

18.1.6 *Calibration of Apparatus*:

NOTE 56—No attempt is made in this section to describe in detail the steps for putting the instrument into operation since this will vary considerably with different instruments. The manufacturer's instructions should be consulted for special techniques or precautions to be employed in the operation, maintenance, or cleaning of the apparatus.

18.1.6.1 Turn on the instrument and allow it to warm up in accordance with the manufacturer's instructions. (A minimum of 30 min is required for most instruments.) Adjust the fuel and oxidant gas pressures as required by the instrument being used. Light and adjust the burner for optimum operation. Make any other adjustments that may be necessary to establish the proper operating conditions for the instrument.

18.1.7 *Procedure*:

18.1.7.1 *Solution of the Cement*—Prepare the solution of the cement in accordance with the procedure specified by the instrument manufacturer. If no procedure is specified, or if desired, proceed as specified in 17.1.7.1.1 or 17.1.7.1.2 (Note 56).

NOTE 57—The presence of SiO_2 in solution affects the accuracy of some flame photometers. In cases where an instrument fails to provide results within the prescribed degree of accuracy outlined in 4.4.2.1-4.4.3 tests should be made on solutions from which the SiO_2 has been removed. For this removal proceed as in .

18.1.7.1.1 Place 1.000 ± 0.001 g of the cement in a 150-mL beaker and disperse with 20 mL of water using a swirling motion of the beaker. While still swirling add 5.0 mL of HCl all at once. Dilute immediately to 50 mL with water. Break up any lumps of cement remaining undispersed with a flat-end stirring rod. Digest on a steam bath or hot plate for 15 min, then filter through a medium-textured filter paper into a 100-mL volumetric flask. Wash beaker and paper thoroughly with hot-water, cool contents of the flask to room temperature, dilute to 100 mL, and mix the solution thoroughly. Continue as given in 18.1.7.2.

18.1.7.1.2 Place 1.000 ± 0.001 g of cement into a platinum evaporating dish and disperse with 10 mL of water using a swirling motion. While still swirling, add 5.0 mL of HCl all at once. Break up any lumps with a flat-end stirring rod and evaporate to dryness on a steam bath. Make certain that the gelatinous appearance is no longer evident. Treat the residue with 2.5 mL of HCl and about 20 mL of water. Digest on a steam bath for 5 to 10 min and filter immediately through a 9-cm medium-textured filter paper into a 100-mL volumetric flask. Wash thoroughly with repeated small amounts of hot water until the total volume of solution is 80 to 95 mL. Cool to room temperature, dilute to the mark, and mix thoroughly.

When it has been demonstrated that the removal of SiO_2 is necessary to obtain the required accuracy described in 4.4.2.1-4.4.3 for a specific flame photometer, SiO_2 must always be removed when making analyses that are used as the basis for rejection of a cement for failure to comply with specifications or where specification compliance may be in question. Where there is no question as to specification compliance, analyses may be made by such instruments without SiO_2 removal provided the deviations from certificate values obtained by the tests prescribed in 4.4.2.1-4.4.3 are not more than twice the indicated limits.

18.1.7.2 If the test method in use requires more dilute solutions, an internal standard, or both, carry out the same dilutions as in 18.1.5.4 as needed. The standard and the sample solutions to be analyzed must be prepared in the same way and to the same dilution as the solutions of standard cements analyzed for the qualification of the instrument.

18.1.7.3 *Procedure for Na_2O (Note 59)*—Warm up and adjust the instrument for the determination of Na_2O as described in 18.1.6.1. Immediately following the adjustment and without changing any instrumental settings, atomize the cement solution and note the scale reading (Note 58). Select the standard solutions which immediately bracket the cement solution in Na_2O content and observe their readings. Their values should agree with the values previously established during calibration of the apparatus. If not, recalibrate the apparatus for that constituent. Finally, alternate the use of the unknown solution and the bracketing standard solutions until readings of the unknown agree within one division on the transmission or meter scale, or within 0.01 weight percent for instruments with digital readout, and readings for the standards similarly agree with the calibration values. Record the average of the last two readings obtained for the unknown solution.

NOTE 58—The order in determining Na_2O or K_2O is optional. In all cases, however, the determination should immediately follow the adjustment of the instrument for that particular constituent.

18.1.7.4 If the reading exceeds the scale maximum, either transfer a 50-mL aliquot of the solution prepared in 18.1.7.1 to a 100-mL volumetric flask or, if desired, prepare a new solution by using 0.500 g of cement and 2.5 mL of HCl (instead of 5.0

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mL) in the initial addition of acid. In the event silica has to be removed from the 0.5-g sample of cement, treat the dehydrated material with 1.25 mL of HCl and about 20 mL of water, then digest, filter, and wash. In either case, add 5.0 mL of calcium chloride stock solution (18.1.5.1) before diluting to mark with water. Dilute to the mark. Proceed as in 18.1.5.4 if more dilute solutions are required by the test method in use. Determine the alkali content of this solution as described in (18.1.7.3) and multiply by a factor of 2 the percentage of alkali oxide.

18.1.7.5 *Procedure for* K_2O—Repeat the procedure described in 18.1.7.3 except that the instrument shall be adjusted for the determination of K_2O. For instruments that read both Na_2O and K_2O simultaneously, determine K_2O at the same time as determining Na_2O.

18.1.8 *Calculation and Report*—From the recorded averages for Na_2O and K_2O in the unknown sample, report each oxide rounded in accordance with Table 3.

18.2 *Water-Soluble Alkalies*:

NOTE 59—The determination of water-soluble alkali should not be considered as a substitute for the determination of total alkali according to 18.1.2.1 to 18.1.8. Moreover, it is not to be assumed that in this method all water-soluble alkali in the cement will be dissolved. Strict adherence to the procedure described is essential where there is a specified limit on the content of water-soluble alkali or where several lots of cement are compared on the basis of water-soluble alkali.

18.2.1 *Procedure*:

18.2.1.1 Weigh 25.0 g of sample into a 500-mL Erlenmeyer flask and add 250 mL of water. Stopper the flask with a rubber stopper and shake continuously for 10 min at room temperature. Filter through a Büchner funnel which contains a well-seated retentive, dry filter paper, into a 500-mL filtering flask, using a weak vacuum. Do not wash.

18.2.1.2 Transfer a 50-mL aliquot (Note 60) of the filtrate to a 100-mL volumetric flask and acidify with 0.5 mL of concentrated HCl (sp gr 1.19). Add 9.0 mL of stock $CaCl_2$ solution (63 000 ppm CaO), described in 18.1.5.1, to the 100-mL flask, and dilute the solution to 100 mL. If the test method in use requires more dilute solutions, an internal standard, or both, carry out the same dilutions as in 18.1.5.4, as needed. Determine the Na_2O and K_2O contents of this solution as described in 18.1.7.3 and 18.1.7.5. Record the parts per million of each alkali in the solution in the 100-mL flask.

NOTE 60—The aliquot of the filtrate taken for the analysis should be based on the expected water-soluble alkali content. If the expected level of either K_2O or Na_2O is more than 0.08 weight % of cement, or if the water soluble alkali level is unknown, a 50-mL aliquot as given in 18.2.1.2 should be used to make up the initial test solution. If either the Na_2O or K_2O exceeds 0.16 %, place a 50-mL aliquot of the solution from 18.2.1.2 in a 100-mL volumetric flask, add 5 mL of $CaCl_2$ stock solution, and dilute to 100 mL. When the level of either K_2O or Na_2O is less than 0.08 %, take a 100-mL aliquot from the original filtrate (obtained by 18.2.1.1), add 1 mL of HCl, and evaporate on a hot plate in a 250-mL beaker to about 70 mL. Add 8 mL of stock $CaCl_2$ solution and transfer the sample to a 100-mL volumetric flask, rinsing the beaker with a small portion of distilled water. Cool the solution to room temperature and dilute to 100 mL.

18.2.2 *Calculations*—Calculate the percentage of the water-soluble alkali, expressed as Na_2O, as follows:

$$\text{Total water-soluble alkali, as } Na_2O = A + E \quad (9)$$

$$A = B/(V \times 10)$$

$$C = D/(V \times 10)$$

$$E = C \times 0.658$$

where:

- A = percentage of water-soluble sodium oxide (Na_2O),
- V = millilitres of original filtrate in the 100-mL flask,
- B = parts per million of Na_2O in the solution in the 100-mL flask,
- C = percent of water-soluble potassium oxide (K_2O),
- D = parts per million of K_2O in the 100-mL flask,
- E = percentage Na_2O equivalent to K_2O determined, and
- *0.658* = molecular ratio of Na_2O to K_2O.

Report the result rounded in accordance with Table 3.

19. Manganic Oxide (*Reference Method*)

19.1 *Summary of Method*—In this procedure, manganic oxide is determined volumetrically by titration with sodium arsenite solution after oxidizing the manganese in the cement with sodium metabismuthate ($NaBiO_3$).

19.2 *Reagents*:

19.2.1 *Sodium Arsenite, Standard Solution* (1 mL = 0.0003 g Mn_2O_3)—Dissolve in 100 mL of water 3.0 g of sodium carbonate (Na_2CO_3) and then 0.90 g of arsenic trioxide (As_2O_3), heating the mixture until the solution is as complete as possible. If the solution is not clear or contains a residue, filter the solution. Cool it to room temperature, transfer to a volumetric flask, and dilute to 1 L.

19.2.1.1 Dissolve 0.58 g of potassium permanganate ($KMnO_4$) in 1 L of water and standardize it against about 0.03 g of sodium oxalate ($Na_2C_2O_4$) oxidimetric standard furnished by NIST (Standard Sample No. 40 or its replacement) according to the directions furnished with the sodium oxalate. Put 30.0 mL of the $KMnO_4$ solution in a 250-mL Erlenmeyer flask. Add 60 mL of HNO_3 (1+4) and 10 mL of sodium nitrite ($NaNO_2$, 50 g/L) to the flask. Boil the solution until the HNO_2 is completely expelled. Cool the solution, add $NaBiO_3$, and finish by titrating with the standard sodium arsenite ($NaAsO_2$) solution as described in 19.3.2. Calculate the manganic oxide (Mn_2O_3) equivalent of the $NaAsO_2$ solution, g/mL, as follows:

$$E = (A \times 7.08)/BC \quad (10)$$

where:

- E = Mn_2O_3 equivalent of the $NaAsO_2$ solution, g/mL,
- A = grams of $Na_2C_2O_4$ used,
- B = millilitres of $KMnO_4$ solution required by the $Na_2C_2O_4$,
- C = millilitres of $NaAsO_2$ solution required by 30.0 mL of $KMnO_4$ solution, and
- *7.08* = molecular ratio of Mn_2O_3 to 5 $Na_2C_2O_4$(0.236) multiplied by 30.0 (millilitres of $KMnO_4$ solution).

19.2.2 *Sodium Metabismuthate* ($NaBiO_3$).

19.2.3 *Sodium Nitrite Solution* (50 g $NaNO_2$/L).

19.3 *Procedure*:

19.3.1 Weigh 1.0 to 3.0 g of the sample (Note 61) into a 250-mL beaker and treat it with 5 to 10 mL of water and then with 60 to 75 mL of HNO_3 (1+4). Boil the mixture until the solution is as complete as possible. Add 10 mL of $NaNO_2$

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solution (50 g/L) to the solution and boil it until the nitrous acid is completely expelled (Note 62), taking care not to allow the volume of the solution to become so small as to cause the precipitation of gelatinous SiO_2. There may be some separated SiO_2, which may be ignored, but if there is still a red or brown residue, use more $NaNO_2$ solution (50 g/L) to effect a complete decomposition, and then boil again to expel the nitrous acid. Filter the solution through a medium-textured paper into a 250-mL Erlenmeyer flask and wash the filter paper with water.

NOTE 61—The amount of cement taken for analysis depends on the content of manganese, varying from 1 g for about 1 % of Mn_2O_3 to 3 g for 0.25 % or less of Mn_2O_3.

NOTE 62—When $NaNO_2$ is added, the expulsion of HNO_2 by boiling must be complete. If any HNO_2 remains in the solution, it will react with the added $NaBiO_3$ and decrease its oxidizing value. If there is any manganese in the cement, the first small quantity of $NaBiO_3$ should bring out a purple color.

19.3.2 The solution should have a volume of 100 to 125 mL. Cool it to room temperature. To the solution add a total of 0.5 g of $NaBiO_3$ in small quantities, while shaking intermittently. After the addition is completed, shake the solution occasionally for 5 min and then add to it 50 mL of cool HNO_3 (1+33) which has been previously boiled to expel nitrous acid. Filter the solution through a pad of ignited asbestos in a Gooch crucible or a carbon or fritted-glass filter with the aid of suction. Wash the residue four times with the cool HNO_3 (1+33). Titrate the filtrate immediately with the standard solution of $NaAsO_2$. The end point is reached when a yellow color is obtained free of brown or purple tints and does not change upon further addition of $NaAsO_2$ solution.

19.3.3 *Blank*—Make a blank determination, following the same procedure and using the same amounts of reagents, and correct the results obtained in the analysis accordingly.

19.4 Calculate the percentage of Mn_2O_3 to the nearest 0.01 as follows:

$$Mn_2O_3, \% = (EV/S) \times 100 \quad (11)$$

where:

E = Mn_2O_3 equivalent of the $NaAsO_2$ solution, g/mL,
V = millilitres of $NaAsO_2$ solution required by the sample, and
S = grams of sample used.

Report the result rounded in accordance with Table 3.

20. Chloride (*Reference Test Method*)

20.1 *Summary of Test Method*—In this test method acid-soluble chloride content of cement is determined by the potentiometric titration of chloride with silver nitrate (See Note 63). The procedure is also applicable to clinker and portland cement raw mix. Under the conditions of the test, no constituent normally present in these materials will interfere (See Note 64).

NOTE 63—In most cases acid-soluble chloride content of a portland cement is total chloride content.

NOTE 64—Species that form insoluble silver salts or stable silver complexes in acid solution interfere with potentiometric measurements. Thus, iodides and bromides interfere while fluorides will not. Sulfide salts in concentrations typical of these materials should not interfere because they are decomposed by acid treatment.

20.2 *Apparatus*:

20.2.1 *Chloride, Silver/Sulfide Ion Selective Electrode,* or a silver billet electrode coated with silver chloride (Note 65), with an appropriate reference electrode.

20.2.2 *Potentiometer,* with millivolt scale readable to 1 mV or better. A digital read-out is preferred but not required.

20.2.3 *Buret,* Class A, 10-mL capacity with 0.05-mL divisions. A buret of the potentiometric type, having a displaced delivery tip, is convenient, but not required.

NOTE 65—Suitable electrodes are available from Orion, Beckman Instruments, and Leeds and Northrup. Carefully following the manufacturer's instructions, add filling solution to the electrodes. The silver billet electrodes must be coated electrolytically with a thin, even layer of silver chloride. To coat the electrode, dip the clean silver billet of the electrode into a saturated solution of potassium chloride (about 40 g/L) in water and pass an electric current through the electrode from a 1½ to 6-V dry cell with the silver billet electrode connected to the positive terminal of the battery. A carbon rod from an all-dry cell or other suitable electrode is connected to the negative terminal and immersed in the solution to complete the electrical circuit. When the silver chloride coating wears off, it is necessary to rejuvenate the electrode by repeating the above procedure. All of the old silver chloride should first be removed from the silver billet by rubbing it gently with fine emery paper followed by water rinsing of the billet.

20.3 *Reagents*:

20.3.1 *Sodium Chloride* (NaCl), primary standard grade.

20.3.2 *Silver Nitrate* ($AgNO_3$), reagent grade.

20.3.3 *Potassium Chloride* (KCl), reagent grade (required for silver billet electrode only).

20.3.4 *Reagent Water* conforming to the requirements of Specification D1193 for Type III reagent water.

20.4 *Preparation of Solutions*:

20.4.1 *Sodium Chloride, Standard Solution* (0.05 *N* NaCl)—Dry sodium chloride (NaCl) at 105 to 110 °C to a constant weight. Weigh 2.9222 g of dried reagent. Dissolve in water and dilute to exactly 1 L in a volumetric flask and mix thoroughly. This solution is the standard and requires no further standardization.

20.4.2 *Silver Nitrate, Standard Solution* (0.05 *N* $AgNO_3$)—Dissolve 8.4938 g of silver nitrate ($AgNO_3$) in water. Dilute to 1 L in a volumetric flask and mix thoroughly. Standardize against 5.00 mL of standard 0.05 *N* sodium chloride solution diluted to 150 mL with water following the titration test method given in 20.5.4 beginning with the second sentence. The exact normality shall be calculated from the average of three determinations as follows:

$$N = 0.25/V \quad (12)$$

where:

N = normality of $AgNO_3$ solution,
0.25 = milliequivalents NaCl (5.0 mL × 0.05 *N*), and
V = volume of $AgNO_3$ solution, mL.

Commercially available standard solutions may be used provided the normality is checked according to the standardization procedure.

20.4.3 *Methyl Orange Indicator*—Prepare a solution containing 2 g of methyl orange per litre of 95 % ethyl alcohol.

20.5 *Procedure*:

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20.5.1 Weigh a 5.0-g sample of the cement into a 250-mL beaker (Note 66). Disperse the sample with 75-mL of water. Without delay slowly add 25 mL of dilute (1+1) nitric acid, breaking up any lumps with a glass rod. If the smell of hydrogen sulfide is strongly evident at this point, add 3 mL of hydrogen peroxide (30 % solution) (Note 67). Add 3 drops of methyl orange indicator and stir. Cover the beaker with a watch glass and allow to stand for 1 to 2 min. If a yellow to yellow-orange color appears on top of the settled solids, the solution is not sufficiently acidic. Add additional dilute nitric acid (1+1) dropwise while stirring until a faint pink or red color persists. Then add 10 drops in excess. Heat the covered beaker rapidly to boiling. Do not allow to boil for more than a few seconds. Remove from the hot plate (Note 68).

NOTE 66—Use a 5-g sample for cement and other materials having an expected chloride content of less than about 0.15 % Cl. Use proportionally smaller samples for materials with higher chloride concentrations. Use cement and other powdered materials as is without grinding. Coarse samples require grinding to pass a 20-mesh sieve. If a sample is too fine, excessive silica gel may form during digestion with nitric acid, thereby slowing subsequent filtration.

NOTE 67—Slags and slag cements contain sulfide sulfur in concentrations that can interfere with the determination.

NOTE 68—It is important to keep the beaker covered during heating and digestion to prevent the loss of chloride by volatilization. Excessive amounts of acid should not be used since this results in early removal of the silver chloride coating from the silver billet electrode. A slurry that is only slightly acidic is sufficient.

20.5.2 Wash a 9-cm coarse-textured filter paper with four 25-mL increments of water using suction filtering provided by a 250-mL or 500-mL Büchner funnel and filtration flask. Discard the washings and rinse the flask once with a small portion of water. Reassemble the suction apparatus and filter the sample solution. Rinse the beaker and the filter paper twice with small portions of water. Transfer the filtrate from the flask to a 250-mL beaker and rinse the flask once with water. The original beaker may be used (Note 69). Cool the filtrate to room temperature. The volume should not exceed 175 mL.

NOTE 69—It is not necessary to clean all the slurry residue from the sides of the beaker nor is it necessary that the filter remove all of the fine material. The titration may take place in a solution containing a small amount of solid matter.

20.5.3 For instruments equipped with dial readout it is necessary to establish an approximate "equivalence point" by immersing the electrodes in a beaker of water and adjusting the instrument to read about 20 mV lower than mid-scale. Record the approximate millivoltmeter reading. Remove the beaker and wipe the electrodes with absorbent paper.

20.5.4 To the cooled sample (Note 70) beaker from 20.5.2, carefully pipet 2.00 mL of standard 0.05 *N* NaCl solution. Place the beaker on a magnetic stirrer and add a TFE-fluorocarbon-coated magnetic stirring bar. Immerse the electrodes into the solution taking care that the stirring bar does not strike the electrodes; begin stirring gently. Place the delivery tip of the 10-mL buret, filled to the mark with standard 0.05 *N* silver nitrate solution, in (preferably) or above the solution (Note 71).

NOTE 70—It is advisable to maintain constant temperature during measurement, for the solubility relationship of silver chloride varies markedly with temperature at low concentrations.

NOTE 71—If the tip of the buret is out of the solution, any adhering droplet should be rinsed onto the beaker with a few millilitres of water following each titration increment.

20.5.5 Gradually titrate, record the amount of standard 0.05 *N* silver nitrate solution required to bring the millivoltmeter reading to −60.0 mV of the equivalence point determined in the water.

20.5.6 Continue the titration with 0.20-mL increments. Record the buret reading and the corresponding millivoltmeter reading in columns 1 and 2 of a four-column recording form like that shown in Appendix X1. Allow sufficient time between each addition for the electrodes to reach equilibrium with the sample solution. Experience has shown that acceptable readings are obtained when the minimum scale reading does not change within a 5-s period (usually within 2 min).

20.5.7 As the equivalence point is approached, the equal additions of $AgNO_3$ solution will cause larger and larger changes in the millivoltmeter readings. Past the equivalence point the change per increment will again decrease. Continue to titrate until three readings past the approximate equivalence point have been recorded.

20.5.8 Calculate the difference in millivolt readings between successive additions of titrant and enter the values in Column 3 of the recording form. Calculate the difference between consecutive values in Column 3 and enter the results in Column 4. The equivalence point of the titration will be within the maximum Δ mV interval recorded in Column 3. The precise equivalence point can be interpolated from the data listed in Column 4 as shown in the Appendix X1.

20.5.9 *Blank*—Make a blank determination using 75 mL of water in place of the sample, following the same procedure starting with the third sentence of 20.5.1 without delay. Correct the results obtained in the analysis accordingly (Note 72) by subtracting the blank.

20.6 *Calculation*— Calculate the percent chloride to the nearest 0.001 % as follows:

$$\text{Cl, \%} = \frac{3.545\,[(V_1 - V_2)N - 0.10]}{W} \qquad (13)$$

where:

V_1 = millilitres of 0.05 *N* $AgNO_3$ solution used for sample titration (equivalence point),
V_2 = millilitres of 0.05 *N* $AgNO_3$ solution used for blank titration (equivalence point),
N = exact normality of 0.05 *N* $AgNO_3$ solution, and
W = weight of sample, g.

Report the result rounded in accordance with Table 3.

NOTE 72—For nonreferee analysis the blank may be omitted.

21. Chloroform-Soluble Organic Substances (*Reference Test Method*)

21.1 *Summary of Test Method*—This test method[8] was specially designed for the determination of Vinsol resin and

[8] The 1965 revision of these test methods deleted the methoxyl test method for determining Vinsol resin. Those interested in this test method should refer to the *1966 Book of ASTM Standards,* Part 9.

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tallow in portland cement, although mineral oil, common rosin, calcium stearate, and other fatty acid compounds, and probably some other substances, if present, will be included in the determination. Extreme care is necessary in the entire procedure. The test method may be applied to types of cement other than portland cement, although if the cement contains a large amount of acid-insoluble matter, the emulsions may separate slowly, and less vigorous shaking, more chloroform, and more washing may be necessary.

21.2 *Reagents*:

21.2.1 *Chloroform*—If the blank determination as described in 21.3.5 exceeds 0.0015 g, the chloroform should be distilled before use. Chloroform recovered in the procedure may be slightly acid but can be reused for the portions to be shaken with the aqueous acid solution of the sample in the 1-L funnel. Chloroform used for washing the filter and transferring the extract should be fresh or distilled from fresh chloroform.

21.2.2 *Stannous Chloride* ($SnCl_2$).

21.3 *Procedure*:

21.3.1 Place 40 g of cement in a 1-L Squibb separatory funnel (Note 73) and mix it with 520 mL of water added in two approximately equal portions. Shake vigorously immediately after the addition of the first portion to effect complete dispersion. Then add the second portion and shake again. At once add rapidly 185 mL of HCl in which 10 g of $SnCl_2$ (Note 74) have been dissolved, rapidly insert the stopper in the funnel, invert, and shake with a swirling motion for a few seconds to loosen and disperse all the cement, taking care to avoid the development of great internal pressure due to unnecessarily violent shaking. Release internal pressure immediately by opening and closing the stopcock. Repeat the shaking and release the pressure until the decomposition of the cement is complete. If necessary, break up persistent lumps with a long glass rod. Cool to room temperature rapidly by allowing tap water to run on the flask.

NOTE 73—The use of grease to lubricate the stopcocks and glass stoppers of the separatory funnels should be avoided. Wetting the stopcocks with water before using will assist in their easy operation.

NOTE 74—The purpose of the $SnCl_2$ is to prevent the oxidation of sulfide sulfur to elemental sulfur, which is soluble in chloroform.

21.3.2 Add 75 mL of chloroform to the solution, stopper the funnel, shake it vigorously for 5 min, and allow the water and chloroform to stand 15 min to separate. Draw off the lower chloroform layer into a 125-mL Squibb separatory funnel, including the scum (Note 75) and a few millilitres of the aqueous layer, making certain that all the scum is transferred. Keep the amount of the aqueous layer transferred to an absolute minimum, since excessive water in the 125-mL funnel may result in incomplete extraction of the scum and may cause an emulsion which does not separate readily. Shake the funnel vigorously to ensure the complete extraction of the scum. Allow the chloroform to separate, and draw it into a 250-mL Squibb separatory funnel which contains 50 mL of water and a few drops of HCl, making sure to keep the scum behind in the 125-mL funnel. Shake the 250-mL funnel, and draw the chloroform into another 250-mL funnel that contains 50 mL of water and a few drops of HCl. Shake this funnel as in the case of the first 250-mL funnel. When the chloroform separates, draw it into a standard-taper flat-bottom boiling flask (Note 76), taking care not to allow any water to enter the flask.

NOTE 75—There is usually a dark colored scum at the liquid interface. It may contain chloroform-soluble organic substance after shaking in the funnel, where the proportion of water to chloroform is great. It may be concentrated and confined to a small volume by gently twirling the funnel after the scum has been drawn into the narrower part of the funnel.

NOTE 76—The liquid is later distilled. No cork or rubber stoppers should be used. A250 or 300-mL soil analysis flask, fitted with a condenser tube by means of a ground joint, is satisfactory. The tube may be bent near the neck and the remaining part fitted with a water-cooling jacket. Chloroform thus recovered may be reused as described in 21.2.1.

21.3.3 Add 25 mL of chloroform to the solution in the original 1-L separatory funnel, and carry out the operations as described in 21.3.2, retaining the original wash water in the 250-mL funnels. Repeat, using another 25-mL portion of chloroform.

21.3.4 Distill the combined chloroform extracts in the boiling flask until their volume is reduced to 10 to 15 mL. Filter the remaining liquid into a weighed 100-mL glass beaker or platinum dish (Note 77) through a small medium-textured filter paper that has been washed with fresh chloroform. Rinse the flask and wash the paper with several small portions of fresh chloroform. Evaporate the extracts at a low temperature (not over 63 °C) to dryness (Note 78) and heat it in an oven at 57 to 63 °C for 3 min. Pass dry air into the vessel for 15 s, cool, and weigh. Repeat the heating and weighing until two successive weighings do not differ by more than 0.0010 g. The higher of the last two weights shall be taken as the true weight.

NOTE 77—A platinum dish is preferable, as it quickly attains the temperature of the balance. If a glass beaker is used, it should be allowed to stand in the case of the balance for at least 20 min before weighing.

NOTE 78—Care should be taken in drying the extract, as many of the chloroform-soluble organic substances are somewhat volatile when heated for a long time at even moderate temperatures. With protection from the accumulation of dust, the solution may be evaporated at room temperature overnight.

When a quick evaporation is desired, the solution may be evaporated on a hot plate at low heat under a stream of dry air through a glass tube (about 10 mm in inside diameter) until it is about 3 mm in depth. Then remove the vessel from the hot plate and continue a slow stream of dry air until the residue appears dry. Then continue with a more rapid stream of dry air for 5 min at room temperature before placing the vessel in the oven at 57 to 63 °C. After each 3-min heating period in the oven, pass dry air into the vessel for about 15 s before weighing. The air may be dried by passing it through a cheap desiccant, such as calcium chloride or sulfuric acid, followed by a desiccant of high efficiency, such as magnesium perchlorate or anhydrous calcium sulfate, with care taken to avoid the carrying of dust from the desiccant by the air. Instead of using compressed air, which is often contaminated with oil, dirt, and moisture, one can place the chloroform solution under a bell glass and induce a stream of air through the desiccants by means of an aspirator or vacuum pump.

When Vinsol resin is known to be the only substance present, the residue is more stable and may be heated at 100 to 105 °C, instead of 57 to 63 °C, in order to expel all possible traces of chloroform.

21.3.5 *Blank*—Make a blank determination. Ignite a 40-g sample of the cement at 950 to 1000 °C for 1 h (Note 79) and regrind. Treat this ignited sample by the same procedure and using the same reagents as in the analysis and correct the results accordingly.

NOTE 79—Care should be taken to completely burn off the organic

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substance. A 100-mL flat platinum dish, in which the sample is well spread out, and a muffle furnace are advised for this purpose. If such a furnace is not available, a large high-temperature burner of the Meker type may be used. Thorough stirring of the sample should be done frequently—every 5 min when a burner is used.

21.4 *Calculation*— Calculate the percentage of chloroform-soluble organic substances to the nearest 0.001 by multiplying the weight in grams of residue (Note 80) by 2.5 (100 divided by the weight of the sample used (40 g)). Report the result rounded in accordance with Table 3.

NOTE 80—If the organic substance in the cement is tallow, the residue is the fatty acids resulting from the hydrolysis of the tallow in the hot acid solution, and its weight should be multiplied by 1.05 to give the weight of the original glycerides in the tallow. If the original substance is calcium stearate, the residue is stearic acid, and its weight multiplied by 1.07 gives the weight of calcium stearate.

ALTERNATIVE TEST METHODS

22. Calcium Oxide (*Alternative Test Method*)

22.1 *Summary of Test Method*:

22.1.1 This test method covers the gravimetric determination of CaO after removal of SiO_2 and the ammonium hydroxide groups and double precipitation of calcium as the oxalate. The precipitate is converted to CaO by ignition and is weighed.

22.1.2 Strontium, usually present in portland cement as a minor constituent, is precipitated with calcium as the oxalate and is subsequently calculated as CaO. If the SrO content is known and correction of CaO for SrO is desired as, for example, for research purposes or to compare results with CRM certificate values, the CaO obtained by this test method may be corrected by subtracting percent SrO. In determining conformance of a cement to specifications the correction of CaO for SrO should not be made.

22.2 *Procedure* (Note 81):

22.2.1 Acidify the combined filtrates obtained in the determination of the ammonium hydroxide group (8.1-8.3) and, if necessary, evaporate to a volume of about 200 mL. Add 5 mL of HCl, a few drops of methyl red indicator solution, and 30 mL of warm ammonium oxalate solution (50 g/L) (Note 37). Heat the solution to 70 to 80 °C and add NH_4OH (1+1) dropwise with stirring until the color changes from red to yellow (see Note 38). Allow the solution to stand without further heating for 1 h (not longer), with occasional stirring during the first 30 min. Filter using a retentive paper and wash moderately with cold ammonium oxalate solution (1 g/L). Reserve the filtrate and washings.

NOTE 81—When analyses are being made for determining conformity to specifications and there is a possibility that sufficient manganese will be present to cause the percentage of magnesium determined by alternate test methods to exceed the specification limit, manganese may be removed as directed in 14.3.2 before CaO is determined by this alternative test method.

22.2.2 Transfer the precipitate and filter paper to the beaker in which the precipitation was made. Dissolve the oxalate in 50 mL of hot HCl (1+4) and macerate the filter paper. Dilute to 200 mL with water, add a few drops of methyl red indicator and 20 mL of ammonium oxalate solution, heat the solution nearly to boiling, and precipitate calcium oxalate again by neutralizing the acid solution with NH_4OH as described in 14.3.1. Allow the solution to stand 1 to 2 h (standing for 2 h at this point does no harm), filter, and wash as before. Combine the filtrate with that already obtained and reserve for the determination of MgO (15.3.1).

22.2.3 Dry the precipitate in a weighed covered platinum crucible. Char the paper without inflaming, burn the carbon at as low a temperature as possible, and, finally, heat with the crucible tightly covered in an electric furnace or over a blast lamp at a temperature of 1100 to 1200 °C. Cool in a desiccator and weigh as CaO. Repeat the ignition to constant weight.

22.2.4 *Blank*—Make a blank determination, following the same procedure and using the same amounts of reagents, and correct the results obtained in the analysis accordingly.

22.3 *Calculation*:

22.3.1 Calculate the percentage of CaO to the nearest 0.1 by multiplying the weight in grams of CaO by 200 (100 divided by the weight of sample used (0.5 g)).

22.3.2 Correct the percent CaO for SrO, if desired, by subtracting the percent SrO.

23. Carbon Dioxide (*Reference Test Method*)

23.1 Any test method may be used, provided that acceptable performance has been demonstrated in accordance with 23.2. See Appendix Appendix X2 for guidance on methods.

23.2 Demonstrate performance by analysis, in duplicate, of at least one Portland cement. Prepare three standards, each in duplicate: Standard A shall be the selected Portland cement; Standard B shall be Standard A containing 2.00 % Certified $CaCO_3$(such as NIST 915a); Standard C shall be Standard A containing 5.00 % Certified $CaCO_3$. Prepare duplicate specimens of each standard. Assign the CO_2 content of Standard A as the average of the two values determined, provided they agree within the required limit of Table 1, Column 2. Assign CO_2 values to Standards B and C as follows: multiply the Certified $CaCO_3$ value (Y) for CO_2(from the certificate value) by the mass fraction of Certified $CaCO_3$ added to that standard (percentage added divided by 100); multiply the value determined for Standard A by the mass fraction of Standard A in each of the other standards (that is, 0.98 and 0.95 for Standards B and C, respectively); add the two values for Standard A and for Standard B, respectively; call these values B and C.

Example:

$B = 0.98A + 0.02Y$

$C = 0.95A + 0.05Y$

Where for Certified $CaCO_3$, if Y = 44.01 %

B = 0.98A + 0.88 % by mass

C = 0.95A + 2.20 % by mass

The difference between the duplicate CO_2 values for Standards B and C, respectively, shall not exceed 0.17 and 0.24 % by mass. The difference between the average of the duplicate values for Standards B and C and their assigned values (B and C) shall not exceed 0.13 and 0.26 % by mass respectively.

23.3 Report the result rounded in accordance with Table 3.

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24. Magnesium Oxide (*Alternative Test Method*)

24.1 *Summary of Test Method*—This alternative test method is a volumetric procedure suitable for use when the determinations of silicon dioxide (SiO_2), aluminum oxide (Al_2O_3), ferric oxide (Fe_2O_3), and calcium oxide (CaO) are omitted.

24.2 *Rapid Volumetric Test Method (Titration of Magnesium Oxyquinolate)*:

24.3 *Reagents*:

24.3.1 *Ammonium Nitrate Solution* (20 g NH_4NO_3/L).

24.3.2 *Ammonium Oxalate Solution* (50 g/L).

24.3.3 *Hydroxyquinoline Solution*—Dissolve 25 g of 8-hydroxyquinoline in 60 mL of acetic acid. When the solution is complete, dilute to 2 L with cold water. One millilitre of this solution is equivalent to 0.0016 g of MgO.

24.3.4 *Potassium Bromate-Potassium Bromide, Standard Solution* (0.2 *N*)—Dissolve 20 g of potassium bromide (KBr) and 5.57 g of potassium bromate ($KBrO_3$) in 200 mL of water and dilute to 1 L. Obtain the ratio of the strength of this solution to that of the 0.1 *N* $Na_2S_2O_3$ solution (22.2.6) as follows: To 200 mL of water in a 500-mL Erlenmeyer flask add 25.0 mL of the 0.2 *N* $KBrO_3$-KBr solution, measured from a pipet or buret. Add 20 mL of HCl, stir, and add immediately 10 mL of potassium iodide (KI) (250 g/L). Mix well and titrate at once with the $Na_2S_2O_3$ solution until nearly colorless. Add 2 mL of starch solution and titrate to the disappearance of the blue color. Calculate the ratio in strength of the $KBrO_3$-KBr solution to the $Na_2S_2O_3$ solution by dividing the volume of $Na_2S_2O_3$ solution by the volume of $KBrO_3$-KBr solution used in the titration.

24.3.5 *Potassium Iodide Solution* (250 g KI/L).

24.3.6 *Sodium Thiosulfate, Standard Solution* (0.1 *N*)—Dissolve 25 g of sodium thiosulfate ($Na_2S_2O_3 \cdot 5H_2O$) in 200 mL of water, add 0.1 g of sodium carbonate (Na_2CO_3), and dilute to 1 L. Let stand at least 1 week. Standardize this solution directly against primary standard potassium dichromate ($K_2Cr_2O_7$). One millilitre of 0.10 *N* $Na_2S_2O_3$ solution is equivalent to 0.000504 g of MgO.

24.3.7 *Starch Solution*— To 500 mL of boiling water add a cold suspension of 5 g of soluble starch in 25 mL of water, cool to room temperature, add a cool solution of 5 g of sodium hydroxide (NaOH) in 50 mL of water, add 15 g of KI, and mix thoroughly.

24.4 *Procedure*:

24.4.1 Disperse 0.5 g (Note 82) of the sample of cement in a 400-mL beaker with 10 mL of water, using a swirling motion. While still swirling, add 10 mL of HCl all at once. Dilute immediately to 100 mL. Heat gently and grind any coarse particles with the flattened end of a glass rod until decomposition is complete, add 2 or 3 drops of HNO_3 and heat to boiling (Note 83).

NOTE 82—If SiO_2, ammonium hydroxide group, and CaO are separated and determined in accordance with the appropriate sections for either the reference or alternative test methods, the remaining filtrate may be used for the determination of MgO as described in 24.4.1, starting with the third from the last sentence of 24.4.2, "Add 5 mL of HCl. . .".

NOTE 83—In the case of cements containing blast-furnace slag or a significant quantity of sulfide sulfur, add 12 drops of HNO_3 and boil for 20 min to oxidize iron and remove sulfide.

24.4.2 Add 3 drops of methyl red indicator to the solution and then add NH_4OH until the solution is distinctly yellow. Heat this solution to boiling and boil for 50 to 60 s. In the event difficulty from bumping is experienced while boiling the ammoniacal solution, a digestion period of 10 min on a steam bath, or a hot plate having the approximate temperature of a steam bath, may be substituted for the 50 to 60-s boiling period. Remove from the burner, steam bath, or hot plate and allow to stand until the precipitate has settled. Using medium-textured paper, filter the solution without delay, wash the precipitate twice with hot NH_4NO_3(20 g/L), and reserve the filtrate. Transfer the precipitate with the filter paper to the beaker and dissolve in 10 mL of HCl (1+1). Macerate the filter paper. Dilute to about 100 mL and heat to boiling. Reprecipitate, filter, and wash the hydroxides as above. Combine this filtrate and washings with those from the first precipitation taking care that the volume does not exceed 300 mL (Note 84). Add 5 mL of HCl, a few drops of methyl red indicator solution and 30 mL of warm ammonium oxalate solution (50 g/L). Heat the solution to 70 to 80 °C and add NH_4OH (1+1) dropwise, while stirring, until the color changes from red to yellow (see Note 38). Allow the solution to stand without further heating for 15 min on a steam bath.

NOTE 84—In the case of cements containing blast-furnace slag, or which are believed to contain a significant quantity of manganese, acidify with HCl, evaporate to about 100 mL, and remove the manganese, using the procedure described in 14.3.1.

24.4.3 Add 10 to 25 mL of the 8-hydroxyquinoline reagent (Note 85) and then 4 mL of NH_4OH/100 mL of solution. Stir the solution on a mechanical stirring machine for 15 min and set aside until the precipitate has settled (Note 86). Filter the solution using medium-textured paper and wash the precipitate with hot NH_4OH (1+40). Dissolve the precipitate in 50 to 75 mL of hot HCl (1+9) in a 500-mL Erlenmeyer flask. Dilute the resulting solution to 200 mL and add 15 mL of HCl. Cool the solution to 25 °C and add 10 to 35 mL of the 0.2 *N* $KBrO_3$-KBr solution (Note 87) from a pipet or buret. Stir the solution and allow to stand for about 30 s to ensure complete bromination. Add 10 mL of KI (250 g/L). Stir the resulting solution well and then titrate with the 0.1 *N* $Na_2S_2O_3$ solution until the color of the iodine becomes faintly yellow. At this point add 2 mL of the starch solution and titrate the solution to the disappearance of the blue color.

NOTE 85—An excess of the 8-hydroxyquinoline reagent is needed to avoid a low result for MgO, but too great an excess will yield high results. The following guide should be used to determine the amount of reagent added:

Approximate Content of MgO, %	Approximate Amount of Reagent Required, mL
0 to 1.5	10
1.5 to 3.0	15
3.0 to 4.5	20
4.5 to 6.0	25

NOTE 86—The precipitate should be filtered within an hour. Prolonged standing may cause high results.

NOTE 87—The amount of the standard $KBrO_3$–KBr solution used should be as follows:

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Approximate Content of MgO, %	Amounts of Standard $KBrO_3$–KBr Solution, mL
0 to 1	10
1 to 2	15
2 to 3	20
3 to 4	25
4 to 5	30
5 to 6	35

24.4.4 *Blank*—Make a blank determination, following the same procedure and using the same amounts of reagents, and correct the results obtained in the analysis accordingly.

24.5 *Calculation*— Calculate the percentage of MgO to the nearest 0.1 as follows: (Note 88)

$$\text{MgO, \%} = E(V_1R - V_2) \times 200 \quad (14)$$

where:

E = MgO equivalent of the $Na_2S_2O_3$ solution, g/mL,
V_1 = millilitres of $KBrO_3$–KBr solution used,
R = ratio in strength of the $KBrO_3$–KBr solution to the $Na_2S_2O_3$ solution,
V_2 = millilitres of $Na_2S_2O_3$ solution used, and
200 = 100 divided by the weight of sample used (0.5 g).

Report the result rounded in accordance with Table 3.

NOTE 88—V_1R represents the volume of $Na_2S_2O_3$ solution equivalent to the volume of $KBrO_3$–KBr solution used. V_2 represents the amount of $Na_2S_2O_3$ required by the excess $KBrO_3$–KBr which is not reduced by magnesium oxyquinolate.

25. Loss on Ignition

25.1 *Portland Blast-Furnace Slag Cement and Slag Cement (Alternative Test Method)*:

25.1.1 *Summary of Test Method*—This test method covers a correction for the gain in weight due to oxidation of sulfides usually present in such cement by determining the decrease in the sulfide sulfur content during ignition. It gives essentially the same result as the reference test method (17.2.1 through 17.2.3) which provides for applying a correction based on the increase in SO_3 content.

25.1.2 *Procedure*:

25.1.2.1 Weigh 1 g of cement in a tared platinum crucible, cover, and ignite in a muffle furnace at a temperature of 950 ± 50 °C for 15 min. Cool to room temperature in a desiccator and weigh. After weighing carefully transfer the ignited material to a 500-mL boiling flask. Break up any lumps in the ignited cement with the flattened end of a glass rod.

25.1.2.2 Determine the sulfide sulfur content of the ignited sample using the procedure described in 16.2.1 through 16.2.5. Using the same procedure, also determine the sulfide sulfur content of a portion of the cement that has not been ignited.

25.1.3 *Calculation*—Calculate the percentage loss of weight occurring during ignition (25.1.2.1) and add twice the difference between the percentages of sulfide sulfur in the original sample and ignited sample as determined in 25.1.2.2. Report this value as the loss on ignition, rounded in accordance with Table 3.

NOTE 89—If a gain of weight is obtained during the ignition, subtract the percentage of gain from the correction for sulfide oxidation.

26. Titanium Dioxide (*Alternative Test Method*)

26.1 *Summary of Test Method*—In this test method, titanium dioxide (TiO_2) is determined colorimetrically by comparing the color intensity of the peroxidized solution of the titanium in the sample with the color intensity of a peroxidized standard solution of titanic sulfate.

26.2 *Interferences*— Interfering elements in the peroxide method for TiO_2 are vanadium, molybdenum, and chromium. In very small quantities the interference of the last two is negligible. However, vanadium in very small quantities causes interference and, as some cements contain this element, the Na_2CO_3 fusion (26.5.4) and extraction with water are necessary.

26.3 *Apparatus*:

26.3.1 *Colorimeter*— The apparatus shall consist of a colorimeter of the Kennicott or Duboscq type, or other colorimeter or spectrophotometer designed to measure light transmittancy, and suitable for measurements at wavelengths between 400 and 450 nm.

26.4 *Reagents*:

26.4.1 *Ammonium Chloride* (NH_4Cl).

26.4.2 *Ammonium Nitrate* (20 g NH_4NO_3/L).

26.4.3 *Ferrous Sulfate Solution* (1 mL = 0.005 g Fe_2O_3)—Dissolve 17.4 g of ferrous sulfate ($FeSO_4 \cdot 7H_2O$) in water containing 50 mL of H_2SO_4 and dilute to 1 L. One millilitre is equivalent to 1 % of Fe_2O_3 in 0.5 g of sample.

26.4.4 *Hydrogen Peroxide* (30 %)—Concentrated hydrogen peroxide (H_2O_2).

26.4.5 *Sodium Carbonate* (20 g Na_2CO_3/L).

26.4.6 *Sodium or Potassium Pyrosulfate* ($Na_2S_2O_7$ or $K_2S_2O_7$).

26.4.7 *Titanic Sulfate, Standard Solution* (1 mL = 0.0002 g TiO_2)—Use standard TiO_2 furnished by NIST (Standard Sample 154 or its replacements). Dry for 2 h at 105 to 110 °C. Transfer a weighed amount, from 0.20 to 0.21 g of the TiO_2 to a 125-mL Phillips beaker. Add 5 g of ammonium sulfate ($(NH_4)_2SO_4$) and 10 mL of H_2SO_4 to the beaker and insert a short-stem glass funnel in the mouth of the beaker. Heat the mixture cautiously to incipient boiling while rotating the flask over a free flame. Continue the heating until complete solution has been effected and no unattacked material remains on the wall of the flask (Note 90). Cool and rapidly pour the solution into 200 mL of cold water while stirring vigorously. Rinse the flask and funnel with H_2SO_4(1+19), stir, and let the solution and washings stand for at least 24 h. Filter into a 1-L volumetric flask, wash the filter thoroughly with H_2SO_4 (1+19), dilute to the mark with H_2SO_4 (1+19), and mix.

NOTE 90—There may be a small residue, but it should not contain more than a trace of TiO_2 if the operations have been properly performed.

26.4.8 Calculate the TiO_2 equivalent of the titanic sulfate solution, g/mL, as follows:

$$E = AB/1000 \quad (15)$$

where:

E = TiO_2 equivalent of the $Ti(SO_4)_2$ solution, g/mL,
A = grams of standard TiO_2 used (corrected for loss on drying),

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B = percentage of TiO_2 in the standard TiO_2 as certified by the National Institute of Standards and Technology, divided by 100, and

1000 = Number of millilitres in the volumetric flask.

26.5 *Procedure*:

26.5.1 Mix thoroughly 0.5 g of the sample of cement and about 0.5 g of NH_4Cl in a 50-mL beaker, cover the beaker with a watch glass, and add cautiously 5 mL of HCl, allowing the acid to run down the lip of the covered beaker. After the chemical action has subsided, lift the cover, stir the mixture with a glass rod, replace the cover, and set the beaker on a steam bath for 30 min (Note 91). During this time of digestion, stir the contents occasionally and break up any remaining lumps to facilitate the complete decomposition of the cement. Fit a medium-textured filter paper to a funnel and transfer the precipitate to the filter. Scrub the beaker with a rubber policeman and rinse the beaker and policeman. Wash the filter two or three times with hot HCl (1+99) and then with ten or twelve small portions of hot water, allowing each portion to drain through completely.

NOTE 91—A hot plate may be used instead of a steam bath if the heat is so regulated as to approximate that of a steam bath.

26.5.2 Transfer the filter and residue to a platinum crucible (Note 92), dry, and ignite slowly until the carbon of the paper is completely consumed without inflaming. Treat the SiO_2 thus obtained with 0.5 to 1 mL of water, about 10 mL of HF, and 1 drop of H_2SO_4, and evaporate cautiously to dryness (Note 93).

NOTE 92—When it is desired to shorten the procedure for purposes other than referee analysis, usually with little sacrifice of accuracy, the procedure given in 26.5.2 may be omitted.

NOTE 93—When a determination of SiO_2 is desired in addition to one of TiO_2, the SiO_2 may be obtained and treated with HF as directed in 7.2.3.1 through 7.2.4.

26.5.3 Heat the filtrate to boiling and add NH_4OH until the solution becomes distinctly alkaline, as indicated by an ammoniacal odor. Add a small amount of filter paper pulp to the solution and boil for 50 to 60 s. Allow the precipitate to settle, filter through a medium-textured paper, and wash twice with hot NH_4NO_3 solution (20 g/L). Place the precipitate in the platinum crucible in which the SiO_2 has been treated with HF and ignite slowly until the carbon of the paper is consumed.

NOTE 94—When a determination of ammonium hydroxide group is desired in addition to one of TiO_2, the precipitation and ignition may be made as described in 8.2.1-8.2.4. However, the crucible must contain the residue from the treatment of the SiO_2 with HF unless circumstances permit its omission as indicated in Note 93.

26.5.4 Add 5 g of Na_2CO_3 to the crucible and fuse for 10 to 15 min (see 24.2.1). Cool, separate the melt from the crucible, and transfer to a small beaker. Wash the crucible with hot water, using a policeman. Digest the melt and washings until the melt is completely disintegrated, then filter through a 9-cm medium-textured filter paper and wash a few times with Na_2CO_3 (20 g/L). Discard the filtrate. Place the precipitate in the platinum crucible and ignite slowly until the carbon of the paper is consumed.

26.5.5 Add 3 g of $Na_2S_2O_7$ or $K_2S_2O_7$ to the crucible and heat below red heat until the residue is dissolved in the melt (Note 95). Cool and dissolve the fused mass in water containing 2.5 mL of H_2SO_4. If necessary, reduce the volume of the solution (Note 96), filter into a 100-mL volumetric flask through a 7-cm medium-textured filter paper, and wash with hot water. Add 5 mL of H_3PO_4, and cool the solution to room temperature. Add H_2O_2 (1.0 mL of 30 % strength or its equivalent) (Note 97), dilute to the mark with water, and mix thoroughly.

NOTE 95—Start the heating with caution because pyrosulfates (also known as fused bisulfates) as received often foam and spatter in the beginning due to an excess of H_2SO_4. Avoid an unnecessarily high temperature or unnecessarily prolonged heating, as fused pyrosulfates may attack platinum. A supply of nonspattering pyrosulfates may be prepared by heating some pyrosulfate in a platinum vessel to eliminate the excess H_2SO_4 and crushing the cool fused mass.

NOTE 96—If the solution is evaporated to too small a volume and allowed to cool, there may be a precipitate of sulfates difficult to redissolve. In case of over-evaporation, do not permit the contents to cool, but add hot water and digest on a steam bath or hot plate until the precipitate is redissolved, with the possible exception of a small amount of SiO_2.

NOTE 97—Hydrogen peroxide deteriorates on standing. Its strength may be determined by adding a measured volume of the solution to 200 mL of cold water and 10 mL of H_2SO_4 (1+1) and titrating with a standard solution of potassium permanganate ($KMnO_4$) prepared in accordance with 14.2.2. If the standard solution contains 0.0056357 g of $KMnO_4$/mL, 49.5 mL of it will be required by 0.50 mL of H_2O_2 (30 %).

26.5.6 Prepare from the standard $Ti(SO_4)_2$ solution a suitable reference standard solution or a series of reference standard solutions in 100-mL volumetric flasks, depending upon the type of colorimeter to be used. To each solution add 3 g of $Na_2S_2O_7$ or $K_2S_2O_7$ dissolved in water, an amount of $FeSO_4$ solution equivalent to the Fe_2O_3 content in 0.5 g of the cement under test, 2.5 mL of H_2SO_4, and 5 mL of H_3PO_4 (Note 98). When the solution is at room temperature, add H_2O_2(1.0 mL of 30 % strength or its equivalent), dilute to the mark with water, and mix thoroughly (Note 99).

NOTE 98—The color imparted to the solution by $Fe_2(SO_4)_2$ is partly offset by the bleaching effect of H_2SO_4, H_3PO_4, and alkali salts on ferric and peritanic ions. The directions should be followed closely for the highest degree of precision. However, when it is desired to shorten this procedure for purposes other than referee analysis, the addition of pyrosulfate, $FeSO_4$ solution and H_3PO_4 to the color comparison solutions may be omitted provided the Fe_2O_3 of the sample cement is less than 5 %. This usually leads to little sacrifice to accuracy.

NOTE 99—The color develops rapidly and is stable for a sufficient period of time, but if the peroxidized solution is allowed to stand a long time, bubbles of oxygen may appear and interfere with color comparison. When the contents of a tube are first mixed, there may be fine bubbles which should be allowed to clear up before the comparison is made. Comparison between the standard and unknown solution should be made not less than 30 min after addition of H_2O_2.

26.5.7 Compare the color, light transmittancy, or absorbance of the unknown solution with the reference standard solution. The technique of comparing colored solutions or measuring transmittancy or absorbance depends on the type of apparatus (see 26.5.8-26.5.10) and should be in accordance with standard practice appropriate to the particular type used or with instructions supplied by the manufacturer of the equipment. If the peroxidized solution of cement is compared with a single standard peroxidized solution, bear in mind that a single peroxidized solution cannot be used for the whole range in TiO

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2 content that may be encountered. The difference in volume or depth for the two liquids should not exceed 50 % of the smaller value. All solutions should contain the prescribed concentrations of H_2SO_4, H_3PO_4, $Fe_2(SO_4)_3$, and persulfate except under the circumstances indicated in Note 99.

26.5.8 *Colorimeter of the Kennicott Type*—By means of a plunger in a reservoir of standard peroxidized solution, adjust the amount of solution through which light passes until it gives the same color intensity as the peroxidized solution of the sample.

26.5.9 *Colorimeter of the Duboscq Type*—Lower or raise the plungers in the cups until the two solutions give the same color intensity when viewed vertically. The color matching may be done either visually or photoelectrically.

26.5.10 *Colorimeter Designed to Measure Light Transmittancy*—The measurement should be made between 400 to 450 nm and may be made either visually or photoelectrically. In most colorimeters of this type, the instrument is calibrated with standard solutions and a calibration curve showing the relation of light transmittancy or absorbance to TiO_2 content is prepared in advance of the analysis of the sample for TiO_2.

26.5.11 *Blank*—Make a blank determination, following the same procedure and using the same amounts of reagent, and correct the results obtained in the analysis accordingly.

26.6 *Calculation*—Calculate the percentage of TiO_2, rounded in accordance with Table 3. When a colorimeter designed to measure light transmittancy is used, read the percentage of TiO_2 from a calibration curve showing the relation of light intensity to TiO_2 content. When the peroxidized solution of the sample is compared with a single reference standard solution, calculate the percentage of TiO_2 as follows (Note 100):

26.6.1 *For Colorimeters of the Kennicott Type*:

$$TiO_2, \% = (100\ VE/S) \times (D/C) \quad (16)$$

26.6.2 *For Colorimeters of the Duboscq Type*:

$$TiO_2, \% = (100\ VE/S) \times (F/G) \quad (17)$$

where:

- V = millilitres of standard $Ti(SO_4)_2$ solution in the peroxidized standard solution,
- E = tiO_2 equivalent of the standard $Ti(SO_4)_2$ solution, g/mL,
- S = Grams of sample used,
- C = total volume of the peroxidized reference standard solution, mL,
- D = Volume of peroxidized reference standard solution that matches the peroxidized solution of the sample, mL,
- F = Depth of peroxidized reference standard solution through which light passes, anD
- G = Depth of peroxidized solution of the sample through which light passes.

NOTE 100—The difference between D and C or between F and G should not exceed 50 % of the smaller value.

27. Phosphorus Pentoxide (*Alternative Test Method*)

27.1 *Summary of Test Method*—In this test method, phosphorus is determined volumetrically by precipitation of the phosphorus as ammonium phosphomolybdate and titration with NaOH and H_2SO_4.

27.2 *Reagents*:

27.2.1 *Ammonium Molybdate Solution*—Prepare the solution in accordance with 10.3.1.

27.2.2 *Ammonium Nitrate* (NH_4NO_3).

27.2.3 *Potassium Nitrate Solution* (10 g/L)—Dissolve 10 g of potassium nitrate (KNO_3) in water freshly boiled to expel CO_2 and cooled, and dilute to 1 L.

27.2.4 *Sodium Hydroxide, Standard Solution* (0.3 *N*)—Dissolve 12 g of sodium hydroxide (NaOH) in 1 L of water that has been freshly boiled to expel CO_2, and cooled. Add 10 mL of a freshly filtered, saturated solution of barium hydroxide ($Ba(OH)_2$). Shake the solution frequently for several hours, and filter it. Protect it from contamination by CO_2 in the air. Standardize the solution against standard acid potassium phthalate (Standard Sample No. 84) or benzoic acid (Standard Sample No. 39) furnished by the National Institute of Standards and Technology, according to the directions furnished with the standard. Calculate the phosphorus pentoxide (P_2O_5) equivalent (Note 103) of the solution, g/mL, as follows:

$$E = N \times 0.003086 \quad (18)$$

where:

- E = P_2O_5 equivalent of the NaOH solution, g/mL,
- N = normality of the NaOH solution, and
- *0.003086* = P_2O_5 equivalent of 1 *N* NaOH solution, g/mL.

NOTE 101—The value of the solution is based on the assumption that the phosphorus in cement is precipitated as ammonium phosphomolybdate ($2(NH_4)_3PO_4 \cdot 12MoO_3$) and that the precipitate reacts with the NaOH solution thus:

$$2(NH_4)_3PO_4 \cdot 12MoO_3 + 46NaOH = 2(NH_4)_2HPO_4 + (NH_4)_2MoO_4 + 23Na_2MoO_4 + 22H_2O \quad (19)$$

The number of 0.003086 is obtained by dividing the molecular weight of P_2O_5 (141.96) by 46 (for 46 NaOH in the equation) and by 1000 (number of millilitres in 1 L).

As the actual composition of the precipitate is influenced by the conditions under which the precipitation is made, it is essential that all the details of the procedure are followed closely as prescribed.

27.2.5 *Sodium Nitrite* (50 g $NaNO_2$/L).

27.2.6 *Sulfuric Acid, Standard Solution* (0.15 *N*)—Dilute 4.0 mL of H_2SO_4 to 1 L with water that has been freshly boiled and cooled. Standardize against the standard NaOH solution. Determine the ratio in strength of the standard H_2SO_4 solution to the standard NaOH solution by dividing the volume of NaOH solution by the volume of H_2SO_4 solution used in the titration.

27.3 *Procedure*:

27.3.1 Weigh 1 to 3 g of the sample (Note 102) and 10 g of NH_4NO_3 into a 150-mL beaker. Mix the contents, add 10 mL of HNO_3, and stir quickly, using the flattened end of a glass rod to crush lumps of cement, until the cement is completely decomposed and the thick gel of silica (SiO_2) is broken up. Cover the beaker with a watch glass, place it on a water bath or a hot plate at approximately 100 °C for 15 to 20 min, and stir the contents occasionally during the heating. Add 20 mL of hot water to the beaker and stir the contents. If the cement contains an appreciable amount of manganese, as shown by the presence of a red or brown residue, add a few millilitres of

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$NaNO_2$(50 g/L) to dissolve this residue. Boil the contents of the beaker until all nitrous fumes are completely expelled. This procedure should not take more than 5 min, and water should be added to replace any lost by evaporation. Filter, using medium-textured paper, into a 400-mL beaker under suction and with a platinum cone to support the filter paper. Wash the residue of SiO_2 with hot water until the volume of filtrate and washings is about 150 mL.

NOTE 102—The amounts of sample and reagents used depend on the content of phosphorus in the cement. The minimum requirements are sufficient if the cement contains 0.5 % P_2O_5 or more. The maximum amounts are required if the content of P_2O_5 is 0.1 % or less.

27.3.2 Heat the solution to 69 to 71 °C, remove it from the heat source, and immediately add 50 to 100 mL of the ammonium molybdate solution. Stir the solution vigorously for 5 min, wash down the sides of the beaker with cool KNO_3 solution (10 g/L), cover the beaker with a watch glass, and allow to stand 2 h. Using suction, filter the precipitate (Note 103), decanting the solution with as little disturbance to the precipitate as possible. Stir the precipitate in the beaker with a stream of the cool KNO_3 solution, decant the liquid, then wash the precipitate onto the filter. Scrub the stirring rod and beaker with a policeman and wash the contents onto the filter. Wash and precipitate until it is acid-free (Note 104), allowing each portion of wash solution to be sucked completely through before adding the next.

NOTE 103—The filter may be a small medium-textured filter paper supported by a platinum cone, or a small Hirsch funnel may be used with filter paper cut to fit and a thin mat of paper pulp or acid-washed asbestos pulp. The filtration should be carried out with care to avoid any loss of the precipitate. The filter should fit well, and the suction should be started before filtration and maintained until the end of the washing.

NOTE 104—About ten washings are usually required. Test the tenth washing with one drop of neutral phenolphthalein indicator and half a drop of the standard NaOH solution. If a definite pink color lasts at least 5 min, the precipitate is considered to be acid-free; otherwise, continue the washing.

27.3.3 Transfer the filter and precipitate to the beaker in which the precipitation took place, using small damp pieces of paper to wipe out the funnel and to pick up portions of the precipitate that may remain on it. Add 20 mL of cool CO_2-free water to the beaker, and break up the filter by stirring rapidly with the policeman that was used to scrub the beaker. Add an excess of the 0.3 *N* NaOH solution, stir the contents until all trace of yellow has disappeared, wash down the policeman and sides of the beaker with 50 mL of cool, CO_2-free water, and add 2 drops of neutral phenolphthalein indicator solution. Treat the solution with a measured quantity of the 0.15 *N* H_2SO_4 solution, sufficient to destroy completely the pink color. Complete the titration with the NaOH solution until there is a definite faint pink color that lasts at least 5 min.

27.3.4 *Blank*—Make a blank determination, following the same procedure and using the same amounts of reagents, and correct the results obtained in the analysis accordingly.

27.4 *Calculation*—Calculate the percentage of P_2O_5 to the nearest 0.01 as follows:

$$P_2O_5, \% = [E(V_1 - V_2R)/S] \times 100 \quad (20)$$

where:

E = P_2O_5 equivalent of the NaOH solution, g/mL,
V_1 = millilitres of NaOH solution used,
V_2 = millilitres of H_2SO_4 solution used,
R = ratio in strength of the H_2SO_4 solution to the NaOH solution, and
S = grams of sample used.

Report the result rounded in accordance with Table 3.

28. Manganic Oxide (*Alternative Test Method*)

28.1 *Summary of Test Method*—In this test method manganic oxide is determined volumetrically by titration with potassium permanganate solution.

28.2 *Reagents*:

28.2.1 *Potassium Permanganate, Standard Solution* (0.18 *N*)—Prepare a solution of potassium permanganate ($KMnO_4$) and standardize as described in 14.2.2, except that the manganic oxide (Mn_2O_3) equivalent of the solution is calculated instead of the calcium oxide (CaO) equivalent. Calculate the Mn_2O_3 equivalent of the solution as follows:

$$E = (B \times 0.3534)/A \quad (21)$$

where:

E = Mn_2O_3 equivalent of the $KMnO_4$ solution, g/mL,
B = grams of $Na_2C_2O_4$ used,
A = millilitres of $KMnO_4$ solution required by the $Na_2C_2O_4$, and
0.3534 = mole ratio of 3 Mn_2O_3 to 10 $Na_2C_2O_4$.

28.2.2 *Zinc Oxide* (ZnO), powder.

28.3 *Procedure*:

28.3.1 Place 2 g of the sample in a 250-mL beaker and add about 50 mL of water to the cement. Stir the mixture until it is in suspension and then add about 15 mL of HCl. Heat the mixture gently until the solution is as complete as possible. Add 5 mL of HNO_3 and 50 mL of water to the solution and boil it until most of the chlorine has been expelled. If necessary, add hot water to maintain the solution at a volume of about 100 mL. Stop the boiling and add ZnO powder to the solution until the acid is neutralized. Add an excess of 3 to 5 g of ZnO powder to the solution and boil it for a few minutes.

28.3.2 Without filtering, and while keeping the solution hot (90 to 100 °C) by intermittent or continuous heating, titrate the solution with the 0.18 *N* $KMnO_4$ solution until a drop of it gives a permanent pink color (Note 105). When the end point is approached, add the standard solution dropwise. After each drop, stir the solution, allow the precipitate to settle a little, and observe the color of the stratum of the solution by looking through the side of the beaker.

NOTE 105—In the case of a cement in which the approximate content of Mn_2O_3 is unknown, a preliminary determination may be made with rapid titration, 0.5 to 1 mL of the standard solution being added at a time, and without an attempt to keep the solution close to the boiling point.

28.3.3 *Blank*—Make a blank determination, following the same procedure and using the same amounts of reagents, and correct the results obtained in the analysis accordingly.

28.4 *Calculation*— Calculate the percentage of Mn_2O_3 to the nearest 0.01 as follows:

$$Mn_2O_3, \% = EV \times 50 \quad (22)$$

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where:
E = Mn_2O_3 equivalent of the $KMnO_4$ solution, g/mL,
V = millilitres of $KMnO_4$ solution used, and
50 = 100 divided by the weight of sample used (2 g).

Report the result rounded in accordance with Table 3.

29. Free Calcium Oxide (*Alternative Test Methods*)

29.1 *Summary of Test Methods*—These are rapid test methods for the determination of free calcium oxide in fresh clinker. When applied to cement or aged clinker, the possibility of the presence of calcium hydroxide should be kept in mind since these methods do not distinguish before free CaO and free $Ca(OH)_2$. Two test methods are provided. Alternate Test Method A is a modified Franke procedure in which uncombined lime is titrated with dilute perchloric acid after solution in an ethylacetoacetate-isobutylalcohol solvent. Alternate Test Method B is an ammonium acetate titration of the alcohol–glycerin solution of uncombined lime with $Sr(NO_3)_2$ as an accelerator.

29.2 *Modified Franke Test Method (Alternative Test Method A)*:

29.2.1 *Apparatus*:

29.2.1.1 *Refluxing Assembly,* consisting of a flask with flat-bottom short neck Erlenmeyer flask with 250-mL capacity. The water-cooled refluxing condenser should have a minimum length of 300 mm. The flask and reflux condenser shall be connected with standard tapered ground glass joints. The reflux condenser shall be fitted with an absorption tube containing a desiccant, such as indicating silica gel, and a material for the removal of CO_2, such as Ascarite. The absorption tube shall be inserted with a rubber stopper in the upper end of the reflux column.

29.2.1.2 *Buret,* having a 10-mL capacity and graduated in units not more than 0.05 mL.

29.2.1.3 *Vacuum Filtration Assembly,* consisting of a Gooch crucible size No. 3, 25-mL capacity in which is placed a suitable filter paper, 21-mm size, a Walter crucible holder, a 500-mL vacuum flask, and vacuum source. The crucible is half filled with compressed filter pulp.

29.2.1.4 *Glass Boiling Beads*:

29.2.2 *Solutions Required*:

29.2.2.1 *Ethyl Acetoacetate–Isobutyl Alcohol Solvent*—3 parts of volume of ethyl acetoacetate and 20 parts by volume of isobutyl alcohol.

29.2.2.2 *Thymol Blue Indicator*—Dissolve 0.1 g of thymol blue indicator powder in 100 mL of isobutyl alcohol.

29.2.2.3 *Perchloric Acid, Standard Solution* (0.2 *N*)—Dilute 22 mL of 70 to 72 % perchloric acid to 1 L with isobutyl alcohol. Standardize this solution as follows: Ignite 0.1000 g of primary standard calcium carbonate in a platinum crucible at 900 to 1000 °C. Cool the crucible and contents in a desiccator and weigh to the nearest 0.0001 g to constant weight. Perform the weighings quickly to prevent absorption of water and CO_2. Immediately transfer the CaO without grinding to a clean, dry Erlenmeyer flask and reweigh the empty crucible to the nearest 0.0001 g to determine the amount of CaO added. Then follow procedure beginning with "Add 70 mL of the ethyl acetoacetate–isobutyl alcohol. . ." in 29.2.3.1. Calculate the CaO equivalents of the standard perchloric acid solution in grams per millilitre by dividing the weight of CaO used by the volume of perchloric acid required for the titration.

29.2.3 *Procedure*:

29.2.3.1 Weigh 1.0000 g of ground sample (Note 106) and transfer it into a clean, dry 250-mL Erlenmeyer flask. Add four to five glass boiling beads. Add 70 mL of prepared ethyl acetoacetate–isobutyl alcohol solvent. Agitate the flask to disperse the sample.

NOTE 106—Thorough grinding of the sample is essential for proper exposure of the free lime grains that often are occluded in crystals of tricalcium silicate in the cement. However, exposure of the sample to the air must be kept at a minimum to prevent carbonation of the free lime. In particular, direct breathing into the sample must be avoided. The sample should be sufficiently fine to easily pass a No. 200 (75-μm) sieve but actual sieving is not recommended. If the sample is not to be immediately tested, it must be kept in an airtight container to avoid unnecessary exposure to the atmosphere.

29.2.3.2 Attach the flask to a reflux condenser and bring the material to a boil. Reflux for 15 min.

29.2.3.3 Remove flask from condenser, stopper, and cool rapidly to room temperature.

29.2.3.4 Filter the sample and solution using the vacuum assembly. Wash the flask and residue with small increments (10 to 15 mL) of isobutyl alcohol until a total of 50 mL has been used for wash solution.

29.2.3.5 Add 12 drops of the thymol blue indicator to the filtrate and immediately titrate with 0.2 *N* perchloride acid to the first distinct color change.

29.2.4 *Calculation*— Calculate the percent free calcium oxide to the nearest 0.1 % as follows:

$$\text{free CaO, \%} = \frac{EV \times 100}{W} \tag{23}$$

where:
E = CaO equivalent of the perchloric acid, g/mL,
V = millilitres of perchloric acid solution required by sample, and
W = weight of the sample, g.

Report the result rounded in accordance with Table 3.

29.3 *Rapid $Sr(NO_3)_2$* Method (Alternative Test Method B):

29.3.1 *Reagents*:

29.3.1.1 *Ammonium Acetate, Standard Solution* (1 mL = 0.005 g CaO)—Prepare a standard solution of ammonium acetate ($NH_4C_2H_3O_2$) by dissolving 16 g of desiccated ammonium acetate in 1 L of ethanol in a dry, clean, stoppered bottle. Standardize this solution by the same procedure as described in 29.3.2.1, except use the following in place of the sample: ignite to constant weight approximately 0.1 g of calcium carbonate ($CaCO_3$) in a platinum crucible at 900 to 1000 °C, cool the contents in a desiccator, and weigh to the nearest 0.0001 g. Perform the weighings quickly to prevent absorption of water and CO_2. Immediately transfer the CaO without grinding to a 250-mL boiling flask (containing glycerin–ethanol solvent and $Sr(NO_3)_2$), and reweigh the empty crucible to determine the weight of CaO to the nearest 0.0001 g. Continue as described in 29.3.2.1 and 29.3.2.2. Calculate the CaO equivalent of the ammonium acetate in grams per millilitre by dividing the weight of CaO used by the volume of solution required.

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29.3.1.2 *Phenolphthalein Indicator*—Dissolve 1.0 g of phenolphthalein in 100 mL of ethanol (Formula 2B) (Note 107).

29.3.1.3 *Glycerin-Ethanol Solvent* (1+2)—Mix 1 volume of glycerin with 2 volumes of ethanol (Formula 2B). To each litre of this solution, add 2.0 mL of phenolphthalein indicator solution.

NOTE 107—Ethanol denatured in accordance with Formula 2B (99.5 % ethanol and 0.5 % benzol) is preferred but may be replaced by isopropyl alcohol, A.R.

29.3.1.4 *Strontium Nitrate* ($Sr(NO_3)_2$), reagent grade.

29.3.2 *Procedure*:

29.3.2.1 Transfer 60 mL of the glycerin–ethanol solvent into a clean, dry, 250-mL standard-taper flat-bottom boiling flask. Add 2 g of anhydrous strontium nitrate ($Sr(NO_3)_2$), and adjust the solvent to slightly alkaline with a dropwise addition of a freshly prepared dilute solution of NaOH in ethanol until a faint pink color is formed. Weigh 1.000 g of the finely ground sample (Note 107) into the flask, add encapsulated stirring bar, and immediately attach a water-cooled condenser (with a standard 24/40 glass joint). Boil the solution in the flask on a magnetic stirrer hot plate for 20 min with mild stirring.

29.3.2.2 Remove the condenser and filter the contents of the flask on a small polypropylene Büchner funnel under vacuum, using a 250-mL filtering flask with side tube. Bring the filtrate to a boil and immediately titrate with standard ammonium acetate solution to a colorless end point.

29.3.3 *Calculation*— Calculate the percent free CaO to the nearest 0.1 % as follows:

$$\text{free CaO, \%} = EV \times 100 \quad (24)$$

where:

E = CaO equivalent of the ammonium acetate solution, g/mL, and

V = millilitres of ammonium acetate solution required by the sample.

Report the result rounded in accordance with Table 3.

30. Keywords

30.1 chemical analysis; compositional analysis; hydraulic cements

APPENDIXES

(Nonmandatory Information)

X1. EXAMPLE OF DETERMINATION OF EQUIVALENCE POINT FOR THE CHLORIDE DETERMINATION

(Column 1) $AgNO_3$, mL	(Column 2) Potential, mV	(Column 3) Δ mV[A]	(Column 4) Δ^2 mV[B]
1.60	125.3		
		5.8	
1.80	119.5		1.4
		7.2	
2.00	112.3		1.3
		8.5	
2.20	103.8		1.3
		9.8	
2.40	94.0		0.6
		9.2	
2.60	84.8		2.3
		6.9	
2.80	77.9		0.8
		6.1	
3.00	71.8		1.3
		4.8	
3.20	67.0		

The equivalence point is in the maximum Δ mV interval (Column 3) and thus between 2.20 and 2.40 mL. The exact equivalence point in this 0.20 increment is calculated from the Δ^2 mV (Column 4) data as follows:

$$E = 2.20 + \left(1.3/(1.3 + 0.6)\right) \times 0.20 = 2.337 \text{ mL. Round to } 2.34.$$

[A] Differences between successive readings in Column 2.

[B] Differences between successive Δ readings in Column 3 "second differentials".

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X2. CO_2 DETERMINATIONS IN HYDRAULIC CEMENTS

X2.1 Scope

X2.1.1 This appendix contains information about methods for determination of carbon dioxide (CO_2) in hydraulic cement. The methods listed received a favorable evaluation by Task Group C01.23.04.

X2.1.2 Section X2.2 lists the analytical methods that received a favorable evaluation, briefly describes each method, suggests analytical techniques or cautions that may be useful, and indicates limitations to some of the methods.

X2.1.3 The methods listed as X2.2.1, X2.2.4, X2.2.5, and X2.2.6 determine total carbon calculated as CO_2. For that reason, they are not appropriate for determination of carbon dioxide in fly ash, limestones containing carbon in the form of graphite or kerogen, in other carbon bearing materials, or in blended cements produced from these materials.

X2.1.4 The methods listed in X2.2.2 and X2.2.3 can determine actual CO_2 directly rather than by calculation from total carbon. They are suggested for analysis of blended cements and blended cement ingredients which are likely to contain non-carbonate carbon.

X2.1.5 The split loss on ignition method in X2.2.1 can give misleading results when used with materials containing $Ca(OH)_2$ (calcium hydroxide). This can occur with aged cement, cement made from aged clinker, or high free lime clinker, in addition to cements with a lime or hydrated lime ingredient.

X2.2 Analytical Methods

X2.2.1 *Split Loss on Ignition*—This procedure is comparable to the analytical method described in Test Methods C114, Section 17.1.1, with the following modifications:

1. A crucible of known mass and containing a sample of known mass is initially heated at 550 °C for 2 h.
2. After being cooled to room temperature in a desiccator, and its mass determined, the crucible with sample is then heated at 950 °C for 2 h.
3. Finally, the crucible with sample is cooled and its mass is determined as per Step No. 2.
4. The difference in residue masses after the respective heat treatments is assumed to be carbon dioxide.

TGA results indicated that $Ca(OH)_2$ can lose a significant portion of its mass above 500 °C. Thus, the Split Loss on Ignition procedure should not be used when situations described in X2.1.5 exist.

X2.2.2 *Thermogravimetric Analysis (TGA)*—This method involves the determination of sample mass loss at various temperatures. The heating of a sample through a temperature range allows for mass loss differentiation based on mineral form (for example, $CaCO_3$, $MgCO_3$, $Ca(OH)_2$, etc.). Specific operational information is provided by the equipment manufacturers. If free carbon is present, an inert atmosphere (for example, nitrogen) should be used for sample analysis.

X2.2.3 *Test Methods C25, Section 22*—"Standard Test Methods for Chemical Analysis of Limestone, Quicklime, and Hydrated Lime." This method involves decomposition of the sample with HCl. The liberated CO_2 is then passed through a series of scrubbers to remove water and sulfides. The CO_2 is absorbed with special Sodium Hydroxide Absorbent (Ascarite). The gain in mass of the absorption tube is determined and calculated as percent CO_2. Calcium carbonate, for instance, can be calculated by multiplying the determined CO_2 content by a conversion factor (for example, $CO_2 \times 2.2742 = CaCO_3$).

X2.2.4 *X-ray Fluorescence Spectroscopy*—In this method the sample is ground to a fine particle size, pressed into a flat pellet and irradiated with the chosen instrument. Carbon content is determined by comparing the collected carbon emissions to calibration standards.

X2.2.5 *Combustion by Induction Furnace/IR*—This method involves volatilization by induction furnace and detection by infrared absorption. Suitable calibration standards (for example, calcium carbonate and synthetic carbon) are available from some instrument manufacturers. NIST cement SRMs with known additions of NIST argillaceous limestone (or other suitable standards) should also be considered to check instrument calibration.

X2.2.6 *"Test Methods E350*—This method, Total Carbon by the Combustion Gravimetric Method from Test Methods for Chemical Analysis of Carbon Steel, Low-Alloy Steel, Silicon Electrical Steel, Ingot Iron, and Wrought Iron," is suitable for the determination of carbon in concentrations from 0.05 to 1.80 % (as carbon dioxide 0.18 to 6.60 %). The test method involves burning the sample in a stream of oxygen; the carbon dioxide in the evolved gases is then collected in a suitable absorbent and its mass determined. Time of analysis is less than 10 min.

X2.3 Cooperative Test Results

X2.3.1 Tables X2.1 and X2.2 list results from two series of cooperative tests using several of the analytical methods evaluated by the Task Group. In all, five of the six methods receiving favorable ratings were included. The sixth method, Test Methods C25, was specifically not tested in these cooperative series, but was rated favorably because of long history of use with related materials.

X2.3.2 Table X2.1 includes results of single determinations using three of the different analytical methods. The methods used were Split Loss on Ignition, Test Methods E350, and Combustion by Induction Furnace with Infra-Red Detection.

X2.3.3 Table X2.2 includes results based on average of three determinations. Results from four of the different analytical methods are included. Methods used were Split Loss on Ignition, X-Ray Fluorescence Analysis, Induction furnace with Infra-Red Detection, and Thermo-Gravimetric Analysis. Test Methods E350 was not used in this series of tests.

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TABLE X2.1 Cooperative Test Series No. 1

	Single Determinations			
	Carbon Dioxide Unknown[A]	Determinations Base Cement[B]	Added CO_2, c% Determined[C]	Added CO_2, % Known[D]
Split LOI	2.40	0.45	1.97	2.00
	2.52	0.56	1.99	
	2.41	0.36	2.07	
	2.39	0.32	2.09	
	2.41	0.36	2.07	
	2.28	0.27	2.02	
Test Methods E350	2.00	0.02	1.98	
	2.00	0.02	1.98	
Induction Furnace/IR	2.46	0.40	2.07	
	2.53	0.48	2.08	
	2.38	0.40	2.00	
	2.42	0.48	1.97	
Average Standard Deviation			2.02	
			0.05	

[A] The Unknown was prepared by blending/grinding a mixture of 5.00 % NIST SRM 1C Argillaceous Limestone and 95.00 % CCRL Portland Cement Reference Sample No. 85. According to the Certificate of Analysis, the SRM 1C had a loss on ignition of 39.9 %. For the purpose of the cooperative test series, the loss on ignition was assumed to be CO_2 only.

[B] The Base Cement was CCRL Portland Cement Reference Sample No. 85.

[C] The Determined % Added CO_2 was obtained by subtracting the Base Cement % CO_2 from the Unknown % CO_2.

[D] The addition of 5.00 % NIST SRM 1C (with a loss on ignition value of 39.9 %) would provide 2.00 % Added CO_2. (Again, it was assumed that the SRM 1C loss on ignition was only carbon dioxide.)

TABLE X2.2 Cooperative Test Series No. 2

	Averages from Three Determinations			
	Carbon Dioxide Unknown[A]	Determinations Base Cement[B]	Added CO_2, % Determined[C]	Added CO_2 % Known[D]
Split LOI	2.00	0.41	1.59	1.60
	1.65	0.32	1.33	
	2.02	0.46	1.56	
	1.91	0.35	1.56	
	2.10	0.43	1.67	
	1.91	0.41	1.50	
	1.98	0.46	1.52	
XRFA	1.68[E]	0.00[E]	1.68[E]	
Induction Furnace/IR	2.23	0.28	1.95	
	1.96	0.28	1.68	
	1.95	0.40	1.55	
TGA	1.77	0.20	1.57	
	1.87	0.25	1.62	
Average Standard Deviation			1.60	
			0.14	

[A] The Unknown was prepared by blending/grinding a mixture of 4.00 % NIST SRM 1C Argillaceous Limestone and 96.00 % CCRL Portland Cement Reference Sample No. 85. According to the Certificate of Analysis, the SRM 1C had a loss on ignition of 39.9 %. For the purpose of the cooperative test series, the loss on ignition was assumed to be CO_2 only.

[B] The Base Cement was CCRL Portland Cement Reference Sample No. 85.

[C] The Determined % Added CO_2 was obtained by subtracting the Base Cement % CO_2 from the Unknown % CO_2.

[D] The addition of 4.00 % NIST SRM 1C (with a loss on ignition value of 39.9 %) would provide 1.60 % Added CO_2. (Again, it was assumed that the SRM 1C loss on ignition was only carbon dioxide.)

[E] The XRF instrument was calibrated using standards composed of the Base Cement (that is, CCRL No. 85) and NIST SRM 1C. It was assumed that the Base Cement contained 0 % CO_2.

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For additional useful information on details of cement test methods, reference may be made to the "Manual of Cement Testing," which appears in Vol 04.01 of the *Annual Book of ASTM Standards.*

SUMMARY OF CHANGES

Committee C01 has identified the location of selected changes to these test methods since the last issue, C114 – 09a, that may impact the use of these test methods. (Approved December 15, 2009)

(*1*) Reordered sections in the standard and renumbered subsequent sections throughout.

Committee C01 has identified the location of selected changes to these test methods since the last issue, C114 – 09, that may impact the use of these test methods. (Approved December 1, 2009)

(*1*) Revised 4.2.1, 4.4.4, and Table 2.

(*2*) Deleted Note 5 and renumbered subsequent notes.

Committee C01 has identified the location of selected changes to these test methods since the last issue, C114 – 07, that may impact the use of these test methods. (Approved February 1, 2009)

(*1*) Revised Section 3.

(*2*) Added new Note 1 and renumbered subsequent notes.

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Designation: C 115 – 96a (Reapproved 2003)

Standard Test Method for Fineness of Portland Cement by the Turbidimeter[1]

This standard is issued under the fixed designation C 115; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope

1.1 This test method covers determination of the fineness of portland cement as represented by a calculated measure of specific surface, expressed as square centimetres of total surface area per gram, or square metres of total surface area per kilogram, of cement, using the Wagner turbidimeter.[2]

1.2 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

1.3 The values stated in SI units are to regarded as the standard. The inch-pound equivalents may be approximate.

2. Referenced Documents

2.1 *ASTM Standards:*

C 114 Test Methods for Chemical Analysis of Hydraulic Cement[3]

C 430 Test Method for Fineness of Hydraulic Cement by the 45-μm (No. 325) Sieve[3]

C 670 Practice for Preparing Precision and Bias Statements for Test Methods for Construction Materials[4]

3. Significance and Use

3.1 The purpose of this test method is to determine whether or not the hydraulic cement under test meets the Wagner turbidimetric fineness requirements of the applicable hydraulic cement specification for which the test is being made. Fineness of the cement component is only one of the many characteristics that influence the strength capabilities of concrete.

4. Apparatus

4.1 *Nature of Apparatus*—The Wagner turbidimeter consists essentially of a source of light maintained at constant intensity and adjusted so that approximately parallel rays of light pass through a suspension of the cement to be tested and impinge upon the sensitive plate of a photoelectric cell. The current generated in the cell is measured by means of a microammeter and the indicated reading is a measure of the turbidity of the suspension. General considerations indicate that turbidity is in turn a measure of the surface area of the suspended sample of cement. The apparatus shall consist specifically of the parts described in 4.2-4.7 and shall be constructed in accordance with the detailed design and dimensional requirements shown in Fig. 1 and Table 1, except that the case may be either of wood or of metal.

4.2 *Turbidimeter*, mounted in a suitable wood or metal case including the following features:

4.2.1 *Source of Light*—The source of light (Fig. 1) shall consist of a concentrated-filament electric lamp of between 3 and 6 cd operated by a source of constant emf. The lamp shall be mounted rigidly in the socket. A clean, bright parabolic metallic reflector shall be rigidly mounted behind the lamp, focused so that approximately parallel rays of light will pass through the sedimentation tank and impinge upon the photoelectric cell. The light intensity shall be regulated by two rheostats of approximately 6 and 30 Ω, respectively, and they shall possess such characteristics that uniform changes in light intensity may be obtained over the full range of resistance. The rheostats shall be mounted in parallel with each other and in series with the lamp.

4.2.2 *Heat-Absorbing Device*—The light shall pass through a suitable heat absorbing device before entering the sedimentation tank in order that radiant heat from the beam shall be absorbed, the device being either (*1*) a water cell or (*2*) a special heat-absorbing glass filter. The water cell shall be made from 76-mm (3-in.) outside diameter seamless brass tubing, 3-mm (⅛-in.) thick wall, 102-mm (4 in.) in length with glass windows sealed in the ends. The cell shall contain a hole for filling with distilled water. The hole shall be sealed with a metal plug. The cell, when mounted on the movable shelf, may have the plug in either the top or bottom position. The heat-absorbing device shall be so arranged that essentially all

[1] This test method is under the jurisdiction of ASTM Committee C01 on Cement and is the direct responsibility of Subcommittee C01.25 on Fineness.

Current edition approved July 10, 2003. Published September 2003. Originally approved in 1934. Last previous edition approved in 1996 as C 115 – 96a.

[2] This turbidimeter was developed by L. A. Wagner, Research Associate of the Cement Reference Laboratory, National Institute of Standards and Technology, Washington, DC. A description of the apparatus and the original mathematical derivations of formulas used are given in the paper: Wagner, L. A., "A Rapid Method for the Determination of the Specific Surface of Portland Cement," *Proceedings*, ASTM, ASTEA, Vol 33, Part II, 1933, p. 553.

[3] *Annual Book of ASTM Standards*, Vol 04.01.

[4] *Annual Book of ASTM Standards*, Vol 04.02.

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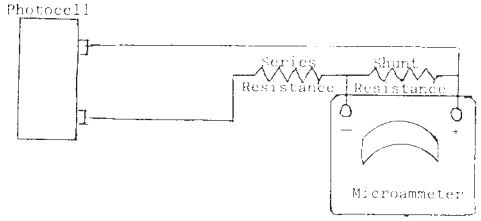

Microammeter Internal Resistance = 90 Ω
Shunt Equivalent Resistance:

$$470\ \Omega \text{ in parallel with } 100\ \Omega = \frac{470 \times 100}{470 + 100} = 82\ \Omega$$

Meter & Shunt Equivalent + Resistance:

$$90\ \Omega \text{ in parallel with } 82\ \Omega = \frac{90 \times 82}{90 + 82} = 43\ \Omega$$

Series Resistance = 90 − 43 = 47 Ω

FIG. 1 Illustrated Example of D'Arsonval Meter Circuit for I_r Determination

rays of light entering the sedimentation tank shall first pass through the heat-absorbing device.

4.2.3 *Retarding Filter*—A light-retarding glass or other device shall be provided that will reduce the intensity of light from that corresponding to 100 µA to a reading of 20 to 30 µA. The light intensity shall be uniformly retarded over the entire area of that portion of the cell which is exposed to light during a test. The retarding filter shall be mounted in a carrier on the shield and shall be capable of being swung out of the light path by means of a handle.

4.2.4 *Sedimentation Tank*—The sedimentation tank shall be either (*1*) constructed of 5 to 6-mm (3⁄16 to 1⁄4-in.) plate glass or borosilicate glass cemented or sealed together to form a rectangular tank, or (*2*) a molded glass tank having walls approximately 5-mm (3⁄16 in.) thick with plane surfaces. The inside dimensions of the rectangular tank shall be 51 mm by 38 mm by 203 mm (2 in. by 1½ in. by 8 in.) in height. The permissible variation on the inside dimensions of the tank shall be ±2.5 mm (0.1 in.) in length and ±0.76 mm (0.03 in.) in width. The 51-mm faces of the tank shall be equidistant within 0.25 mm (0.1 in.) at all points. A mark shall be placed on the side of the tank to indicate a volumetric content of 335 mL, which is the level to which the tank will be filled in a test. A tank filled to the mark with clear kerosine and placed in the turbidimeter light beam shall yield uniform microammeter readings, within ±0.1 µA, for the entire usable portion of the tank.

4.2.5 *Photoelectric Cell*—The means of measuring the light intensity shall be a sensitive photoelectric cell[5] connected directly to a microammeter. A hood with a horizontal slot 13 mm (½ in.) in height by 35 mm (1 3⁄8 in.) in width shall be mounted over the photoelectric cell. The front of the hood shall be 25 ± 1 mm (1 ± 1⁄16 in.) in front of the face of the cell. The face of the photocell shall be parallel to the tank faces within 0.5 mm (0.02 in.).

4.2.6 *Shield*—A metallic shield having a slot 16 mm (5⁄8 in.) in height by 38 mm (1½ in.) in width, as indicated in Fig. 1, shall be placed between the heat absorbing device and the sedimentation tank.

4.2.7 *Elevating Device*—The source of the light, the heat-absorbing device, the photoelectric cell, the retarding filter, and the shield shall be mounted on a movable shelf which may be raised or lowered by two connected lead screws, and which may be readily and accurately adjusted so that the turbidity of the suspension may be determined at any desired depth. The center of the light source, the heat absorbing device, the photocell, the center of the slots of the metal shield, and the hood shall be on a straight line which is parallel to the shelf. The sedimentation tank shall be mounted on a base which is independent of the rest of the apparatus so that the tank shall be free from vibration caused by moving the shelf. Care shall be taken that the shelf shall be level at all points of elevation and that the tank shall be normal to the shelf. The distance between the tank and the edges of the opening in the shelf shall vary not more than 1⁄64 in. (0.4 mm) between the "30–50" and "0" positions. The level of the light beam with reference to the surface of the suspension shall be indicated by a pointer which will travel along a scale mounted on the cabinet. The zero of the scale shall indicate that position at which the center lines of the slots for the light beam are at the same elevation as the surface of the liquid in the tank when filled to the 335-mL level. The lines on the scale to be marked 7.5, 10, 15, 20, 25, and 30–50, shall be located at distances from the zero mark equal to suspension depth values, *h*, in Table 2. The scale, when compared with a standard scale accurate to within 0.1 mm at all points, shall not show a deviation at any point greater than 0.25 mm and shall indicate the positions at which the pointer should be located when turbidity readings for these values of *h* are taken. The interior of the turbidimeter cabinet and the exterior surfaces of the shelf, the parabolic reflector, the heat absorbing device, the shield, and the photoelectric cell hood shall be painted with a dull flat black paint.

NOTE 1—The requirement of the 0 to 50 markings on the scale shall apply only to new Wagner Turbidimeters and not to equipment in use which meets the other requirements of this method.

4.3 *Microammeters*:

4.3.1 *D'Arsonval-Type Microammeters* shall have a range from 0 to 50 µA and shall be readable to 0.1 µA. New microammeters shall be accurate to ±0.5 % of full scale value at any part of the scale value at any part of the scale at 77°F (25°C). For microammeters, in use, the accuracy shall be the same as for new instruments except that the accuracy at 40 and 50 µA shall be ±1 % of full scale. The internal resistance of the microammeter shall be between 50 and 150 Ω . The microammeter shall not be mounted upon a working surface containing or consisting of iron or steel, or near other magnetic influence.

4.3.2 *Digital Microammeter*:

NOTE 2—A meter with a range of 199.9 µA is satisfactory for use and enables the operator to read the theoretical I_0 directly without supplementary devices. The high internal resistance of the digital microammeter does not affect the linearity of readings at the light intensity levels encountered in a Wagner turbidimetric determination of fineness.

4.4 *Source of Current*—A 6-V automobile starting and lighting storage battery or a source of constant emf shall be used for supplying current to the lamp.

4.5 *Sieve*—The sieve shall conform to the requirements of Test Method C 430.

[5] Weston Photronic type, Model 594YY is acceptable.

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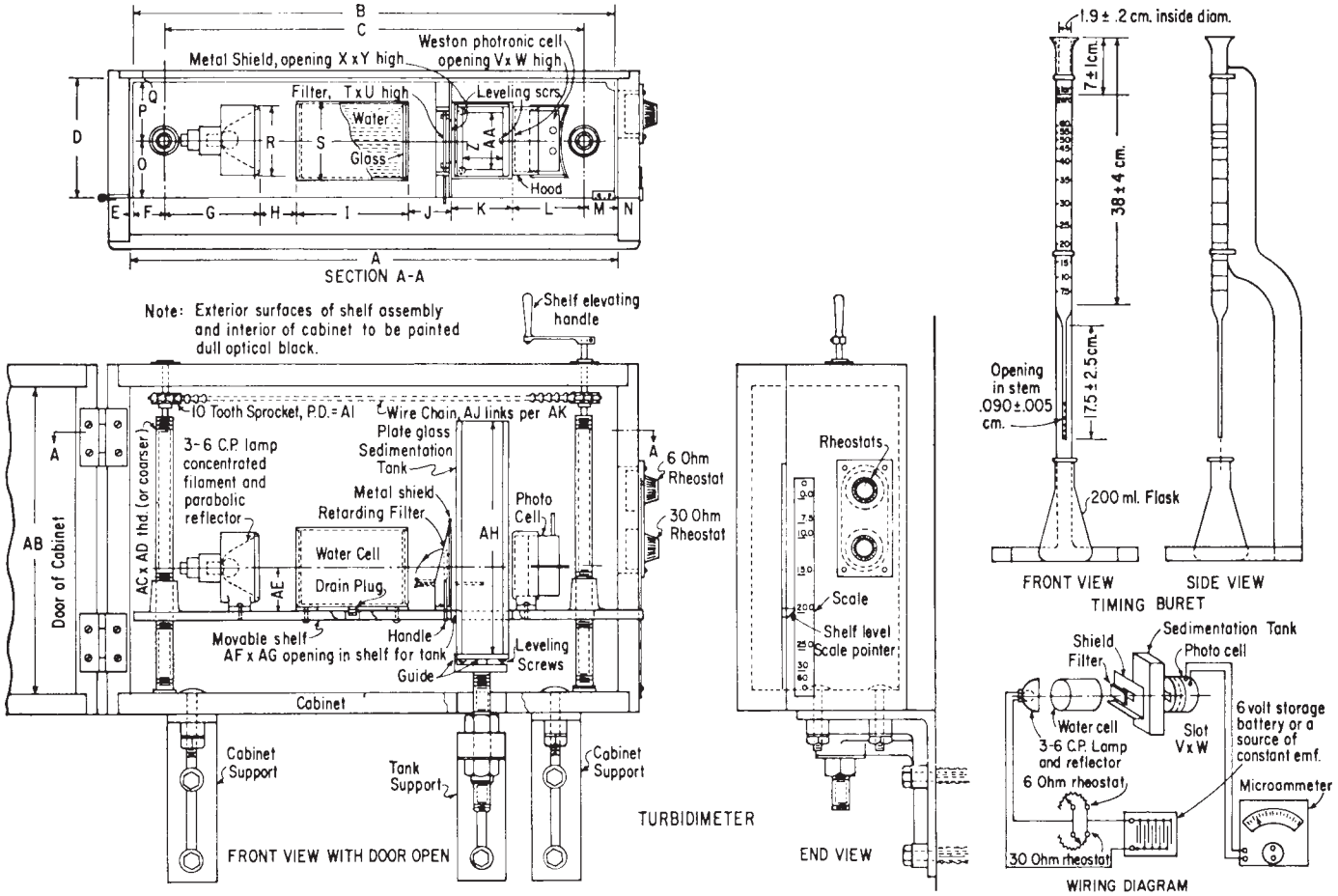

FIG. 2 Dimensional Details of Turbidimeter Fineness Test Apparatus (see Table 1)

TABLE 1 Turbidimeter Apparatus Dimensions (see Fig. 1)

Letter	mm	in.	Letter	mm	in.
A	445	17½	T	51	2
B	438	17¼	U	22.2	⅞
C	381	15	V	34.9	1⅜
D	105	4⅛	W	13	½
E	3.0	⅛	X	38	1½
F	28.6	1⅛	Y	15.9	⅝
G	85.7	3⅜	Z	38 ± 0.76	1½ ± 0.03
H	33.3	1⁵⁄₁₆	AA	51 ± 2.5	2 ± 0.10
I	102	4	AB	267	10½
J	39.7	1⁹⁄₁₆	AC	...	⅝ [A]
K	55.6	2³⁄₁₆	AD	...	11[A]
L	65.1	2⁹⁄₁₆	AE	39.7	1⁹⁄₁₆
M	28.6	1⅛	AF	55.6	2³⁄₁₆
N	3.0	⅛	AG	66.7	2⅝
O	51	2	AH	203	8
P	51	2	AI	23.6	0.93
Q	3.0	⅛	AJ	1.38[A]	3½ [A]
R	61.1	2¹³⁄₃₂	AK	cm[A]	in.[A]
S	69.8	2¾			

[A] These are pure numbers such as parts of a thread designation and numbers of links per unit; consequently, they do not correspond with the column titles.

4.6 *Stirring Apparatus*—The stirring apparatus shall consist of either (*1*) a cylindrical brush, 19 mm (¾ in.) in diameter and about 45 mm (1¾ in.) in length, with an end approximately fitting the contour of the bottom of a 22-mm (⅞-in.) diameter test tube, or (*2*) any other stirring device that will be equally efficient in dispersion as measured by specific surface determinations on a standard sample. The stirring apparatus shall rotate at a speed of approximately 3500 r/min.

4.7 *Timing Buret*—The time of settling for the different-sized particles shall be obtained by use of a buret from which kerosine is allowed to flow. The buret shall consist of a glass tube having a capillary tube fused into the lower end. The

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TABLE 2 Values of *h*, *d*, and h/d^2 to be Used in Calibration of the Turbidimeter Apparatus

Particle Diameter, *d*, μm	Depth of Suspension, *h*, cm	h/d^2
50	15	0.00600
45	15	0.00741
40	15	0.00938
35	15	0.01224
30	15	0.01667
25	13.1	0.0210
20	10	0.0250
15	6.6	0.0293
10	3.3	0.0330
7.5	2.1	0.0373

upper end of the large tube shall be flared to serve as a funnel for introducing kerosine into the tube. The buret shall conform to the limiting dimensions given in Table 3. The graduation lines on the buret shall be complete circles. A filter made of No. 325 (45-μm) wire cloth shall be used with the timing buret and a cover shall be placed over the top of the buret when it is not in use.

4.8 *Weights and Weighing Devices*, shall conform to the requirements of Methods C 114.

5. Materials

5.1 *Suspending Liquid*—Clear white kerosine shall be used with the turbidimeter apparatus. The kerosine shall not be reused.

6. Test Specimen or Sample

6.1 *Size of Test Sample*—Select the size of the sample of cement for test so that the initial microammeter reading is between 12 and 20 μA.

NOTE 3—The following approximations will be helpful in many instances in selecting the size of sample: 0.25 g for normal fineness cements and 0.20 g for high fineness cements.

7. Calibration

7.1 *Calibration of Turbidimeter*—Calibrate the turbidimeter apparatus in accordance with the following procedure:

7.1.1 *Calibration of Buret Scale*:

7.1.1.1 For calibration of the buret scale use a kerosine having a known viscosity and density for the temperature at which the calibration is to be made. Density and viscosity of the kerosine should be determined. Calculate the times of flow from the buret that correspond to the times of settling for the different sized particles, from the following equation:

TABLE 3 Buret Dimensions[A]

	Dimension, cm	Permissible Variation, cm
Length of large tube	38	±4
Inside diameter of large tube	1.9	±0.2
Length of capillary	17.5	±2.5
Diameter of capillary	0.09	±0.005
Top of buret to zero line	7	±1

[A] Since glass tubing of desired dimensions is not always obtainable, the wide permissible variations listed above allow selection of dimensions to produce a buret having a duration of flow which will permit calibration as described in 7.1.1.

$$t = [1{,}837{,}000\eta/(\rho_1 - \rho_2)] \times (h/d^2) \quad (1)$$

where:

- t = time of settling, or time of flow, s,
- η = viscosity of kerosine at the temperature of calibration, P,
- ρ_1 = density of cement particles, Mg/m^3 (g/cm^3) = 3.15 for portland cement (Note 4),
- ρ_2 = density of kerosine, Mg/m^3 at the temperature of calibration,
- h = depth of suspension to level of light, cm, and
- d = diameter of particle, μm.

Values of h/d^2 are given in Table 2.

7.1.1.2 Fill the buret with kerosine at the calibrating temperature, start a timing clock at the instant the kerosine in the buret drains past the zero line, and mark on the buret the levels reached by the draining kerosine for each of the time intervals, *t*, calculated as described above. At these marks, etch permanent lines and numbers on the buret indicating the corresponding diameters (Note 5). The construction and the graduation of the buret shall be such that at the temperature of calibration the time required for the kerosine to pass the permanent lines of the buret agrees with the calculated time of settling within 1 percent, except that the permissible variation shall be not less than 1 s.

NOTE 4—The density of portland cement does not vary greatly and in this work it is considered constant at 3.15. A variation of 0.15 from this value when substituted in Stokes' law gives a variation of 2.5 % in the diameter of the particle measured.

NOTE 5—By using the calibrated buret the apparatus may be used within the normal range of room temperatures without further correction, the change in rate of flow of the kerosine from the buret automatically compensating for change in viscosity of the suspension due to temperature. The temperature of the kerosine in the buret and that of the suspension should be kept the same within 0.5°C (1°F). This condition will ordinarily exist if the supply of kerosine is kept in the same room as the apparatus.

Care must be taken to ascertain that only clean kerosine is used in the buret, and, in addition, the capillary should be examined frequently to make sure that no small pieces of lint or other foreign material have become lodged in it.

7.1.2 *Calibration of No. 325 (45-μm) Sieve*—Calibration shall be made in accordance with Method C 430, basing the percentage sieve correction on the difference between the test residue obtained and the assigned residue value indicated by the electroformed sheet sieve fineness specified for the standard sample, expressed as a percentage of the test residue.

7.1.3 *Determination of the Proper Light Intensity, I_r*:

7.1.3.1 Fill the sedimentation tank to the mark with clear kerosine.

7.1.3.2 For a turbidimeter equipped with a digital-type microammeter with a range of 199.9 μA, place the sedimentation tank containing clear kerosine against the guides of the tank support in the turbidimeter. Set the light intensity so that the microammeter reads 100.0 μA. Readjust the light intensity until equilibrium is established at this reading. Place the light retarding filter in the path of the light beam. When equilibrium is established, record this meter reading as I_r. This meter reading becomes the reference value for the intensity of the light. Meter readings are also taken at the beginning and end of

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each test through the light retarding filter alone to check the requirements of 8.3.8.

7.1.3.3 For a turbidimeter equipped with a D'Arsonval-type microammeter, place the sedimentation tank containing clear kerosine against the guides of the turbidimeter. Set the light intensity so that the microammeter reads 50.0 μA with the light retarding filter removed from the light path. Readjust the light intensity until equilibrium is established at this reading. Connect resistors or resistor combinations as indicated in Fig. 1 so that the meter reading is reduced to an equilibrium value between 23.0 and 25.0 μA. Increase the light intensity until the equilibrium light reading obtained between 23.0 and 25.0 μA is exactly doubled. Readjust the light intensity until the equilibrium is established at this doubled meter reading level. Place the light-retarding filter in the path of the light beam. Remove the resistors from the meter circuit. When equilibrium is established, record this meter reading as I_r. This becomes the reference value for the intensity of the light. Adjust the rheostats at the beginning of each test to give this meter reading through the filter plus the tank of clear kerosine. This meter reading corresponds to a meter reading of 100.0 μA through the tank containing clear kerosine with the light filter removed from the light path. Meter readings are also taken at the beginning and at the end of each test through the light retarding filter alone to check the requirements of 8.3.8.

NOTE 6—A half-watt carbon resistor preferably with 5 % tolerance limits can be used to obtain the desired meter readings. The shunt resistor or resistor combination as shown in Fig. 1 shall have a resistance value between 85 and 100 % of the value of the internal resistance of the meter as printed on the card in the meter cover. The series resistor shall have a resistance value equal to the difference between the internal resistance of the meter and the calculated resistance of the meter and shunt combination.

NOTE 7—A less exact but still acceptable procedure for determining a meter setting that corresponds to a current of 100.0 μA through the meter with the light filter removed from the light path can be achieved by eliminating the series resistor in the meter circuit. The internal resistance of the photocell is sufficiently large to cause only a minor error of approximately 0.5 % in the desired setting when the series resistor is omitted from the circuit.

7.1.3.4 *Example*—If the internal resistance of the meter is 90 Ω, and the meter is shunted with a 470-Ω resistor in parallel with a 100 Ω resistor, the combined resistance of the meter and shunts would be reduced to 43 Ω. This would reduce the meter reading from 50.0 μA to a calculated value of 23.9 μA.

7.1.4 *Determination of the Value of K in the Specific Surface Equation*—Using the regular procedure in 8.1-8.3; and with the light adjusted in accordance with the appropriate procedure in 7.1.3, make a specific surface determination on the current lot of National Institute of Standards and Technology's Reference Material No. 114.[6] Determine the value of *K* in the specific surface equation in 10.1.1 by dividing the assigned specific surface of the standard sample by the value obtained for the expression in brackets [ ]. Repeat this calibration procedure twice more. Use the average of the three results (Note 8) obtained for the value of *K* during calibration in specific surface equation in 10.1.1.

7.1.5 *Frequency of Calibration*—The turbidimeter apparatus shall have been calibrated within 6 months prior to testing a cement sample.

NOTE 8—The three individual values of *K* determined during calibration should not vary from the average value by more than 1.5 %.

8. Procedure

8.1 *Sieve Determination*—Make a No. 325 (45-μm) sieve determination on a 1-g sample of cement in accordance with the procedure stated in Test Method C 430. Record the percentage (corrected) of cement passing the sieve as *r*.

8.2 *Preparation of the Suspension*:

8.2.1 *Dispersion of the Sample*—Place the cement sample in a test tube together with 10 to 15 mL of kerosine and 5 drops of dispersing agent—oleic acid or aged linseed oil (Note 9). Stir the mixture for 1 min, using the apparatus described in 4.6, and then transfer to the sedimentation tank. Wash the stirring apparatus and the tube with clear kerosine, which is then added together with additional clear kerosine until the total volume of the suspension in the tank is 335 mL (Note 10).

NOTE 9—The oleic acid, if used, shall be of USP grade. The aged linseed oil, if used, shall have a density in the range from 0.948 to 0.953 Mg/m^3 (g/cm^3). These dispersing agents have slight or no effect on the viscosity of the kerosine. Each of these dispersing agents changes with age or with exposure to heat and light—hence should be kept in well-stoppered, dark-glass bottles. Dropping bottles should be emptied, thoroughly cleaned, dried, and refilled periodically. Where conditions are such that poor dispersion is obtained with oleic acid or when foaming of the suspension occurs (possibly due to traces of water in the kerosine) aged linseed oil shall be used as the dispersing agent. The same dispersing agent shall be used for both the instrument calibration and the fineness determination.

NOTE 10—Since it is important that the level of the liquid in the tank coincide with the zero mark on the scale of the instrument (see 4.2.7), it is correspondingly important that the volume of the suspension be close to 335 mL, as specified. This may be accomplished by the use of a flask, calibrated to deliver 335 mL, from which all the kerosine used in making up a suspension is taken; or a point gage may be used, consisting essentially of a flat plate approximately 50 by 63 mm (2 by 2½ in.), to the center of which is attached vertically a metal pin of such length that, when the plate is placed in position on top of the tank, the point of the pin is at the 335-mL level. Either of these methods should ensure the position of the liquid level within a few tenths of a millimetre.

8.2.2 *Agitation of the Suspension*—Just before placing the tank in the path of the light beam, agitate the contents to effect a uniformity of the suspension. Cover the tank with a ground-glass cover and oscillate 180° about a horizontal axis through the center of the tank, turning the tank upside down and back again to its original upright position approximately once each second for about 1 min (Note 11). Take care to prevent loss of kerosine (Note 12). The suspension is then ready to place in its proper position in the path of the light beam.

NOTE 11—The procedure described for oscillating the suspension shall be carefully followed. The procedure used in shaking a cocktail shall not be employed.

NOTE 12—The lid to the tank shall fit so that no kerosine drains down the outside faces of the tank. The faces of the glass tank shall be clean when the suspension is added, and care shall be taken to avoid the necessity of cleaning the faces until the determination is complete.

[6] Available from National Institute of Standards and Technology (NIST), 100 Bureau Dr., Stop 3460, Gaithersburg, MD 20899-3460.

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8.3 *Operation of Turbidimeter*—Operate the turbidimeter apparatus in accordance with the following procedure:

8.3.1 With retarding filter and sedimentation tank containing approximately 100 mL of clear kerosine in the light path, adjust the light to the intensity, I_r, as determined in 7.1.3 by taking repeated readings at 1-min intervals until an unchanging value indicates that the lamp and the photoelectric cell are in equilibrium. Remove the tank, check, and record the intensity of the lamp.

NOTE 13—To protect the microammeter, the lamp shall be turned on only with a suspension or the retarding filter in position to reduce the light intensity to a value within the range of the microammeter. A freshly charged storage battery should be momentarily short-circuited to reduce the voltage to constant value. If the microammeter indication continues to fluctuate, look for loose connections in the lamp and photoelectric cell circuits, see that the rheostat contacts are clean, and make certain that the lamp, socket, and reflector are rigidly fixed in their mounting.

8.3.2 Weigh the sample of cement in the appropriate amount and record the weight to the nearest 0.0002 g. Prepare a suspension in accordance with 8.2.

8.3.3 Place the shelf level pointer at the 30–50 µm position.

8.3.4 Fill the buret to the predetermined height with kerosine from the same lot and at the same temperature as the kerosine used in the suspension, and start oscillation of the tank containing the suspension in accordance with 8.2.2. Continue the oscillation until the kerosine drains to the zero line on the buret; then stop the agitation. Immediately place the tank in position in the path of the light beam.

8.3.5 Immediately remove the retarding filter from the light path and close the cabinet door.

8.3.6 Read the microammeter to the nearest 0.1 µA at the instant the kerosine in the buret drains past marks 50, 45, 40, 35, and 30.

8.3.7 Raise the shelf successively to the marks 25, 20, 15, 10, and 7.5 on the pointer scale, reading the microammeter at each position as the kerosine drains past the corresponding mark on the buret.

8.3.8 Lower the shelf to the 30–50 µm position. Replace the filter in the path of the light beam, remove the tank, and check the intensity of the lamp. If the microammeter indication has shifted more than 0.3 µA from the initial setting through the filter alone, the test must be repeated.

9. Data Recording

9.1 The form shown in Table 4 is suggested for the recording of turbidimeter data and for the calculation of specific surface.

10. Calculation

10.1 *Calculation of Specific Surface*:

10.1.1 Calculate the turbimetric specific surface as follows:

$$S = K\left[\frac{r(2 - \log I_{50})}{1.5 + 0.75 \log I_{7.5} + \log I_{10} + \log I_{15} \ldots + \log I_{45} - 9.5 \log I_{50}}\right] \quad (2)$$

TABLE 4 Illustrative Form for Recording Turbidimeter Test Data and Calculation of Specific Surface

NOTE—Values shown are for purpose of illustration only.

Sample identification	sample X
Passing 45-µm (No. 325) sieve, *r*, corrected, *T*	90.4
Calibration factor, *K*	33.9
Meter reading through filter alone, µA:	
Before test	17.5
After test	17.5
Weight of sample tested, g	0.25

Particle Size, µm	*I*, µA		log *I*	
50	17.3		...	1.238[A]
45	17.4		1.241	
40	17.6		1.246	
35	17.9		1.253	
30	18.4		1.265	
25	19.1		1.281	
20	20.1		1.303	
15	21.6		1.334	
10	23.9		1.378	
7.5	25.6		...	1.408[A]
	0.75	× 1.408 =	1.056	
			1.500	
		Sum =	12.857	
		9.5 × 1.238 =	11.761	
		Difference =	1.096	
$S = (33.9 \times 90.4 \times 0.762)/1.096 = 2131$ cm²/g (Round to 2130 cm²/g or 213 m²/kg)				

[A] For convenience in calculation, log I_{50} and log $I_{7.5}$ are recorded in a separate column.

where:

S = specific surface of the sample, m²/kg,
K = calibration factor as determined in 7.1.4
r = corrected weight percent of sample passing the 45-µm (No. 325) sieve (Note 14), and $I_{7.5}$, I_{10}, I_{15}..., I_{50} = microammeter readings, µA, that correspond to the particle diameters 7.5, 10, 15 ⋯, 50 µm.

NOTE 14—The value of K as determined in 7.1.3 applies only to a material having the density of portland cement (approximately 3.15 Mg/m³ or g/cm³). For any other material, the corresponding value must be calculated for this factor which, in the derivation of the formula, varies inversely as the density of the particles (g/cm³).

10.1.2 To calculate the specific surface values in square metres per kilogram, multiply the surface area in cm²/g by the factor of 0.1.

10.1.3 Round values in cm²/g to the nearest 10 units (in m²/kg to the nearest unit).

10.2 *Specific Surface From First Turbidity Reading I_{50}*—This test method may be used for successive determinations from the same plant, provided that the same size test samples are used and that there is no great change in fineness, color, or other properties of the cement. Under these conditions the specific surface of a sample may be calculated from the first turbidity reading, I_{50}, by using the following equation:

$$S = c(2 - \log I_{50}) \quad (3)$$

where:

S = specific surface of the sample, m²/kg,
I_{50} = microammeter reading corresponding to particle diameter of 50 µm, and
c = transmittancy constant for the particular plant.

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NOTE 15—The transmittancy constant, *c*, may be evaluated by substituting in the above equation known values of *S* and $2 - \log I_{50}$ as determined from a complete turbidimeter test. The average of not less than five values of *c*, as determined from complete tests, should be used in the above equation.

10.3 If fineness of a sample as determined in accordance with 10.2 fails to conform with the specification requirements for fineness, a retest shall be made using the complete procedure in 8.3, 9.1, and 10.1.

11. Precision and Bias

11.1 *Single-Operator Precision*—The single-operator coefficient of variation has been found to be 2.6 % (Note 16). Therefore, results of two properly conducted tests by the same operator, on the same sample should not differ by more than 7.3 % (Note 13) of their average.

11.2 *Multilaboratory Precision*—The multilaboratory coefficient of variation has been found to be 3.8 % (Note 16). Therefore, results of two different laboratories on identical samples of a material should not differ from each other by more than 10.6 % (Note 16) of their average.

NOTE 16—These numbers represent, respectively, the (D1S %) and (D2S %) limits as described in Practice C 670.

11.3 Since there is no accepted reference material suitable for determining any bias that may be associated with this test method, no statement on bias is being made.

12. Keywords

12.1 fineness; portland cement; turbidimeter; Wagner

APPENDIX

(Nonmandatory Information)

X1. CALCULATION OF PARTICLE SIZE DISTRIBUTION

X1.1 For research or comparative purposes particle-size distributions to a minimum of 7.5 µm may be of value.

X1.2 Calculate the particle size distribution as follows:

The form shown in Table X1.1 is suggested for the calculation of particle size distribution.

TABLE X1.1 Illustrative Form for Calculation of Particle Size Distribution from Recorded Turbimetric Test Data

Particle Size, µm	I,µ A	$\log_I$	Difference	Average Particle Size, d_1	$d_1 \times$ Difference	Weight, %	
						Fractional	Cumulative
50	17.3	1.238	0.003	47.5	.143	2.34	90.4
45	17.4	1.241	0.005	42.5	.213	3.49	88.1
40	17.6	1.246	0.007	37.5	.263	4.31	84.6
35	17.9	1.253	0.012	32.5	.390	6.39	80.3
30	18.4	1.265	0.016	27.5	.440	7.21	73.9
25	19.1	1.281	0.022	22.5	.495	8.11	66.7
20	20.1	1.303	0.031	17.5	.543	8.89	58.6
15	21.6	1.334	0.044	12.5	.550	9.01	49.7
10	23.9	1.378	0.030	8.75	.263	4.31	40.7
7.5	25.6	1.408	0.592	3.75	2.220	36.36	36.4
(0)	(100.0)	(2.000)			...		
					5.520		

$F = r/\text{Sum } (d_1 \times \text{diff}) = 90.4/5.520 = 16.377$

% fraction = $F(d_1 \times \text{diff})$

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Designation: C 117 – 04

Standard Test Method for Materials Finer than 75-μm (No. 200) Sieve in Mineral Aggregates by Washing[1]

This standard is issued under the fixed designation C 117; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

This standard has been approved for use by agencies of the Department of Defense.

1. Scope

1.1 This test method covers the determination of the amount of material finer than a 75-μm (No. 200) sieve in aggregate by washing. Clay particles and other aggregate particles that are dispersed by the wash water, as well as water-soluble materials, will be removed from the aggregate during the test.

1.2 Two procedures are included, one using only water for the washing operation, and the other including a wetting agent to assist the loosening of the material finer than the 75-μm (No. 200) sieve from the coarser material. Unless otherwise specified, Procedure A (water only) shall be used.

1.3 The values stated in SI units are to be regarded as the standard.

1.4 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

2. Referenced Documents

2.1 *ASTM Standards:* [2]

C 136 Test Method for Sieve Analysis of Fine and Coarse Aggregates

C 670 Practice for Preparing Precision and Bias Statements for Test Methods for Construction Materials

C 702 Practice for Reducing Field Samples of Aggregate to Testing Size

D 75 Practice for Sampling Aggregates

E 11 Specification for Wire Cloth and Sieves for Testing Purposes

2.2 *AASHTO Standard:*

T11 Method of Test for Amount of Material Finer than 0.075-mm Sieve in Aggregate[3]

3. Summary of Test Method

3.1 A sample of the aggregate is washed in a prescribed manner, using either plain water or water containing a wetting agent, as specified. The decanted wash water, containing suspended and dissolved material, is passed through a 75-μm (No. 200) sieve. The loss in mass resulting from the wash treatment is calculated as mass percent of the original sample and is reported as the percentage of material finer than a 75-μm (No. 200) sieve by washing.

4. Significance and Use

4.1 Material finer than the 75-μm (No. 200) sieve can be separated from larger particles much more efficiently and completely by wet sieving than through the use of dry sieving. Therefore, when accurate determinations of material finer than 75 μm in fine or coarse aggregate are desired, this test method is used on the sample prior to dry sieving in accordance with Test Method C 136. The results of this test method are included in the calculation in Test Method C 136, and the total amount of material finer than 75 μm by washing, plus that obtained by dry sieving the same sample, is reported with the results of Test Method C 136. Usually, the additional amount of material finer than 75 μm obtained in the dry sieving process is a small amount. If it is large, the efficiency of the washing operation should be checked. It could also be an indication of degradation of the aggregate.

4.2 Plain water is adequate to separate the material finer than 75 μm from the coarser material with most aggregates. In some cases, the finer material is adhering to the larger particles, such as some clay coatings and coatings on aggregates that have been extracted from bituminous mixtures. In these cases, the fine material will be separated more readily with a wetting agent in the water.

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[1] Available from American Association of State Highway and Transportation Officials (AASHTO), 444 N. Capitol St., NW, Suite 249, Washington, DC 20001.

This test method is under the jurisdiction of ASTM Committee C09 on Concrete and Concrete Aggregates and is the direct responsibility of Subcommittee C09.20 on Normal Weight Aggregates.

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[2] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

[3] Available from American Association of State Highway and Transportation Officials (AASHTO), 444 N. Capitol St., NW, Suite 249, Washington, DC 20001.

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5. Apparatus and Materials

5.1 *Balance*—A balance or scale readable and accurate to 0.1 g or 0.1 % of the test load, whichever is greater, at any point within the range of use.

5.2 *Sieves*—A nest of two sieves, the lower being a 75-µm (No. 200) sieve and the upper a 1.18-mm (No. 16) sieve, both conforming to the requirements of Specification E 11.

5.3 *Container*—A pan or vessel of a size sufficient to contain the sample covered with water and to permit vigorous agitation without loss of any part of the sample or water.

5.4 *Oven*—An oven of sufficient size, capable of maintaining a uniform temperature of 110 ± 5 °C (230 ± 9 °F).

5.5 *Wetting Agent*—Any dispersing agent, such as liquid dishwashing detergents, that will promote separation of the fine materials.

NOTE 1—The use of a mechanical apparatus to perform the washing operation is not precluded, provided the results are consistent with those obtained using manual operations. The use of some mechanical washing equipment with some samples may cause degradation of the sample.

6. Sampling

6.1 Sample the aggregate in accordance with Practice D 75. If the same test sample is to be tested for sieve analysis according to Test Method C 136, comply with the applicable requirements of that test method.

6.2 Thoroughly mix the sample of aggregate to be tested and reduce the quantity to an amount suitable for testing using the applicable methods described in Practice C 702. If the same test sample is to be tested according to Test Method C 136, the minimum mass shall be as described in the applicable sections of that method. Otherwise, the mass of the test sample, after drying, shall conform with the following:

Nominal Maximum Size	Minimum Mass, g
4.75 mm (No. 4) or smaller	300
Greater than 4.75 mm (No. 4) to 9.5 mm (⅜ in.)	1000
Greater than 9.5 mm (⅜ in.) to 19.0 mm (¾ in.)	2500
Greater than 19.0 mm (¾ in.)	5000

7. Selection of Procedure

7.1 Procedure A shall be used, unless otherwise specified by the Specification with which the test results are to be compared, or when directed by the agency for which the work is performed.

8. Procedure A—Washing with Plain Water

8.1 Dry the test sample in the oven to constant mass at a temperature of 110 ± 5 °C (230 ± 9 °F). Determine the mass to the nearest 0.1 % of the mass of the test sample.

8.2 If the applicable specification requires that the amount passing the 75-µm (No. 200) sieve shall be determined on a portion of the sample passing a sieve smaller than the nominal maximum size of the aggregate, separate the sample on the designated sieve and determine the mass of the material passing the designated sieve to 0.1 % of the mass of this portion of the test sample. Use this mass as the original dry mass of the test sample in 10.1.

NOTE 2—Some specifications for aggregates with a nominal maximum size of 50 mm or greater, for example, provide a limit for material passing the 75-µm (No. 200) sieve determined on that portion of the sample passing the 25.0-mm sieve. Such procedures are necessary since it is impractical to wash samples of the size required when the same test sample is to be used for sieve analysis by Test Method C 136.

8.3 After drying and determining the mass, place the test sample in the container and add sufficient water to cover it. No detergent, dispersing agent, or other substance shall be added to the water. Agitate the sample with sufficient vigor to result in complete separation of all particles finer than the 75-µm (No. 200) sieve from the coarser particles, and to bring the fine material into suspension. Immediately pour the wash water containing the suspended and dissolved solids over the nested sieves, arranged with the coarser sieve on top. Take care to avoid, as much as feasible, the decantation of coarser particles of the sample.

8.4 Add a second charge of water to the sample in the container, agitate, and decant as before. Repeat this operation until the wash water is clear.

NOTE 3—If mechanical washing equipment is used, the charging of water, agitating, and decanting may be a continuous operation.

8.5 Return all material retained on the nested sieves by flushing to the washed sample. Dry the washed aggregate in the oven to constant mass at a temperature of 110 ± 5 °C (230 ± 9 °F) and determine the mass to the nearest 0.1 % of the original mass of the sample.

NOTE 4—Following the washing of the sample and flushing any material retained on the 75-µm (No. 200) sieve back into the container, no water should be decanted from the container except through the 75-µm sieve, to avoid loss of material. Excess water from flushing should be evaporated from the sample in the drying process.

9. Procedure B—Washing Using a Wetting Agent

9.1 Prepare the sample in the same manner as for Procedure A.

9.2 After drying and determining the mass, place the test sample in the container. Add sufficient water to cover the sample, and add wetting agent to the water (Note 5). Agitate the sample with sufficient vigor to result in complete separation of all particles finer than the 75-µm (No. 200) sieve from the coarser particles, and to bring the fine material into suspension. Immediately pour the wash water containing the suspended and dissolved solids over the nested sieves, arranged with the coarser sieve on top. Take care to avoid, as much as feasible, the decantation of coarser particles of the sample.

NOTE 5—There should be enough wetting agent to produce a small amount of suds when the sample is agitated. The quantity will depend on the hardness of the water and the quality of the detergent. Excessive suds may overflow the sieves and carry some material with them.

9.3 Add a second charge of water (without wetting agent) to the sample in the container, agitate, and decant as before. Repeat this operation until the wash water is clear.

9.4 Complete the test as for Procedure A.

10. Calculation

10.1 Calculate the amount of material passing a 75-µm (No. 200) sieve by washing as follows:

$$A = [(B - C)/B] \times 100 \quad (1)$$

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where:

A = percentage of material finer than a 75-µm (No. 200) sieve by washing,
B = original dry mass of sample, g, and
C = dry mass of sample after washing, g.

11. Report

11.1 Report the following information:

11.1.1 Report the percentage of material finer than the 75-µm (No. 200) sieve by washing to the nearest 0.1 %, except if the result is 10 % or more, report the percentage to the nearest whole number.

11.1.2 Include a statement as to which procedure was used.

12. Precision and Bias

12.1 *Precision*—The estimates of precision of this test method listed in Table 1 are based on results from the AASHTO Materials Reference Laboratory Proficiency Sample Program, with testing conducted by this test method and AASHTO Method T 11. The significant differences between the methods at the time the data were acquired is that Method T 11 required, while Test Method C 117 prohibited, the use of a wetting agent. The data are based on the analyses of more than 100 paired test results from 40 to 100 laboratories.

12.1.1 The precision values for fine aggregate in Table 1 are based on nominal 500-g test samples. Revision of this test method in 1994 permits the fine aggregate test sample size to be 300 g minimum. Analysis of results of testing of 300-g and 500-g test samples from Aggregate Proficiency Test Samples 99 and 100 (Samples 99 and 100 were essentially identical) produced the precision values in Table 2, which indicates only minor differences due to test sample size.

NOTE 6—The values for fine aggregate in Table 1 will be revised to reflect the 300-g test sample size when a sufficient number of Aggregate Proficiency Tests have been conducted using that sample size to provide reliable data.

12.2 *Bias*—Since there is no accepted reference material suitable for determining the bias for the procedure in this test method, no statement on bias is made.

TABLE 1 Precision

	Standard Deviation (1s)[A], %	Acceptable Range of two Results (d2s)[A], %
Coarse Aggregate[B]		
Single-Operator Precision	0.10	0.28
Multilaboratory Precision	0.22	0.62
Fine Aggregate[C]		
Single-Operator Precision	0.15	0.43
Multilaboratory Precision	0.29	0.82

[A] These numbers represent the (1s) and (d2s) limits as described in Practice C 670.

[B] Precision estimates are based on aggregates having a nominal maximum size of 19.0 mm (¾ in.) with less than 1.5% finer than the 75-µm (No. 200) sieve.

[C] Precision estimates are based on fine aggregates having 1.0 to 3.0% finer than the 75-µm (No. 200) sieve.

13. Keywords

13.1 aggregate; coarse aggregate; fine aggregate; grading; loss by washing; 75 µm (No. 200) sieve; size analysis

TABLE 2 Precision Data for 300-g and 500-g Test Samples

Fine Aggregate Proficiency Sample				Within Laboratory		Between Laboratory	
Test Result	Sample Size	No. of Labs	Average	1s	d2s	1s	d2s
AASHTO T11/ASTM C117	500 g	270	1.23	0.08	0.24	0.23	0.66
Total material passing the No. 200 sieve by washing (%)	300 g	264	1.20	0.10	0.29	0.24	0.68

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Designation: C 123 – 04

American Association State
Highway and Transportation Standard
AASHTO No.: T 113

Standard Test Method for Lightweight Particles in Aggregate[1]

This standard is issued under the fixed designation C 123; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope

1.1 This test method covers the determination of the percentage of lightweight particles in aggregate by means of sink-float separation in a heavy liquid of suitable specific gravity.

1.2 The values given in SI units are to be regarded as the standard. The values given in parentheses are for information only.

1.3 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.* For a specific hazard statement, see 6.1.4.

2. Referenced Documents

2.1 *ASTM Standards:* [2]

C 33 Specification for Concrete Aggregates

C 125 Terminology Relating to Concrete and Concrete Aggregates

C 127 Test Method for Density, Relative Density (Specific Gravity), and Absorption of Coarse Aggregate

C 128 Test Method for Density, Relative Density (Specific Gravity), and Absorption of Fine Aggregate

C 702 Practice for Reducing Field Samples of Aggregate to Testing Size

C 1005 Specification for Reference Masses and Devices for Determining Mass and Volume for Use in the Physical Testing of Hydraulic Cements

D 75 Practice for Sampling Aggregates

D 3665 Practice for Random Sampling of Construction Materials

E 11 Specification for Wire Cloth and Sieves for Testing Purposes

E 100 Specification for ASTM Hydrometers

3. Terminology

3.1 For definitions of terms used in this test method, refer to Terminology C 125.

4. Significance and Use

4.1 This test method is used to determine conformance with provisions of Specification C 33 pertaining to the amount of lightweight material in fine and coarse aggregates. A heavy liquid with a specific gravity of 2.0 is used to separate particles which may be classified as coal or lignite. Heavier liquids are to be used to check the percentages of other lightweight particles such as chert and shale having a specific gravity less than 2.40.

4.2 The test method is useful in identifying porous aggregate particles in research activities or in petrographic analyses.

5. Apparatus

5.1 *Balances*—For determining the mass of fine aggregates, a balance having a capacity of not less than 500 g, sensitive to at least 0.1 g: for determining the mass of coarse aggregate, a balance having a capacity of not less than 5000 g, sensitive to at least 1 g. Both balances shall conform to the accuracy criterion of the applicable sections of Specification C 1005.

5.2 *Containers* suitable for drying the aggregate sample, and containers suitable for holding the heavy liquid during the sink-float separation.

5.3 *Skimmer*—A piece of 300-μm (No. 50) sieve cloth, conforming to Specification E 11, of suitable size and shape for separating the floating particles from the heavy liquid.

5.4 *Hot Plate or Oven*.

5.5 *Sieves*, 300-μm (No. 50) and 4.75-mm (No. 4) conforming to Specification E 11.

5.6 *Specific Gravity Measurement*—A hydrometer conforming to the physical requirement sections for individual hydrometers of Specification E 100, or a suitable combination of graduated glassware and balance capable of measuring the liquid specific gravity within ±0.01.

6. Heavy Liquid

6.1 The heavy liquid shall consist of one of the following (see 6.1.4):

[1] This test method is under the jurisdiction of ASTM Committee C09 on Concrete and Concrete Aggregates and is the direct responsibility of Subcommittee C09.20 on Normal Weight Aggregates.

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[2] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

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6.1.1 A solution of zinc chloride in water (for a specific gravity up to about 2.0).

6.1.2 A mixture of kerosene with 1,1,2,2-tetrabromoethane, proportioned to produce desired specific gravities. (1,1,2,2-tetrabromoethane has a specific gravity of about 2.95) (see Note 1).

6.1.3 A solution of zinc bromide in water (for a specific gravity up to about 2.4).

6.1.4 **Warning**—The chemicals listed in 6.1.2 are toxic, both by absorption through the skin and by inhalation. They shall be used only in a hood (preferably of the down-draft type) or out-of-doors, and care shall be taken to avoid inhalation or contact with the eyes or skin. There is no particular hazard from the fumes of zinc-chloride solution (6.1.1) or zinc-bromide solution (6.1.3) but goggles and gloves shall be worn to prevent contact with the eyes or skin.

6.2 The specific gravity of the heavy liquid shall be maintained within ±0.01 of the specified value at all times during the test.

NOTE 1—1,1,2,2-tetrabromoethane is highly toxic and extremely dangerous to use and when heated emits highly toxic fumes of bromine, hydrogen bromide, and carbonyl bromide. It should be handled only by personnel trained and qualified in its use. Its storage should be in a secured location.

7. Sampling

7.1 Secure a field sample of the aggregate in accordance with Practices D 75 and D 3665. Reduce the sample to test portion size in accordance with Practice C 702.

7.2 Dry the test portion to constant mass at a temperature of 110 ± 5 °C (230 ± 9 °F) before testing and sieve to remove the undersize material as specified in 8.1 and 8.2. The minimum size of the test specimen shall be as follows:

Nominal Maximum Size of Aggregate (square-opening sieves)		Minimum Mass of Sample, g
4.75 mm or smaller	(No. 4 or smaller)	200
9.5 mm	(⅜ in.)	1 500
12.5 to 19.0 mm	(½ to ¾ in.)	3 000
25 to 37.5 mm	(1 to 1½ in.)	5 000
50 mm or larger	(2 in. or larger)	10 000

8. Procedure

8.1 *Fine Aggregate*—Allow the dried test specimen of fine aggregate to cool to room temperature and then sieve over a 300-µm (No. 50) sieve until less than 1 % of the retained material passes the sieve in 1 min of continuous sieving. Determine the mass of the material coarser than the 300-µm (No. 50) sieve to the nearest 0.1 g, and bring this material to a saturated-surface-dry condition by means of the procedure specified in Test Method C 128 (see 8.1.1), then introduce it into the heavy liquid (see 6.1.4) in a suitable container. The volume of liquid shall be at least three times the absolute volume of the aggregate. Pour the liquid, including the floating particles, into a second container, passing it through the skimmer, taking care that only the floating particles are poured off with the liquid and that none of the fine aggregate that sinks is decanted onto the skimmer. Return to the first container the liquid that has been collected in the second container and, after further agitation of the sample by stirring, repeat the decanting process just described until the specimen is free of floating particles. Wash the decanted particles contained on the skimmer in an appropriate solvent to remove the heavy liquid. Alcohol is appropriate for 1,1,2,2-tetrabromoethane and water for the zinc-chloride and zinc-bromide solutions. After the decanted particles have been washed, allow them to dry (see 8.1.2). Brush the dry decanted particles from the skimmer onto the balance pan and determine the mass to the nearest 0.1 g. If more precise determination is required, the decanted particles shall be dried to constant mass at 110 ± 5 °C to determine the value of W_1 used for the calculation in 9.1 (see 8.1.3).

8.1.1 If the absorption as determined in accordance with Test Method C 128 is known, the fine aggregate is permitted to be prepared for test by adding to a known mass of dry sand the amount of water it will absorb, mixing thoroughly, and permitting the sand to stand in a covered pan for 30 min before use.

8.1.2 Drying shall take place in the hood or out-of-doors if other than zinc chloride or zinc bromide is used. An oven or hot plate is permitted to be used to accelerate the drying providing that it is done in the hood or that the oven is forced-air ventilated to the outside of the building and that a temperature of 115 °C is not exceeded.

8.1.3 Normally the discrepancy between oven-dry mass and saturated-surface-dry mass of the decanted particles will not significantly affect the calculated percentage of light-weight particles.

8.2 *Coarse Aggregate*—Allow the dried test specimen of coarse aggregate to cool to room temperature and sieve over a 4.75-mm (No. 4) sieve. Determine the mass of the material coarser than the 4.75-m (No. 4) sieve to the nearest 1 g, and bring to a saturated-surface-dry condition by means of the procedure specified in Test Method C 127; then introduce it into the heavy liquid in a suitable container. The volume of liquid shall be at least three times the absolute volume of the aggregate. Using the skimmer, remove the particles that float to the surface, and save them. Repeatedly agitate the remaining particles, and remove the floating particles until no additional particles rise to the surface. Wash the particles which are skimmed off in an appropriate solvent to remove the heavy liquid (see 8.1). After the heavy liquid has been removed, allow the particles to dry (see 8.1.2). Determine the mass of the decanted particles to the nearest 1 g. If a more precise determination is required, dry the particles to constant mass at 110 ± 5 °C to determine the value of W_1 used for the calculation in 9.1 (see 8.1.3).

9. Calculation

9.1 Calculate the percentage by mass of lightweight particles (particles floating on the heavy liquid) as follows:

For fine aggregate:

$$L = (W_1/W_2) \times 100 \quad (1)$$

For coarse aggregate:

$$L = (W_1/W_3) \times 100 \quad (2)$$

where:

L = percentage by mass of lightweight particles,
W_1 = dry mass of particles that float,

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W_2 = dry mass of portion of specimen coarser than 300-µm (No. 50) sieve, and

W_3 = dry mass of portion of specimen coarser than the 4.75-mm (No. 4) sieve.

10. Report

10.1 Report the following information:

10.1.1 Identification of the aggregate as to source, type and nominal maximum size,

10.1.2 The mass of the test sample used,

10.1.3 Type and specific gravity of heavy liquid used for the test, and

10.1.4 Percentage by mass of lightweight particles rounded to nearest 0.1 %.

11. Precision and Bias

11.1 *Precision*—No interlaboratory or intralaboratory studies have been conducted using this test method to determine precision indices. The committee is seeking pertinent data from users of the test method.

11.2 *Bias*—Bias of the test method may be estimated by running separate specific gravity and absorption determinations on individual particles of the separate sink, or float fractions, or both.

12. Keywords

12.1 aggregate; heavy liquid; lightweight particles

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Designation: C125 – 09a

Standard Terminology Relating to Concrete and Concrete Aggregates[1]

This standard is issued under the fixed designation C125; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

This standard has been approved for use by agencies of the Department of Defense.

1. Scope*

1.1 This standard is a compilation of general terminology related to hydraulic cement concrete, concrete aggregates, and other materials used in or with hydraulic cement concrete.

1.2 Other terminology under the jurisdiction of Committee C09 is included in two specialized standards. Terms relating to constituents of concrete aggregates are defined in Descriptive Nomenclature C294. Terms relating to constituents of aggregates for radiation-shielding concrete are defined in Descriptive Nomenclature C638.

1.3 Related terminology for hydraulic cement is included in Terminology C219. Additional related terminology can be found in ACI 116R.

1.4 When a term is used in an ASTM standard for which Committee C09 is responsible, it is included herein only if used in more than one Committee C09 standard.

1.5 Definitions that are adopted from those published by other ASTM committees or other standards organizations are identified with the ASTM designation (for example, Terminology C219) or with the abbreviation of the name of the other organization.

1.6 A definition in this standard is a statement of the meaning of a word or word group expressed in a single sentence with additional information included in notes or discussion.

NOTE 1—The subcommittee responsible for this standard will review definitions on a five-year basis to determine if the definition is still appropriate as stated. Revisions will be made when determined necessary. The year shown in parentheses at the end of a definition indicates the year the definition or revision to the definition was approved. A letter R and a year indicate when the definition was reviewed. No date indicates the term has not yet been reviewed.

2. Referenced Documents

2.1 *ASTM Standards:*[2]

C109/C109M Test Method for Compressive Strength of Hydraulic Cement Mortars (Using 2-in. or [50-mm] Cube Specimens)

C143/C143M Test Method for Slump of Hydraulic-Cement Concrete

C219 Terminology Relating to Hydraulic Cement

C294 Descriptive Nomenclature for Constituents of Concrete Aggregates

C403/C403M Test Method for Time of Setting of Concrete Mixtures by Penetration Resistance

C494/C494M Specification for Chemical Admixtures for Concrete

C511 Specification for Mixing Rooms, Moist Cabinets, Moist Rooms, and Water Storage Tanks Used in the Testing of Hydraulic Cements and Concretes

C638 Descriptive Nomenclature of Constituents of Aggregates for Radiation-Shielding Concrete

C939 Test Method for Flow of Grout for Preplaced-Aggregate Concrete (Flow Cone Method)

C1074 Practice for Estimating Concrete Strength by the Maturity Method

C1240 Specification for Silica Fume Used in Cementitious Mixtures

C1611/C1611M Test Method for Slump Flow of Self-Consolidating Concrete

[1] This terminology is under the jurisdiction of ASTM Committee C09 on Concrete and Concrete Aggregates and is the direct responsibility of Subcommittee C09.91 on Terminology.

Current edition approved Dec. 15, 2009. Published February 2010. Originally approved in 1936. Last previous edition approved in 2009 as C125 – 09. DOI: 10.1520/C0125-09a.

[2] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

***A Summary of Changes section appears at the end of this standard.**

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2.2 *American Concrete Institute Publications:*[3]
308 Practice for Curing Concrete
116R Cement and Concrete Terminology

3. Terms and Their Definitions

absorption, *n*—the process by which a liquid is drawn into and tends to fill permeable pores in a porous solid body; also, the increase in mass of a porous solid body resulting from the penetration of a liquid into its permeable pores. (R 2008)

DISCUSSION—In the case of concrete and concrete aggregates, unless otherwise stated, the liquid involved is water, the increase in mass is that which does not include water adhering to the outside surface, the increase in mass is expressed as a percentage of the dry mass of the body and the body is considered to be "dry" when it has been treated by an appropriate process to remove uncombined water, such as drying to constant mass at a temperature between 100 and 110 °C.

admixture, *n*—a material other than water, aggregates, hydraulic cementitious material, and fiber reinforcement that is used as an ingredient of a cementitious mixture to modify its freshly mixed, setting, or hardened properties and that is added to the batch before or during its mixing. (R 2008)
accelerating admixture, n—admixture that accelerates the setting and early strength development of concrete. (C494/C494M)
air-entraining admixture, n—admixture that causes the development of a system of microscopic air bubbles in concrete or mortar during mixing.
chemical admixture, n—a nonpozzolanic admixture in the form of a liquid, suspension, or water-soluble solid.
mineral admixture, n—deprecated term.

DISCUSSION—This term has been used to refer to different types of water insoluble, finely divided materials such as pozzolanic materials, cementitious materials, and aggregate. These materials are not similar, and it is not useful to group them under a single term. The name of the specific material should be used, for example, use "pozzolan," "ground granulated blast-furnace slag," or "finely divided aggregate," as is appropriate.

retarding admixture, n—admixture that retards the setting of concrete. (C494/C494M)
water-reducing admixture, n—admixture that either increases the slump of freshly mixed mortar or concrete without increasing the water content or that maintains the slump with a reduced amount of water due to factors other than air entrainment.
water-reducing admixture, high-range, n—a water-reducing admixture capable of producing at least 12 % reduction of water content when tested in accordance with Specification C494/C494M and meeting the other relevant requirements of Specification C494/C494M.

aggregate, *n*—granular material, such as sand, gravel, crushed stone, or iron blast-furnace slag, used with a cementing medium to form hydraulic-cement concrete or mortar. (R 2008)
coarse aggregate, n—(1) aggregate predominantly retained on the 4.75-mm (No. 4) sieve; or *(2)* that portion of an aggregate retained on the 4.75-mm (No. 4) sieve.

DISCUSSION—The definitions are alternatives to be applied under differing circumstances. Definition *(1)* is applied to an entire aggregate either in a natural condition or after processing. Definition *(2)* is applied to a portion of an aggregate. Requirements for properties and grading should be stated in the specification.

fine aggregate, n—(1) aggregate passing the 9.5-mm (⅜-in.) sieve and almost entirely passing the 4.75-mm (No. 4) sieve and predominantly retained on the 75-μm (No. 200) sieve; or *(2)* that portion of an aggregate passing the 4.75-mm (No. 4) sieve and retained on the 75-μm (No. 200) sieve.

DISCUSSION—The definitions are alternatives to be applied under differing circumstances. Definition *(1)* is applied to an entire aggregate either in a natural condition or after processing. Definition *(2)* is applied to a portion of an aggregate. Requirements for properties and grading should be stated in the specifications.

heavyweight aggregate, n—see *high-density aggregate*.
high-density aggregate, n—aggregate with relative density greater than 3.3, such as: barite, magnetite, limonite, ilmenite, iron, or steel.
lightweight aggregate, n—see *low-density aggregate*.
low-density aggregate, n—aggregate with bulk density less than 1120 kg/m^3 (70 lb/ft^3), such as: pumice, scoria, volcanic cinders, tuff, and diatomite; expanded or sintered clay, shale, slate, diatomaceous shale, perlite, vermiculite, or slag; and end products of coal or coke combustion.
normal-density aggregate, n—aggregate that is neither high nor low density.

DISCUSSION—This term refers to aggregate with relative density typically ranging between 2.4 and 3.0, or with bulk density typically ranging between 1120 kg/m^3 (70 lb/ft^3) and 1920 kg/m^3 (120 lb/ft^3).

normalweight aggregate, n—see *normal-density aggregate*.

air content, *n*—the volume of air voids in cement paste, mortar, or concrete, exclusive of pore space in aggregate particles, usually expressed as a percentage of total volume of the paste, mortar, or concrete. (R 2008)

air-cooled blast-furnace slag—see **blast-furnace slag, air-cooled.**

air void—see **void, air.**

blast-furnace slag, *n*—the nonmetallic product, consisting essentially of silicates and aluminosilicates of calcium and other bases, that is developed in a molten condition simultaneously with iron in a blast furnace. (R 2008)

blast-furnace slag, air-cooled , *n*—the material resulting from solidification of molten blast-furnace slag under atmospheric conditions; subsequent cooling may be accelerated by application of water to the solidified surface. (R 2008)

blast-furnace slag, granulated, *n*—the glassy, granular material formed when molten blast-furnace slag is rapidly chilled, as by immersion in water. (R 2008)

bleeding, *n*—the autogenous flow of mixing water within, or its emergence from, newly placed concrete or mortar caused by the settlement of the solid materials within the mass, also called water gain. (R 2008)

bulk density, *n—of aggregate,* the mass of a unit volume of bulk aggregate material (the unit volume includes the volume of the individual particles and the volume of the

[3] Available from American Concrete Institute (ACI), P.O. Box 9094, Farmington Hills, MI 48333-9094, http://www.concrete.org.

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voids between the particles). (R 2008)

DISCUSSION—This term replaces the deprecated term **unit weight**—*of aggregate*.

bulk specific gravity, *n*—the ratio of the mass of a volume of a material (including the permeable and impermeable voids in the material, but excluding the voids between particles of the material) at a stated temperature to the mass of an equal volume of distilled water at a stated temperature. (R 2008)

bulk specific gravity *(saturated surface dry)***,** *n*—the ratio of the mass of a volume of a material including the mass of water within the pores in the material (but excluding the voids between particles) at a stated temperature, to the mass of an equal volume of distilled water at a stated temperature. (R 2008)

cellular concrete—see **concrete, cellular.**

cement, hydraulic, *n*—a cement that sets and hardens by chemical reaction with water and is capable of doing so under water. (R 2008)

cementitious material *(hydraulic)***,** *n*—an inorganic material or a mixture of inorganic materials that sets and develops strength by chemical reaction with water by formation of hydrates and is capable of doing so under water. (R 2008)

cementitious mixture, *n*—a mixture (mortar, concrete, or grout) containing hydraulic cement. (R 2008)

concrete, *n*—a composite material that consists essentially of a binding medium within which are embedded particles or fragments of aggregate; in hydraulic-cement concrete, the binder is formed from a mixture of hydraulic cement and water. (R 2008)

concrete, cellular, *n*—a lightweight hydraulic-cement concrete having a homogeneous void or cell structure attained using gas-forming chemicals or foaming agents. (R 2008)

concrete, fresh, *n*—concrete which possesses enough of its original workability so that it can be placed and consolidated by the intended methods. (R 2008)

concrete, hardened, *n*—concrete that has developed sufficient strength to serve some defined purpose or resist a stipulated loading without failure. (R 2008)

concrete, roller-compacted, RCC, *n*—concrete compacted while fresh by a roller, often a vibratory roller. (R 2008)

concrete, self-consolidating, SCC, *n*—concrete that can flow around reinforcement and consolidate under its own weight without additional effort and without exceeding specified limits of segregation. (R 2008)

DISCUSSION—Project specifications shall indicate the acceptable segregation based upon a specified test method. Although there currently are no ASTM test methods approved to define specified limits of segregation, they are under development; also, there are industry methods available to specifiers.

consistency, *n—of fresh concrete, mortar, or grout,* the relative mobility or ability to flow. (R 2008)

DISCUSSION—This characteristic of fresh cementitious mixtures is difficult to quantify and empirical test methods have been adopted to provide indicators of consistency. For example, the slump test described in Test Method C143/C143M is used for concrete, the flow table method described in Test Method C109/C109M is used for mortar, and the flow cone method described in Test Method C939 is used for grout.

consolidation, *n—of cementitious mixtures,* the process of increasing the density of a fresh cementitious mixture in a form, mold, or container by reducing the volume of voids. (2009)

DISCUSSION—Except for **self-consolidating concrete**, consolidation is accomplished by inputting mechanical energy, typically by rodding, tamping, tapping, vibration, or some combination of these actions. Specific apparatus and methods for consolidation are defined in the relevant C09 Standards.

crushed gravel—see **gravel, crushed.**

crushed stone—see **stone, crushed.**

curing, *n*—action taken to maintain moisture and temperature conditions in a freshly-placed cementitious mixture to allow hydraulic cement hydration and (if applicable) pozzolanic reactions to occur so that the potential properties of the mixture may develop (see ACI 308). (R 2008)

curing compound, *n*—a liquid that, when applied as a coating to the surface of newly-placed concrete, forms a membrane that retards the evaporation of water and, in the case of white pigmented compounds, reflects heat (see also **curing**). (R 2008)

D-cracking, *n—in concrete*, a series of cracks near to and roughly parallel to features such as joints, edges, and structural cracks.

density, *n*—mass per unit volume (preferred over deprecated term **unit weight**).

elongated piece *(of aggregate)***,** *n*—a particle of aggregate for which the ratio of the length to width of its circumscribing rectangular prism is greater than a specified value (see also **flat piece** (*of aggregate*)).

entrained air—see **void, air.**

entrapped air—see **void, air.**

expanded blast-furnace slag, *n*—the lightweight cellular material obtained by controlled processing of molten blast-furnace slag with water or water and other agents, such as steam or compressed air or both.

fibers, *n*—slender filaments, which may be discrete or in the form of bundles, networks, or strands of natural or manufactured materials, which can be distributed uniformly throughout a fresh cementitious mixture.

fineness modulus, *n—of aggregate*, a factor obtained by adding the percentages of material in the sample that is coarser than each of the following sieves (cumulative percentages retained), and dividing the sum by 100: 150-μm (No. 100), 300-μm (No. 50), 600-μm (No. 30), 1.18-mm (No. 16), 2.36-mm (No. 8), 4.75-mm (No. 4), 9.5-mm (⅜-in.), 19.0-mm (¾-in.), 37.5-mm (1½-in.), 75-mm (3-in.), 150-mm (6-in.).

flat piece *(of aggregate)***,** *n*—a particle of aggregate for which the ratio of the width to thickness of its circumscribing rectangular prism is greater than a specified value (see also **elongated piece** (*of aggregate*)).

fly ash, *n*—the finely divided residue that results from the combustion of ground or powdered coal and that is transported by flue gases from the combustion zone to the particle removal system.

fog room, *n*—a moist room in which the humidity is controlled by atomization of water. (see Specification C511)

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fresh concrete—see **concrete, fresh.**

granulated blast-furnace slag—see **blast-furnace slag, granulated.**

gravel, *n*—coarse aggregate resulting from natural disintegration and abrasion of rock or processing of weakly bound conglomerate.

gravel, crushed, *n*—the product resulting from the artificial crushing of gravel with substantially all fragments having at least one face resulting from fracture.

grout, *n*—a cementitious mixture, with or without admixtures, that is used primarily to fill voids.

grout, hydraulic–cement, *n*—a grout made with hydraulic cement.

grout (nonshrink), hydraulic-cement, *n*—a hydraulic-cement grout that produces a volume that, when hardened under stipulated test conditions, is greater than or equal to the original installed volume, often used as a transfer medium between load-bearing members.

hardened concrete—see **concrete, hardened**.

hardening, *n*—gain of strength, and other properties, of a cementitious mixture as a result of hydration after final setting (for the definition of hydration, see Terminology C219).

hydraulic cement—see **cement, hydraulic**.

laitance, *n*—a layer of weak material derived from cementitious material and aggregate fines either: 1) carried by bleeding to the surface or to internal cavities of freshly placed concrete, or 2) separated from the concrete and deposited on the concrete surface or in internal cavities during placement of concrete under water.

lime-saturated water, *n—for curing test specimens*, water containing calcium hydroxide at saturation level and in contact with solid calcium hydroxide so that saturation is maintained.

manufactured sand—see **sand, manufactured**.

maturity, *n*—the extent of the development of a property of a cementitious mixture.

DISCUSSION—This term is usually used to describe the extent of relative strength development of concrete. However, the term can also be applied to the evolution of other properties which are dependent on the chemical reactions which occur in the cementitious materials. At any age, maturity is dependent on the curing history.

maturity function, *n*—a mathematical expression which uses the measured temperature history of a cementitious mixture during the curing period to calculate an index that is indicative of the maturity at the end of that period.

maturity index, *n*—an indicator of maturity which is calculated from the temperature history of the cementitious mixture by using a maturity function.

DISCUSSION—The calculated index is indicative of maturity provided there has been a sufficient supply of water for hydration or pozzolanic reaction of the cementitious materials during the time interval used in the calculation. Two widely used maturity indexes are the temperature-time factor and the equivalent age. See Practice C1074.

maximum size *(of aggregate)***,** *n*—in specifications for, or description of aggregate, the smallest sieve opening through which the entire amount of aggregate is required to pass.

moist room, *n*—an enclosed room for storage and curing of paste, mortar, and concrete specimens in which temperature and high relative humidity can be controlled within specified limits. (see Specification C511)

nominal maximum size *(of aggregate)***,** *n*—in specifications for, or description of aggregate, the smallest sieve opening through which the entire amount of the aggregate is permitted to pass.

DISCUSSION—Specifications on aggregates usually stipulate a sieve opening through which all of the aggregate may, but need not, pass so that a stated maximum proportion of the aggregate may be retained on that sieve. A sieve opening so designated is the *nominal maximum size* of the aggregate.

pozzolan, *n*—a siliceous or siliceous and aluminous material, which in itself possesses little or no cementitious value but will, in finely divided form and in the presence of moisture, chemically react with calcium hydroxide at ordinary temperatures to form compounds possessing cementitious properties.

*relative density***,** *n*—see **specific gravity**

rodding, *n*—consolidation of a fresh cementitious mixture by repeated insertion of a rod. (2009)

roller-compacted concrete, RCC—see **concrete, roller-compacted.**

sand, *n*—fine aggregate resulting from natural disintegration and abrasion of rock or processing of completely friable sandstone.

sand, manufactured, *n*—fine aggregate produced by crushing rock, gravel, iron blast-furnace slag, or hydraulic-cement concrete.

*saturated-lime water***,** *n*—see **lime-saturated water**.

segregation, *n*—the unintentional separation of the constituents of concrete or particles of an aggregate, causing a lack of uniformity in their distribution.

self-consolidating concrete, SCC—see **concrete, self-consolidating.**

setting, *n*—the process, due to chemical reactions, occurring after the addition of mixing water, that results in a gradual development of rigidity of a cementitious mixture.

shotcrete, *n*—a mortar or concrete that is projected pneumatically at high velocity onto a surface.

dry–mixture shotcrete, n—shotcrete in which most of the mixing water is added at the nozzle.

wet–mix shotcrete, n—shotcrete in which most of the ingredients, including water, are mixed prior to introduction into the delivery hose.

silica fume, *n*—very fine pozzolanic material, composed mostly of amorphous silica produced by electric arc furnaces as a by-product of the production of elemental silicon or ferro-silicon alloys (also known as condensed silica fume and microsilica). (C1240) (2009)

slump flow, *n*—the average diameter of the spread concrete mass, obtained from two measurements perpendicular to each other, after a self-consolidating concrete has ceased to flow during a slump-flow test.

DISCUSSION—Slump flow of self-consolidating concrete is measured using Test Method C1611/C1611M.

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specific gravity, *n*—the ratio of mass of a volume of a material at a stated temperature to the mass of the same volume of distilled water at a stated temperature.

stability, *n—of self-consolidating concrete (SCC),* the ability of self-consolidating concrete to resist separation of the paste from the aggregates.

stone, crushed, *n*—the product resulting from the artificial crushing of rocks, boulders, or large cobblestones, substantially all faces of which have resulted from the crushing operation.

tamping, *n*—consolidation of a fresh cementitious mixture by repeated blows to the surface of the mixture. (2009)

tapping, *n*—striking the side of a mold to close voids in a fresh cementitious mixture created by rodding or an internal vibrator. (2009)

time of setting, *n*—the elapsed time from the addition of mixing water to a cementitious mixture until the mixture reaches a specified degree of rigidity as measured by a specific procedure.

DISCUSSION—Development of rigidity during setting is a gradual and continuous process, and the time of setting is defined arbitrarily in terms of a given test method. For cementitious mixtures, time of setting is usually defined as the elapsed time to attain a specified level of resistance to penetration by a probe. For example, the time of initial setting of concrete is determined by Test Method C403/C403M and is defined as the elapsed time, after initial contact of cement and water, for the mortar sieved from the concrete to reach a penetration resistance of 500 psi (3.5 MPa).

time of final setting (of concrete), n—the elapsed time, after initial contact of cement and water, required for the mortar sieved from the concrete to reach a penetration resistance of 4000 psi (27.6 MPa). (C403/C403M).

time of initial setting (of concrete), n—the elapsed time, after initial contact of cement and water, required for the mortar sieved from the concrete to reach a penetration resistance of 500 psi (3.5 MPa). (C403/C403M)

unit weight, *n—of aggregate*, mass per unit volume. (Deprecated term—use preferred term **bulk density**).

vibration, *n*—agitation of a fresh cementitious mixture by an internal or external vibrating device to assist in consolidating the mixture in a form, mold, or container. (2009)

void, air , *n*—a space in cement paste, mortar, or concrete filled with air; an entrapped air void is characteristically 1 mm or more in width and irregular in shape; an entrained air void is typically between 10 and 1000 μm in diameter and spherical or nearly so.

DISCUSSION—The content of the voids may include atmospheric air incorporated into the concrete during mixing of air or other gases released by chemical or other processes within the fresh concrete.

water-cement ratio, *n*—the ratio of the mass of water, exclusive only of that absorbed by the aggregates, to the mass of portland cement in concrete, mortar, or grout, stated as a decimal.

DISCUSSION—This term, abbreviated as *w/c*, is applicable only to cementitious mixtures in which the only cementitious material is portland cement. For cementitious mixtures containing blended hydraulic cement, or a combination of portland cement and separate addition of another cementitious material (such as a pozzolan), use the term **water-cementitious material ratio**.

water-cementitious material ratio, *n*—the ratio of the mass of water, exclusive only of that absorbed by the aggregates, to the mass of cementitious material (*hydraulic*) in concrete, mortar, or grout, stated as a decimal (see also **water-cement ratio**).

DISCUSSION—This term, abbreviated as *w/cm*, is applicable only to cementitious mixtures which contain cementitious material other than just portland cement, such as a blended hydraulic cement, or a combination of portland cement and separate addition of another cementitious material (such as a pozzolan). When portland cement is the only cementitious material contained in the cementitious mixture, use the term **water-cement ratio**.

workability, *n—of concrete*, that property determining the effort required to manipulate a freshly mixed quantity of concrete with minimum loss of homogeneity.

4. Keywords

4.1 aggregates; concrete; definitions; terminology

SUMMARY OF CHANGES

Committee C09 has identified the location of selected changes to this terminology since the last issue, C125 – 09, that may impact the use of this terminology. (Approved December 15, 2009)

(*1*) Added new terms **consolidation**, **rodding**, **silica fume**, **tamping**, **tapping**, and **vibration**.

Committee C09 has identified the location of selected changes to this terminology since the last issue, C125 – 07, that may impact the use of this terminology. (Approved December 1, 2009)

(*1*) Revised Note 1.

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Designation: C 127 – 07

Standard Test Method for Density, Relative Density (Specific Gravity), and Absorption of Coarse Aggregate[1]

This standard is issued under the fixed designation C 127; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

This standard has been approved for use by agencies of the Department of Defense.

1. Scope*

1.1 This test method covers the determination of the average density of a quantity of coarse aggregate particles (not including the volume of voids between the particles), the relative density (specific gravity), and the absorption of the coarse aggregate. Depending on the procedure used, the density (kg/m^3 (lb/ft^3)) is expressed as oven-dry (OD), saturated-surface-dry (SSD), or as apparent density. Likewise, relative density (specific gravity), a dimensionless quantity, is expressed as OD, SSD, or as apparent relative density (apparent specific gravity). The OD density and OD relative density are determined after drying the aggregate. The SSD density, SSD relative density, and absorption are determined after soaking the aggregate in water for a prescribed duration.

1.2 This test method is used to determine the density of the essentially solid portion of a large number of aggregate particles and provides an average value representing the sample. Distinction is made between the density of aggregate particles as determined by this test method, and the bulk density of aggregates as determined by Test Method C 29/C 29M, which includes the volume of voids between the particles of aggregates.

1.3 This test method is not intended to be used with lightweight aggregates.

1.4 The values stated in SI units are to be regarded as the standard for conducting the tests. The test results for density shall be reported in either SI units or inch-pound units, as appropriate for the use to be made of the results.

1.5 The text of this test method references notes and footnotes which provide explanatory material. These notes and footnotes (excluding those in tables and figures) shall not be considered as requirements of this test method.

1.6 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

2. Referenced Documents

2.1 *ASTM Standards:* [2]

C 29/C 29M Test Method for Bulk Density ("Unit Weight") and Voids in Aggregate

C 125 Terminology Relating to Concrete and Concrete Aggregates

C 128 Test Method for Density, Relative Density (Specific Gravity), and Absorption of Fine Aggregate

C 136 Test Method for Sieve Analysis of Fine and Coarse Aggregates

C 566 Test Method for Total Evaporable Moisture Content of Aggregate by Drying

C 670 Practice for Preparing Precision and Bias Statements for Test Methods for Construction Materials

C 702 Practice for Reducing Samples of Aggregate to Testing Size

D 75 Practice for Sampling Aggregates

D 448 Classification for Sizes of Aggregate for Road and Bridge Construction

E 11 Specification for Wire Cloth and Sieves for Testing Purposes

2.2 *AASHTO Standard:*

AASHTO No. T 85 Specific Gravity and Absorption of Coarse Aggregate[3]

3. Terminology

3.1 *Definitions:*

3.1.1 *absorption*, *n*—the increase in mass of aggregate due to water penetration into the pores of the particles during a

[1] This test method is under the jurisdiction of ASTM Committee C09 on Concrete and Concrete Aggregates and is the direct responsibility of Subcommittee C09.20 on Normal Weight Aggregates.

Current edition approved Aug. 1, 2007. Published September 2007. Originally approved in 1936. Last previous edition approved in 2004 as C 127 – 04.

[2] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

[3] Available from American Association of State Highway and Transportation Officials (AASHTO), 444 N. Capitol St., NW, Suite 249, Washington, DC 20001, http://www.transportation.org.

***A Summary of Changes section appears at the end of this standard.**

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prescribed period of time, but not including water adhering to the outside surface of the particles, expressed as a percentage of the dry mass.

3.1.2 *oven-dry (OD), adj—related to aggregate particles,* the condition in which the aggregates have been dried by heating in an oven at 110 ± 5 °C for sufficient time to reach a constant mass.

3.1.3 *saturated-surface-dry (SSD), adj—related to aggregate particles*, the condition in which the permeable pores of aggregate particle are filled with water to the extent achieved by submerging in water for the prescribed period of time, but without free water on the surface of the particles.

3.1.4 *density, n*—the mass per unit volume of a material, expressed as kilograms per cubic metre (pounds per cubic foot).

3.1.4.1 *density (OD), n*—the mass of oven dry aggregate per unit volume of aggregate particles, including the volume of permeable and impermeable pores within the particles, but not including the voids between the particles.

3.1.4.2 *density (SSD), n*—the mass of saturated-surface-dry aggregate per unit volume of the aggregate particles, including the volume of impermeable pores and permeable, water-filled pores within the particles, but not including the voids between the particles.

3.1.4.3 *apparent density, n*—the mass per unit volume of the impermeable portion of the aggregate particles.

3.1.5 *relative density (specific gravity), n*—the ratio of the density of a material to the density of distilled water at a stated temperature; the values are dimensionless.

3.1.5.1 *relative density (specific gravity) (OD), n*—the ratio of the density (OD) of the aggregate to the density of distilled water at a stated temperature.

3.1.5.2 *relative density (specific gravity) (SSD), n*—the ratio of the density (SSD) of the aggregate to the density of distilled water at a stated temperature.

3.1.5.3 *apparent relative density (apparent specific gravity), n*—the ratio of the apparent density of aggregate to the density of distilled water at a stated temperature.

3.1.6 For definitions of other terms related to aggregates, see Terminology C 125.

4. Summary of Test Method

4.1 A sample of aggregate is immersed in water for 24 ± 4 h to essentially fill the pores. It is then removed from the water, the water dried from the surface of the particles, and the mass determined. Subsequently, the volume of the sample is determined by the displacement of water method. Finally, the sample is oven-dried and the mass determined. Using the mass values thus obtained and formulas in this test method, it is possible to calculate density, relative density (specific gravity), and absorption.

5. Significance and Use

5.1 Relative density (specific gravity) is the characteristic generally used for calculation of the volume occupied by the aggregate in various mixtures containing aggregate, including portland cement concrete, bituminous concrete, and other mixtures that are proportioned or analyzed on an absolute volume basis. Relative density (specific gravity) is also used in the computation of voids in aggregate in Test Method C 29/C 29M. Relative density (specific gravity) (SSD) is used if the aggregate is wet, that is, if its absorption has been satisfied. Conversely, the relative density (specific gravity) (OD) is used for computations when the aggregate is dry or assumed to be dry.

5.2 Apparent density and apparent relative density (apparent specific gravity) pertain to the solid material making up the constituent particles not including the pore space within the particles which is accessible to water.

5.3 Absorption values are used to calculate the change in the mass of an aggregate due to water absorbed in the pore spaces within the constituent particles, compared to the dry condition, when it is deemed that the aggregate has been in contact with water long enough to satisfy most of the absorption potential. The laboratory standard for absorption is that obtained after submerging dry aggregate for a prescribed period of time. Aggregates mined from below the water table commonly have a moisture content greater than the absorption determined by this test method, if used without opportunity to dry prior to use. Conversely, some aggregates which have not been continuously maintained in a moist condition until used are likely to contain an amount of absorbed moisture less than the 24-h soaked condition. For an aggregate that has been in contact with water and that has free moisture on the particle surfaces, the percentage of free moisture is determined by deducting the absorption from the total moisture content determined by Test Method C 566.

5.4 The general procedures described in this test method are suitable for determining the absorption of aggregates that have had conditioning other than the 24-h soak, such as boiling water or vacuum saturation. The values obtained for absorption by other test methods will be different than the values obtained by the prescribed soaking, as will the relative density (specific gravity) (SSD).

5.5 The pores in lightweight aggregates are not necessarily filled with water after immersion for 24 h. In fact, the absorption potential for many such aggregates is not satisfied after several days' immersion in water. Therefore, this test method is not intended for use with lightweight aggregate.

6. Apparatus

6.1 *Balance*—A device for determining mass that is sensitive, readable, and accurate to 0.05 % of the sample mass at any point within the range used for this test, or 0.5 g, whichever is greater. The balance shall be equipped with suitable apparatus for suspending the sample container in water from the center of the platform or pan of the balance.

6.2 *Sample Container*—A wire basket of 3.35 mm (No. 6) or finer mesh, or a bucket of approximately equal breadth and height, with a capacity of 4 to 7 L for 37.5-mm (1½-in.) nominal maximum size aggregate or smaller, and a larger container as needed for testing larger maximum size aggregate. The container shall be constructed so as to prevent trapping air when the container is submerged.

6.3 *Water Tank*—A watertight tank into which the sample container is placed while suspended below the balance.

6.4 *Sieves*—A 4.75-mm (No. 4) sieve or other sizes as needed (see 7.2-7.4), conforming to Specification E 11.

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6.5 *Oven*—An oven of sufficient size, capable of maintaining a uniform temperature of 110 ± 5 °C (230 ± 9 °F).

7. Sampling

7.1 Sample the aggregate in accordance with Practice D 75.

7.2 Thoroughly mix the sample of aggregate and reduce it to the approximate quantity needed using the applicable procedures in Practice C 702. Reject all material passing a 4.75-mm (No. 4) sieve by dry sieving and thoroughly washing to remove dust or other coatings from the surface. If the coarse aggregate contains a substantial quantity of material finer than the 4.75-mm sieve (such as for Size No. 8 and 9 aggregates in Classification D 448), use the 2.36-mm (No. 8) sieve in place of the 4.75-mm sieve. Alternatively, separate the material finer than the 4.75-mm sieve and test the finer material according to Test Method C 128.

NOTE 1—If aggregates smaller than 4.75 mm (No. 4) are used in the sample, check to ensure that the size of the openings in the sample container is smaller than the minimum size aggregate.

7.3 The minimum mass of test sample to be used is given as follows. Testing the coarse aggregate in several size fractions is permitted. If the sample contains more than 15 % retained on the 37.5-mm (1½-in.) sieve, test the material larger than 37.5 mm in one or more size fractions separately from the smaller size fractions. When an aggregate is tested in separate size fractions, the minimum mass of test sample for each fraction shall be the difference between the masses prescribed for the maximum and minimum sizes of the fraction.

Nominal Maximum Size, mm (in.)	Minimum Mass of Test Sample, kg (lb)
12.5 (½) or less	2 (4.4)
19.0 (¾)	3 (6.6)
25.0 (1)	4 (8.8)
37.5 (1½)	5 (11)
50 (2)	8 (18)
63 (2½)	12 (26)
75 (3)	18 (40)
90 (3½)	25 (55)
100 (4)	40 (88)
125 (5)	75 (165)

7.4 If the sample is tested in two or more size fractions, determine the grading of the sample in accordance with Test Method C 136, including the sieves used for separating the size fractions for the determinations in this method. In calculating the percentage of material in each size fraction, ignore the quantity of material finer than the 4.75-mm (No. 4) sieve (or 2.36-mm (No. 8) sieve when that sieve is used in accordance with 7.2).

NOTE 2—When testing coarse aggregate of large nominal maximum size requiring large test samples, it may be more convenient to perform the test on two or more subsamples, and the values obtained combined for the computations described in Section 9.

8. Procedure

8.1 Dry the test sample in the oven to constant mass at a temperature of 110 ± 5 °C, cool in air at room temperature for 1 to 3 h for test samples of 37.5-mm (1½-in.) nominal maximum size, or longer for larger sizes until the aggregate has cooled to a temperature that is comfortable to handle (approximately 50 °C). Subsequently immerse the aggregate in water at room temperature for a period of 24 ± 4 h.

8.2 Where the absorption and relative density (specific gravity) values are to be used in proportioning concrete mixtures in which the aggregates will be in their naturally moist condition, the requirement in 8.1 for initial drying is optional, and, if the surfaces of the particles in the sample have been kept continuously wet until tested, the requirement in 8.1 for 24 ± 4 h soaking is also optional.

NOTE 3—Values for absorption and relative density (specific gravity) (SSD) may be significantly higher for aggregate not oven dried before soaking than for the same aggregate treated in accordance with 8.1. This is especially true of particles larger than 75 mm since the water may not be able to penetrate the pores to the center of the particle in the prescribed soaking period.

8.3 Remove the test sample from the water and roll it in a large absorbent cloth until all visible films of water are removed. Wipe the larger particles individually. A moving stream of air is permitted to assist in the drying operation. Take care to avoid evaporation of water from aggregate pores during the surface-drying operation. Determine the mass of the test sample in the saturated surface-dry condition. Record this and all subsequent masses to the nearest 0.5 g or 0.05 % of the sample mass, whichever is greater.

8.4 After determining the mass in air, immediately place the saturated-surface-dry test sample in the sample container and determine its apparent mass in water at 23 ± 2.0 °C. Take care to remove all entrapped air before determining its mass by shaking the container while immersed.

NOTE 4—The difference between the mass in air and the mass when the sample is submerged in water equals the mass of water displaced by the sample.

NOTE 5—The container should be immersed to a depth sufficient to cover it and the test sample while determining the apparent mass in water. Wire suspending the container should be of the smallest practical size to minimize any possible effects of a variable immersed length.

8.5 Dry the test sample in the oven to constant mass at a temperature of 110 ± 5 °C, cool in air at room temperature 1 to 3 h, or until the aggregate has cooled to a temperature that is comfortable to handle (approximately 50 °C), and determine the mass.

9. Calculations

9.1 *Relative Density (Specific Gravity)*:

9.1.1 *Relative Density (Specific Gravity) (OD)*—Calculate the relative density (specific gravity) on the basis of oven-dry aggregate as follows:

$$\text{Relative density (specific gravity) (OD)} = A/(B - C) \quad (1)$$

where:

A = mass of oven-dry test sample in air, g,
B = mass of saturated-surface-dry test sample in air, g, and
C = apparent mass of saturated test sample in water, g.

9.1.2 *Relative Density (Specific Gravity) (SSD)*—Calculate the relative density (specific gravity) on the basis of saturated-surface-dry aggregate as follows:

$$\text{Relative density (specific gravity) (SSD)} = B/(B - C) \quad (2)$$

9.1.3 *Apparent Relative Density (Apparent Specific Gravity)*—Calculate the apparent relative density (apparent specific gravity) as follows:

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$$\text{Apparent relative density (apparent specific gravity)} = A/(A - C) \quad (3)$$

9.2 *Density*:

9.2.1 *Density (OD)*—Calculate the density on the basis of oven-dry aggregate as follows:

$$\text{Density (OD), kg/m}^3, = 997.5\ A/(B - C) \quad (4)$$

$$\text{Density (OD), lb/ft}^3, = 62.27\ A/(B - C) \quad (5)$$

NOTE 6—The constant values used in the calculations in 9.2.1-9.2.3 (997.5 kg/m^3 and 62.27 lb/ft^3) are the density of water at 23 °C.

9.2.2 *Density (SSD)*—Calculate the density on the basis of saturated-surface-dry aggregate as follows:

$$\text{Density (SSD), kg/m}^3, = 997.5\ B/(B - C) \quad (6)$$

$$\text{Density (SSD), lb/ft}^3, = 62.27\ B/(B - C) \quad (7)$$

9.2.3 *Apparent Density*—Calculate the apparent density as follows:

$$\text{Apparent density, kg/m}^3 = 997.5\ A/(A - C) \quad (8)$$

$$\text{Apparent density, lb/ft}^3 = 62.27\ A/(A - C) \quad (9)$$

9.3 *Average Density and Relative Density (Specific Gravity) Values*—When the sample is tested in separate size fractions, compute the average values for density or relative density (specific gravity) of the size fraction computed in accordance with 9.1 or 9.2 using the following equation:

$$G = \frac{1}{\frac{P_1}{100\,G_1} + \frac{P_2}{100\,G_2} + \cdots \frac{P_n}{100\,G_n}} \text{ (see AppendixX1)} \quad (10)$$

where:

G = average density or relative density (specific gravity). All forms of expression of density or relative density (specific gravity) can be averaged in this manner,

$G_1, G_2 \ldots G_n$ = appropriate average density or relative density (specific gravity) values for each size fraction depending on the type of density or relative density (specific gravity) being averaged, and

$P_1, P_2, \ldots P_n$ = mass percentages of each size fraction present in the original sample (not including finer material—see 7.4).

9.4 *Absorption*—Calculate the percentage of absorption, as follows:

$$\text{Absorption, \%} = [(B - A)/A] \times 100 \quad (11)$$

NOTE 7—Some authorities recommend using the density of water at 4 °C (1000 kg/m^3 or 1.000 Mg/m^3 or 62.43 lb/ft ^{3}) as being sufficiently accurate.

9.5 *Average Absorption Value*—When the sample is tested in separate size fractions, the average absorption value is the average of the values as computed in 9.4, weighted in proportion to the mass percentages of each size fraction present in the original sample (not including finer material—see 7.4) as follows:

$$A = (P_1A_1/100) + (P_2A_2/100) + \ldots\ (P_nA_n/100) \quad (12)$$

where:

A = average absorption, %,

$A_1, A_2 \ldots A_n$ = absorption percentages for each size fraction, and

$P_1, P_2, \ldots P_n$ = mass percentages of each size fraction present in the original sample.

10. Report

10.1 Report density results to the nearest 10 kg/m^3, or 0.5 lb/ft^3, relative density (specific gravity) results to the nearest 0.01, and indicate the basis for density or relative density (specific gravity), as either (OD), (SSD), or apparent.

10.2 Report the absorption result to the nearest 0.1 %.

10.3 If the density, relative density (specific gravity) and absorption values were determined without first drying the aggregate, as permitted in 8.2, note that fact in the report.

11. Precision and Bias

11.1 The estimates of precision of this test method listed in Table 1 are based on results from the AASHTO Materials Reference Laboratory Proficiency Sample Program, with testing conducted by this test method and AASHTO Method T 85. The significant difference between the methods is that Test Method C 127 requires a saturation period of 24 ± 4 h, while AASHTO Method T 85 requires a saturation period of 15 h minimum. This difference has been found to have an insignificant effect on the precision indices. The data are based on the analyses of more than 100 paired test results from 40 to 100 laboratories. The precision estimates for density were calculated from values determined for relative density (specific gravity), using the density of water at 23 °C for the conversion.

11.2 *Bias*—Since there is no accepted reference material for determining the bias for the procedure in this test method, no statement on bias is being made.

TABLE 1 Precision

	Standard Deviation (1s)[A]	Acceptable Range of Two Results (d2s)[A]
Single-Operator Precision:		
Density (OD), kg/m^3	9	25
Density (SSD), kg/m^3	7	20
Apparent density, kg/m^3	7	20
Relative density (specific gravity) (OD)	0.009	0.025
Relative density (specific gravity) (SSD)	0.007	0.020
Apparent relative density (apparent specific gravity)	0.007	0.020
Multilaboratory Precision:		
Density (OD), kg/m^3	13	38
Density (SSD), kg/m^3	11	32
Apparent density, kg/m^3	11	32
Relative density (specific gravity) (OD)	0.013	0.038
Relative density (specific gravity) (SSD)	0.011	0.032
Apparent relative density (apparent specific gravity)	0.011	0.032

[A] These numbers represent, respectively, the (1s) and (d2s) limits as described in Practice C 670. The precision estimates were obtained from the analysis of combined AASHTO Materials Reference Laboratory proficiency sample data from laboratories using 15 h minimum saturation times and other laboratories using 24 ± 4 h saturation times. Testing was performed on normal-weight aggregates, and started with aggregates in the oven-dry condition.

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12. Keywords

12.1 absorption; aggregate; apparent density; apparent relative density; coarse aggregate; density; relative density; specific gravity

APPENDIXES

(Nonmandatory Information)

X1. DEVELOPMENT OF EQUATIONS

X1.1 The derivation of the equation is from the following simplified cases using two solids. Solid 1 has a mass M_1 in grams and a volume V_1 in millilitres; its relative density (specific gravity) (G_1) is therefore M_1/V_1. Solid 2 has a mass M_2 and volume V_2, and $G_2 = M_2/V_2$. If the two solids are considered together, the relative density (specific gravity) of the combination is the total mass in grams divided by the total volume in millilitres:

$$G = (M_1 + M_2) / (V_1 + V_2) \tag{X1.1}$$

Manipulation of this equation yields the following:

$$G = \frac{1}{\frac{V_1 + V_2}{M_1 + M_2}} = \frac{1}{\frac{V_1}{M_1 + M_2} + \frac{V_2}{M_1 + M_2}} \tag{X1.2}$$

$$G = \frac{1}{\frac{M_1}{M_1 + M_2}\left(\frac{V_1}{M_1}\right) + \frac{M_2}{M_1 + M_2}\left(\frac{V_2}{M_2}\right)} \tag{X1.3}$$

However, the mass fractions of the two solids are:

$$M_1/(M_1 + M_2) = P_1/100 \text{ and } M_2/(M_1 + M_2) = P_2/100 \tag{X1.4}$$

and,

$$1/G_1 = V_1/M_1 \text{ and } 1/G_2 = V_2/M_2 \tag{X1.5}$$

Therefore,

$$G = \frac{1}{\frac{P_1}{100}\frac{1}{G_1} + \frac{P_2}{100}\frac{1}{G_2}} \tag{X1.6}$$

An example of the computation is given in Table X1.1.

TABLE X1.1 Example of Calculation of Weighted Values of Relative Density (Specific Gravity) and Absorption for a Coarse Aggregate Tested in Separate Sizes

Size Fraction, mm (in.)	% in Original Sample	Sample Mass Used in Test, g	Relative Density (Specific Gravity) (SSD)	Absorption, %
4.75 to 12.5 (No. 4 to ½)	44	2213.0	2.72	0.4
12.5 to 37.5 (½ to 1½)	35	5462.5	2.56	2.5
37.5 to 63 (1½ to 2½)	21	12593.0	2.54	3.0

Average Relative Density (Specific Gravity) (SSD)

$$G_{SSD} = \frac{1}{\frac{0.44}{2.72} + \frac{0.35}{2.56} + \frac{0.21}{2.54}} = 2.62$$

Average Absorption

$$A = (0.44)\,(0.4) + (0.35)\,(2.5) + (0.21)\,(3.0) = 1.7\ \%$$

X2. INTERRELATIONSHIPS BETWEEN RELATIVE DENSITIES (SPECIFIC GRAVITIES) AND ABSORPTION AS DEFINED IN TEST METHODS C 127 AND C 128

X2.1 Where:

S_d = relative density (specific gravity) (OD),
S_s = relative density (specific gravity) (SSD),
S_a = apparent relative density (apparent specific gravity), and
A = absorption in %.

X2.2 Calculate the values of each as follows:

$$S_s = (1 + A/100)S_d \tag{X2.1}$$

$$S_a = \frac{1}{\frac{1}{S_d} - \frac{A}{100}} = \frac{S_d}{1 - \frac{AS_d}{100}} \tag{X2.2}$$

$$S_a = \frac{1}{\frac{1 + A/100}{S_s} - \frac{A}{100}} = \frac{S_s}{1 - \left[\frac{A}{100}(S_s - 1)\right]} \tag{X2.3}$$

$$A = \left(\frac{S_s}{S_d} - 1\right) 100 \tag{X2.4}$$

$$A = \left(\frac{S_a - S_s}{S_a(S_s - 1)}\right) 100 \tag{X2.5}$$

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SUMMARY OF CHANGES

Committee C09 has identified the location of selected changes to this test method since the last issue, C 127 – 04, that may impact the use of this test method. (Approved August 1, 2007)

(*1*) Revised 3.1.4.2.

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Designation: C 128 – 07a

Standard Test Method for Density, Relative Density (Specific Gravity), and Absorption of Fine Aggregate[1]

This standard is issued under the fixed designation C 128; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

This standard has been approved for use by agencies of the Department of Defense.

1. Scope*

1.1 This test method covers the determination of the average density of a quantity of fine aggregate particles (not including the volume of voids between the particles), the relative density (specific gravity), and the absorption of the fine aggregate. Depending on the procedure used, the density, in kg/m^3(lb/ft^3) is expressed as oven-dry (OD), saturated-surface-dry (SSD), or as apparent density. Likewise, relative density (specific gravity), a dimensionless quality, is expressed as OD, SSD, or as apparent relative density (apparent specific gravity). The OD density and OD relative density are determined after drying the aggregate. The SSD density, SSD relative density, and absorption are determined after soaking the aggregate in water for a prescribed duration.

1.2 This test method is used to determine the density of the essentially solid portion of a large number of aggregate particles and provides an average value representing the sample. Distinction is made between the density of aggregate particles as determined by this test method, and the bulk density of aggregates as determined by Test Method C 29/C 29M, which includes the volume of voids between the particles of aggregates.

1.3 This test method is not intended to be used for lightweight aggregates.

1.4 The values stated in SI units are to be regarded as the standard for conducting the tests. The test results for density shall be reported in either SI units or inch-pound units, as appropriate for the use to be made of the results.

1.5 The text of this test method references notes and footnotes which provide explanatory material. These notes and footnotes (excluding those in tables and figures) shall not be considered as requirements of this test method.

1.6 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

2. Referenced Documents

2.1 *ASTM Standards:* [2]

C 29/C 29M Test Method for Bulk Density ("Unit Weight") and Voids in Aggregate

C 70 Test Method for Surface Moisture in Fine Aggregate

C 117 Test Method for Materials Finer than 75-µm (No. 200) Sieve in Mineral Aggregates by Washing

C 125 Terminology Relating to Concrete and Concrete Aggregates

C 127 Test Method for Density, Relative Density (Specific Gravity), and Absorption of Coarse Aggregate

C 188 Test Method for Density of Hydraulic Cement

C 566 Test Method for Total Evaporable Moisture Content of Aggregate by Drying

C 670 Practice for Preparing Precision and Bias Statements for Test Methods for Construction Materials

C 702 Practice for Reducing Samples of Aggregate to Testing Size

D 75 Practice for Sampling Aggregates

D 854 Test Methods for Specific Gravity of Soil Solids by Water Pycnometer

2.2 *AASHTO Standard:*

AASHTO No. T 84 Specific Gravity and Absorption of Fine Aggregates[3]

3. Terminology

3.1 *Definitions:*

3.1.1 *absorption*, *n*—the increase in mass of aggregate due to water penetrating into the pores of the particles, during a

[1] This test method is under the jurisdiction of ASTM Committee C09 on Concrete and Concrete Aggregates and is the direct responsibility of Subcommittee C09.20 on Normal Weight Aggregates.

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[2] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

[3] Available from American Association of State Highway and Transportation Officials (AASHTO), 444 N. Capitol St., NW, Suite 249, Washington, DC 20001, http://www.transportation.org.

***A Summary of Changes section appears at the end of this standard.**

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prescribed period of time but not including water adhering to the outside surface of the particles, expressed as percentage of the dry mass.

3.1.2 *density*, *n*—the mass per unit volume of a material, expressed as kilograms per cubic metre (pounds per cubic foot).

3.1.2.1 *density (OD), n*—the mass of oven-dry aggregate particles per unit volume of aggregate particles, including the volume of permeable and impermeable pores within particles, but not including the voids between the particles.

3.1.2.2 *density (SSD), n*—the mass of saturated-surface-dry aggregate per unit volume of the aggregate particles, including the volume of impermeable pores and permeable, water-filled pores within the particles, but not including the voids between the particles.

3.1.2.3 *apparent density, n*—the mass per unit volume of the impermeable portion of the aggregate particles.

3.1.3 *oven-dry (OD), adj—related to aggregate particles,* the condition in which the aggregates have been dried by heating in an oven at 110 ± 5 °C for sufficient time to reach a constant mass.

3.1.4 *relative density (specific gravity), n*—the ratio of the density of a material to the density of water at a stated temperature; the values are dimensionless.

3.1.4.1 *relative density (specific gravity), (OD), n*—the ratio of the density (OD) of the aggregate to the density of water at a stated temperature.

3.1.4.2 *relative density (specific gravity), (SSD), n*—The ratio of the density (SSD) of the aggregate to the density of water at a stated temperature.

3.1.4.3 *apparent relative density (apparent specific gravity), n*—the ratio of the apparent density of aggregate to the density of water at a stated temperature.

3.1.5 *saturated-surface-dry (SSD), adj—related to aggregate particles,* the condition in which the permeable pores of aggregate particles are filled with water to the extent achieved by submerging in water for the prescribed period of time, but without free water on the surface of the particles.

3.1.6 For definitions of other terms related to aggregates see Terminology C 125.

4. Summary of Test Method

4.1 A sample of aggregate is immersed in water for 24 ± 4 h to essentially fill the pores. It is then removed from the water, the water is dried from the surface of the particles, and the mass determined. Subsequently, the sample (or a portion of it) is placed in a graduated container and the volume of the sample is determined by the gravimetric or volumetric method. Finally, the sample is oven-dried and the mass determined again. Using the mass values thus obtained and formulas in this test method, it is possible to calculate density, relative density (specific gravity), and absorption.

5. Significance and Use

5.1 Relative density (specific gravity) is the characteristic generally used for calculation of the volume occupied by the aggregate in various mixtures containing aggregate including portland cement concrete, bituminous concrete, and other mixtures that are proportioned or analyzed on an absolute volume basis. Relative density (specific gravity) is also used in the computation of voids in aggregate in Test Method C 29/C 29M. Relative density (specific gravity) (SSD) is used in the determination of surface moisture on fine aggregate by displacement of water in Test Method C 70. Relative density (specific gravity) (SSD) is used if the aggregate is wet, that is, if its absorption has been satisfied. Conversely, the density or relative density (specific gravity) (OD) is used for computations when the aggregate is dry or assumed to be dry.

5.2 Apparent density and apparent relative density (apparent specific gravity) pertain to the solid material making up the constituent particles not including the pore space within the particles that is accessible to water. This value is not widely used in construction aggregate technology.

5.3 Absorption values are used to calculate the change in the mass of an aggregate material due to water absorbed in the pore spaces within the constituent particles, compared to the dry condition, when it is deemed that the aggregate has been in contact with water long enough to satisfy most of the absorption potential. The laboratory standard for absorption is that obtained after submerging dry aggregate for a prescribed period of time. Aggregates mined from below the water table commonly have a moisture content greater than the absorption determined by this test method, if used without opportunity to dry prior to use. Conversely, some aggregates which have not been continuously maintained in a moist condition until used are likely to contain an amount of absorbed moisture less than the 24-h soaked condition. For an aggregate that has been in contact with water and that has free moisture on the particle surfaces, the percentage of free moisture is determined by deducting the absorption from the total moisture content determined by Test Method C 566 by drying.

5.4 The general procedures described in this test method are suitable for determining the absorption of aggregates that have had conditioning other than the 24-h soak, such as boiling water or vacuum saturation. The values obtained for absorption by other test methods will be different than the values obtained by the prescribed 24-h soak, as will the density (SSD) or relative density (specific gravity (SSD).

5.5 The pores in lightweight aggregates are not necessarily filled with water after immersion for 24 h. In fact, the absorption potential for many such aggregates is not satisfied after several days immersion in water. Therefore, this test method is not intended for use with lightweight aggregate.

6. Apparatus

6.1 *Balance*—A balance or scale having a capacity of 1 kg or more, sensitive to 0.1 g or less, and accurate within 0.1 % of the test load at any point within the range of use for this test method. Within any 100-g range of test load, a difference between readings shall be accurate within 0.1 g.

6.2 *Pycnometer (for Use with Gravimetric Procedure)*—A flask or other suitable container into which the fine aggregate test sample can be readily introduced and in which the volume content can be reproduced within ± 0.1 cm^3. The volume of the container filled to mark shall be at least 50 % greater than

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the space required to accommodate the test sample. A volumetric flask of 500-cm^3 capacity or a fruit jar fitted with a pycnometer top is satisfactory for a 500-g test sample of most fine aggregates.

6.3 *Flask (for Use with Volumetric Procedure)*—A Le Chatelier flask as described in Test Method C 188 is satisfactory for an approximately 55-g test sample.

6.4 *Mold and Tamper for Surface Moisture Test*—The metal mold shall be in the form of a frustum of a cone with dimensions as follows: 40 ± 3-mm inside diameter at the top, 90± 3-mm inside diameter at the bottom, and 75 ± 3 mm in height, with the metal having a minimum thickness of 0.8 mm. The metal tamper shall have a mass of 340 ± 15 g and a flat circular tamping face 25 ± 3 mm in diameter.

6.5 *Oven*—An oven of sufficient size, capable of maintaining a uniform temperature of 110 ± 5 °C (230 ± 9 °F).

7. Sampling

7.1 Sample the aggregate in accordance with Practice D 75. Thoroughly mix the sample and reduce it to obtain a test specimen of approximately 1 kg using the applicable procedures described in Practice C 702.

8. Preparation of Test Specimen

8.1 Place the test specimen in a suitable pan or vessel and dry in the oven to constant mass at a temperature of 110 ± 5 °C (230 ± 9 °F). Allow it to cool to comfortable handling temperature (approximately 50 °C), cover with water, either by immersion or by the addition of at least 6 % moisture to the fine aggregate, and permit to stand for 24 ± 4 h.

8.1.1 Where the absorption and relative density (specific gravity) values are to be used in proportioning concrete mixtures in which the aggregates will be in their naturally moist condition, the requirement in 8.1 for initial drying is optional, and, if the surfaces of the particles in the sample have been kept continuously wet until tested, the requirement in 8.1 for 24 ± 4 h soaking is also optional.

NOTE 1—Values for absorption and for relative density (specific gravity) (SSD) may be significantly higher for aggregate not oven dried before soaking than for the same aggregate treated in accordance with 8.1.

8.2 Decant excess water with care to avoid loss of fines (see also Appendix X1), spread the sample on a flat nonabsorbent surface exposed to a gently moving current of warm air, and stir frequently to secure homogeneous drying. Employ mechanical aids such as tumbling or stirring to assist in achieving the saturated surface-dry condition, if desired. Continue this operation until the test specimen approaches a free-flowing condition. Follow the procedure in 8.3 to determine if surface moisture is still present on the constituent fine aggregate particles. Make the first trial for surface moisture when there is still some surface water in the test specimen. Continue drying with constant stirring and test at frequent intervals until the test indicates that the specimen has reached a surface-dry condition. If the first trial of the surface moisture test indicates that moisture is not present on the surface, it has been dried past the saturated surface-dry condition. In this case, thoroughly mix a few millilitres of water with the fine aggregate and permit the specimen to stand in a covered container for 30 min. Then resume the process of drying and testing at frequent intervals for the onset of the surface-dry condition.

8.3 *Test for Surface Moisture*—Hold the mold firmly on a smooth nonabsorbent surface with the large diameter down. Place a portion of the partially dried fine aggregate loosely in the mold by filling it to overflowing and heaping additional material above the top of the mold by holding it with the cupped fingers of the hand holding the mold. Lightly tamp the fine aggregate into the mold with 25 light drops of the tamper. Start each drop approximately 5 mm above the top surface of the fine aggregate. Permit the tamper to fall freely under gravitational attraction on each drop. Adjust the starting height to the new surface elevation after each drop and distribute the drops over the surface. Remove loose sand from the base and lift the mold vertically. If surface moisture is still present, the fine aggregate will retain the molded shape. Slight slumping of the molded fine aggregate indicates that it has reached a surface-dry condition.

8.3.1 Some fine aggregate with predominately angular-shaped particles or with a high proportion of fines does not slump in the cone test upon reaching the surface-dry condition. Test by dropping a handful of the fine aggregate from the cone test onto a surface from a height of 100 to 150 mm, and observe for fines becoming airborne; presence of airborne fines indicates this problem. For these materials, consider the saturated surface-dry condition as the point that one side of the fine aggregate slumps slightly upon removing the mold.

NOTE 2—The following criteria have also been used on materials that do not readily slump:

(1) Provisional Cone Test—Fill the cone mold as described in 8.3 except only use 10 drops of the tamper. Add more fine aggregate and use 10 drops of the tamper again. Then add material two more times using 3 and 2 drops of the tamper, respectively. Level off the material even with the top of the mold, remove loose material from the base; and lift the mold vertically.

(2) Provisional Surface Test—If airborne fines are noted when the fine aggregate is such that it will not slump when it is at a moisture condition, add more moisture to the sand, and at the onset of the surface-dry condition, with the hand lightly pat approximately 100 g of the material on a flat, dry, clean, dark or dull nonabsorbent surface such as a sheet of rubber, a worn oxidized, galvanized, or steel surface, or a black-painted metal surface. After 1 to 3 s, remove the fine aggregate. If noticeable moisture shows on the test surface for more than 1 to 2 s then surface moisture is considered to be present on the fine aggregate.

(3) Colorimetric procedures described by Kandhal and Lee, Highway Research Record No. 307, p. 44.

(4) For reaching the saturated surface-dry condition on a single size material that slumps when wet, hard-finish paper towels can be used to surface dry the material until the point is just reached where the paper towel does not appear to be picking up moisture from the surfaces of the fine aggregate particles.

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9. Procedure

9.1 Test by either the gravimetric procedure in 9.2 or the volumetric procedure in 9.3. Make all determinations of mass to 0.1 g.

9.2 *Gravimetric (Pycnometer) Procedure*:

9.2.1 Partially fill the pycnometer with water. Introduce into the pycnometer 500 ± 10 g of saturated surface-dry fine aggregate prepared as described in Section 8, and fill with additional water to approximately 90 % of capacity. Agitate the pycnometer as described in 9.2.1.1 (manually) or 9.2.1.2 (mechanically).

9.2.1.1 Manually roll, invert, or agitate the pycnometer (or use a combination of these actions) to eliminate visible air bubbles.

NOTE 3—About 15 to 20 min are normally required to eliminate the air bubbles by manual methods. Dipping the tip of a paper towel into the pycnometer has been found to be useful in dispersing the foam that sometimes builds up when eliminating the air bubbles. Optionally, a small amount of isopropyl alcohol may be used to disperse the foam.

9.2.1.2 Mechanically agitate the pycnometer by external vibration in a manner that will not degrade the sample. A level of agitation adjusted to just set individual particles in motion is sufficient to promote de-airing without degradation. A mechanical agitator shall be considered acceptable for use if comparison tests for each six-month period of use show variations less that the acceptable range of two results (d2s) indicated in Table 1 from the results of manual agitation on the same material.

9.2.2 After eliminating all air bubbles, adjust the temperature of the pycnometer and its contents to 23.0 ± 2.0 °C if necessary by partial immersion in circulating water, and bring the water level in the pycnometer to its calibrated capacity. Determine the total mass of the pycnometer, specimen, and water.

9.2.3 Remove the fine aggregate from the pycnometer, dry in the oven to constant mass at a temperature of 110 ± 5 °C (230 ± 9 °F), cool in air at room temperature for 1 ± ½ h, and determine the mass.

9.2.4 Determine the mass of the pycnometer filled to its calibrated capacity with water at 23.0 ± 2.0 °C.

9.3 *Volumetric (Le Chatelier Flask) Procedure*:

9.3.1 Fill the flask initially with water to a point on the stem between the 0 and the 1-mL mark. Record this initial reading with flask and contents within the temperature range of 23.0 ± 2.0 °C. Add 55 ± 5 g of fine aggregate in the saturated surface-dry condition (or other measured quantity as necessary). After all fine aggregate has been introduced, place the stopper in the flask and roll the flask in an inclined position, or gently whirl it in a horizontal circle so as to dislodge all entrapped air, continuing until no further bubbles rise to the surface (Note 4). Take a final reading with the flask and contents within 1 °C of the original temperature.

NOTE 4—A small measured amount (not to exceed 1 mL) of isopropyl alcohol may be used to eliminate foam appearing on the water surface. The volume of alcohol used must be subtracted from the final reading (R_2).

9.3.2 For determination of the absorption, use a separate 500 ± 10-g portion of the saturated surface-dry fine aggregate, dry to constant mass, and determine the dry mass.

TABLE 1 Precision

	Standard Deviation (1s)[A]	Acceptable Range of Two Results (d2s)[A]
Single-Operator Precision:		
Density (OD), kg/m^3	11	13
Density (SSD), kg/m^3 [B†]	9.5	27
Apparent density, kg/m^3	9.5	27
Relative density (specific gravity) (OD)	0.011	0.032
Relative density (specific gravity) (SSD)	0.0095	0.027
Apparent relative density (apparent specific gravity)	0.0095	0.027
Absorption[C], %	0.11	0.31
Multilaboratory Precision:		
Density (OD), kg/m^3	23	64
Density (SSD), kg/m^3	20	56
Apparent density, kg/m^3	20	56
Relative density (specific gravity) (OD)	0.023	0.066
Relative density (specific gravity) (SSD)	0.020	0.056
Apparent relative density (apparent specific gravity)	0.020	0.056
Absorption[C], %	0.23	0.66

[A] These numbers represent, respectively, the (1s) and (d2s) limits as described in Practice C 670. The precision estimates were obtained from the analysis of combined AASHTO Materials Reference Laboratory proficiency sample data from laboratories using 15 to 19-h saturation times and other laboratories using 24 ± 4-h saturation time. Testing was performed on normal weight aggregates, and started with aggregates in the oven-dry condition.

[B†] Revised editorially to correct a typographical error in August 2003.

[C] Precision estimates are based on aggregates with absorptions of less than 1 % and may differ for manufactured fine aggregates and the aggregates having absorption values greater than 1 %.

10. Calculations

10.1 *Symbols*:

A = mass of oven dry specimen, g

B = mass of pycnometer filled with water, to calibration mark, g

C = mass of pycnometer filled with specimen and water to calibration mark, g

R_1= initial reading of water level in Le Chatelier flask, mL

R_2= final reading of water in Le Chatelier flask, mL

S = mass of saturated surface-dry specimen (used in the gravimetric procedure for density and relative density (specific gravity), or for absorption with both procedures), g

S_1= mass of saturated surface-dry specimen (used in the volumetric procedure for density and relative density (specific gravity)), g

10.2 *Relative Density (Specific Gravity)*:

10.2.1 *Relative Density (Specific Gravity) (Oven dry)*—Calculate the relative density (specific gravity) on the basis of oven-dry aggregate as follows:

10.2.1.1 *Gravimetric Procedure*:

$$\text{Relative density (specific gravity) (OD)} = A/(B + S - C) \quad (1)$$

10.2.1.2 *Volumetric Procedure*:

$$\text{Relative density (specific gravity) (OD)} = [S_1\,(A/S)]/[0.9975\,(R_2 - R_1)] \quad (2)$$

10.2.2 *Relative Density (Specific Gravity) Saturated Surface-dry)*—Calculate the relative density (specific gravity) on the basis of saturated surface-dry aggregate as follows:

10.2.2.1 *Gravimetric Procedure*:

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$$\text{Relative density (specific gravity) (SSD)} = S/(B + S - C) \quad (3)$$

10.2.2.2 *Volumetric Procedure*:

$$\text{Relative density (specific gravity) (SSD)} = S_1/[0.9975\ (R_2 - R_1)] \quad (4)$$

10.2.3 *Apparent Relative Density (Apparent Specific Gravity)*—Calculate the apparent relative density (apparent specific gravity) as follows:

10.2.3.1 *Gravimetric Procedure*:

$$\text{Apparent relative density (apparent specific gravity)} = A/(B + A - C) \quad (5)$$

10.2.3.2 *Volumetric Procedure*:

$$\text{Apparent relative density (apparent specific gravity)} = \frac{S_1\ (A/S)}{0.9975\ (R_2 - R_1) - [(S_1/S)(S - A)]} \quad (6)$$

10.3 *Density*:

10.3.1 *Density (Oven-dry)*—Calculate the density on the basis of oven-dry aggregates as follows:

10.3.1.1 *Gravimetric Procedure*:

$$\text{Density (OD), kg/m}^3 = 997.5\ A/(B + S - C) \quad (7)$$

$$\text{Density (OD), lb/ft}^3 = 62.27\ A/(B + S - C) \quad (8)$$

10.3.1.2 *Volumetric Procedure*:

$$\text{Density (OD), kg/m}^3 = 997.5\ S_1\ (A/S)/[0.9975\ (R_2 - R_1)] \quad (9)$$

$$\text{Density (OD), lb/ft}^3 = 62.27\ S_1\ (A/S)/[0.9975\ (R_2 - R_1)] \quad (10)$$

NOTE 5—The constant values used in the calculations in 10.3.1-10.3.3 (997.5 kg/m^3 and 62.27 lb/ft^3) are the density of water at 23 °C. Some authorities recommend using the density of water at 4 °C (1000 kg/m^3 or 1000 Mg/m^3 or 62.43 lb/ft^3) as being sufficiently accurate.

10.3.2 *Density (Saturated surface-dry)*—Calculate the density on the basis of saturated surface-dry aggregate as follows:

10.3.2.1 *Gravimetric Procedure*:

$$\text{Density (SSD), kg/m}^3 = 997.5\ S/(B + S - C) \quad (11)$$

$$\text{Density (SSD), lb/ft}^3 = 62.27\ S/(B + S - C) \quad (12)$$

10.3.2.2 *Volumetric Procedure*:

$$\text{Density (SSD), kg/m}^3 = 997.5\ S_1/[0.9975\ (R_2 - R_1)] \quad (13)$$

$$\text{Density (SSD), lb/ft}^3 = 62.27\ S_1/[0.9975\ (R_2 - R_1)] \quad (14)$$

10.3.3 *Apparent Density*—Calculate the apparent density as follows:

10.3.3.1 *Gravimetric Procedure*:

$$\text{Apparent density (SSD), kg/m}^3 = 997.5\ A/(B + A - C) \quad (15)$$

$$\text{Apparent density (SSD), lb/ft}^3 = 62.27\ A/(B + A - C) \quad (16)$$

10.3.3.2 *Volumetric Procedure*:

$$\text{Apparent density (SSD), kg/m}^3, = \frac{997.5\ S_1\ (A/S)}{0.9975\ (R_2 - R_1) - [(S_1/S)(S - A)]} \quad (17)$$

$$\text{Apparent density (SSD), lb/ft}^3, = \frac{62.27\ S_1\ (A/S)}{0.9975\ (R_2 - R_1) - [(S_1/S)(S - A)]} \quad (18)$$

10.4 *Absorption*—Calculate the percentage of absorption as follows:

$$\text{Absorption, \%} = 100\ [(S - A)/A] \quad (19)$$

11. Report

11.1 Report density results to the nearest 10 kg/m^3, or 0.5 lb/ft^3, relative density (specific gravity) results to the nearest 0.01, and indicate the basis for density or relative density (specific gravity), as either oven-dry (OD), saturated-surface-dry (SSD), or apparent.

11.2 Report the absorption result to the nearest 0.1 %.

11.3 If the density and relative density (specific gravity) values were determined without first drying the aggregate, as permitted in 8.2, note that fact in the report.

12. Precision and Bias

12.1 *Precision*—The estimates of precision of this test method (listed in Table 1) are based on results from the AASHTO Materials Reference Laboratory Proficiency Sample Program, with testing conducted by this test method and AASHTO Method T 84. The significant difference between the methods is that Test Method C 128 requires a saturation period of 24 ± 4 h, and AASHTO Test Method T 84 requires a saturation period of 15 to 19 h. This difference has been found to have an insignificant effect on the precision indices. The data are based on the analyses of more than 100 paired test results from 40 to 100 laboratories. The precision estimates for density were calculated from values determined for relative density (specific gravity), using the density of water at 23 °C for the conversion.

12.2 *Bias*—Since there is no accepted reference material suitable for determining the bias for this test method, no statement on bias is being made.

13. Keywords

13.1 absorption; aggregate; apparent density; apparent relative density; density; fine aggregate; relative density; specific gravity

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APPENDIXES

(Nonmandatory Information)

X1. POTENTIAL DIFFERENCES IN BULK RELATIVE DENSITY AND ABSORPTION DUE TO PRESENCE OF MATERIAL FINER THAN 75 µm

X1.1 It has been found that there may be significant differences in bulk relative density and absorption between fine aggregate samples tested with the material finer than 75 µm (No. 200) present and not present in the samples. Samples from which the material finer than 75 µm is not removed usually give a higher absorption and a lower bulk relative density compared with testing the same fine aggregate from which the material finer than 75 µm is removed following the procedures of Test Method C 117. Samples with material finer than 75 µm may build up a coating around the coarser fine aggregate particles during the surface drying process. The resultant relative density and absorption that is subsequently measured is that of the agglomerated and coated particles and not that of the parent material. The difference in absorption and relative density determined between samples from which the material finer than 75 µm have not been removed and samples from which the material finer than 75 µm have been removed depends on both the amount of the material finer than 75 µm present and the nature of the material. When the material finer than 75 µm is less than about 4 % by mass, the difference in relative density between washed and unwashed samples is less than 0.03. When the material finer than 75 µm is greater than about 8 % by mass, the difference in relative density obtained between washed and unwashed samples may be as great as 0.13. It has been found that the relative density determined on fine aggregate from which the material finer than 75 µm has been removed prior to testing more accurately reflects the relative density of the material.

X1.2 The material finer than 75 µm, which is removed, can be assumed to have the same relative density as the fine aggregate. Alternatively, the relative density (specific gravity) of the material finer than 75 µm may be further evaluated using Test Method D 854, however, this test determines the apparent relative density and not the bulk relative density.

X2. INTERRELATIONSHIPS BETWEEN RELATIVE DENSITIES (SPECIFIC GRAVITIES) AND ABSORPTION AS DEFINED IN TEST METHODS C 127 AND C 128

X2.1 This appendix gives mathematical interrelationships among the three types of relative densities (specific gravities) and absorption. These may be useful in checking the consistency of reported data or calculating a value that was not reported by using other reported data.

X2.2 Where:

S_d = relative density (specific gravity) (OD),
S_s = relative density (specific gravity) (SSD),
S_a = apparent relative density (apparent specific gravity), and
A = absorption, in %.

Calculate the values of each as follows:

$$S_s = (1 + A/100)S_d \quad \text{(X2.1)}$$

$$S_s = \frac{1}{\frac{1}{S_d} - \frac{A}{100}} = \frac{S_d}{1 - \frac{AS_d}{100}} \quad \text{(X2.2)}$$

$$\text{or } S_a = \frac{1}{\frac{1 + A/100}{S_s} - \frac{A}{100}} \quad \text{(X2.3)}$$

$$= \frac{S_s}{1 = \frac{A}{100}(S_s - 1)}$$

$$A = \left(\frac{S_s}{S_d} - 1\right) 100 \quad \text{(X2.4)}$$

$$A = \left(\frac{S_a - S_s}{S_a (S_s - 1)}\right) 100 \quad \text{(X2.5)}$$

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SUMMARY OF CHANGES

Committee C09 has identified the location of selected changes to this test method since the last issue, C 128 – 07, that may impact the use of this test method. (Approved August 1, 2007)

(*1*) Revised 3.1.2.2.

(*2*) Revised 9.2.1.1.

Committee C09 has identified the location of selected changes to this test method since the last issue, C 128 – 04a, that may impact the use of this test method. (Approved February 1, 2007)

(*1*) Revised 9.2.1.1.

(*2*) Added new Appendix X1 and renumbered subsequent sections.

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Designation: C 131 – 06

Standard Test Method for Resistance to Degradation of Small-Size Coarse Aggregate by Abrasion and Impact in the Los Angeles Machine[1]

This standard is issued under the fixed designation C 131; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

This standard has been approved for use by agencies of the Department of Defense.

1. Scope*

1.1 This test method covers a procedure for testing sizes of coarse aggregate smaller than 37.5 mm (1½ in.) for resistance to degradation using the Los Angeles testing machine (Note 1).

NOTE 1—A procedure for testing coarse aggregate larger than 19.0 mm (¾ in.) is covered in Test Method C 535.

1.2 The values stated in SI units are to be regarded as the standard. The inch-pound values given in parentheses are for information only.

1.3 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

2. Referenced Documents

2.1 *ASTM Standards:* [2]

A 6/A 6M Specification for General Requirements for Rolled Structural Steel Bars, Plates, Shapes, and Sheet Piling

C 125 Terminology Relating to Concrete and Concrete Aggregates

C 136 Test Method for Sieve Analysis of Fine and Coarse Aggregates

C 535 Test Method for Resistance to Degradation of Large-Size Coarse Aggregate by Abrasion and Impact in the Los Angeles Machine

C 670 Practice for Preparing Precision and Bias Statements for Test Methods for Construction Materials

C 702 Practice for Reducing Samples of Aggregate to Testing Size

D 75 Practice for Sampling Aggregates

E 11 Specification for Wire Cloth and Sieves for Testing Purposes

3. Terminology

3.1 *Definitions*—For definitions of terms used in this test method, refer to Terminology C 125.

4. Summary of Test Method

4.1 This test is a measure of degradation of mineral aggregates of standard gradings resulting from a combination of actions including abrasion or attrition, impact, and grinding in a rotating steel drum containing a specified number of steel spheres, the number depending upon the grading of the test sample. As the drum rotates, a shelf plate picks up the sample and the steel spheres, carrying them around until they are dropped to the opposite side of the drum, creating an impact-crushing effect. The contents then roll within the drum with an abrading and grinding action until the shelf plate picks up the sample and the steel spheres, and the cycle is repeated. After the prescribed number of revolutions, the contents are removed from the drum and the aggregate portion is sieved to measure the degradation as percent loss.

5. Significance and Use

5.1 This test has been widely used as an indicator of the relative quality or competence of various sources of aggregate having similar mineral compositions. The results do not automatically permit valid comparisons to be made between sources distinctly different in origin, composition, or structure. Assign specification limits with extreme care in consideration of available aggregate types and their performance history in specific end uses.

6. Apparatus

6.1 *Los Angeles Machine*—A Los Angeles machine, conforming in all essential characteristics to the design shown in Fig. 1, shall be used. The machine shall consist of a hollow steel cylinder, with a wall thickness of not less than 12.4 mm (Note 2) closed at both ends, conforming to the dimensions shown in Fig. 1, having an inside diameter of 711 ± 5 mm (28

[1] This test method is under the jurisdiction of ASTM Committee C09 on Concrete and Concrete Aggregates and is the direct responsibility of Subcommittee C09.20 on Normal Weight Aggregates.

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[2] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

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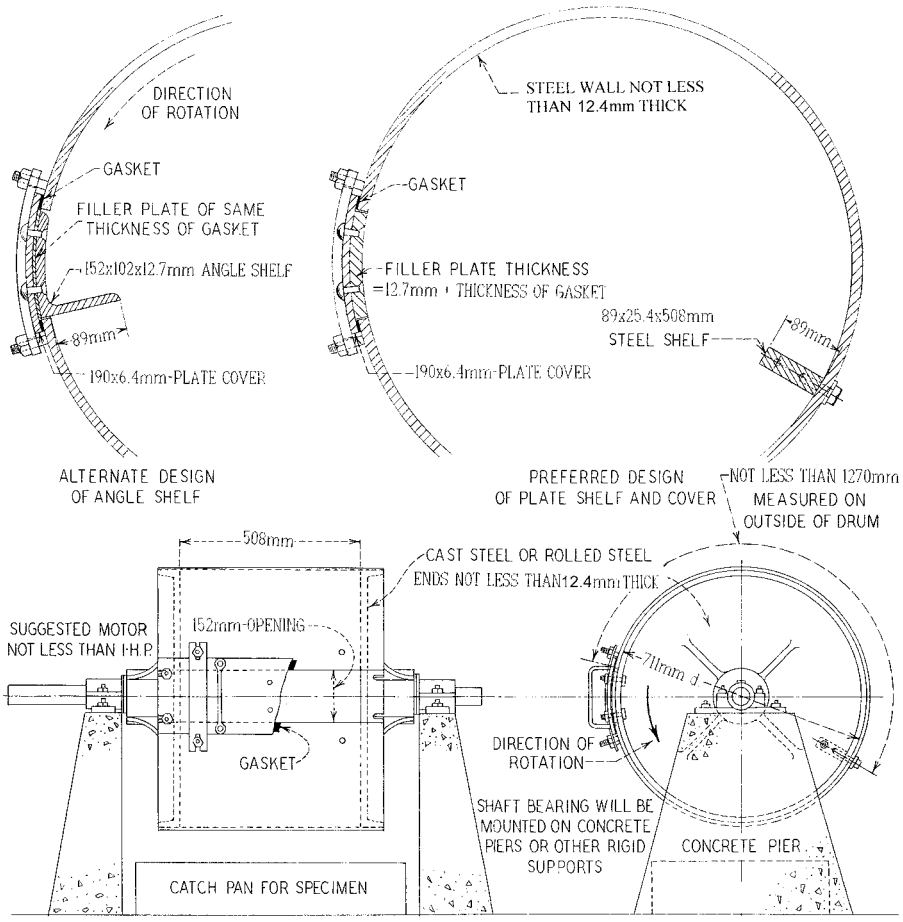

Inch Equivalents

mm	6.4	12.7	25.4	89	102	152	190	508	711	1270
in.	¼	½	1	3½	4	6	7½	20	28	50

FIG. 1 Los Angeles Testing Machine

± 0.2 in.), and an inside length of 508 ± 5 mm (20 ± 0.2 in.). The interior surface of the cylinder shall be free from protrusions disrupting the path of the sample and steel spheres except for the shelf described below. The cylinder shall be mounted on stub shafts attached to the ends of the cylinder but not entering it, and shall be mounted in such a manner that it rotates with the axis in a horizontal position within a tolerance in slope of 1 in 100. An opening in the cylinder shall be provided for the introduction of the test sample. A suitable, dust-tight cover shall be provided for the opening with means for bolting the cover in place. The cover shall be so designed as to maintain the cylindrical contour of the interior surface unless the shelf is so located that the charge will not fall on the cover, or come in contact with it during the test. A removable steel shelf extending the full length of the cylinder and projecting inward 89 ± 2 mm (3.5 ± 0.1 in.) shall be mounted on the interior cylindrical surface of the cylinder, in such a way that a plane centered between the large faces coincides with an axial plane. The shelf shall be of such thickness and so mounted, by bolts or other suitable means, as to be firm and rigid. The position of the shelf (Note 3) shall be such that the sample and the steel spheres shall not impact on or near the opening and its cover, and that the distance from the shelf to the opening, measured along the outside circumference of the cylinder in the direction of rotation, shall be not less than 1270 mm (50 in.). Inspect the shelf periodically to determine that it is not bent either lengthwise or from its normal radial position with respect to the cylinder. If either condition is found, repair or replace the shelf before further tests are conducted.

NOTE 2—This is the minimum tolerance permitted on 12.7 mm (½ in.) rolled steel plate as described in Specification A 6/A 6M.

NOTE 3—The use of a shelf of wear-resistant steel, rectangular in cross section and mounted independently of the cover, is preferred. However, a shelf consisting of a section of rolled angle, properly mounted on the inside of the cover plate, may be used provided the direction of rotation is such that the charge will be caught on the outside face of the angle.

6.1.1 The machine shall be so driven and so counterbalanced as to maintain a substantially uniform peripheral speed (Note 4). If an angle is used as the shelf, the direction of rotation shall be such that the charge is caught on the outside surface of the angle.

NOTE 4—Back-lash or slip in the driving mechanism is very likely to furnish test results which are not duplicated by other Los Angeles machines producing constant peripheral speed.

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TABLE 1 Gradings of Test Samples

Sieve Size (Square Openings)		Mass of Indicated Sizes, g			
Passing	Retained on	Grading			
		A	B	C	D
37.5 mm (1½ in.)	25.0 mm (1 in.)	1 250 ± 25	...	...	...
25.0 mm (1 in.)	19.0 mm (¾ in.)	1 250 ± 25	...	...	...
19.0 mm (¾ in.)	12.5 mm (½ in.)	1 250 ± 10	2 500 ± 10	...	...
12.5 mm (½ in.)	9.5 mm (⅜ in.)	1 250 ± 10	2 500 ± 10	...	...
9.5 mm (⅜ in.)	6.3 mm (¼ in.)	...	...	2 500 ± 10	...
6.3 mm (¼ in.)	4.75-mm (No. 4)	...	...	2 500 ± 10	...
4.75-mm (No. 4)	2.36-mm (No. 8)	...	...	...	5 000 ± 10
Total		5 000 ± 10	5 000 ± 10	5 000 ± 10	5 000 ± 10

6.2 *Sieves*, conforming to Specification E 11.

6.3 *Balance*—A balance or scale accurate within 0.1 % of test load over the range required for this test.

6.4 *Charge*—The charge shall consist of steel spheres averaging approximately 46.8 mm (1 27/32 in.) in diameter and each having a mass of between 390 and 445 g.

6.4.1 The charge, (Note 5) depending upon the grading of the test sample as described in Section 8, shall be as follows:

Grading	Number of Spheres	Mass of Charge, g
A	12	5000 ± 25
B	11	4584 ± 25
C	8	3330 ± 20
D	6	2500 ± 15

NOTE 5—Steel ball bearings 46.0 mm (1 13/16 in.) and 47.6 mm (1 7/8 in.) in diameter, having a mass of approximately 400 and 440 g each, respectively, are readily available. Steel spheres 46.8 mm (1 27/32 in.) in diameter having a mass of approximately 420 g may also be obtainable. The charge may consist of a mixture of these sizes conforming to the mass tolerances of 6.4 and 6.4.1.

7. Sampling

7.1 Obtain the field sample in accordance with Practice D 75, and reduce the field sample to adequate sample size in accordance with Practice C 702.

8. Test Sample Preparation

8.1 Wash the reduced sample and oven dry at 110 ± 5 °C (230 ± 9 °F) to substantially constant mass (see 9.1.1), separate into individual size fractions, and recombine to the grading of Table 1 most nearly corresponding to the range of sizes in the aggregate as furnished for the work. Record the mass of the sample prior to test to the nearest 1 g.

9. Procedure

9.1 Place the test sample and the charge in the Los Angeles testing machine and rotate the machine at a speed of 30 to 33 r/min for 500 revolutions (Note 6). After the prescribed number of revolutions, discharge the material from the machine and make a preliminary separation of the sample on a sieve coarser than the 1.70-mm (No. 12) sieve. Sieve the finer portion on a 1.70-mm sieve in a manner conforming to Test Method C 136. Wash the material coarser than the 1.70-mm (No. 12) sieve and oven-dry at 110 ± 5 °C (230 ± 9 °F) to substantially constant mass (see 9.1.1), and determine the mass to the nearest 1 g (Note 7).

9.1.1 If the aggregate is essentially free of adherent coatings and dust, the requirement for washing after the test is optional. However, in the case of referee testing, the washing procedure shall be performed.

NOTE 6—Valuable information concerning the uniformity of the sample under test may be obtained by determining the loss after 100 revolutions. The loss should be determined by dry sieving the material on the 1.70-mm sieve without washing. The ratio of the loss after 100 revolutions to the loss after 500 revolutions should not greatly exceed 0.20 for material of uniform hardness. When this determination is made, take care to avoid losing any part of the sample; return the entire sample, including the dust of fracture, to the testing machine for the final 400 revolutions required to complete the test.

NOTE 7—Elimination of washing after test will seldom reduce the measured loss by more than about 0.2 % of the original sample mass.

10. Calculation

10.1 Calculate the loss (difference between the original mass and the final mass of the test sample) as a percentage of the original mass of the test sample. Report this value as the percent loss (Note 8).

NOTE 8—The percent loss determined by this test method has no known consistent relationship to the percent loss for the same material when tested by Test Method C 535.

11. Report

11.1 Report the following information:

11.1.1 Identification of the aggregate as to source, type, and nominal maximum size;

11.1.2 Grading designation from Table 1 used for the test; and

11.1.3 Loss by abrasion and impact of the sample expressed to the nearest 1 % by mass.

12. Precision and Bias

12.1 For nominal 19.0-mm (¾-in.) maximum size coarse aggregate with percent losses in the range of 10 to 45 %, the multilaboratory coefficient of variation has been found to be 4.5 %.[3] Therefore, results of two properly conducted tests from two different laboratories on samples of the same coarse aggregates are not expected to differ from each other by more

[3] These numbers represent, respectively, the (1s%) and (d2s%) limits as described in Practice C 670.

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than 12.7 %[3] (95 % probability) of their average. The single-operator coefficient of variation has been found to be 2.0 %.[3] Therefore, results of two properly conducted tests by the same operator on the same coarse aggregate are not expected to differ from each other by more than 5.7 % (95 % probability) of their average.[3]

12.2 *Bias*—Since there is no accepted reference material suitable for determining the bias for this procedure, no statement on bias is being made.

13. Keywords

13.1 abrasion; aggregate (coarse; small size); degradation; impact; Los Angeles machine

APPENDIX

(Nonmandatory Information)

X1. MAINTENANCE OF SHELF

X1.1 The shelf of the Los Angeles machine is subject to severe surface wear and impact. With use, the working surface of the shelf is peened by the balls and tends to develop a ridge of metal parallel to and about 32 mm (1¼ in.) from the junction of the shelf and the inner surface of the cylinder. If the shelf is made from a section of rolled angle, not only may this ridge develop but the shelf itself may be bent longitudinally or transversely from its proper position.

X1.2 The shelf should be inspected periodically to determine that it is not bent either lengthwise or from its normal radial position with respect to the cylinder. If either condition is found, the shelf should be repaired or replaced before further tests are made. The influence on the test result of the ridge developed by peening of the working face of the shelf is not known. However, for uniform test conditions, it is recommended that the ridge be ground off if its height exceeds 2 mm (0.1 in.).

SUMMARY OF CHANGES

Committee C09 has identified the location of selected changes to this test method since the last issue, C 131 – 03, that may impact the use of this test method. (Approved August 1, 2006)

(*1*) Revised 6.1.

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Designation: C 136 – 06

Standard Test Method for Sieve Analysis of Fine and Coarse Aggregates[1]

This standard is issued under the fixed designation C 136; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

This standard has been approved for use by agencies of the Department of Defense.

1. Scope*

1.1 This test method covers the determination of the particle size distribution of fine and coarse aggregates by sieving.

1.2 Some specifications for aggregates which reference this test method contain grading requirements including both coarse and fine fractions. Instructions are included for sieve analysis of such aggregates.

1.3 The values stated in SI units are to be regarded as the standard. The values in parentheses are provided for information purposes only. Specification E 11 designates the size of sieve frames with inch units as standard, but in this test method the frame size is designated in SI units exactly equivalent to the inch units.

1.4 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

2. Referenced Documents

2.1 *ASTM Standards:* [2]

C 117 Test Method for Materials Finer than 75-µm (No. 200) Sieve in Mineral Aggregates by Washing

C 125 Terminology Relating to Concrete and Concrete Aggregates

C 637 Specification for Aggregates for Radiation-Shielding Concrete

C 670 Practice for Preparing Precision and Bias Statements for Test Methods for Construction Materials

C 702 Practice for Reducing Samples of Aggregate to Testing Size

D 75 Practice for Sampling Aggregates

E 11 Specification for Wire Cloth and Sieves for Testing Purposes

2.2 *AASHTO Standard:*

AASHTO No. T 27 Sieve Analysis of Fine and Coarse Aggregates[3]

3. Terminology

3.1 *Definitions*—For definitions of terms used in this standard, refer to Terminology C 125.

4. Summary of Test Method

4.1 A sample of dry aggregate of known mass is separated through a series of sieves of progressively smaller openings for determination of particle size distribution.

5. Significance and Use

5.1 This test method is used primarily to determine the grading of materials proposed for use as aggregates or being used as aggregates. The results are used to determine compliance of the particle size distribution with applicable specification requirements and to provide necessary data for control of the production of various aggregate products and mixtures containing aggregates. The data may also be useful in developing relationships concerning porosity and packing.

5.2 Accurate determination of material finer than the 75-µm (No. 200) sieve cannot be achieved by use of this test method alone. Test Method C 117 for material finer than 75-µm sieve by washing should be employed.

5.3 Refer to methods of sampling and testing in Specification C 637 for heavyweight aggregates.

6. Apparatus

6.1 *Balances*—Balances or scales used in testing fine and coarse aggregate shall have readability and accuracy as follows:

6.1.1 For fine aggregate, readable to 0.1 g and accurate to 0.1 g or 0.1 % of the test load, whichever is greater, at any point within the range of use.

[1] This test method is under the jurisdiction of ASTM Committee C09 on Concrete and Concrete Aggregates and is the direct responsibility of Subcommittee C09.20 on Normal Weight Aggregates.

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[2] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

[3] Available from American Association of State Highway and Transportation Officials, 444 North Capitol St. N.W., Suite 225, Washington, DC 20001.

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6.1.2 For coarse aggregate, or mixtures of fine and coarse aggregate, readable and accurate to 0.5 g or 0.1 % of the test load, whichever is greater, at any point within the range of use.

6.2 *Sieves*—The sieve cloth shall be mounted on substantial frames constructed in a manner that will prevent loss of material during sieving. The sieve cloth and standard sieve frames shall conform to the requirements of Specification E 11. Nonstandard sieve frames shall conform to the requirements of Specification E 11 as applicable.

NOTE 1—It is recommended that sieves mounted in frames larger than standard 203.2-mm (8 in.) diameter be used for testing coarse aggregate to reduce the possibility of overloading the sieves. See 8.3.

6.3 *Mechanical Sieve Shaker*—A mechanical sieving device, if used, shall create motion of the sieves to cause the particles to bounce, tumble, or otherwise turn so as to present different orientations to the sieving surface. The sieving action shall be such that the criterion for adequacy of sieving described in 8.4 is met in a reasonable time period.

NOTE 2—Use of a mechanical sieve shaker is recommended when the size of the sample is 20 kg or greater, and may be used for smaller samples, including fine aggregate. Excessive time (more than approximately 10 min) to achieve adequate sieving may result in degradation of the sample. The same mechanical sieve shaker may not be practical for all sizes of samples, since the large sieving area needed for practical sieving of a large nominal size coarse aggregate very likely could result in loss of a portion of the sample if used for a small sample of coarse aggregate or fine aggregate.

6.4 *Oven*—An oven of appropriate size capable of maintaining a uniform temperature of 110 ± 5 °C (230 ± 9 °F).

7. Sampling

7.1 Sample the aggregate in accordance with Practice D 75. The size of the field sample shall be the quantity shown in Practice D 75 or four times the quantity required in 7.4 and 7.5 (except as modified in 7.6), whichever is greater.

7.2 Thoroughly mix the sample and reduce it to an amount suitable for testing using the applicable procedures described in Practice C 702. The sample for test shall be approximately the quantity desired when dry and shall be the end result of the reduction. Reduction to an exact predetermined quantity shall not be permitted.

NOTE 3—Where sieve analysis, including determination of material finer than the 75-µm sieve, is the only testing proposed, the size of the sample may be reduced in the field to avoid shipping excessive quantities of extra material to the laboratory.

7.3 *Fine Aggregate*—The size of the test sample, after drying, shall be 300 g minimum.

7.4 *Coarse Aggregate*—The size of the test sample of coarse aggregate shall conform with the following:

Nominal Maximum Size, Square Openings, mm (in.)	Test Sample Size, min, kg (lb)
9.5 (⅜)	1 (2)
12.5 (½)	2 (4)
19.0 (¾)	5 (11)
25.0 (1)	10 (22)
37.5 (1½)	15 (33)
50 (2)	20 (44)
63 (2½)	35 (77)
75 (3)	60 (130)
90 (3½)	100 (220)
100 (4)	150 (330)
125 (5)	300 (660)

7.5 *Coarse and Fine Aggregate Mixtures*—The size of the test sample of coarse and fine aggregate mixtures shall be the same as for coarse aggregate in 7.4.

7.6 *Samples of Large Size Coarse Aggregate*—The size of sample required for aggregate with 50-mm nominal maximum size or larger is such as to preclude convenient sample reduction and testing as a unit except with large mechanical splitters and sieve shakers. As an option when such equipment is not available, instead of combining and mixing sample increments and then reducing the field sample to testing size, conduct the sieve analysis on a number of approximately equal sample increments such that the total mass tested conforms to the requirement of 7.4.

7.7 In the event that the amount of material finer than the 75-µm (No. 200) sieve is to be determined by Test Method C 117, proceed as follows:

7.7.1 For aggregates with a nominal maximum size of 12.5 mm (1/2 in.) or less, use the same test sample for testing by Test Method C 117 and this test method. First test the sample in accordance with Test Method C 117 through the final drying operation, then dry sieve the sample as stipulated in 8.2-8.7 of this test method.

7.7.2 For aggregates with a nominal maximum size greater than 12.5 mm (½ in.), use a single test sample as described in 7.7.1, or optionally use separate test samples for Test Method C 117 and this test method.

7.7.3 Where the specifications require determination of the total amount of material finer than the 75-µm sieve by washing and dry sieving, use the procedure described in 7.7.1.

8. Procedure

8.1 Dry the sample to constant mass at a temperature of 110 ± 5 °C (230 ± 9 °F).

NOTE 4—For control purposes, particularly where rapid results are desired, it is generally not necessary to dry coarse aggregate for the sieve analysis test. The results are little affected by the moisture content unless: (*1*) the nominal maximum size is smaller than about 12.5 mm (½ in.); (*2*) the coarse aggregate contains appreciable material finer than 4.75 mm (No. 4); or (*3*) the coarse aggregate is highly absorptive (a lightweight aggregate, for example). Also, samples may be dried at the higher temperatures associated with the use of hot plates without affecting results, provided steam escapes without generating pressures sufficient to fracture the particles, and temperatures are not so great as to cause chemical breakdown of the aggregate.

8.2 Select sieves with suitable openings to furnish the information required by the specifications covering the material to be tested. Use additional sieves as desired or necessary to provide other information, such as fineness modulus, or to regulate the amount of material on a sieve. Nest the sieves in order of decreasing size of opening from top to bottom and place the sample on the top sieve. Agitate the sieves by hand or by mechanical apparatus for a sufficient period, established by trial or checked by measurement on the actual test sample, to meet the criterion for adequacy or sieving described in 8.4.

8.3 Limit the quantity of material on a given sieve so that all particles have opportunity to reach sieve openings a number of times during the sieving operation. For sieves with openings

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smaller than 4.75-mm (No. 4), the quantity retained on any sieve at the completion of the sieving operation shall not exceed 7 kg/m^2 of sieving surface area (Note 5). For sieves with openings 4.75 mm (No. 4) and larger, the quantity retained in kg shall not exceed the product of 2.5 × (sieve opening, mm × (effective sieving area, m^2)). This quantity is shown in Table 1 for five sieve-frame dimensions in common use. In no case shall the quantity retained be so great as to cause permanent deformation of the sieve cloth.

8.3.1 Prevent an overload of material on an individual sieve by one of the following methods:

8.3.1.1 Insert an additional sieve with opening size intermediate between the sieve that may be overloaded and the sieve immediately above that sieve in the original set of sieves.

8.3.1.2 Split the sample into two or more portions, sieving each portion individually. Combine the masses of the several portions retained on a specific sieve before calculating the percentage of the sample on the sieve.

8.3.1.3 Use sieves having a larger frame size and providing greater sieving area.

NOTE 5—The 7 kg/m^2 amounts to 200 g for the usual 203.2-mm (8-in.) diameter sieve (with effective sieving surface diameter of 190.5 mm (7.5 in.)).

8.4 Continue sieving for a sufficient period and in such manner that, after completion, not more than 1 % by mass of the material retained on any individual sieve will pass that sieve during 1 min of continuous hand sieving performed as follows: Hold the individual sieve, provided with a snug-fitting pan and cover, in a slightly inclined position in one hand. Strike the side of the sieve sharply and with an upward motion against the heel of the other hand at the rate of about 150 times per minute, turn the sieve about one sixth of a revolution at intervals of about 25 strokes. In determining sufficiency of sieving for sizes larger than the 4.75-mm (No. 4) sieve, limit the material on the sieve to a single layer of particles. If the size of the mounted testing sieves makes the described sieving motion impractical, use 203-mm (8 in.) diameter sieves to verify the sufficiency of sieving.

TABLE 1 Maximum Allowable Quantity of Material Retained on a Sieve, kg

Sieve Opening Size, mm	Nominal Dimensions of Sieve[A]				
	203.2-mm dia[B]	254-mm dia[B]	304.8-mm dia[B]	350 by 350 mm	372 by 580 mm
	Sieving Area, m^2				
	0.0285	0.0457	0.0670	0.1225	0.2158
125	[C]	[C]	[C]	[C]	67.4
100	[C]	[C]	[C]	30.6	53.9
90	[C]	[C]	15.1	27.6	48.5
75	[C]	8.6	12.6	23.0	40.5
63	[C]	7.2	10.6	19.3	34.0
50	3.6	5.7	8.4	15.3	27.0
37.5	2.7	4.3	6.3	11.5	20.2
25.0	1.8	2.9	4.2	7.7	13.5
19.0	1.4	2.2	3.2	5.8	10.2
12.5	0.89	1.4	2.1	3.8	6.7
9.5	0.67	1.1	1.6	2.9	5.1
4.75	0.33	0.54	0.80	1.5	2.6

[A] Sieve frame dimensions in inch units: 8.0-in. diameter; 10.0-in. diameter, 12.0-in. diameter; 13.8 by 13.8 in. (14 by 14 in. nominal); 14.6 by 22.8 in. (16 by 24 in. nominal).

[B] The sieve area for round sieve frames is based on an effective diameter 12.7 mm (½ in.) less than the nominal frame diameter, because Specification E 11 permits the sealer between the sieve cloth and the frame to extend 6.35 mm (¼ in.) over the sieve cloth. Thus the effective sieving diameter for a 203.2-mm (8.0-in.) diameter sieve frame is 190.5 mm (7.5 in.). Sieves produced by some manufacturers do not infringe on the sieve cloth by the full 6.35 mm (¼ in.).

[C] Sieves indicated have less than five full openings and should not be used for sieve testing except as provided in 8.6.

8.5 In the case of coarse and fine aggregate mixtures, refer to 8.3.1 to prevent overloading of individual sieves.

8.5.1 Optionally, reduce the portion finer than the 4.75-mm (No. 4) sieve using a mechanical splitter according to Practice C 702. If this procedure is followed, compute the mass of each size increment of the original sample as follows:

$$A = \frac{W_1}{W_2} \times B \quad (1)$$

where:

A = mass of size increment on total sample basis,
W_1 = mass of fraction finer than 4.75-mm (No. 4) sieve in total sample,
W_2 = mass of reduced portion of material finer than 4.75-mm (No. 4) sieve actually sieved, and
B = mass of size increment in reduced portion sieved.

8.6 Unless a mechanical sieve shaker is used, hand sieve particles larger than 75 mm (3 in.) by determining the smallest sieve opening through which each particle will pass. Start the test on the smallest sieve to be used. Rotate the particles, if necessary, in order to determine whether they will pass through a particular opening; however, do not force particles to pass through an opening.

8.7 Determine the mass of each size increment on a scale or balance conforming to the requirements specified in 5.1 to the nearest 0.1 % of the total original dry sample mass. The total mass of the material after sieving should check closely with original mass of sample placed on the sieves. If the amounts differ by more than 0.3 %, based on the original dry sample mass, the results should not be used for acceptance purposes.

8.8 If the sample has previously been tested by Test Method C 117, add the mass finer than the 75-µm (No. 200) sieve determined by that test method to the mass passing the 75-µm (No. 200) sieve by dry sieving of the same sample in this test method.

9. Calculation

9.1 Calculate percentages passing, total percentages retained, or percentages in various size fractions to the nearest 0.1 % on the basis of the total mass of the initial dry sample. If the same test sample was first tested by Test Method C 117, include the mass of material finer than the 75-µm (No. 200) size by washing in the sieve analysis calculation; and use the total dry sample mass prior to washing in Test Method C 117 as the basis for calculating all the percentages.

9.1.1 When sample increments are tested as provided in 7.6, total the masses of the portion of the increments retained on each sieve, and use these masses to calculate the percentages as in 9.1.

9.2 Calculate the fineness modulus, when required, by adding the total percentages of material in the sample that is coarser than each of the following sieves (cumulative percentages retained), and dividing the sum by 100: 150-µm (No.

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100), 300-µm (No. 50), 600-µm (No. 30), 1.18-mm (No. 16), 2.36-mm (No. 8), 4.75-mm (No. 4), 9.5-mm (⅜-in.), 19.0-mm (¾-in.), 37.5-mm (1½-in.), and larger, increasing in the ratio of 2 to 1.

10. Report

10.1 Depending upon the form of the specifications for use of the material under test, the report shall include the following:

10.1.1 Total percentage of material passing each sieve, or

10.1.2 Total percentage of material retained on each sieve, or

10.1.3 Percentage of material retained between consecutive sieves.

10.2 Report percentages to the nearest whole number, except if the percentage passing the 75-µm (No. 200) sieve is less than 10 %, it shall be reported to the nearest 0.1 %.

10.3 Report the fineness modulus, when required, to the nearest 0.01.

11. Precision and Bias

11.1 *Precision*—The estimates of precision for this test method are listed in Table 2. The estimates are based on the results from the AASHTO Materials Reference Laboratory Proficiency Sample Program, with testing conducted by Test Method C 136 and AASHTO No. T 27. The data are based on the analyses of the test results from 65 to 233 laboratories that tested 18 pairs of coarse aggregate proficiency test samples and test results from 74 to 222 laboratories that tested 17 pairs of fine aggregate proficiency test samples (Samples No. 21 through 90). The values in the table are given for different ranges of total percentage of aggregate passing a sieve.

11.1.1 The precision values for fine aggregate in Table 2 are based on nominal 500-g test samples. Revision of this test method in 1994 permits the fine aggregate test sample size to be 300 g minimum. Analysis of results of testing of 300-g and 500-g test samples from Aggregate Proficiency Test Samples 99 and 100 (Samples 99 and 100 were essentially identical) produced the precision values in Table 3, which indicate only minor differences due to test sample size.

NOTE 6—The values for fine aggregate in Table 2 will be revised to reflect the 300-g test sample size when a sufficient number of Aggregate Proficiency Tests have been conducted using that sample size to provide reliable data.

TABLE 2 Precision

	Total Percentage of Material Passing		Standard Deviation (1s), %[A]	Acceptable Range of Two Results (d2s), %[A]
Coarse Aggregate:[B]				
Single-operator precision	<100	≥95	0.32	0.9
	<95	≥85	0.81	2.3
	<85	≥80	1.34	3.8
	<80	≥60	2.25	6.4
	<60	≥20	1.32	3.7
	<20	≥15	0.96	2.7
	<15	≥10	1.00	2.8
	<10	≥5	0.75	2.1
	<5	≥2	0.53	1.5
	<2	>0	0.27	0.8
Multilaboratory precision	<100	≥95	0.35	1.0
	<95	≥85	1.37	3.9
	<85	≥80	1.92	5.4
	<80	≥60	2.82	8.0
	<60	≥20	1.97	5.6
	<20	≥15	1.60	4.5
	<15	≥10	1.48	4.2
	<10	≥5	1.22	3.4
	<5	≥2	1.04	3.0
	<2	>0	0.45	1.3
Fine Aggregate:				
Single-operator precision	<100	≥95	0.26	0.7
	<95	≥60	0.55	1.6
	<60	≥20	0.83	2.4
	<20	≥15	0.54	1.5
	<15	≥10	0.36	1.0
	<10	≥2	0.37	1.1
	<2	>0	0.14	0.4
Multilaboratory precision	<100	≥95	0.23	0.6
	<95	≥60	0.77	2.2
	<60	≥20	1.41	4.0
	<20	≥15	1.10	3.1
	<15	≥10	0.73	2.1
	<10	≥2	0.65	1.8
	<2	>0	0.31	0.9

[A] These numbers represent, respectively, the (1s) and (d2s) limits described in Practice C 670.

[B] The precision estimates are based on aggregates with nominal maximum size of 19.0 mm (¾ in.).

11.2 *Bias*—Since there is no accepted reference material suitable for determining the bias in this test method, no statement on bias is made.

12. Keywords

12.1 aggregate; coarse aggregate; fine aggregate; gradation; grading; sieve analysis; size analysis

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TABLE 3 Precision Data for 300-g and 500-g Test Samples

Fine Aggregate Proficiency Sample				Within Laboratory		Between Laboratory	
Test Result	Sample Size	Number Labs	Average	1s	d2s	1s	d2s
Test Method C 136/AASHTO No. T 27							
Total material passing the No. 4 sieve (%)	500 g	285	99.992	0.027	0.066	0.037	0.104
	300 g	276	99.990	0.021	0.060	0.042	0.117
Total material passing the No. 8 sieve (%)	500 g	281	84.10	0.43	1.21	0.63	1.76
	300 g	274	84.32	0.39	1.09	0.69	1.92
Total material passing the No. 16 sieve (%)	500 g	286	70.11	0.53	1.49	0.75	2.10
	300 g	272	70.00	0.62	1.74	0.76	2.12
Total material passing the No. 30 sieve (%)	500 g	287	48.54	0.75	2.10	1.33	3.73
	300 g	276	48.44	0.87	2.44	1.36	3.79
Total material passing the No. 50 sieve (%)	500 g	286	13.52	0.42	1.17	0.98	2.73
	300 g	275	13.51	0.45	1.25	0.99	2.76
Total material passing the No. 100 sieve (%)	500 g	287	2.55	0.15	0.42	0.37	1.03
	300 g	270	2.52	0.18	0.52	0.32	0.89
Total Material passing the No. 200 sieve (%)	500 g	278	1.32	0.11	0.32	0.31	0.85
	300 g	266	1.30	0.14	0.39	0.31	0.85

SUMMARY OF CHANGES

Committee C09 has identified the location of selected changes to this test method since the last issue, C 136 – 05, that may impact the use of this test method. (Approved February 15, 2006)

(*1*) Revised 8.5.1.
(*2*) Revised 7.7.2.
(*3*) Revised 8.5.

Committee C09 has identified the location of selected changes to this test method since the last issue, C 136 – 04, that may impact the use of this test method. (Approved February 1, 2005)

(*1*) Added 5.3.
(*2*) Revised 8.5.

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Designation: C 138/C 138M – 09

American Association State
Highway and Transportation Officials Standard
AASHTO No.: T121

Standard Test Method for Density (Unit Weight), Yield, and Air Content (Gravimetric) of Concrete[1]

This standard is issued under the fixed designation C 138/C 138M; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

This standard has been approved for use by agencies of the Department of Defense.

1. Scope*

1.1 This test method covers determination of the density (see Note 1) of freshly mixed concrete and gives formulas for calculating the yield, cement content, and air content of the concrete. Yield is defined as the volume of concrete produced from a mixture of known quantities of the component materials.

1.2 The values stated in either SI units or inch-pound units are to be regarded separately as standard. The values stated in each system may not be exact equivalents; therefore, each system shall be used independently of the other. Combining values from the two systems may result in non-conformance with the standard.

NOTE 1—Unit weight was the previous terminology used to describe the property determined by this test method, which is mass per unit volume.

1.3 The text of this test method references notes and footnotes that provide explanatory information. These notes and footnotes (excluding those in tables) shall not be considered as requirements of this test method.

2. Referenced Documents

2.1 *ASTM Standards:*[2]

C 29/C 29M Test Method for Bulk Density ("Unit Weight") and Voids in Aggregate
C 31/C 31M Practice for Making and Curing Concrete Test Specimens in the Field
C 143/C 143M Test Method for Slump of Hydraulic-Cement Concrete
C 150 Specification for Portland Cement
C 172 Practice for Sampling Freshly Mixed Concrete
C 173/C 173M Test Method for Air Content of Freshly Mixed Concrete by the Volumetric Method
C 188 Test Method for Density of Hydraulic Cement
C 231 Test Method for Air Content of Freshly Mixed Concrete by the Pressure Method

3. Terminology

3.1 *Symbols*:

A = air content (percentage of voids) in the concrete
C = actual cement content, lb/yd^3 or kg/m^3
C_b = mass of cement in the batch, lb or kg
D = density (unit weight) of concrete, lb/ft^3 or kg/m^3
M = total mass of all materials batched, lb or kg (see Note 3)
M_c = mass of the measure filled with concrete, lb or kg
M_m = mass of the measure, lb or kg
R_y = relative yield
T = theoretical density of the concrete computed on an airfree basis, lb/ft^3 or kg/m^3 (see Note 2)
Y = yield, volume of concrete produced per batch, yd^3 or m^3
Y_d = volume of concrete which the batch was designed to produce, yd^3 or m^3
Y_f = volume of concrete produced per batch, ft^3
V = total absolute volume of the component ingredients in the batch, ft^3 or m^3
V_m = volume of the measure, ft^3 or m^3

NOTE 2—The theoretical density is, customarily, a laboratory determination, the value for which is assumed to remain constant for all batches made using identical component ingredients and proportions. It is calculated from the following equation:

$$T = M/V \quad (1)$$

The absolute volume of each ingredient in cubic feet is equal to the quotient of the mass of that ingredient divided by the product of its specific gravity times 62.4. The absolute volume of each ingredient in cubic metres is equal to the mass of the ingredient in kilograms divided by 1000 times its specific gravity. For the aggregate components, the bulk

[1] This test method is under the jurisdiction of ASTM Committee C09 on Concrete and Concrete Aggregates and is the direct responsibility of Subcommittee C09.60 on Testing Fresh Concrete.

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[2] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

***A Summary of Changes section appears at the end of this standard.**

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specific gravity and mass should be based on the saturated, surface-dry condition. For cement, the actual specific gravity should be determined by Test Method C 188. A value of 3.15 may be used for cements manufactured to meet the requirements of Specification C 150.

NOTE 3—The total mass of all materials batched is the sum of the masses of the cement, the fine aggregate in the condition used, the coarse aggregate in the condition used, the mixing water added to the batch, and any other solid or liquid materials used.

4. Apparatus

4.1 *Balance*—A balance or scale accurate to 0.1 lb [45 g] or to within 0.3 % of the test load, whichever is greater, at any point within the range of use. The range of use shall be considered to extend from the mass of the measure empty to the mass of the measure plus its contents at 160 lb/ft^3 [2600 kg/m^3].

4.2 *Tamping Rod*—A round, straight steel rod, with a ⅝ in. [16 mm] ± 1/16 in. [2 mm] diameter. The length of the tamping rod shall be at least 4 in. [100 mm] greater than the depth of the measure in which rodding is being performed, but not greater than 24 in. [600 mm] in overall length (See Note 4). The length tolerance for the tamping rod shall be ± ⅛ in. [4 mm]. The rod shall have the tamping end or both ends rounded to a hemispherical tip of the same diameter as the rod.

NOTE 4—A rod length of 16 in. [400 mm] to 24 in. [600 mm] meets the requirements of the following: Practice C 31/C 31M, Test Method C 138/C 138M, Test Method C 143/C 143M, Test Method C 173/C 173M and Test Method C 231.

4.3 *Internal Vibrator*—Internal vibrators may have rigid or flexible shafts, preferably powered by electric motors. The frequency of vibration shall be 7000 vibrations per minute or greater while in use. The outside diameter or the side dimension of the vibrating element shall be at least 0.75 in. [19 mm] and not greater than 1.50 in. [38 mm]. The length of the shaft shall be at least 24 in. [600 mm].

4.4 *Measure*—A cylindrical container made of steel or other suitable metal (see Note 5). The minimum capacity of the measure shall conform to the requirements of Table 1 based on the nominal size of aggregate in the concrete to be tested. All measures, except for measuring bowls of air meters which are also used for Test Method C 138/C 138M tests, shall conform to the requirements of Test Method C 29/C 29M. When measuring bowls of air meters are used, they shall conform to the requirements of Test Method C 231, and shall be calibrated for volume as described in Test Method C 29/C 29M. The top rim of the air meter bowls shall be smooth and plane within 0.01 in. [0.3 mm] (see Note 6).

TABLE 1 Capacity of Measures

Nominal Maximum Size of Coarse Aggregate		Capacity of Measure[A]	
in.	mm	ft^3	L
1	25.0	0.2	6
1½	37.5	0.4	11
2	50	0.5	14
3	75	1.0	28
4½	112	2.5	70
6	150	3.5	100

[A] The indicated size of measure shall be used to test concrete containing aggregates of a nominal maximum size equal to or smaller than that listed. The actual volume of the measure shall be at least 95 % of the nominal volume listed.

NOTE 5—The metal should not be readily subject to attack by cement paste. However, reactive materials such as aluminum alloys may be used in instances where as a consequence of an initial reaction, a surface film is rapidly formed which protects the metal against further corrosion.

NOTE 6—The top rim is satisfactorily plane if a 0.01-in. [0.3-mm] feeler gage cannot be inserted between the rim and a piece of ¼-in. [6-mm] or thicker plate glass laid over the top of the measure.

4.5 *Strike-Off Plate*—A flat rectangular metal plate at least ¼ in. [6 mm] thick or a glass or acrylic plate at least ½ in. [12 mm] thick with a length and width at least 2 in. [50 mm] greater than the diameter of the measure with which it is to be used. The edges of the plate shall be straight and smooth within a tolerance of 1/16 in. [2 mm].

4.6 *Mallet*—A mallet (with a rubber or rawhide head) having a mass of 1.25 ± 0.50 lb [600 ± 200 g] for use with measures of 0.5 ft^3 [14 L] or smaller, and a mallet having a mass of 2.25 ± 0.50 lb [1000 ± 200 g] for use with measures larger than 0.5 ft^3.

4.7 *Scoop*—of a size large enough so each amount of concrete obtained from the sampling receptacle is representative and small enough so it is not spilled during placement in the measure.

5. Sample

5.1 Obtain the sample of freshly mixed concrete in accordance with Practice C 172.

6. Procedure

6.1 Base the selection of the method of consolidation on the slump, unless the method is stated in the specifications under which the work is being performed. The methods of consolidation are rodding and internal vibration. Rod concretes with a slump greater than 3 in. [75 mm]. Rod or vibrate concrete with a slump of 1 to 3 in. [25 to 75 mm]. Consolidate concretes with a slump less than 1 in. by vibration.

NOTE 7—Nonplastic concrete, such as is commonly used in the manufacture of pipe and unit masonry, is not covered by this test method.

6.2 Place the concrete in the measure using the scoop described in 4.7. Move the scoop around the perimeter of the measure opening to ensure an even distribution of the concrete with minimal segregation. Fill the measure in the number of layers required by the consolidation method (6.3 or 6.4).

6.3 *Rodding*—Place the concrete in the measure in three layers of approximately equal volume. Rod each layer with 25 strokes of the tamping rod when nominal 0.5-ft^3 [14-L] or smaller measures are used, 50 strokes when nominal 1-ft^3 [28-L] measures are used, and one stroke per 3 in.^{2} [20 cm^3] of surface for larger measures. Rod each layer uniformly over the cross section with the rounded end of the rod using the required number of strokes. Rod the bottom layer throughout its depth. In rodding this layer, use care not to damage the bottom of the measure. For each upper layer, allow the rod to penetrate through the layer being rodded and into the layer below approximately 1 in. [25 mm]. After each layer is rodded, tap the sides of the measure 10 to 15 times with the appropriate mallet (see 4.6) using such force so as to close any voids left by the tamping rod and to release any large bubbles of air that may have been trapped. Add the final layer so as to avoid overfilling.

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6.4 *Internal Vibration*—Fill and vibrate the measure in two approximately equal layers. Place all of the concrete for each layer in the measure before starting vibration of that layer. Insert the vibrator at three different points for each layer. In compacting the bottom layer, do not allow the vibrator to rest on or touch the bottom or sides of the measure. In compacting the final layer, the vibrator shall penetrate into the underlying layer approximately 1 in. [25 mm]. Take care that the vibrator is withdrawn in such a manner that no air pockets are left in the specimen. The duration of vibration required will depend upon the workability of the concrete and the effectiveness of the vibrator (see Note 8). Continue vibration only long enough to achieve proper consolidation of the concrete (see Note 9). Observe a constant duration of vibration for the particular kind of concrete, vibrator, and measure involved.

NOTE 8—Usually, sufficient vibration has been applied as soon as the surface of the concrete becomes relatively smooth.

NOTE 9—Overvibration may cause segregation and loss of appreciable quantities of intentionally entrained air.

6.5 On completion of consolidation the measure must not contain a substantial excess or deficiency of concrete. An excess of concrete protruding approximately ⅛ in. [3 mm] above the top of the mold is optimum. A small quantity of concrete may be added to correct a deficiency. If the measure contains a great excess of concrete at completion of consolidation, remove a representative portion of the excess concrete with a trowel or scoop immediately following completion of consolidation and before the measure is struck-off.

6.6 *Strike-Off*—After consolidation, strike-off the top surface of the concrete and finish it smoothly with the flat strike-off plate using great care to leave the measure just level full. The strike-off is best accomplished by pressing the strike-off plate on the top surface of the measure to cover about two thirds of the surface and withdrawing the plate with a sawing motion to finish only the area originally covered. Then place the plate on the top of the measure to cover the original two thirds of the surface and advance it with a vertical pressure and a sawing motion to cover the whole surface of the measure and continue to advance it until it slides completely off the measure. Several final strokes with the inclined edge of the plate will produce a smooth finished surface.

6.7 *Cleaning and Weighing*—After strike-off, clean all excess concrete from the exterior of the measure and determine the mass of the concrete and measure to an accuracy consistent with the requirements of 4.1.

7. Calculation

7.1 *Density (Unit Weight)*—Calculate the net mass of the concrete in pounds or kilograms by subtracting the mass of the measure, M_m, from the mass of the measure filled with concrete, M_c. Calculate the density, D, ft^3 or yd^3,by dividing the net mass of concrete by the volume of the measure, V_m as follows:

$$D = (M_c - M_m)/V_m \quad (2)$$

7.2 *Yield*—Calculate the yield as follows:

$$Y(yd^3) = M/(D \times 27) \quad (3)$$

or

$$Y(m^3) = M/D \quad (4)$$

7.3 *Relative Yield*—Relative yield is the ratio of the actual volume of concrete obtained to the volume as designed for the batch (see Note 10) calculated as follows:

$$R_y = Y/Y_d \quad (5)$$

NOTE 10—A value for R_y greater than 1.00 indicates an excess of concrete being produced whereas a value less than this indicates the batch to be "short" of its designed volume. In practice, a ratio of yield in cubic feet per cubic yard of design concrete mixture is frequently used, for example, 27.3 ft^3/yd^3.

7.4 *Cement Content*—Calculate the actual cement content as follows:

$$C = C_b/Y \quad (6)$$

7.5 *Air Content*—Calculate the air content as follows:

$$A = [(T - D)/T] \times 100 \quad (7)$$

or

$$A = [(Y_f - V)/Y_f] \times 100 \text{ (inch–pound units)} \quad (8)$$

or

$$A = [(Y - V)/Y] \times 100 \text{ (SI units)} \quad (9)$$

8. Report

8.1 Report the following information:

8.1.1 Identification of concrete represented by the sample.

8.1.2 Date of test.

8.1.3 Volume of density measure to the nearest 0.001 ft^3 [0.01 L].

8.1.4 Density (Unit Weight) to the nearest 0.1 lbs/ft^3 [1.0 kg/m^3].

8.1.5 Yield, when requested, to the nearest 0.1 yd^3 [0.1 m^3].

8.1.6 Relative Yield, when requested, to the nearest 0.01.

8.1.7 Cement Content, when requested, to the nearest 1.0 lb [0.5 kg].

8.1.8 Air Content, when requested, to the nearest 0.1 percent.

9. Precision and Bias

9.1 The following estimates of precision for this test method are based on a collection of data from various locations by the National Ready Mixed Concrete Association.[3] The data represent concrete mixtures with slump ranging from 3 to 6 in. [75 to 150 mm] and density ranging from 115 to 155 lb/ft^3 [1842 to 2483 kg/m^3] and included air-entrained and non air-entrained concrete. The study was conducted using 0.25 ft^3 [7-L] and 0.5 ft^3 [14-L] measures.

9.1.1 *Single-Operator Precision*—The single operator standard deviation of density of freshly mixed concrete has been found to be 0.65 lb/ft^3 [10.4 kg/m^3] (1s). Therefore, results of two properly conducted by the same operator on the same sample of concrete should not differ by more than 1.85 lb/ft^3 [29.6 kg/m^3] (d2s).

9.1.2 *Multi-Operator Precision*—The multi-operator standard deviation of density of freshly mixed concrete has been

[3] Mullings, G. M., NRMCA/NAA Joint Research Lab Study "Series D 324 Accuracy of Concrete Density Test," Feb. 17, 2000.

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found to be 0.82 lb/ft^3 [13.1 kg/m^3] (1s). Therefore, results of two properly conducted tests by the two operators on the same sample of concrete should not differ by more than 2.31 lb/ft^3 [37.0 kg/m^3] (d2s).

9.2 *Bias*—This test method has no bias since the density is defined only in terms of this test method.

10. Keywords

10.1 air content; cement content; concrete; relative yield; unit weight; yield

SUMMARY OF CHANGES

Committee C09 has identified the location of selected changes to this test method since the last issue, C 138/C 138M – 08, that may impact the use of this test method. (Approved June 1, 2009)

(*1*) Revised 4.2 to alter requirements of tamping rod.
(*2*) Added Note 4 describing acceptable tamping rod length.
(*3*) Revised 6.3 to alter wording of tamping rod use.

Committee C09 has identified the location of selected changes to this test method since the last issue, C 138/C 138M – 07, that may impact the use of this test method. (Approved March 1, 2008)

(*1*) Added new 4.7 to define a scoop.
(*2*) Added new 6.2 to describe how to use a scoop.

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Designation: C141/C141M – 09

Standard Specification for Hydrated Hydraulic Lime for Structural Purposes[1]

This standard is issued under the fixed designation C141/C141M; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

This standard has been approved for use by agencies of the Department of Defense.

1. Scope*

1.1 This specification covers hydrated hydraulic lime for structural purposes.

1.2 Hydrated hydraulic lime may be used in the scratch or brown coat of plaster, stucco, mortar, or in portland-cement concrete either as blend, amendment, or admixture.

1.3 The values stated in either SI units or inch-pound units are to be regarded separately as standard. Within the text, the inch-pound units are shown in brackets. The values stated in each system may not be exact equivalents; therefore, each system shall be used independently of the other. Combining values from the two systems may result in non-conformance with the standard.

1.4 The following precautionary caveat pertains only to the test method portion, Section 11 of this specification: *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

2. Referenced Documents

2.1 *ASTM Standards:*[2]

C25 Test Methods for Chemical Analysis of Limestone, Quicklime, and Hydrated Lime

C50 Practice for Sampling, Sample Preparation, Packaging, and Marking of Lime and Limestone Products

C51 Terminology Relating to Lime and Limestone (as used by the Industry)

C109/C109M Test Method for Compressive Strength of Hydraulic Cement Mortars (Using 2-in. or [50-mm] Cube Specimens)

C110 Test Methods for Physical Testing of Quicklime, Hydrated Lime, and Limestone

C187 Test Method for Normal Consistency of Hydraulic Cement

C191 Test Methods for Time of Setting of Hydraulic Cement by Vicat Needle

C230/C230M Specification for Flow Table for Use in Tests of Hydraulic Cement

C270 Specification for Mortar for Unit Masonry

C305 Practice for Mechanical Mixing of Hydraulic Cement Pastes and Mortars of Plastic Consistency

C778 Specification for Standard Sand

3. Terminology

3.1 For definitions of terms related to this specification, see Terminology C51.

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *hydrated hydraulic lime*, *n*—the product resulting from the slaking of hydraulic quicklime generally to a powder, without any addition, and with or without grinding. It has the property of setting and hardening under water and by reaction of carbon dioxide from the air. The hydraulic properties of this material comes only from the composition of the raw materials.

3.2.2 *hydraulic quicklime*, *n*—a cementitious product obtained by calcining argillaceous or siliceous limestone, or a mixture of similar composition to form sufficient free lime to permit hydration by slaking.

3.2.3 *reworkability*, *n*—the ability of a material which has setting and hardening properties to be remixed after a given period without significantly compromising the final hardened properties of the material.

3.2.4 *period of reworkability*—the length of time a material can be reworked after initial mixing; it shall be expressed in hours.

NOTE 1—Hydrated hydraulic limes have a long working time lasting up to 24 h. The user should seek advice from the producer as to maximum working time.

4. Chemical Composition

4.1 The hydrated hydraulic lime shall conform to the following requirements as to chemical composition, calculated to the nonvolatile basis:

[1] This specification is under the jurisdiction of ASTM Committee C07 on Lime and is the direct responsibility of Subcommittee C07.02 on Specifications and Guidelines

Current edition approved Oct. 1, 2009. Published November 2009. Originally approved in 1938. Last previous edition approved in 2005 as C141 – 97(2005). DOI: 10.1520/C0141_C0141M-09.

[2] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

***A Summary of Changes section appears at the end of this standard.**

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	Min	Max
Calcium and magnesium oxides (CaO and MgO calculated to the nonvolatile basis), %	50	75
Silica (SiO_2 calculated to the nonvolatile basis), %	4	20
Iron and aluminum oxides (Fe_2O_3 and Al_2O_3 caculated to the nonvolatile basis), %	...	7
Carbon dioxide (CO_2 on an as received basis), %	...	16
Available lime (CaO calculated with Test Methods C25 Section 28), %	16	...

5. Fineness

5.1 The sample shall leave a residue of not more than 0.5 % on a 600-µm [No. 30] sieve and not more than 10 % on a 75-µm [No. 200] sieve when tested as described in 11.2.

6. Time of Setting

6.1 The neat lime paste mixed to normal consistency shall not develop an initial set in less than 2 h as determined by the Vicat needle method (see 11.4). Final set shall be attained within 48 h at 100 % RH.

7. Reworkability

7.1 Test for reworkability as described in section 11.7.1. The average compressive strength value of the second set of cubes (set B) shall not be less than 30 % of the first set (set A).

8. Soundness

8.1 The samples when made, stored, and autoclaved as described in 11.5 shall not have an expansion of more than 1.0 %.

9. Compressive Strength

9.1 The average compressive strength of at least three 50-mm [2-in.] cubes, made, stored, and tested in accordance with 11.6, shall be not less than 1.7 N/mm^2 [250 psi] and no more than 10.3 N/mm^2 [1500 psi] at the age of 28 days.

9.2 The producer shall state the compressive strength, when tested in accordance with 11.6, at the age of 28 days.

9.3 The product shall be reworkable at 24 h as tested in accordance with 11.7.

NOTE 2—For quality control convenience, compressive strengths are tested at 28 days. Hydrated hydraulic limes will gain considerably in strength over time (up to 90 % of final strength being realized at 12 months).

10. Sampling

10.1 Each sample selected for purpose of tests shall weigh at least 2.3 kg [5 lb] and shall represent not more than 22 680 kg [50 000 lb]. If only one sample is taken, it shall weigh at least 4.5 kg [10 lb].

10.2 The sample shall be given a preliminary sieving by being passed through a 850-µm [No. 20] sieve in order to thoroughly mix the sample and break up lumps.

10.3 Samples shall be shipped and stored in airtight, moistureproof containers.

10.4 The sampling, inspection, rejection, retesting, packaging, and marking shall be conducted in accordance with Practice C50.

11. Test Methods:

11.1 *Chemical Analysis*:

11.1.1 Analyses for chemical composition shall be carried out in accordance with Test Methods C25.

11.2 *Fineness*:

11.2.1 Wet sieve testing should be determined by Test Methods C110 paragraph 15.4.

11.3 *Normal Consistency*:

11.3.1 Determine normal consistency by the Vicat apparatus in accordance with Test Method C187.

11.4 *Time of Setting*:

11.4.1 Determine time of setting by the Vicat needle method in accordance with Test Method C191. The test will be done on a sample kept at 100 % RH. It will only be removed for measuring.

11.5 *Autoclave Expansion*:

11.5.1 Determine autoclave expansion in accordance with Test Methods C110 paragraph 9.3, with the following modifications:

11.5.1.1 Weigh 25 ± 0.1 g of HHL. Add 3 ± 1 ml of water to the weighed sample and mix by hand until wetted. If the balance allows it, work directly in the specimen mold. If this is not possible, work in an intermediate container and transfer the mixture to the specimen mold in as a complete state as possible. Press to 5.0 ± 1.5 N/mm^2 [725 ± 218 psi] for 10 s and demold specimen and autoclave as described.

11.6 *Compressive Strength*:

11.6.1 *Apparatus*:

11.6.1.1 *Scales and Weights, Sieves, Glass Graduates, Specimen Molds, Tamper, Trowel, and Testing Machine*, in accordance with Test Method C109/C109M.

11.6.1.2 *Flow Table*, conforming to the requirements of Specification C230/C230M.

11.6.1.3 *Mixing Apparatus*, conforming to the requirements of Practice C305.

11.6.2 *Standard Sand*—Use 20–30 sand meeting the requirements of Specification C778.

11.6.3 *Proportions for Standard Mortar*— The mortar shall consist of 1 part of hydrated hydraulic lime to 3 parts of Specification C778 sand, by weight. The quantity of water measured in millilitres shall be such as to produce a flow of 100 to 115 % as determined by the flow table in 11.6.5.

NOTE 3—This proportion is by weight and differs from Specification C270, which is by volume.

11.6.4 *Preparation of Standard Mortar*— Mix the mortar in accordance with Section 7 of Practice C305, using 500 g of hydrated hydraulic lime and 1500 g of Specification C778 sand with the necessary water to give the desired flow.

11.6.5 *Determination of Flow*—Determine the flow in accordance with Section 8.3 of Test Method C109/C109M.

11.6.6 *Molding of Test Specimens*:

11.6.6.1 Prepare molds in accordance with Section 9 of Test Method C109/C109M.

11.6.6.2 The temperature of the air in the vicinity of the mixing slab and of the dry materials, molds, base plates, and mixing bowl, shall be maintained between 20 and 27.5 °C [68 and 81.5 °F]. The temperature of the mixing water, moist closet or moist room, and water in the storage tank shall not vary from 23 °C [73.4 °F] by more than ± 1.7 °C [± 3 °F]. The

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moist closet or moist room shall be so constructed as to provide storage facilities for test specimens at a relative humidity of not less than 90 %.

11.6.6.3 Mold test specimens in accordance with 10.4 of Test Method C109/C109M.

11.6.7 *Storage of Test Specimens*—Keep all test specimens, immediately after molding, in the molds on plane plates in a damp closet, maintained at a relative humidity of 90 % or more, for from 48 to 52 h in such a manner that the upper surfaces are exposed to the moist air. Then remove the specimens from the molds and maintain them at a relative humidity of not less than 90% until the 28 day tests are performed.

11.6.8 *Testing of Specimens*:

11.6.8.1 Test the specimens for 28-day strengths after removal from storage as described in 11.6.7.

11.6.8.2 The remainder of the testing procedure shall be in accordance with 8.6 and Section 9 of Test Method C109/C109M.

11.6.9 *Faulty Specimens*—Specimens that are manifestly faulty or that give strengths differing by more than 15 % from the average value of all test specimens made from the same sample and tested at the same period, shall not be considered in determining the compressive strength.

11.7 *Reworkability: Testing of Specimen*:

11.7.1 Prepare a mortar mix in accordance with 11.6.4 in sufficient amount to be able to fill two sets of three 2-in. cubes. Cut the mix in half, use first half to prepare a first set of cubes (set A). Store second half in a hermetic container and let rest for 24 (±1) h. Once waiting time is achieved, mix the mortar of the second set to achieve required flow as 11.6.5 and prepare a second set of three cubes (set B). Store all cubes as described in 11.6.7. Measure compressive strength of both sets at 28 days of age starting with first mixing time as per 11.6.

12. Storage

12.1 The hydrated hydraulic lime shall be stored in such a manner as to permit easy access for proper inspection and identification of each shipment, and in a suitable weathertight building that will protect the hydrated hydraulic lime from damage.

13. Inspection

13.1 Every producer shall provide the purchaser with the opportunity to sample and inspect the material either at the place of manufacture or at the destination, as may be specified by the purchaser.

14. Rejection

14.1 *Product*—The hydrated hydraulic lime may be rejected if it fails to meet any of the requirements of this specification. At least 31 days shall be allowed for completion of the 28-day test.

14.2 *Packaging*—Packages varying more than 10 % from the weight marked thereon may be rejected, and if the average weight of packages in any shipment, as shown by weighing 50 packages taken at random, is less than the weight marked thereon, the entire shipment may be rejected.

15. Packaging and Marking

15.1 The hydrated hydraulic lime shall be delivered in suitable containers with the brand and name of the manufacturer and the net weight plainly marked thereon. All packages shall be in good condition at the time of inspection.

16. Keywords

16.1 compressive strength; hydrated hydraulic lime; hydraulic lime; mortar; portland cement concrete; plaster; stucco

SUMMARY OF CHANGES

Committee C07 has identified the location of the selected changes to this specification since the last issue, C141 – 97(2005), that may impact the use of this specification (Approved October 1, 2009)

(*1*) The standard was revised throughout, including changing the title and making the standard a dual units specification.

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Designation: C 142 – 97 (Reapproved 2004)

American Association of State
Highway and Transportation Officials Standard
AASHTO No. T112

Standard Test Method for Clay Lumps and Friable Particles in Aggregates[1]

This standard is issued under the fixed designation C 142; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

This standard has been approved for use by agencies of the Department of Defense.

1. Scope

1.1 This test method covers the approximate determination of clay lumps and friable particles in aggregates.

1.2 The values given in SI units are to be regarded as the standard. The values given in parentheses are provided for information purposes only.

1.3 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

2. Referenced Documents

2.1 *ASTM Standards:* [2]

C 33 Specification for Concrete Aggregates

C 117 Test Method for Materials Finer Than 75-µm (No. 200) Sieve in Mineral Aggregates by Washing

C 125 Terminology Relating to Concrete and Concrete Aggregates

C 1005 Specification for Reference Masses and Devices for Determining Mass for Use in the Physical Testing of Hydraulic Cements

E 11 Specification for Wire Cloth and Sieves for Testing Purposes

3. Significance and Use

3.1 This test method is of primary significance in determining the acceptability of aggregate with respect to the requirements of Specification C 33.

4. Apparatus

4.1 *Balance*—A balance or scale accurate to within 0.1 % of the mass of the test sample at any point within the range of use. Balances shall conform to the accuracy of the applicable sections of Specification C 1005.

4.2 *Containers*—Rust-resistant containers of a size and shape that will permit the spreading of the sample on the bottom in a thin layer.

4.3 *Sieves*—Sieves conforming to Specification E 11.

4.4 *Drying Oven*—An oven providing free circulation of air and capable of maintaining a temperature of 110 ± 5°C (230 ± 9°F).

5. Samples

5.1 Aggregate for this test method shall consist of the material remaining after completion of testing in accordance with Test Method C 117. To provide the quantities designated in 5.3 and 5.4, it may be necessary to combine material from more than one test by Test Method C 117.

5.2 Dry the aggregate to substantially constant mass at a temperature of 110 ± 5°C (230 ± 9°F).

5.3 Test samples of fine aggregate shall consist of the particles coarser than a 1.18-mm (No. 16) sieve and shall have a mass not less than 25 g.

5.4 Separate the test samples of coarse aggregate into different sizes, using the following sieves: 4.75-mm (No. 4), 9.5-mm (⅜-in.), 19.0-mm (¾-in.), and 37.5-mm (1½-in.). The test sample shall have a mass not less than indicated in the following table:

Size of Particles Making Up Test Sample	Mass of Test Sample, min, g
4.75 to 9.5-mm (No. 4 to ⅜-in.)	1000
9.5 to 19.0-mm (⅜ to ¾-in.)	2000
19.0 to 37.5-mm (¾ to 1½-in.)	3000
Over 37.5-mm (1½-in.)	5000

[1] This test method is under the jurisdiction of ASTM Committee C09 on Concrete and Concrete Aggregates and is the direct responsibility of Subcommittee C09.20 on Normal Weight Aggregates.

Current edition approved Aug. 1, 2004. Published August 2004. Originally approved in 1938. Last previous edition approved in 1997 as C 142 – 97.

[2] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

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5.5 In the case of mixtures of fine and coarse aggregates, separate the material on the 4.75-mm (No. 4) sieve, and prepare the samples of fine and coarse aggregates in accordance with 5.3 and 5.4.

6. Procedure

6.1 Determine the mass of the test sample to the accuracy specified in 4.1 and spread it in a thin layer on the bottom of the container, cover it with distilled water, and soak it for a period of 24 ± 4 h. Roll and squeeze particles individually between the thumb and forefinger to attempt to break the particle into smaller sizes. Do not use the fingernails to break up particles, or press particles against a hard surface or each other. Classify any particles that can be broken with the fingers into fines removable by wet sieving as clay lumps or friable particles. After all discernible clay lumps and friable particles have been broken, separate the detritus from the remainder of the sample by wet sieving over the sieve prescribed in the following table:

Size of Particles Making Up Sample	Size of Sieve for Removing Residue of Clay Lumps and Friable Particles
Fine aggregate (retained on 1.18-mm (No. 16) sieve)	850-µm (No. 20)
4.75 to 9.5-mm (No. 4 to ⅜-in.)	2.36-mm (No. 8)
9.5 to 19.0-mm (⅜ to ¾-in.)	4.75-mm (No. 4)
19.0 to 37.5-mm (¾ to 1½-in.)	4.75-mm (No. 4)
Over 37.5-mm (1½-in.)	4.75-mm (No. 4)

Perform the wet sieving by passing water over the sample through the sieve while manually agitating the sieve, until all undersize material has been removed.

6.2 Remove the retained particles carefully from the sieve, dry to substantially constant mass at a temperature of 110 ± 5°C (230 ± 9°F), allow to cool, and determine the mass to the nearest 0.1 % of the mass of the test sample as defined in 5.3 or 5.4.

7. Calculation

7.1 Calculate the percent of clay lumps and friable particles in fine aggregate or individual sizes of coarse aggregate as follows:

$$P = [(M - R)/M] \times 100 \quad (1)$$

where:

P = percent of clay lumps and friable particles,
M = mass of test sample (for fine aggregate the mass of the portion coarser than the 1.18-mm (No. 16) sieve as described in 5.3), and
R = mass of particles retained on designated sieve as determined in accordance with 6.2.

7.2 For coarse aggregates, the percent of clay lumps and friable particles shall be an average based on the percent of clay lumps and friable particles in each sieve size fraction weighted in accordance with the grading of the original sample before separation or, preferably, the average grading of the supply represented by the sample. Should the aggregate contain less than 5 % of any of the sizes specified in 6.1, that size shall not be tested but, for the purpose of calculating the weighted average, shall be considered to contain the same percent of clay lumps and friable particles as the next larger or next smaller size, whichever is present.

8. Precision and Bias

8.1 *Precision*[3]—The estimate of the precision of this test method is provisional and is based on samples of one fine aggregate that was tested by ten different operators at nine different laboratories. For that sample, the average "percent of clay lumps and friable particles" in the aggregate was 1.2 %, and the standard deviation was 0.6 %. Based on this standard deviation, the acceptable range of two test results on samples from the same aggregate sent to different laboratories is 1.7 %.

8.2 *Bias*—Since there is no acceptable reference material for determining the bias for the procedure in this test method, no statement is being made.

9. Keywords

9.1 aggregates; clay lumps; friable particles

[3] Supporting data have been filed at ASTM International Headquarters and may be obtained by requesting Research Report RR: C09-1016.

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Designation: C143/C143M – 10

Standard Test Method for Slump of Hydraulic-Cement Concrete[1]

This standard is issued under the fixed designation C143/C143M; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

This standard has been approved for use by agencies of the Department of Defense.

1. Scope*

1.1 This test method covers determination of slump of hydraulic-cement concrete, both in the laboratory and in the field.

1.2 The values stated in either SI units or inch-pound units are to be regarded separately as standard. Within the text, the SI units are shown in brackets. The values stated in each system may not be exact equivalents; therefore, each system shall be used independently of the other. Combining values from the two systems may result in non-conformance with the standard.

1.3 The text of this standard references notes and footnotes which provide explanatory material. These notes and footnotes (excluding those in tables and figures) shall not be considered as requirements of the standard.

1.4 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.* (**Warning**—Fresh hydraulic cementitious mixtures are caustic and may cause chemical burns to skin and tissue upon prolonged exposure.[2])

2. Referenced Documents

2.1 *ASTM Standards:*[3]

C31/C31M Practice for Making and Curing Concrete Test Specimens in the Field

C138/C138M Test Method for Density (Unit Weight), Yield, and Air Content (Gravimetric) of Concrete

C172 Practice for Sampling Freshly Mixed Concrete

C173/C173M Test Method for Air Content of Freshly Mixed Concrete by the Volumetric Method

C231 Test Method for Air Content of Freshly Mixed Concrete by the Pressure Method

C670 Practice for Preparing Precision and Bias Statements for Test Methods for Construction Materials

3. Summary of Test Method

3.1 A sample of freshly mixed concrete is placed and compacted by rodding in a mold shaped as the frustum of a cone. The mold is raised, and the concrete allowed to subside. The vertical distance between the original and displaced position of the center of the top surface of the concrete is measured and reported as the slump of the concrete.

4. Significance and Use

4.1 This test method is intended to provide the user with a procedure to determine slump of plastic hydraulic-cement concretes.

NOTE 1—This test method was originally developed to provide a technique to monitor the consistency of unhardened concrete. Under laboratory conditions, with strict control of all concrete materials, the slump is generally found to increase proportionally with the water content of a given concrete mixture, and thus to be inversely related to concrete strength. Under field conditions, however, such a strength relationship is not clearly and consistently shown. Care should therefore be taken in relating slump results obtained under field conditions to strength.

4.2 This test method is considered applicable to plastic concrete having coarse aggregate up to 1½ in. [37.5 mm] in size. If the coarse aggregate is larger than 1½ in. [37.5 mm] in size, the test method is applicable when it is performed on the fraction of concrete passing a 1½-in. [37.5-mm] sieve, with the larger aggregate being removed in accordance with the section titled "Additional Procedure for Large Maximum Size Aggregate Concrete" in Practice C172.

4.3 This test method is not considered applicable to non-plastic and non-cohesive concrete.

NOTE 2—Concretes having slumps less than ½ in. [15 mm] may not be adequately plastic and concretes having slumps greater than about 9 in.

[1] This test method is under the jurisdiction of ASTM Committee C09 on Concrete and Concrete Aggregates and is the direct responsibility of Subcommittee C09.60 on Testing Fresh Concrete.

Current edition approved Feb. 1, 2010. Published March 2010. Originally approved in 1922. Last previous edition approved in 2009 as C143/C143M–09. DOI: 10.1520/C0143_C0143M-10.

[2] Section on Safety Precautions, Manual of Aggregate and Concrete Testing, *Annual Book of ASTM Standards*, Vol. 04.02.

[3] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

***A Summary of Changes section appears at the end of this standard.**

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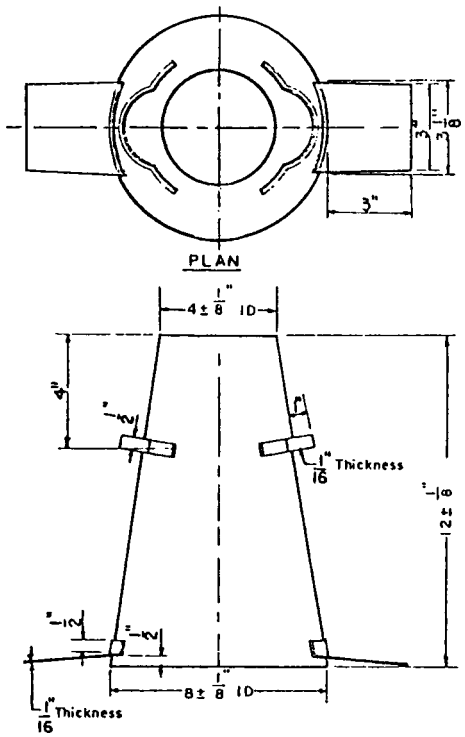
[230 mm] may not be adequately cohesive for this test to have significance. Caution should be exercised in interpreting such results.

5. Apparatus

5.1 *Mold*—The test specimen shall be formed in a mold made of metal not readily attacked by the cement paste. The metal shall not be thinner than 0.060 in. [1.5 mm] and if formed by the spinning process, there shall be no point on the mold at which the thickness is less than 0.045 in. [1.15 mm]. The mold shall be in the form of the lateral surface of the frustum of a cone with the base 8 in. [200 mm] in diameter, the top 4 in. [100 mm] in diameter, and the height 12 in. [300 mm]. Individual diameters and heights shall be within ±⅛ in. [3 mm] of the prescribed dimensions. The base and the top shall be open and parallel to each other and at right angles to the axis of the cone. The mold shall be provided with foot pieces and handles similar to those shown in Fig. 1. The mold shall be constructed without a seam. The interior of the mold shall be relatively smooth and free from projections. The mold shall be free from dents, deformation, or adhered mortar. A mold which clamps to a nonabsorbent base plate is acceptable instead of the one illustrated, provided the clamping arrangement is such that it can be fully released without movement of the mold and the base is large enough to contain all of the slumped concrete in an acceptable test.

5.1.1 Check and record conformance to the mold's specified dimensions when it is purchased or first placed in service and at least annually thereafter.

5.1.2 Mold with alternative materials.



Dimensional Units									
in.	1/16	1/8	1/2	1	3	3 1/8	4	8	12
mm	[2]	[3]	[15]	[25]	[75]	[80]	[100]	[200]	[300]

FIG. 1 Mold for Slump Test

5.1.2.1 Molds other than metal are allowed if the following requirements are met: The mold shall meet the shape, height, and internal dimensional requirements of 5.1. The mold shall be sufficiently rigid to maintain the specified dimensions and tolerances during use, resistant to impact forces, and shall be nonabsorbent. The mold shall be demonstrated to provide test results comparable to those obtained when using a metal mold meeting the requirements of 5.1. Comparability shall be demonstrated on behalf of the manufacturer by an independent testing laboratory. Test for comparability shall consist of not less than 10 consecutive pairs of comparisons performed at each of 3 different slumps ranging from 2 to 8 in. [50 to 200 mm] (Note 3). No individual test results shall vary by more than 0.50 in. [15 mm] from that obtained using the metal mold. The average test results of each slump range obtained using the mold constructed of alternative material shall not vary by more than 0.25 in. [6 mm] from the average of test results obtained using the metal mold. Manufacturer comparability test data shall be available to users and laboratory inspection authorities (Note 4). If any changes in material or method of manufacture are made, tests for comparability shall be repeated.

NOTE 3—The phrase "consecutive pairs of comparisons" does not mean without interruption or all in one day. At a schedule selected by the testing entity, the pairs of tests leading to 10 consecutive pairs may be accomplished in small groups. The word "consecutive" prevents ignoring pairs of tests which may not meet the criteria.

NOTE 4—Because the slump of concrete decreases with time and higher temperatures, it will be advantageous for the comparability tests to be performed by alternating the use of metal cones and alternative material cones, to utilize several technicians, and to minimize the time between test procedures.

5.1.2.2 If the condition of any individual mold is suspected of being out of tolerance from the as manufactured condition, a single comparative test shall be performed. If the test results differ by more than 0.50 in. [15 mm] from that obtained using the metal mold, the mold shall be removed from service.

5.2 *Tamping Rod*—A round, straight steel rod, with a ⅝ in. [16 mm] ± 1/16 in. [2 mm] diameter. The length of the tamping rod shall be at least 4 in. [100 mm] greater than the depth of the mold in which rodding is being performed, but not greater than 24 in. [600 mm] in overall length (Note 5). The length tolerance for the tamping rod shall be ± ⅛ in. [4 mm]. The rod shall have the tamping end or both ends rounded to a hemispherical tip of the same diameter as the rod.

NOTE 5—A rod length of 16 in. [400 mm] to 24 in. [600 mm] meets the requirements of the following: Practice C31/C31M, Test Method C138/C138M, Test Method C143/C143M, Test Method C173/C173M, and Test Method C231.

5.3 *Measuring Device*—A ruler, metal roll-up measuring tape, or similar rigid or semi-rigid length measuring instrument marked in increments of ¼ in. [5 mm] or smaller. The instruement length shall be at least 12 in. [300 mm].

5.4 *Scoop*—of a size large enough so each amount of concrete obtained from the sampling receptacle is representative and small enough so it is not spilled during placement in the mold.

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6. Sample

6.1 The sample of concrete from which test specimens are made shall be representative of the entire batch. It shall be obtained in accordance with Practice C172.

7. Procedure

7.1 Dampen the mold and place it on a rigid, flat, level, moist, nonabsorbent surface, free of vibration, and that is large enough to contain all of the slumped concrete. It shall be held firmly in place during filling and perimeter cleaning by the operator standing on the two foot pieces or by a clamping arrangement to a base plate as described in 5.1. From the sample of concrete obtained in accordance with Section 6, immediately fill the mold in three layers, each approximately one third the volume of the mold (See Note 6). Place the concrete in the mold using the scoop described in 5.4. Move the scoop around the perimeter of the mold opening to ensure an even distribution of the concrete with minimal segregation.

NOTE 6—One third of the volume of the slump mold fills it to a depth of 2⅝ in. [70 mm]; two thirds of the volume fills it to a depth of 6⅛ in. [160 mm].

7.2 Rod each layer 25 times uniformly over the cross section with the rounded end of the rod. For the bottom layer, this will necessitate inclining the rod slightly and making approximately half of the strokes near the perimeter, and then progressing with vertical strokes spirally toward the center. Rod the bottom layer throughout its depth. For each upper layer, allow the rod to penetrate through the layer being rodded and into the layer below approximately 1 in. [25 mm].

7.3 In filling and rodding the top layer, heap the concrete above the mold before rodding is started. If the rodding operation results in subsidence of the concrete below the top edge of the mold, add additional concrete to keep an excess of concrete above the top of the mold at all times. After the top layer has been rodded, strike off the surface of the concrete by means of a screeding and rolling motion of the tamping rod. Continue to hold the mold down firmly and remove concrete from the area surrounding the base of the mold to preclude interference with the movement of slumping concrete. Remove the mold immediately from the concrete by raising it carefully in a vertical direction. Raise the mold a distance of 12 in. [300 mm] in 5 ± 2 s by a steady upward lift with no lateral or torsional motion. Complete the entire test from the start of the filling through removal of the mold without interruption and complete it within an elapsed time of 2½ min.

7.4 Immediately measure the slump by determining the vertical difference between the top of the mold and the displaced original center of the top surface of the specimen. If a decided falling away or shearing off of concrete from one side or portion of the mass occurs (Note 7), disregard the test and make a new test on another portion of the sample.

NOTE 7—If two consecutive tests on a sample of concrete show a falling away or shearing off of a portion of the concrete from the mass of the specimen, the concrete probably lacks necessary plasticity and cohesiveness for the slump test to be applicable.

8. Report

8.1 Report the slump in terms of inches [millimetres] to the nearest ¼ in. [5 mm] of subsidence of the specimen during the test.

9. Precision and Bias [4]

9.1 *Precision*—The estimates of precision for this test method are based upon results from tests conducted in Fayetteville, Arkansas by 15 technicians from 14 laboratories representing 3 states. All tests at 3 different slump ranges, from 1.0 in. [25 mm] to 6.5 in. [160 mm], were performed using one load of truck-mixed concrete. The concrete was delivered and tested at a low slump, with water then being added and mixed into the remaining concrete to independently produce moderate and finally high-slump concrete. The concrete mixture that used a No. 67 crushed limestone aggregate and a washed river sand, contained 500 lb of cementitious materials per cubic yard [297 kg of cementitious material per cubic metre]. The 500 lb [227 kg] were equally divided between a C150, Type I/II cement and a Class C fly ash. A double dosage of a chemical retarder was used in an attempt to minimize slump losses and maintain workability of the concrete. Concrete temperatures ranged from 86 to 93 °F [30 to 34 °C]. Slump losses averaged 0.68 in. [17 mm] during the 20 min required to perform a series of 6 tests at 1 slump range. Testing was performed alternately using metal and plastic molds, which were determined to produce comparable results. Precision data thus applies to both metal and plastic molds. A total of 270 slump tests were performed.

9.1.1 *Inch-Pound [SI]*—The data used to develop the precision statement were obtained using metric units (millimetres). The precision values shown in inch-pound units are conversions from the millimetre measurements, which were recorded to the nearest 1 mm.

9.1.2 *Measure of Variability*—The standard deviation was determined to be the most consistent measure of variability and was found to vary with the slump value.

9.1.3 *Single-Operator Precision*—The single-operator standard deviation represented by (1s) is shown in Table 1 by average slump values. The reported results for the replicate

[4] The test data used to develop this precision statement were based on tests performed in September 1997. Supporting data have been filed at ASTM International Headquarters and may be obtained by requesting Research Report RR:C09-1022.

TABLE 1 Precision

Slump and Type Index	Standard Deviation (1s)[A]		Acceptable Range of Two Results (d2s)[A]	
Single-Operator Precision:	in.	[mm]	in.	[mm]
Slump 1.2 in. [30 mm]	0.23	[6]	0.65	[17]
Slump 3.4 in. [85 mm]	0.38	[9]	1.07	[25]
Slump 6.5 in. [160 mm]	0.40	[10]	1.13	[28]
Multilaboratory Precision:				
Slump 1.2 in. [30 mm]	0.29	[7]	0.82	[20]
Slump 3.4 in. [85 mm]	0.39	[10]	1.10	[28]
Slump 6.5 in. [160 mm]	0.53	[13]	1.50	[37]

[A] These numbers represent, respectively, the (1s) and (d2s) limits as described in Practice C670.

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readings apply to tests conducted by the same operator performing successive tests, one immediately following the other. Acceptable results of two properly conducted tests by the same operator on the same material (Note 8) will not differ from each other by more than the (d2s) value of the last column of Table 1 for the appropriate slump value and single-operator precision.

9.1.4 *Multilaboratory Precision*—The multilaboratory standard deviation represented by (1s) is shown in Table 1 by average slump values. The reported results for the replicate readings apply to tests conducted by different operators from different laboratories performing tests less than 4 min apart. Therefore, acceptable results of two properly conducted slump tests on the same material (Note 8) by two different laboratories will not differ from each other by more than the (d2s) value of the last column of Table 1 for the appropriate slump value and multilaboratory precision.

NOTE 8—"Same materials," is used to mean freshly mixed concrete from one batch.

9.2 *Bias*—This test method has no bias since slump is defined only in terms of this test method.

10. Keywords

10.1 concrete; cone; consistency; plasticity; slump; workability

SUMMARY OF CHANGES

Committee C09 has identified the location of selected changes to this test method since the last issue, C143/C143M – 09, that may impact the use of this test method. (Approved February 1, 2010)

(*1*) Revised the first sentence of 7.1.

Committee C09 has identified the location of selected changes to this test method since the last issue, C143/C143M – 08, that may impact the use of this test method. (Approved August 1, 2009)

(*1*) Revised 5.2 to alter tamping rod requirements.
(*2*) Added Note 5 describing acceptable tamping rod length.
(*3*) Revised 7.2 to alter wording of tamping rod use.

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Designation: C 150/C 150M – 09

Standard Specification for Portland Cement[1]

This standard is issued under the fixed designation C 150/C 150M; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

This standard has been approved for use by agencies of the Department of Defense.

1. Scope*

1.1 This specification covers ten types of portland cement, as follows (see Note 2):

1.1.1 *Type I*—For use when the special properties specified for any other type are not required.

1.1.2 *Type IA*—Air-entraining cement for the same uses as Type I, where air-entrainment is desired.

1.1.3 *Type II*—For general use, more especially when moderate sulfate resistance is desired.

1.1.4 *Type IIA*—Air-entraining cement for the same uses as Type II, where air-entrainment is desired.

1.1.5 *Type II(MH)*—For general use, more especially when moderate heat of hydration and moderate sulfate resistance are desired.

1.1.6 *Type II(MH)A*—Air-entraining cement for the same uses as Type II(MH), where air-entrainment is desired.

1.1.7 *Type III*—For use when high early strength is desired.

1.1.8 *Type IIIA*—Air-entraining cement for the same use as Type III, where air-entrainment is desired.

1.1.9 *Type IV*—For use when a low heat of hydration is desired.

1.1.10 *Type V*—For use when high sulfate resistance is desired.

NOTE 1—Some cements are designated with a combined type classification, such as Type I/II, indicating that the cement meets the requirements of the indicated types and is being offered as suitable for use when either type is desired.

NOTE 2—Cement conforming to the requirements for all types are not carried in stock in some areas. In advance of specifying the use of cement other than Type I, determine whether the proposed type of cement is, or can be made, available.

1.2 The values stated in either SI units or inch-pound units are to be regarded separately as standard. The values stated in each system may not be exact equivalents; therefore, each system shall be used independently of the other. Combining values from the two systems may result in non-conformance with the standard. Values in SI units [or inch-pound units] shall be obtained by measurement in SI units [or inch-pound units] or by appropriate conversion, using the Rules for Conversion and Rounding given in IEEE/ASTM SI 10, of measurements made in other units [or SI units]. Values are stated in only SI units when inch-pound units are not used in practice.

1.3 The text of this standard references notes and footnotes which provide explanatory material. These notes and footnotes (excluding those in tables and figures) shall not be considered as requirements of the standard.

2. Referenced Documents

2.1 *ASTM Standards:*[2]

C 33 Specification for Concrete Aggregates

C 51 Terminology Relating to Lime and Limestone (as used by the Industry)

C 109/C 109M Test Method for Compressive Strength of Hydraulic Cement Mortars (Using 2-in. or [50-mm] Cube Specimens)

C 114 Test Methods for Chemical Analysis of Hydraulic Cement

C 115 Test Method for Fineness of Portland Cement by the Turbidimeter

C 151 Test Method for Autoclave Expansion of Hydraulic Cement

C 183 Practice for Sampling and the Amount of Testing of Hydraulic Cement

C 185 Test Method for Air Content of Hydraulic Cement Mortar

C 186 Test Method for Heat of Hydration of Hydraulic Cement

C 191 Test Methods for Time of Setting of Hydraulic Cement by Vicat Needle

C 204 Test Methods for Fineness of Hydraulic Cement by Air-Permeability Apparatus

C 219 Terminology Relating to Hydraulic Cement

C 226 Specification for Air-Entraining Additions for Use in the Manufacture of Air-Entraining Hydraulic Cement

C 266 Test Method for Time of Setting of Hydraulic-Cement Paste by Gillmore Needles

[1] This specification is under the jurisdiction of ASTM Committee C01 on Cement and is the direct responsibility of Subcommittee C01.10 on Hydraulic Cements for General Concrete Construction.

Current edition approved June 15, 2009. Published July 2009. Originally approved in 1940. Last previous edition approved in 2007 as C 150 – 07.

[2] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

***A Summary of Changes section appears at the end of this standard.**

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C 451 Test Method for Early Stiffening of Hydraulic Cement (Paste Method)
C 452 Test Method for Potential Expansion of Portland-Cement Mortars Exposed to Sulfate
C 465 Specification for Processing Additions for Use in the Manufacture of Hydraulic Cements
C 563 Test Method for Approximation of Optimum SO_3 in Hydraulic Cement Using Compressive Strength
C 1038 Test Method for Expansion of Hydraulic Cement Mortar Bars Stored in Water
E 29 Practice for Using Significant Digits in Test Data to Determine Conformance with Specifications
IEEE/ASTM SI 10 American National Standard for Use of the International System of Units (SI): The Modern Metric System

3. Terminology

3.1 *Definitions*—See Terminology C 219.

4. Ordering Information

4.1 Orders for material under this specification shall include the following:

4.1.1 This specification number and date,

4.1.2 Type or types allowable. If no type is specified, Type I shall be supplied,

4.1.3 Any optional chemical requirements from Table 2, if desired, and

4.1.4 Any optional physical requirements from Table 4, if desired.

5. Ingredients

5.1 The cement covered by this specification shall contain no ingredients except as follows:

5.1.1 Portland cement clinker.

5.1.2 Water or calcium sulfate, or both. The amounts shall be such that the limits shown in Table 1 for sulfur trioxide and loss-on-ignition are not exceeded.

5.1.3 Limestone. The amount shall not be more than 5.0 % by mass such that the chemical and physical requirements of this standard are met (See Note 3). The limestone, defined in Terminology C 51, shall be naturally occurring and consist of at least 70 % by mass of one or more of the mineral forms of calcium carbonate.

NOTE 3—The standard permits up to 5 % by mass of the final cement product to be naturally occurring, finely ground limestone, but does not require that limestone be added to the cement. Cement without ground limestone can be specified in the contract or order.

5.1.4 Inorganic processing additions. The amount shall be not more than 5.0 % by mass of cement. Not more than one inorganic processing addition shall be used at a time. For amounts greater than 1.0 %, they shall have been shown to meet the requirements of Specification C 465 for the inorganic processing addition in the amount used or greater. If an inorganic processing addition is used, the manufacturer shall report the amount (or range) used, expressed as a percentage of cement mass, along with the oxide composition of the processing addition.

5.1.5 Organic Processing additions. They shall have been shown to meet the requirements of Specification C 465 in the amounts used or greater and the total amount of organic processing additions used shall not exceed 1.0 % by mass of cement.

5.1.6 Air-entraining addition (for air-entraining portland cement only). The interground addition shall conform to the requirements of Specification C 226.

TABLE 1 Standard Composition Requirements

Cement Type[A]	Applicable Test Method	I and IA	II and IIA	II(MH) and II(MH)A	III and IIIA	IV	V
Aluminum oxide (Al_2O_3), max, %	C 114	...	6.0	6.0	...	...	...
Ferric oxide (Fe_2O_3), max, %	C 114	...	6.0[B]	6.0[B,C]	...	6.5	...
Magnesium oxide (MgO), max, %	C 114	6.0	6.0	6.0	6.0	6.0	6.0
Sulfur trioxide (SO_3),[D] max, %	C 114						
When $(C_3A)^E$ is 8 % or less		3.0	3.0	3.0	3.5	2.3	2.3
When $(C_3A)^E$ is more than 8 %		3.5	[F]	[F]	4.5	[F]	[F]
Loss on ignition, max, %	C 114	3.0	3.0	3.0	3.0	2.5	3.0
Insoluble residue, max, %	C 114	0.75	0.75	0.75	0.75	0.75	0.75
Tricalcium silicate $(C_3S)^E$, max, %	See Annex A1	...	...	...	...	35[C]	...
Dicalcium silicate $(C_2S)^E$, min, %	See Annex A1	...	...	...	...	40[C]	...
Tricalcium aluminate $(C_3A)^E$, max, %	See Annex A1	...	8	8	15	7[C]	5[B]
Sum of $C_3S + 4.75C_3A^G$, max, %	See Annex A1	...	...	100[H]	...	...	...
Tetracalcium aluminoferrite plus twice the tricalcium aluminate $(C_4AF + 2(C_3A))$, or solid solution $(C_4AF + C_2F)$, as applicable, max, %	See Annex A1	...	...	...	...	...	25[B]

[A] See Note 2.
[B] Does not apply when the sulfate resistance limit in Table 4 is specified.
[C] Does not apply when the heat of hydration limit in Table 4 is specified.
[D] It is permissible to exceed the values in the table for SO_3 content, provided it has been demonstrated by Test Method C 1038 that the cement with the increased SO_3 will not develop expansion exceeding 0.020 % at 14 days. When the manufacturer supplies cement under this provision, supporting data shall be supplied to the purchaser. See Note 5.
[E] See Annex A1 for calculation.
[F] Not applicable.
[G] See Note 4.
[H] In addition, 7-day heat of hydration testing by Test Method C 186 shall be conducted at least once every six months. Such testing shall not be used for acceptance or rejection of the cement, but results shall be reported for informational purposes.

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TABLE 2 Optional Composition Requirements[A]

Cement Type	Applicable Test Method	I and IA	II and IIA	II(MH) and II(MH)A	III and IIIA	IV	V	Remarks
Tricalcium aluminate (C_3A)[B], max, %	See Annex A1	...	...	...	8	...	...	for moderate sulfate resistance
Tricalcium aluminate (C_3A)[B], max, %	See Annex A1	...	...	...	5	...	...	for high sulfate resistance
Equivalent alkalies ($Na_2O + 0.658K_2O$), max, %	C 114	0.60[C]	0.60[C]	0.60[C]	0.60[C]	0.60[C]	0.60[C]	low-alkali cement

[A] These optional requirements apply only when specifically requested. Verify availability before ordering. See Note 2.
[B] See Annex A1 for calculation.
[C] Specify this limit when the cement is to be used in concrete with aggregates that are potentially reactive and no other provisions have been made to protect the concrete from deleteriously reactive aggregates. Refer to Specification C 33 for information on potential reactivity of aggregates.

6. Chemical Composition

6.1 Portland cement of each of the ten types shown in Section 1 shall conform to the respective standard chemical requirements prescribed in Table 1. In addition, optional chemical requirements are shown in Table 2.

NOTE 4—The limit on the sum, $C_3S + 4.75C_3A$, in Table 1 provides control on the heat of hydration of the cement and is consistent with a Test Method C 186 7-day heat of hydration limit of 335 kJ/kg [80 cal/g].

NOTE 5—There are cases where performance of a cement is improved with SO_3 in excess of the Table 1 limits in this specification. Test Method C 563 is one of several methods a manufacturer can use to evaluate the effect of sulfate content on cement characteristics. Whenever SO_3 content of a cement exceeds Table 1 limits, Test Method C 1038 results provide evidence that excessive expansion does not occur at this higher sulfate content.

7. Physical Properties

7.1 Portland cement of each of the ten types shown in Section 1 shall conform to the respective standard physical requirements prescribed in Table 3. In addition, optional physical requirements are shown in Table 4.

8. Sampling

8.1 When the purchaser desires that the cement be sampled and tested to verify compliance with this specification, perform sampling and testing in accordance with Practice C 183.

8.2 Practice C 183 is not designed for manufacturing quality control and is not required for manufacturer's certification.

9. Test Methods

9.1 Determine the applicable properties enumerated in this specification in accordance with the following test methods:

9.1.1 *Air Content of Mortar*—Test Method C 185.

9.1.2 *Chemical Analysis*—Test Methods C 114.

9.1.3 *Strength*—Test Method C 109/C 109M.

9.1.4 *False Set*—Test Method C 451.

9.1.5 *Fineness by Air Permeability*—Test Method C 204.

9.1.6 *Fineness by Turbidimeter*—Test Method C 115.

9.1.7 *Heat of Hydration*—Test Method C 186.

9.1.8 *Autoclave Expansion*—Test Method C 151.

9.1.9 *Time of Setting by Gillmore Needles*—Test Method C 266.

9.1.10 *Time of Setting by Vicat Needles*—Test Method C 191.

9.1.11 *Sulfate Resistance*—Test Method C 452 (sulfate expansion).

9.1.12 *Calcium Sulfate (expansion of) Mortar*—Test Method C 1038.

10. Inspection

10.1 Inspection of the material shall be made as agreed upon between the purchaser and the seller as part of the purchase contract.

11. Rejection

11.1 The cement shall be rejected if it fails to meet any of the requirements of this specification.

11.2 At the option of the purchaser, retest, before using, cement remaining in bulk storage for more than 6 months or cement in bags in local storage in the custody of a vendor for more than 3 months after completion of tests and reject the cement if it fails to conform to any of the requirements of this specification. Cement so rejected shall be the responsibility of the owner of record at the time of resampling for retest.

11.3 Packages shall identify the mass contained as net weight. At the option of the purchaser, packages more than 2 % below the mass marked thereon shall be rejected and if the average mass of packages in any shipment, as shown by determining the mass of 50 packages selected at random, is less than that marked on the packages, the entire shipment shall be rejected.

12. Manufacturer's Statement

12.1 At the request of the purchaser, the manufacturer shall state in writing the nature, amount, and identity of any air-entraining addition and of any processing addition used, and also, if requested, shall supply test data showing compliance of such air-entraining addition with Specification C 226 and of such processing addition with Specification C 465.

12.2 When limestone is used, the manufacturer shall state in writing the amount thereof and, if requested by the purchaser, shall supply comparative test data on chemical and physical properties of the cement with and without the limestone (See Note 6). The comparative tests do not supersede the normal

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TABLE 3 Standard Physical Requirements

Cement Type[A]	Applicable Test Method	I	IA	II	IIA	II(MH)	II(MH)A	III	IIIA	IV	V
Air content of mortar,[B] volume %:	C 185										
max		12	22	12	22	12	22	12	22	12	12
min		...	16	...	16	...	16	...	16	...	...
Fineness,[C] specific surface, m^2/kg (alternative methods):											
Turbidimeter test	C 115										
min		150	150	150	150	150	150	...	...	150	150
max		...	...	...	...	245[D]	245[D]	...	...	245	...
Air permeability test	C 204										
min		260	260	260	260	260	260	...	...	260	260
max		...	...	...	...	430[D]	430[D]	...	...	430	...
Autoclave expansion, max, %	C 151	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80
Strength, not less than the values shown for the ages indicated as follows:[E]											
Compressive strength, MPa [psi]:	C 109/ C 109M										
1 day		...	...	...	...	...	...	12.0 [1740]	10.0 [1450]	...	...
3 days		12.0 [1740]	10.0 [1450]	10.0 [1450]	8.0 [1160]	10.0 [1450] 7.0[F] [1020][F]	8.0 [1160] 6.0[F] [870][F]	24.0 [3480]	19.0 [2760]	...	8.0 [1160]
7 days		19.0 [2760]	16.0 [2320]	17.0 [2470]	14.0 [2030]	17.0 [2470] 12.0[F] [1740][F]	14.0 [2030] 9.0[F] [1310][F]	...	...	7.0 [1020]	15.0 [2180]
28 days		...	...	...	...	...	...	...	...	17.0 [2470]	21.0 [3050]
Time of setting; Vicat test:[G]	C 191										
Time of setting, min, not less than		45	45	45	45	45	45	45	45	45	45
Time of setting, min, not more than		375	375	375	375	375	375	375	375	375	375

[A] See Note 2.
[B] Compliance with the requirements of this specification does not necessarily ensure that the desired air content will be obtained in concrete.
[C] The testing laboratory shall select the fineness method to be used. However, when the sample fails to meet the requirements of the air-permeability test, the turbidimeter test shall be used, and the requirements in this table for the turbidimetric method shall govern.
[D] Maximum fineness limits do not apply if the sum of $C_3S + 4.75C_3A$ is less than or equal to 90.
[E] The strength at any specified test age shall be not less than that attained at any previous specified test age.
[F] When the optional heat of hydration in Table 4 is specified.
[G] The time of setting is that described as initial setting time in Test Method C 191.

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TABLE 4 Optional Physical Requirements[A]

Cement Type	Applicable Test Method	I and II	IA and IIA	II(MH)	II(MH)A	III	IIIA	IV	V
False set, final penetration, min, %	C 451	50	50	50	50	50	50	50	50
Heat of hydration:	C 186								
7 days, max, kJ/kg [cal/g]		...	...	290 [70][B]	290 [70][B]	...	...	250 [60][C]	...
28 days, max, kJ/kg [cal/g]		...	...	...	...	...	...	290 [70][C]	...
Strength, not less than the values shown:									
Compressive strength, MPa [psi]	C 109/ C 109M								
28 days		28.0 [4060]	22.0 [3190]	28.0 [4060] 22.0[B] [3190][B]	22.0 [3190] 18.0[B] [2610][B]	...	...	...	...
Sulfate resistance,[D] 14 days, max, % expansion	C 452	...[E]	...[E]	...[E]	...[E]	...	...	...	0.040
Gillmore test:	C 266								
Initial set, min, not less than		60	60	60	60	60	60	60	60
Final set, min, not more than		600	600	600	600	600	600	600	600

[A] These optional requirements apply only when specifically requested. Verify availability before ordering. See Note 2.
[B] The limit for the sum of $C_3S + 4.75C_3A$ in Table 1 shall not apply when this optional limit is requested. These strength requirements apply when the optional heat of hydration requirement is requested.
[C] When the heat of hydration limit is specified, it shall be instead of the limits of C_3S, C_2S, C_3A, and Fe_2O_3 listed in Table 1.
[D] When the sulfate resistance is specified, it shall be instead of the limits of C_3A, $C_4AF + 2\ C_3A$, and Fe_2O_3 listed in Table 1.
[E] Cement meeting the high sulfate resistance limit for Type V is deemed to meet the moderate sulfate resistance requirement of Type II and Type II(MH).

testing to confirm that the cement meets chemical and physical requirements of this standard. The amount of limestone in cement shall be determined in accordance with Annex A2.

NOTE 6—Comparative test data may be from qualification tests performed by the manufacturer during formulation of the cement with limestone.

13. Packaging and Package Marking

13.1 When the cement is delivered in packages, the words "Portland Cement," the type of cement, the name and brand of the manufacturer, and the mass of the cement contained therein shall be plainly marked on each package. When the cement is an air-entraining type, the words "air-entraining" shall be plainly marked on each package. Similar information shall be provided in the shipping documents accompanying the shipment of packaged or bulk cement. All packages shall be in good condition at the time of inspection.

NOTE 7—With the change to SI units, it is desirable to establish a standard SI package for portland cements. To that end 42 kg [92.6 lb] provides a convenient, even-numbered mass reasonably similar to the traditional 94-lb [42.6-kg] package.

14. Storage

14.1 The cement shall be stored in such a manner as to permit easy access for proper inspection and identification of each shipment, and in a suitable weather-tight building that will protect the cement from dampness and minimize warehouse set.

15. Manufacturer's Certification

15.1 Upon request of the purchaser in the contract or order, a manufacturer's report shall be furnished at the time of shipment stating the results of tests made on samples of the material taken during production or transfer and certifying that the cement conforms to applicable requirements of this specification.

NOTE 8—Guidance on preparing the manufacturer's report is provided in Appendix X1.

16. Keywords

16.1 hydraulic cement; portland cement; specification

ANNEXES

(Mandatory Information)

A1. CALCULATION OF POTENTIAL CEMENT PHASE COMPOSITION

A1.1 All values calculated as described in this annex shall be rounded according to Practice E 29. When evaluating conformance to a specification, round values to the same number of places as the corresponding table entry before making comparisons. The expressing of chemical limitations by means of calculated assumed phases does not necessarily mean that the oxides are actually or entirely present as such phases.

A1.2 When expressing phases, $C = CaO$, $S = SiO_2$, $A = Al_2O_3$, $F = Fe_2O_3$. For example, $C_3A = 3CaO{\cdot}Al_2O_3$. Titanium dioxide and phosphorus pentoxide (TiO_2 and P_2O_5) shall not be included with the Al_2O_3 content. See Note A1.1.

NOTE A1.1—When comparing oxide analyses and calculated phases from different sources or from different historic times, be aware that they may not have been reported on exactly the same basis. Chemical data obtained by Reference and Alternate Test Methods of Test Methods C 114

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(wet chemistry) may include titania and phosphorus as alumina unless proper correction has been made (see Test Methods C 114), while data obtained by rapid instrumental methods usually do not. This can result in small differences in the calculated phases. Such differences are usually within the precision of the analytical methods, even when the methods are properly qualified under the requirements of Test Methods C 114.

A1.3 When the ratio of percentages of aluminum oxide to ferric oxide is 0.64 or more, the percentages of tricalcium silicate, dicalcium silicate, tricalcium aluminate, and tetracalcium aluminoferrite shall be calculated from the chemical analysis as follows:

$$\text{Tricalcium silicate } (C_3S) = (4.071 \times \%\ CaO) - (7.600 \times \%\ SiO_2) - (6.718 \times \%\ Al_2O_3) - (1.430 \times \%\ Fe_2O_3) - (2.852 \times \%\ SO_3) \quad \text{(A1.1)}$$

$$\text{Dicalcium silicate } (C_2S) = (2.867 \times \%\ SiO_2) - (0.7544 \times \%\ C_3S) \quad \text{(A1.2)}$$

$$\text{Tricalcium aluminate } (C_3A) = (2.650 \times \%\ Al_2O_3) - (1.692 \times \%\ Fe_2O_3) \quad \text{(A1.3)}$$

$$\text{Tetracalcium aluminoferrite } (C_4AF) = 3.043 \times \%\ Fe_2O_3 \quad \text{(A1.4)}$$

A1.3.1 When the alumina-ferric oxide ratio is less than 0.64, a calcium aluminoferrite solid solution (expressed as $ss(C_4AF + C_2F)$) is formed. No tricalcium aluminate will be present in cements of this composition. Dicalcium silicate shall be calculated as in Eq A1.2. Contents of this solid solution and of tricalcium silicate shall be calculated by the following formulas:

$$ss\ (C_4AF + C_2F) = (2.100 \times \%\ Al_2O_3) + (1.702 \times \%\ Fe_2O_3) \quad \text{(A1.5)}$$

$$\text{Tricalcium silicate } (C_3S) = (4.071 \times \%\ CaO) - (7.600 \times \%\ SiO_2) - (4.479 \times \%\ Al_2O_3) - (2.859 \times \%\ Fe_2O_3) - (2.852 \times \%\ SO_3) \quad \text{(A1.6)}$$

A1.4 If no limestone or inorganic processing additions are used in the cement, or in the absence of information on limestone or inorganic processing additions use in the cement, phases shall be calculated using procedures in Eq A1.1-A1.6 without adjustment.

A1.5 In absence of information on limestone or inorganic processing additions content, results shall note that no adjustment has been made for possible use of limestone or inorganic processing additions.

A1.6 When inorganic processing additions or limestone or both are used with the base cement (portland cement clinker and any added calcium sulfate), the contents of C_3S, C_2S, C_3A, and C_4AF, shall be adjusted as follows:

A1.6.1 The percentage of C_3S, C_2S, C_3A, and C_4AF in the base cement shall be determined based on chemical analyses using methods in Test Methods C 114 and using Eq A1.1-A1.6 as appropriate. The contents of each of these phases shall be adjusted to account for the use of limestone or inorganic processing additions as follows:

$$X_f = X_b \times \frac{(100 - L - P)}{100}$$

where:

X_b = the percentage by mass of C_3S, C_2S, C_3A, or C_4AF in the base cement (portland cement clinker and any calcium sulfate),
L = the percentage by mass of limestone,
P = the percentage by mass of inorganic processing addition, and
X_f = the percentage by mass of C_3S, C_2S, C_3A, or C_4AF in the finished cement.

The adjusted values for the finished cement shall be reported on the manufacturer's report.

NOTE A1.2—For example:

Where the cement includes 3.5 % limestone and 3.0 % of an inorganic processing addition and the base cement has 60 % C_3S, 15 % C_2S, 7 % C_3A, and 10 % C_4AF, the adjusted phase composition is:

$$C_3S_f = \frac{60 \times (100 - 3.5 - 3.0)}{100} = 56\ \%$$

$$C_2S_f = \frac{15 \times (100 - 3.5 - 3.0)}{100} = 14\ \%$$

$$C_3A_f = \frac{7 \times (100 - 3.5 - 3.0)}{100} = 7\ \%$$

$$C_4AF_f = \frac{10 \times (100 - 3.5 - 3.0)}{100} = 9\ \%$$

A2. LIMESTONE CONTENT OF PORTLAND CEMENT

A2.1 When limestone is used, the limestone content in portland cement shall be derived from the determination of CO_2 in the finished cement. Analysis of CO_2 shall be based on methods described in Test Methods C 114. The percent limestone in the cement is calculated from the CO_2 analysis based on the CO_2 content of the limestone used.

The manufacturer shall include the CO_2 content and calculated limestone content of the cement on the Mill Test Report.

The limestone content of the cement is calculated as follows:

$$\frac{\%\ CO_2 \text{ in the cement}}{\%\ CO_2 \text{ in the limestone}} \times 100 = \%\ \text{limestone in cement}$$

NOTE A2.1—*For example*:

Where the determined CO_2 content in the finished cement = 1.5 % and the CO_2 content of the limestone = 43 % ($CaCO_3$ in limestone = 98 %)

Then:

$$\frac{1.5}{43} \times 100 = 3.5\ \%\ \text{limestone content in cement}$$

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A2.2 This specification requires that the limestone to be used must contain a minimum of 70 % $CaCO_3$. The manufacturer shall include the $CaCO_3$ content of the limestone on the manufacturer's report. Calculate the $CaCO_3$ content of the limestone as follows: % $CaCO_3 = 2.274 \times$ % CO_2.

NOTE A2.2—For verification of limestone content of cement, the purchaser must analyze for CO_2 content and make a correction for the content of $CaCO_3$ in the limestone in order for the data to be comparable to the manufacturer's report.

A2.3 Portland cements that do not contain limestone can contain baseline levels of CO_2 inherent in manufacture, for example, due to carbonation. This baseline CO_2 content is included as part of any calculated limestone content.

APPENDIX

(Nonmandatory Information)

X1. MANUFACTURER'S CERTIFICATION (MILL TEST REPORT)

X1.1 To provide uniformity for reporting the results of tests performed on cements under this specification, as required by Section 15 of Specification C 150 entitled "Manufacturer's Certification," an example Mill Test Report is shown in Fig. X1.1.

X1.2 The identity information given should unambiguously identify the cement production represented by the Mill Test Report and may vary depending upon the manufacturer's designation and purchaser's requirements.

X1.3 The Manufacturer's Certification statement may vary depending upon the manufacturer's procurement order, or legal requirements, but should certify that the cement shipped is represented by the certificate and that the cement conforms to applicable requirements of the specification at the time it was tested (or retested) or shipped.

X1.4 The sample Mill Test Report has been developed to reflect the chemical and physical requirements of this specification and recommends reporting all analyses and tests normally performed on cements meeting Specification C 150. Purchaser reporting requirements should govern if different from normal reporting by the manufacturer or from those recommended here.

X1.5 Cements may be shipped prior to later-age test data being available. In such cases, the test value may be left blank. Alternatively, the manufacturer can generally provide estimates based on historical production data. The report should indicate if such estimates are provided.

X1.6 In reporting limits from the tables in Specification C 150 on the Mill Test Report, only those limits specifically applicable should be listed. In some cases, Specification C 150 table limits are superceded by other provisions.

X1.7 When limestone or inorganic processing additions or both are used in the cement, additional data are reported by the manufacturer. An example additional data report is shown in Fig. X1.2.

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ABC Portland Cement Company
Qualitytown, N.J.

Plant Example | Cement Type II(MH) | Date March 9, 20xx

Production Period March 2, 20xx – March 8, 20xx

STANDARD REQUIREMENTS
ASTM C 150 Tables 1 and 3

CHEMICAL

Item	Spec. Limit	Test Result
SiO_2(%)	[A]	20.6
Al_2O_3(%)	6.0 max	4.4
Fe_2O_3(%)	6.0 max	3.3
CaO (%)	[A]	62.9
MgO (%)	6.0 max	2.2
SO_3(%)	3.0 max	3.2
Ignition loss (%)	3.0 max	2.7
Na_2O (%)	[A]	0.19
K_2O (%)	[A]	0.50
Insoluble residue (%)	0.75 max	0.27
CO_2 (%)	[A]	1.5
Limestone (%)	5.0 max	3.5
$CaCO_3$ in limestone (%)	70 min	98
Inorganic processing addition (ground, granulated blastfurnace slag)	5.0 max	3.0
Potential phase composition (%)[C]		
C_3S	[A]	59
C_2S	[A]	11
C_3A	8 max	5
C_4AF	[A]	10
$C_4AF + 2(C_3A)$	[A]	20
$C_3S + 4.75C_3A$	100 max	83

PHYSICAL

Item	Spec. Limit	Test Result
Air content of mortar (volume %)	12 max	8
Blaine fineness (m^2/kg)	260 min 430 max	377
Autoclave expansion (%)	0.80 max	0.04
Compressive strength (MPa)	min:	
1 day	[A]	
3 days	7.0	23.4
7 days	12.0	29.8
28 days	[A]	
Time of setting (minutes)		
(Vicat)		
Initial Not less than	45	124
Not more than	375	
Heat of hydration (kJ/kg)		
7 days	[B]	300
Test Method C 1038 Mortar Bar Expansion (%)	[D]	0.010[E]

[A]Not applicable.
[B]Test result represents most recent value and is provided for information only.
[C]Adjusted per A1.6.
[D]Required only if percent SO_3 exceeds the limit in Table 1, in which case the Test Method C 1038 expansion shall not exceed 0.020 % at 14 days.
[E]Test result for this production period not available. Most recent test result provided.

OPTIONAL REQUIREMENTS
ASTM C 150 Tables 2 and 4

CHEMICAL

Item	Spec. Limit	Test Result
Equivalent alkalies (%)	[F]	0.52

PHYSICAL

Item	Spec. Limit	Test Result
False set (%)	50 min	82
Compressive strength (MPa)		
28 days	28.0 min	[G]

[F]Limit not specified by purchaser. Test result provided for information only.
[G]Test result for this production period not yet available.

We certify that the above described cement, at the time of shipment, meets the chemical and physical requirements of the ASTM C 150 – XX or (other) _____ specification.

Signature: _____ Title: _____

FIG. X1.1 Example Mill Test Report

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ABC Portland Cement Company
Qualitytown, N.J.

Plant: Example Cement Type II Date March 9, 20xx

Production Period March 2, 20xx – March 8, 20xx

Additional Data

Inorganic Processing Addition Data

Type	Ground, granulated blast furnace slag
Amount (%)	3.0
SiO_2(%)	33.1
Al_2O_3(%)	10.9
Fe_2O_3(%)	1.1
CaO (%)	44.4
SO_3(%)	0.2

Base Cement Phase Composition

C_3S (%)	63
C_2S (%)	12
C_3A (%)	5
C_4AF(%)	11

We certify that the above described data represents the materials used in the cement manufactured during the production period indicated.

Signature: _____ Title: _____

FIG. X1.2 Example Additional Data Report

SUMMARY OF CHANGES

Committee C01 has identified the location of selected changes to this specification since the last issue, C 150 – 07, that may impact the use of this specification. (Approved June 15, 2009)

(*1*) Revised the standard as a dual units specification, including revision to the units statement in 1.2.
(*2*) Revised the desciption of Type II in 1.1.3.
(*3*) Included new designations for Type II(MH) and Type II(MH)A as new paragraphs 1.1.5 and 1.1.6.
(*4*) Added IEEE/ASTM SI 10 to 1.2 and Referenced Documents.
(*5*) Revised Table 1 to remove heat index requirement from Type II and include new columns for Type II(MH) and Type II(MH)A with those requirements.
(*6*) Revised Footnote D in Table 1.
(*7*) Revised Table 2 to include Type II(MH) and Type II(MH)A.
(*8*) Removed limits in Table 3 for average fineness.
(*9*) Revised Table 3 to remove maximum fineness and alternate 3- and 7-day strength requirements from Type II and include new columns for Type II(MH) and Type II(MH)A with those requirements.
(*10*) Deleted Footnotes D and E in Table 3 and renumbered subsequent footnotes.
(*11*) Revised Table 4 to include appropriate optional 28-day strength criteria for Type II, Type IIA, Type II(MH), and Type II(MH)A.
(*12*) Added new 5.1.4 on "inorganic processing additions" and renumbered subsequent paragraphs.
(*13*) Revised 5.1.5 as paragraph on "organic processing additions."
(*14*) Added new Note 5 and renumbered subsequent notes.
(*15*) Deleted 9.1.13.
(*16*) Revised Annex A1 calculation to drop CO_2 term and associated text.
(*17*) Added new A1.4-A1.6 with guidance on and adjustments to Bogue calculations.
(*18*) Added new X1.7 with information on additional reporting requirements noted in 5.1.4.
(*19*) Revised Fig. X1.1.
(*20*) Added new Fig. X1.2.

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Designation: C 151/C 151M – 09

Standard Test Method for Autoclave Expansion of Hydraulic Cement[1]

This standard is issued under the fixed designation C 151/C 151M; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope*

1.1 This test method covers determination of the autoclave expansion of hydraulic cement by means of a test on a neat cement specimen.

1.2 The values stated in either SI units or inch-pound units are to be regarded separately as standard. The values stated in each system may not be exact equivalents; therefore, each system shall be used independently of the other. Combining values from the two systems may result in non-conformance with the standard.

1.3 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*For specific precaution statements, see the section on Safety Precautions.

2. Referenced Documents

2.1 *ASTM Standards:*[2]

C 187 Test Method for Normal Consistency of Hydraulic Cement

C 305 Practice for Mechanical Mixing of Hydraulic Cement Pastes and Mortars of Plastic Consistency

C 490 Practice for Use of Apparatus for the Determination of Length Change of Hardened Cement Paste, Mortar, and Concrete

C 511 Specification for Mixing Rooms, Moist Cabinets, Moist Rooms, and Water Storage Tanks Used in the Testing of Hydraulic Cements and Concretes

C 856 Practice for Petrographic Examination of Hardened Concrete

C 1005 Specification for Reference Masses and Devices for Determining Mass and Volume for Use in the Physical Testing of Hydraulic Cements

C 1157 Performance Specification for Hydraulic Cement

3. Significance and Use

3.1 The autoclave expansion test provides an index of potential delayed expansion caused by the hydration of CaO, or MgO, or both, when present in hydraulic cement.[3]

4. Interferences

4.1 Pozzolans containing fine-grained quartz have been reported to cause excessive expansion under autoclave test conditions due to alkali-silica reaction that will not occur under normal service conditions.[4] When excessive expansion of paste containing pozzolans occurs, it is recommended that the specimens be examined (See Practice C 856) for evidence of alkali-silica reaction (Note 1).

NOTE 1—If the excessive expansion has resulted from alkali-silica reaction under autoclave conditions, the pozzolan can be evaluated for alkali reactivity using the procedure described in Performance Specification C 1157.

5. Apparatus

5.1 *Weighing Devices and Weights*, for determining the mass of materials conforming to the requirements of Specification C 1005.

5.2 *Glass Graduates*, 200 or 250-mL capacity, and conforming to the requirements of Practice C 490.

5.3 *Molds*, conforming to the requirements of Practice C 490 for test specimens used in the determination of length change of cement paste.

5.4 *Flat Trowel*, conforming to the requirements of Test Method C 187.

5.5 *Autoclave*, consisting of a high-pressure steam vessel provided with a thermometer well. The autoclave shall be equipped with automatic controls and a rupture disk with a bursting pressure of 2.4 MPa [350 psi] ± 5 %. In locations where the use of a rupture disk is not permitted, the autoclave shall be equipped with a safety valve. In addition, the autoclave shall be equipped with a vent valve to allow the escape of air during the early part of the heating period and to release any

[1] This test method is under the jurisdiction of ASTM Committee C01 on Cement and is the direct responsibility of Subcommittee C01.31 on Volume Change.

Current edition approved Jan. 1, 2009. Published January 2009. Originally approved in 1940. Last previous edition approved in 2005 as C 151 – 05.

[2] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

[3] Gonnerman, H. F., Lerch, W. and Whiteside, T. M. , "Investigations of the Hydration Expansion Characteristics of Portland Cements," *Portland Cement Association Research Department Bulletin 45* , pp. 1-168, 1953.

[4] Wang, H., "Autoclave Soundness Test Mischaracterizes Cement-Fly Ash Blends by Introducing Alkali-Quartz Reaction," *Cement, Concrete, and Aggregates*, Vol. 24, No. 2, pp. 68-72, 2002.

***A Summary of Changes section appears at the end of this standard.**

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steam pressure remaining at the end of the cooling period. The pressure gage shall have a nominal capacity of 4.0 MPa [600 psi], a dial with a nominal diameter of 115 mm [4½ in.] and shall be graduated from 0 to 4.0 MPa [0 to 600 psi] with scale divisions not exceeding 0.03 MPa [5 psi]. The error in the gage shall not exceed ± 0.02 MPa [± 3 psi] at the operating pressure of 2 MPa [295 psi]. The capacity of the heating unit shall be such that with maximum load (water plus specimens) the pressure of the saturated steam in the autoclave may be raised to a gage pressure of 2 MPa [295 psi] in 45 to 75 min from the time the heat is turned on. The automatic control shall be capable of maintaining the gage pressure at 2 ± 0.07 MPa [295 ± 10 psi] for at least 3 h. A gage pressure of 2 ± 0.07 MPa [295 ± 10 psi] corresponds to a temperature of 216 ± 2 °C [420 ± 3 °F]. The autoclave shall be designed to permit the gage pressure to drop from 2 MPa to less than 0.07 MPa [295 psi to less than 10 psi] in 1½ h after the heat supply has been shut off.

5.5.1 *Rupture Disk*—The rupture disk shall be made of a material having a tensile strength that is relatively insensitive to temperature in the range 20 to 216 °C [68 to 420 °F] and that is electrochemically compatible with the pipe leading to it and to its holder.[5]

5.6 *Length Comparator*—The comparator used for measuring length change of specimens shall conform to the requirements of Practice C 490.

6. Temperature and Humidity

6.1 *Molding Room*—Maintain the temperature of the molding room, dry materials and mixing water, and the relative humidity of the molding room within the limits of Practice C 490.

6.2 *Moist Storage Facilities*—Maintain the temperature and humidity of the moist storage facilities to the requirements of Specification C 511.

7. Safety Precautions

7.1 The pressure gage shall have a capacity of 4.0 MPa [600 psi]. A gage with too small or too large a capacity may be a hazard, since for pressure above the specified maximum working pressure, with a smaller capacity gage, the pressure may be off scale, and with a larger capacity gage, the arc of movement may be too small to invite attention. The operator shall be sure the gage hand has not passed the maximum graduation on the scale.

7.2 Test the pressure gage for proper operation. Always use a thermometer together with the pressure gage, so as to provide a means of detecting any failure of the pressure gage to operate properly, and to indicate any unusual condition.

7.3 Maintain the automatic control in proper working order at all times.

7.4 Set the safety valve to relieve the pressure at about 6 to 10 % above the maximum of 2.1 MPa [305 psi] specified in this test method, that is, at about 2.3 MPa [330 psi]. Unless the manufacturer has given specific instructions as to maintenance of the safety valve, test the valve twice each year.[6] Test with a gage testing device, or by adjusting the automatic controls to allow the autoclave to reach a pressure of about 2.3 MPa [330 psi], at which pressure the safety valve will either open or be adjusted to open. Direct the safety valve discharge away from the operator.

NOTE 2—Unexpected combinations of conditions may occur. For example, in one case the automatic control had failed, the safety valve had become stuck, and the gage hand, which at first glance appeared to be at about zero, had passed the maximum graduation and had come to stop on the wrong side of the pin. This condition of the gage was finally detected and the pressure, then of an unknown magnitude, was released before failure could occur in the apparatus.

7.5 Wear heavy leather work gloves to prevent burning of the hands when removing the top of the autoclave at the end of the test. Direct the vent valve away from the operator. When removing the autoclave lid, tilt it so that any steam escaping from beneath the lid will be discharged away from the operator. Care shall be taken to avoid scalding by any liquid that may have been used in the autoclave well.

7.6 The operator shall be made aware that for many autoclave pressure gages the return of the gage hand to the initial rest or starting point does not necessarily indicate zero pressure within the autoclave; there may then still remain an appreciable dangerous pressure.

8. Number of Test Specimens

8.1 Make at least one test specimen.

9. Preparation of Specimen Molds

9.1 Prepare the specimen molds in accordance with the requirements of Practice C 490 except that molds need not be sealed.

10. Preparation of Test Specimens

10.1 *Mixing Cement Paste*—Prepare the standard batch consisting of 650 g of cement and sufficient water to give a paste of normal consistency in accordance with the procedure described in Test Method C 187. Mix this batch in accordance with the procedure described in Practice C 305. Both a time of setting specimen and an autoclave bar may be made from the same batch. If the paste to be used for time of setting is the paste sample already used to determine normal consistency, then the autoclave bar may be prepared immediately from the remainder of the batch.

10.2 *Molding Specimens*—Immediately following preparation of the time of setting specimen or completion of mixing, mold the test specimen in two approximately equal layers, each layer being compacted with the thumbs or forefingers by pressing the paste into the corners, around the gage studs, and along the surface of the mold until a homogeneous specimen is obtained. Compact the top layer, cut off the paste flush with the top of the mold with a thin-edged trowel, and smooth the surface with a few strokes of the flat trowel. During the operations of mixing and molding, protect the hands with rubber gloves.

[5] A list of suppliers of autoclave rupture disks and gaskets is maintained at ASTM Headquarters.

[6] A list of facilities for testing autoclave safety valves is maintained at ASTM Headquarters.

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10.3 *Storage of Test Specimens*—After filling the mold, place it in the moist closet or moist room. Store the specimens in the molds in the moist enclosure for at least 20 h; if removed from the molds before 24 h, they shall be kept in the moist closet or moist room until time of test.

11. Procedure

11.1 At 24 h ± 30 min after molding, remove the specimens from the moist atmosphere, immediately obtain a length comparator reading for each specimen, and place in the autoclave at room temperature in a rack so that all sides of the specimen will be exposed to saturated steam. The autoclave shall contain enough water, at an initial temperature of 20 to 28 °C [68 to 82 °F], to maintain an atmosphere of saturated steam vapor during the entire test. Ordinarily 7 to 10 % of the volume of the autoclave should be occupied by the water.

11.2 To permit air to escape from the autoclave during the early portion of the heating period, leave the vent valve open until steam begins to escape. (**Warning**—See the section on Safety Precautions). Close the valve and raise the temperature of the autoclave at a rate that will bring the gage pressure of the steam to 2 MPa [295 psi] in 45 to 75 min from the time the heat is turned on. Maintain the 2 ± 0.07 MPa [295 ± 10 psi] pressure for 3 h. At the end of the 3-h period, shut off the heat supply and cool the autoclave at such a rate that the pressure will be less than 0.07 MPa [10 psi] at the end of 1½ h. At the end of the 1½-h period, slowly release any remaining pressure by partially opening the vent valve until atmospheric pressure is attained. Then open the autoclave and place the test specimen in water at a temperature above 90 °C [194 °F]. Cool the water surrounding the bars at a uniform rate by adding cold water so that the temperature of the water will be lowered to 23 °C [74 °F] in 15 min. Maintain the water surrounding the specimens at 23 °C [74 °F] for an additional 15 min; then, remove one specimen at a time from the water, blot the pins, but not the specimen, and obtain a length comparator reading.

12. Calculation

12.1 Calculate the change in length of the test specimen by subtracting the length comparator reading before autoclaving from that after autoclaving, and report as percent of effective gage length to the nearest 0.01 %. Report the percentage of increase in length as the autoclave expansion. Indicate a decrease in length by a minus sign prefixed to the percent value.

13. Precision and Bias

13.1 *Precision*—The single-operator (within-laboratory) standard deviation has been found to be 0.024 % throughout the range of 0.11 % to 0.94 % expansions. Therefore, results of two properly conducted tests by the same operator for expansions of similar batches should not differ from each other by more than 0.07 % expansion. The multi-laboratory (between laboratory) standard deviation has been found to be 0.030 % throughout the range of 0.11 % to 0.94 % expansions. Therefore, results of two properly conducted tests from two different laboratories for expansions of similar batches should not differ from each other by more than 0.09 % expansion.

13.2 *Bias*—Since there is no accepted reference material suitable for determining bias, bias has not been determined.

14. Keywords

14.1 autoclave; autoclave expansion; expansion; hydraulic cement; soundness

For additional useful information on details of cement test methods, reference may be made to the "Manual of Cement Testing," which appears in the *Annual Book of ASTM Standards,* **Vol 04.01.**

SUMMARY OF CHANGES

Committee C01 has identified the location of selected changes to this test method since the last issue, C 151 – 05, that may impact the use of this test method. (Approved January 1, 2009)

(*1*) Revised the standard as a combined units standard.

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Designation: C156 – 09a

Standard Test Method for Water Loss [from a Mortar Specimen] Through Liquid Membrane-Forming Curing Compounds for Concrete[1]

This standard is issued under the fixed designation C156; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

This standard has been approved for use by agencies of the Department of Defense.

1. Scope*

1.1 This test method covers laboratory determination of the efficiency of liquid membrane-forming compounds for curing concrete, as measured by their ability to reduce moisture loss during the early hardening period.

1.2 The values stated in SI units are to be regarded as standard. The values given in parentheses are mathematical conversions to inch-pound units that are provided for information only and are not considered standard.

1.3 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*(**Warning—**Fresh hydraulic cementitious mixtures are caustic and may cause chemical burns to skin and tissue upon prolonged exposure.)[2]

2. Referenced Documents

2.1 *ASTM Standards:*[3]

C87 Test Method for Effect of Organic Impurities in Fine Aggregate on Strength of Mortar

C150 Specification for Portland Cement

C230/C230M Specification for Flow Table for Use in Tests of Hydraulic Cement

C305 Practice for Mechanical Mixing of Hydraulic Cement Pastes and Mortars of Plastic Consistency

C778 Specification for Standard Sand

D1475 Test Method For Density of Liquid Coatings, Inks, and Related Products

D1653 Test Methods for Water Vapor Transmission of Organic Coating Films

D2369 Test Method for Volatile Content of Coatings

E178 Practice for Dealing With Outlying Observations

3. Significance and Use

3.1 The moisture retaining ability of a product as determined by this test method is used to assess the suitability of materials for contributing to an appropriate curing environment for concrete. The laboratory test method is used both in formulating and in specifying or qualifying curing products. This test method gives the user a measure of the ability of tested curing materials to impede the escape of moisture from a hydraulic cement mortar. Since it is desirable to retain moisture in fresh concrete to promote the hydration process, failure of the product to minimize the escape of moisture may lead to loss of strength, cracking, shrinkage, or low abrasion resistance of the hardened concrete, or a combination thereof.

3.2 Many factors affect the laboratory test results. Test results obtained may be highly variable as indicated by the precision statement. Critical factors include the precision of the control of the temperature, humidity and air circulation in the curing cabinet, preparation and sealing of the mortar specimens, the age and surface condition of the mortar specimen when the curing product is applied, and the uniformity and quantity of application of the curing membrane.

4. Apparatus

4.1 *Mechanical Mortar Mixer*, as described in Practice C305, or a larger size mixture operating on the same principle.

4.2 *Flow Table*, as described in Specification C230/C230M.

4.3 *Molds* shall be made of metal, glass, hard rubber, or plastic, and shall be watertight and rigidly constructed to prevent distortion during molding of the specimens or handling of the mold containing fresh mortar. They shall have a minimum surface area of 12000 mm^2 (18.6 $in.^2$), and a minimum depth of 19 mm (¾ in.). The top surface shall be

[1] This test method is under the jurisdiction of ASTM Committee C09 on Concrete and Concrete Aggregates and is the direct responsibility of Subcommittee C09.22 on Materials Applied to New Concrete Surfaces.

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[2] Section on Safety Precautions, Manual of Aggregate and Concrete Testing, *Annual Book of ASTM Standards*, Vol 04.02.

[3] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

***A Summary of Changes section appears at the end of this standard.**

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round, square, or rectangular with length not more than twice the width. The top of the mold shall have a rim to provide a firm level surface to support the wood float and to facilitate the grooving and sealing steps of the procedure. The rim shall be parallel with the bottom surface of the mold.

NOTE 1—Take care to avoid use of an excessive amount of oil, grease, or mold release compound on molds, particularly along the top rim where sealing compound will be applied. Use of masking tape on the top rim during application of release compound to prevent contamination has been found expedient.

4.4 *Spoon*—A stainless steel serving spoon having a bowl 75 to 100 mm (3 to 4 in.) long and 50 to 75 mm (2 to 3 in.) wide for transferring the mortar from the mixing bowl to the mold.

4.5 *Gloves*, of rubber or plastic, to be worn while molding the specimens.

4.6 *Tamper*, of a nonabsorptive, nonabrasive material such as medium-hard rubber or seasoned oak rendered nonabsorptive by immersion for 15 min in paraffin at approximately 200 °C. The tamper shall be rectangular with a 25 by 50-mm (1 by 2-in.) cross section and it shall be a convenient length (150 to 300 mm (6 to 12 in.)).

4.7 *Wood Float*, approximately 75 by 280 by 20 mm thick (3 by 11 by ¾ in.).

NOTE 2—A commercial wood float equipped with a substantial handle can be readily reduced to these dimensions. The float shall be resurfaced or replaced when there is noticeable wear to the floating surface.

4.8 *Brush*, medium-soft bristle 50-mm (2-in.) paint brush to brush the surface of the specimens prior to sealing.

4.9 *Curing Cabinet*, maintained at a temperature of 37.8 ± 1.1°C (100± 2 °F) and a relative humidity of 32 ± 2 %. The curing cabinet shall be of a design that allows movement of conditioned air such that the solvent from the curing compound will be readily evaporated and eliminated from the system. Air flow over the specimens shall be adjusted to provide an evaporation rate of 2.0 to 3.4 g/h as measured by the procedure of Annex A1. The evaporation rate shall initially be measured for each position in the cabinet in which a specimen will be placed, and shall be verified annually and whenever any changes are made to the cabinet. The range of evaporation rates for all specimen positions in the test cabinet shall be reported.

4.10 *Balance*, having the capacity to determine the mass of a filled specimen mold to the nearest 0.1 g or less.

4.11 *Applicator*—For spray application, any apparatus that can be used to apply the curing compound uniformly and with minimum overspray is acceptable. For brush or roller application, use the equipment recommended by the curing compound manufacturer.

5. Materials

5.1 *Portland Cement*, conforming to the requirements for Type I of Specification C150.

5.2 *Graded Standard Sand*, conforming to the requirements of Specification C778.

5.3 *Sealing Compound*, that will not be affected by the curing material and which effectively seals against moisture loss between the boundary of the specimen and the edge of the mold.

NOTE 3—Tissue embedding wax, readily available from scientific supply houses, is a convenient and reliable sealant.

6. Conditioning

6.1 The temperature of the room and of all materials when used in this test shall be 23 ± 2 °C (73 ± 4 °F) unless otherwise specified, and the room humidity shall be 50 ± 10 %.

7. Number of Specimens

7.1 A set of three or more test specimens shall be made in order to constitute a test of a given curing material.

NOTE 4—When more than one set of specimens is to be prepared, each set should be handled as a group throughout the preparation to make the elapsed time between molding and application of the curing product as uniform as possible. This may require mixing the mortar for each set separately.

7.2 For determining the quantity of curing compound to be applied (MA) calculate the total top surface area of the specimen, including the seal and the rim of the mold in square millimetres using appropriate geometric formulae.

NOTE 5—The area (A) used in calculating the mass loss per unit area (L) is calculated in 14.2 from the surface dimensions measured inside the seal of the specimen.

8. Proportioning and Mixing Mortar

8.1 *Proportioning*—Determine the sand content of the mortar by adding dry sand to a cement paste having a water-cement ratio of 0.40 by weight, to produce a flow of 35 ± 5 in 10 drops of the flow table, following the procedure described in Test Method C87. Discard the mix used to determine the proportion of sand to cement.

NOTE 6—The sand:cement ratio required varies with the source of the cement. A ratio of 2.5:1 is suggested as a starting point. Flow may be determined on a 3 to 4 kg batch of mortar which is conveniently mixed in the mixer described in Practice C305. The mixture used to establish the sand:cement ratio is discarded because it is thought that the age and mixing history of the mortar affect the final moisture loss results and must be controlled.

8.2 *Mixing*—Combine the components of the mortar in a mortar-mixing machine to produce a homogeneous mortar not more than 6 min from the time the water and the cement are combined.

NOTE 7—A generally effective sequence is to add the cement to all of the water in the mixing bowl and allow it to stand for 30 s. Then, mix at low speed for 30 s and, without stopping the mixer, add the sand within 30 s and continue mixing for 1 min. Stop the mixer for 1 min. During the first 15 s, scrape down the sides of the bowl. Finish by mixing for an additional 1 min, and promptly begin molding the specimens.

9. Preparing Specimens

9.1 Thoroughly clean the molds before each use. Use of a mold release is acceptable provided that care is taken to avoid its application to the top rim of the mold to prevent interference with sealing of the edge.

9.2 Half fill the mold and spread the mortar with the back of the spoon to create a layer of approximately uniform thickness. Tamp over the entire surface with one stroke of the 25 by 50 mm (1 by 2 in.) face of the tamper per 1000 mm^2 of surface

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area rounded to the nearest integer. Place a second layer of mortar, sufficient in amount to slightly overfill the mold and tamp in a similar manner. Using the 25-mm (1-in.) wide by 150 to 300-mm (6 to 12-in.) long edge of the tamper, fill the indentations made by the tamping and level the surface by pressing down firmly with a series of contacts across the entire surface. Strike off the specimen level with the top of the mold using a wood float with one pass only, in the direction of the long axis of the specimen for rectangular molds, using a sawing motion of the float. Keep the 75-mm (3-in.) face of the float firmly in contact with the mortar and edges of the mold so that the float creates a uniformly dense surface free of voids and cracks.

9.3 Immediately after molding, wipe the outside surfaces of the molds clean, and place the specimens in the curing cabinet maintained at the conditions specified in 4.9. The specimens shall be level and not subject to vibration. The spacing between the individual specimens and between the specimens and the side walls of the cabinet shall be between 50 and 175 mm (2 to 7 in.). Within these limits the spacing shall be the same for all specimens. Use dummy specimens to fill any empty spaces in the cabinet.

10. Surface Preparation and Edge Sealing

10.1 Remove the specimens from the cabinet immediately upon disappearance of the surface water and lightly brush the surface using just sufficient force to remove the laitance and glaze without scarifying the mortar surface. If surface water appears after brushing, return the specimen to the cabinet but immediately remove the specimen upon the disappearance of the surface water brought to the surface by the brushing operation, and brush again. The mortar shall be free of surface water but shall not be dry below the surface. The proper surface condition will be attained when brushing does not bring free water to the surface, or produce smearing, and can be determined by gently rubbing an area with the finger tip.

NOTE 8—The exposure time in the cabinet and the initial moisture loss that will result in the proper surface condition is characteristic of the curing cabinet used and other testing conditions related to the laboratory performing the test. Uniformity of test surface conditions may be maintained by setting an expected exposure time or initial moisture loss. When any test condition is changed (sand, cement, and so forth), a new exposure time or initial moisture loss, or both, shall be determined.

10.2 Form a V-shaped groove approximately 3 mm (⅛ in.) deep and not more than 3 mm (⅛ in.) wide between the edge of the mortar specimen and the mold. Fill the groove with the sealing compound. The sealing compound shall not extend more than 6 mm (¼ in.) from the edge of the mold onto the surface of the specimen.

NOTE 9—To cut out the groove for sealing, the tip of a pointed trowel, a pointed spatula, a pointed triangular can opener, or a "hawksbill point" ground on the end of a spatula or knife blade have all been reported to be effective.

11. Application of Curing Materials

11.1 Calculate the mass of the curing compound to be applied, *MA*, to the nearest 0.1 g based on the specified application rate, the total surface area calculated per 7.2, and the density of the curing compound determined in accordance with Test Method D1475. If no rate is specified, apply the curing compound at the rate of 5.0 m^2/L (200 ft^2/gal). The method of application shall be in accordance with the manufacturer's recommendations.

11.2 Immediately after sealing, weigh the specimen to the nearest 0.1 g (M_1); then uniformly apply the curing compound at the specified rate of application. Application shall be made expeditiously to only one specimen at a time.

NOTE 10—It is desirable to use a spray booth or a laboratory hood to control overspray and solvent fumes especially for curing compounds that are sprayed. However, the velocity of air movement in the vicinity of the specimen must be kept at a minimum so as to prevent, as much as possible, significant loss of volatiles during spraying and before the final weighing. Spraying shall be accomplished with the minimum pressure and flow rate of air with which an acceptable spray pattern can be attained.

11.3 Determine the proper coverage by comparing the initial mass of the specimen (M_1), before applying the curing compound, to the mass after coating. The final mass shall equal the initial mass of the specimen plus the predetermined mass of the curing compound to be applied. This will necessitate frequent weighing of the specimen during application as full coverage is approached. In the case of brush application, proper coverage may be determined by weighing the container, brush, and curing compound before and after application of the compound to the specimen. Total time for application shall not exceed 2 min. Weigh to the nearest 0.1 g (M_2). If the final amount of curing compound applied differs from the calculated amount for the specified coverage by more than 10 %, the specimen shall be discarded.

NOTE 11—In previous versions of this test method, coverage was determined by weighing the application equipment and the curing compound before and after application to the specimen. Which method is more precise has not been established.

11.4 Return the specimens to the cabinet without delay.

NOTE 12—Unusual loss caused by a leaking mold or a faulty seal may be detected by weighing the specimens 3 to 4 h after application of the curing material. If one specimen has lost considerably more than the others, this specimen is probably faulty. If only three specimens are being tested, consider the test invalid (see 14.4).

12. Determination of Non-Volatile Content of Curing Compounds

12.1 Determine the proportion of non-volatile matter in the curing compound (*NV*) in accordance with Test Method D2369.

13. Duration of Test

13.1 Specimens shall be stored in the test cabinet for 72 h, then removed, and immediately weighed (M_3). Other test times may be specified by the purchaser.

14. Calculation

14.1 *Loss of Mass*:

14.1.1 Calculate the loss of mass from each specimen in grams as follows:

$$ML = M_1 + (NV \times MA) - M_3 \quad (1)$$

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ML = mass loss of the specimen, g,
M_1 = mass of the sealed specimen, g,
NV = proportion of non-volatile matter in the curing compound, g,
MA = mass of the curing compound applied, g, = $M_2 - M_1$,
M_2 = mass of the specimen immediately after applying curing compound, g, and
M_3 = mass of specimen at the conclusion of the test, g.

14.2 *Specimen Area*:

14.2.1 Calculate the area of the specimen (A) in square millimetres by measuring the dimensions of the surface from the inner edges of the seal to the nearest millimetre and applying the appropriate geometric formula.

14.3 For each specimen, calculate the mass loss per unit area (L) in kg/m^2 as:

$$L = 1000 \times ML/A \quad (2)$$

14.4 *Rejection of Results*:

14.4.1 In a set of three or more specimens, if the difference in moisture loss between the specimen having the greatest loss and that with the least loss exceeds 0.15 kg/m^2, the test shall be repeated and the average taken as that of all specimens in the original and repeat tests. If, after the repeat test, it is determined that the result on a single specimen, whether from the original or repeat test, meets the criteria for rejection as an outlier as given in Practice E178, such value shall be disregarded and a new average calculated that does not include such outlying value.

15. Report

15.1 Report the following information for the materials tested:

15.1.1 Manufacturer's name, address, and brand designation,

15.1.2 Type of curing material,

15.1.3 Manufacturer's batch number,

15.1.4 Quantity of material represented by the sample,

15.1.5 Date sampled, and

15.1.6 Source of the sample.

15.2 Report the following information regarding the test:

15.2.1 Laboratory sample identification,

15.2.2 Surface area inside the seal and depth of mortar specimens,

15.2.3 Brand of cement used,

15.2.4 Proportions of mortar by weight,

15.2.5 Method of application,

15.2.6 Duration of the test,

15.2.7 Range of evaporation rates of test cabinet,

15.2.8 Rate of application, and

15.2.9 Average loss of water per unit area.

16. Precision and Bias

16.1 *Precision*—Efforts to establish a more meaningful measure of the precision of this test method continue. The previous version of this test method, containing some differences in testing technique, contained a precision statement. The single-operator standard deviation was reported as 0.13 kg/m^2 and the multilaboratory standard deviation as 0.30 kg/m^2.[4]

16.2 *Bias*—Since there is no accepted reference material suitable for determining the bias of this test method, no statement on bias is being made.

17. Keywords

17.1 concrete curing materials; liquid membrane-forming curing compounds; moisture retention by concrete curing materials

[4] See Test Method C156 – 80a, *1987 Annual Book of ASTM Standards*, Vol 04.02.

ANNEX

(Mandatory Information)

A1. STANDARDIZATION OF EVAPORATION RATE IN TEST CABINETS

A1.1 This procedure provides a means for measuring the rate of evaporation of water from a standard surface in order to characterize a controlled set of environmental conditions (temperature, humidity, air circulation) by providing a system which will lose water at a nearly constant rate for a period of time long enough to establish a characteristic rate. Comparison of results from different positions in the same cabinet can establish whether or not conditions are uniform throughout the cabinet. Comparisons between labs may help to rationalize differing results.

A1.2 *Apparatus:*

A1.2.1 *Cup*—A permeability cup, conforming to the specifications of Test Method D1653.

A1.2.2 *Filter Paper*—7 cm disks.

A1.2.3 *Absorbent Filler*—Absorbent cotton balls.

A1.2.4 *Mold Cover*—Stiff cardboard or sheet metal plate having the same dimensions as the top of the specimen mold, and having a 63 mm (2½ in.) diameter hole in its center.

A1.2.5 *Balance*—Any balance having a capacity of 200 g or more and a sensitivity and accuracy of 0.01 g or less.

A1.3 *Procedure:*

A1.3.1 Fill the permeability cup with the absorbent filler using three cotton balls pulled together to make a uniform sponge. Fill the cup with distilled water, lay a disk of filter paper over the cup, and complete assembly of the cup. Place the mold cover on top of an empty specimen mold and fasten it in place with masking tape. Put the cup in the hole in the center of the mold. Place the mold and cup in the test cabinet in the position to be tested and allow 1 h for it to reach temperature equilibrium. Determine the mass of the cup to the

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nearest 0.01 g and immediately return it to the cabinet. Reweigh at approximately 1 h intervals for 5 to 7 h. Record the mass and the total elapsed time to the nearest 2 min for each interval.

A1.4 *Calculation:*

A1.4.1 Calculate the total mass loss at each time interval as follows:

$$L = m_i - m_t \quad \text{(A1.1)}$$

where:
L = cumulative mass loss,
m_i = initial mass, and
m_t = mass at time, t.

A1.4.2 Plot the cumulative mass loss (L) versus elapsed time (t) and determine the slope for the test period. Report as loss rate in grams per hour. Alternatively, the slope may be calculated by a "least squares" method. (The rate of loss should be nearly constant throughout the test period.)

A1.5 : *Precision and Bias:*

A1.5.1 *Precision*—Data for a precision statement is being collected.

A1.5.2 *Bias*—This test method has no bias because the evaporation rate is defined only in terms of this test method.

SUMMARY OF CHANGES

Committee C09 has identified the location of selected changes to this test method since the last issue, C156 – 09, that may impact the use of this test method. (Approved December 15, 2009)

(*1*) Revised the title of the standard.

Committee C09 has identified the location of selected changes to this test method since the last issue, C156 – 05, that may impact the use of this test method. (Approved November 1, 2009)

(*1*) Replaced the word "sample" with the word "specimen" in 4.9, 11.3, and Eq 1.

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Designation: C 157/C 157M – 08

Standard Test Method for Length Change of Hardened Hydraulic-Cement Mortar and Concrete[1]

This standard is issued under the fixed designation C 157/C 157M; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

This standard has been approved for use by agencies of the Department of Defense.

1. Scope*

1.1 This test method covers the determination of the length changes that are produced by causes other than externally applied forces and temperature changes in hardened hydraulic-cement mortar and concrete specimens made in the laboratory and exposed to controlled conditions of temperature and moisture.

1.2 The values stated in either SI units or inch-pound units are to be regarded separately as standard. An exception is with regard to sieve sizes and nominal size of aggregate, in which the SI values are the standard as stated in Specification E 11. Within the text, the SI units are shown in brackets. The values stated in each system may not be exact equivalents; therefore, each system shall be used independently of the other. Combining values from the two systems may result in nonconformance with the standard.

1.3 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

2. Referenced Documents

2.1 *ASTM Standards:* [2]

C 125 Terminology Relating to Concrete and Concrete Aggregates

C 143/C 143M Test Method for Slump of Hydraulic-Cement Concrete

C 172 Practice for Sampling Freshly Mixed Concrete

C 192/C 192M Practice for Making and Curing Concrete Test Specimens in the Laboratory

C 305 Practice for Mechanical Mixing of Hydraulic Cement Pastes and Mortars of Plastic Consistency

C 490 Practice for Use of Apparatus for the Determination of Length Change of Hardened Cement Paste, Mortar, and Concrete

C 511 Specification for Mixing Rooms, Moist Cabinets, Moist Rooms, and Water Storage Tanks Used in the Testing of Hydraulic Cements and Concretes

C 596 Test Method for Drying Shrinkage of Mortar Containing Hydraulic Cement

C 1347 Practice for Preparation and Dissolution of Uranium Materials for Analysis

E 11 Specification for Wire Cloth and Sieves for Testing Purposes

E 337 Test Method for Measuring Humidity with a Psychrometer (the Measurement of Wet- and Dry-Bulb Temperatures)

3. Terminology

3.1 *Definitions*—The terms used in this test method are defined in Terminology C 125.

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *length change*, *n*—an increase or decrease in the length of a test specimen that has been caused to change by any factor other than externally applied forces and temperature changes.

4. Significance and Use

4.1 Measurement of length change permits assessment of the potential for volumetric expansion or contraction of mortar or concrete due to various causes other than applied force or temperature change. This test method is particularly useful for comparative evaluation of this potential in different hydraulic-cement mortar or concrete mixtures.

4.2 This test method provides useful information for experimental purposes or for products that require testing under nonstandard mixing, placing, handling, or curing conditions, such as high product workability or different demolding times. Standard conditions are described in 5.4.1.

4.3 If conditions for mixing, curing, sampling, and storage other than specified in this test method are required, they shall be reported but are not to be considered as standard conditions

[1] This test method is under the jurisdiction of ASTM Committee C09 on Concrete and Concrete Aggregates and is the direct responsibility of Subcommittee C09.68 on Volume Change.

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[2] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

***A Summary of Changes section appears at the end of this standard.**

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of this test method. Nonstandard conditions and the reasons for departure from standard conditions shall be reported clearly and prominently with comparator values.

5. Apparatus

5.1 *Molds and Length Comparator*—The molds for casting test specimens and the length comparator for measuring length change shall conform to the requirements of Practice C 490.

5.2 *Tamper*—The tamper shall be made of a nonabsorptive, nonabrasive material such as medium-hard rubber or seasoned oak wood rendered nonabsorptive by immersion for 15 min in paraffin at approximately 392 °F [200 °C], and shall have a cross section of ½ by 1.0 in. [13 by 25 mm] and a convenient length of about 6 in. [150 mm]. The tamping face of the tamper shall be flat and at right angles to the length of the tamper.

5.3 *Tamping Rod*—The tamping rod shall be a straight steel rod ⅜ in. [10 mm] in diameter and not less than 10 in. [250 mm] in length, having at least the tamping end rounded to a hemispherical tip of the same diameter.

5.4 *Drying Room and Controls*—A drying room with suitable racks shall be provided when storing specimens in air. The racks shall be designed for free circulation of air around specimens, except for necessary supports, and shall be so situated with respect to the nearest wall or other obstruction that air circulation is not restricted in the intervening space. The supports shall be horizontal and shall consist of two nonabsorptive members not deeper than 1 in. [25 mm] and having a bearing area of not more than ¼ in. [6 mm] in width. Conditioned air shall be circulated into and out of the room in a uniform manner so that the specified rate of evaporation is attained adjacent to all specimens.

5.4.1 The air in the room shall be maintained at a temperature of 73 ± 3 °F [23 ± 2 °C] and a relative humidity of 50 ± 4 %. The air movement past all specimens shall be such that the rate of evaporation is 77 ± 30-mL/24 h from an atmometer or 13 ± 5-mL/24 h from a 400-mL Griffin low-form beaker filled to ¾ in. [20 mm] from the top. The temperature and relative humidity of the air in the room shall be measured with either a sling or Assmann psychrometer at least twice each working day. The psychrometer shall comply with Test Method E 337, except that thermometers having an overall length of 10 in. [250 mm] and marked in subdivisions of 0.5 °F [0.25 °C] are permitted. The room shall be equipped with a means of measuring and recording wet- and dry-bulb temperatures continuously. Correction factors as indicated by the sling or Assmann psychrometer shall be applied to the recorded data. The rate of evaporation within the room shall be determined daily by the use of the atmometer or by the loss of mass of water from a 400-mL Griffin low-form beaker filled initially to ¾ in. [20 mm] from the top.

5.5 *Atmometer*—The atmometer shall be constructed as shown in Fig. 1.

5.5.1 *Mounting*—Fig. 2 shows a suggested arrangement for operating the atmometer. Punch a central hole ½ in. [13 mm] in diameter in a filter paper, place it on the atmometer, and secure it in place while dry, by turning the torque handle only, until it just starts to slip. Mount the atmometer on a stand with the filter paper in a horizontal position. Mount a 100-mL glass graduate so that the 100-mL mark is from 1 to 3 in. [25 to 75 mm] below the level of the filter paper. Stopper the graduate so that entrance is provided for two short glass tubes not extending to the water level and one long tube extending to the bottom of the graduate. Connect the glass tubing leading from the bottom of the graduate to the inlet of the atmometer by means of clear plastic tubing.

5.5.2 *Operation*—Use clear plastic tubing to connect a squeeze bottle containing distilled or deionized water to one of the short glass tubes into the graduate. Force water into the graduate until it is about half full and then close the remaining glass tube into the graduate. Continue to force water through the graduate into the atmometer until the filter paper is saturated and there are no air bubbles in the system. Open the glass tube into the graduate and release pressure on the squeeze bottle gradually to avoid trapping air in the tube leading to the atmometer. Adjust the level of water in the graduate to approximately the 100-mL mark. If the atmometer is to be used under variable temperature conditions, disconnect the squeeze bottle after filling the graduate to avoid the possibility of additional water being forced into the graduate. Permit evaporation of water from the filter paper for 1 h before recording the time and initial reading of the graduate. It is not permitted to omit the waiting period during subsequent use of the atmometer provided the filter paper does not become dry. Change the filter paper whenever it shows signs of contamination but not less frequently than once every two weeks.

5.6 *Filter Paper*—The filter paper to be used with the atmometer shall be white with a smooth surface texture. It shall be 6 in. [152 mm] in diameter and 0.050 ± 0.003 in. [1.27 ± 0.08 mm] thick and shall have a cotton fiber content of not less than 75 weight %. The density shall be between 0.400 and 0.425 g/cm^3. The Mullen bursting strength shall not be less than 50 psi [345 kPa].

NOTE 1—E and D filter paper No. 625[3] has been found suitable.

5.7 *Apparatus for Demolding Specimens*—It is useful to construct an apparatus for demolding specimens molded in double molds as detailed in Fig. 3 or to a different design that serves the same purpose. When this device is to be used, the center side plate of the double mold must be appropriately drilled and tapped to receive the 8-32 by ⅝ in. [4.5-0.74 IMC by 16 mm] machine screw of the demolding thumbscrew. Fig. 4 shows the details of a suitable apparatus for demolding specimens molded in single molds.

[3] The sole source of supply of the apparatus known to the committee at this time is Ahlstrom Filtration Co., Mt. Holly Springs, PA 17065. If you are aware of alternative suppliers, please provide this information to ASTM International Headquarters. Your comments will receive careful consideration at a meeting of the responsible technical committee,[1] which you may attend.

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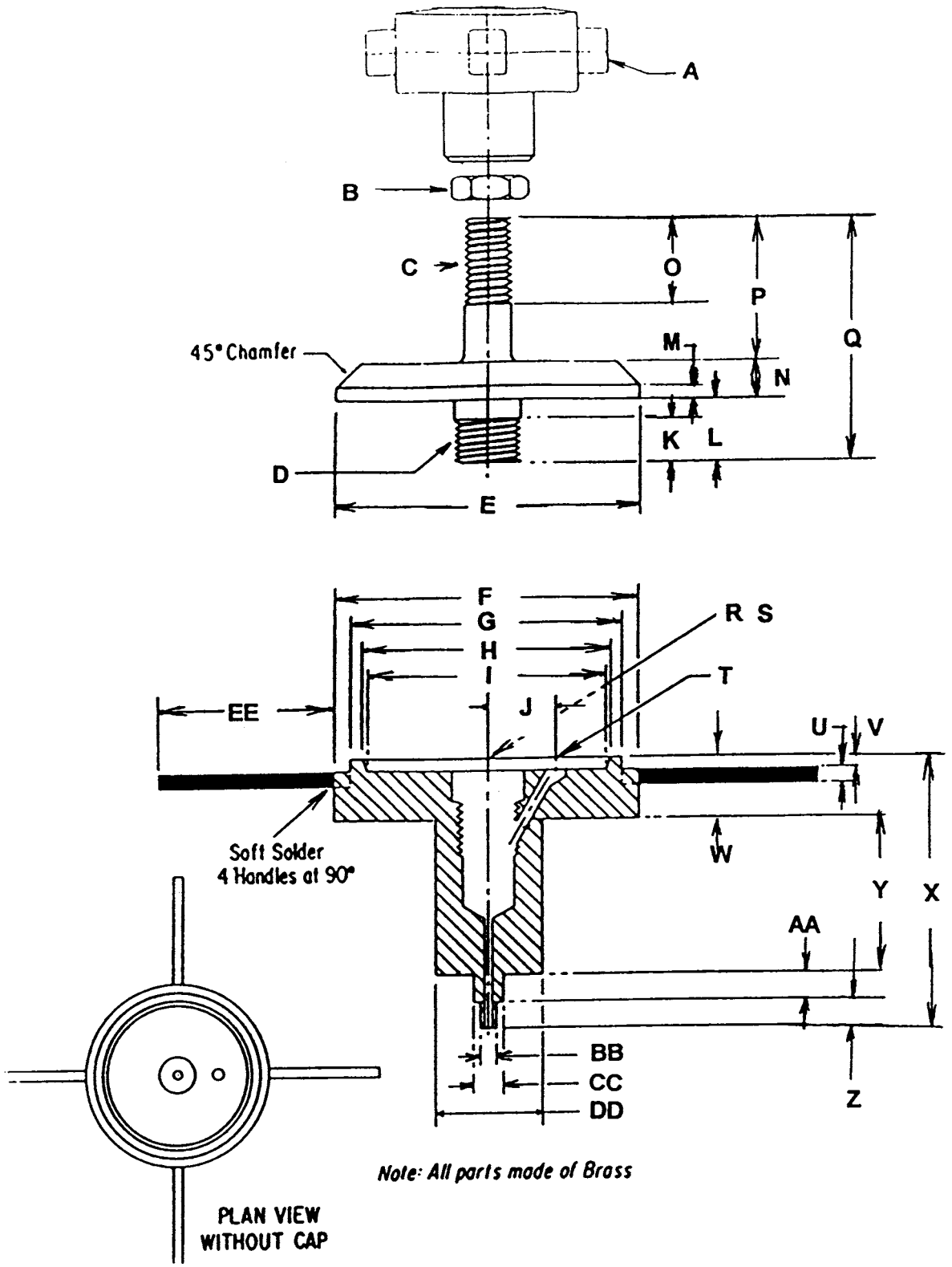

FIG. 1 Atmometer

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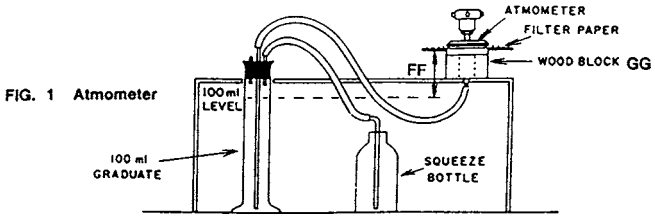
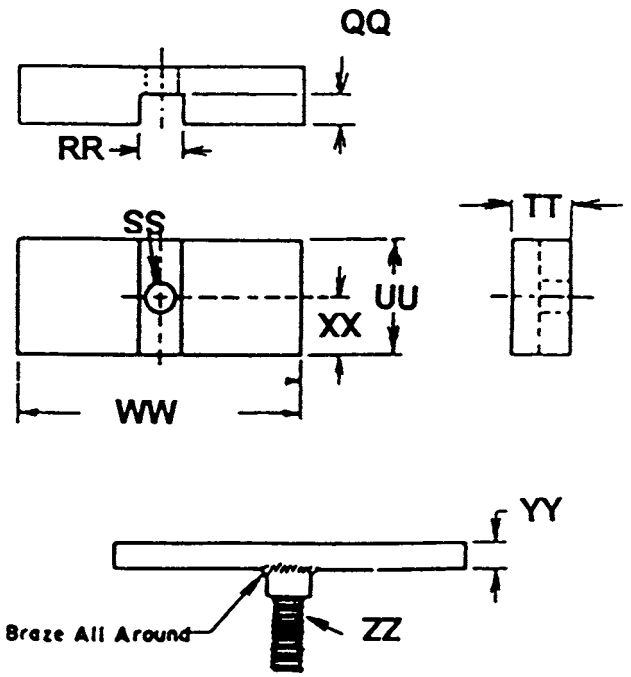


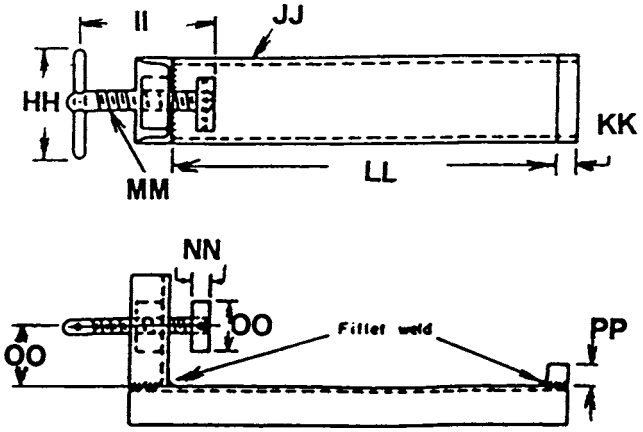
FIG. 1 Atmometer

FIG. 2 Atmometer Assembly



Instructions for Use—Remove the end and the outer side plates leaving the base, center side plate, and gage stud holders in place. Engage the machine screw in the drilled and tapped end of the center side plate. Turn the thumbscrew to loosen the bars.

FIG. 3 Device for Detaching 1-in. [25-mm] Square by 11¼-in. [285-mm] Bars from Center Side Plate of Double Molds



NOTE—Dimensions shown are appropriate for one design of mold for 3-in. [75-mm] square specimens. Change dimensions as required for other molds.

FIG. 4 Device for Demolding Specimens from Single Molds

ASTM C 157 FIGURES

Figure Dimensions	SI Units	Inch-Pound Units
A	Adjustable torque handle 1.4–1.7 Nm	Adjustable torque handle 12–15 in.lb
B	Jam nut 10–15 IMC	Jam nut ⅜-in.–16 NC
C	10-mm diameter 1.5 IMC Thd.	⅜-in. dia–16 NC Thd.
D	12-mm diameter 1.5 IMC Thd.	½-in. dia–20 NC Thd.
E	64-mm diameter	2.50-in. diameter
F	64-mm diameter	2.50-in. diameter
G	57-mm diameter	2.25-in. diameter
H	52-mm diameter	2.06-in. diameter
I	51-mm diameter	2.00-in. diameter
J	14 mm	0.56 in.
K	8 mm	0.31 in.
L	13 mm	0.50 in.
M	3 mm	0.125 in.
N	8 mm	0.31 in.
O	19 mm	0.75 in.
P	32 mm	1.25 in.
Q	53 mm	2.06 in.
R	1.5-mm drill through 11.5-mm C' drill 32-mm deep tap 12-mm 1.5-mm IMF Thd	1/16-in. drill through 29/64-in. C' drill 1¼-in. deep tap ½-in.–20 Thd
S	19 mm deep 16 mm C' bore 6 mm deep	¾-in. deep ⅝-in. C' bore ¼ in. deep
T	5-mm drill 3-mm deep C' drill at 60° as shown through to center tapped hole	3/16-in. drill ⅛-in. deep C' drill at 60° as shown through to center tapped hole
U	3 mm	0.12 in. diameter
V	2 mm	0.09 in.
W	10 mm	0.40 in.
X	60 mm	2.36 in.
Y	35 mm	1.37 in.
Z	6 mm	0.25 in.
AA	6 mm	0.25 in.
BB	4 mm	0.15 in.
CC	6 mm	0.25 in.
DD	23 mm	0.87 in.
EE	38 mm	1.50 in.
FF	25 to 75 mm	1 to 3 in.
GG	35 mm high	1.37 in. high
HH	100 mm	4 in.
II	130 mm	5 in.
JJ	8 cm–6.1 kg/m channel	3 in.–4.1 lb/ft channel
KK	20 mm	¾ in.
LL	330 mm	13 in.
MM	14–2.0 IMC Thd.	½ in.–12 Thd.
NN	20 mm	¾ in.
OO	50 mm	2 in.
PP	20 mm	¾ in.
QQ	60 mm	¼ in.
RR	10 mm	⅜ in.
SS	Drill Cl. hole for 4.5–0.75 IMC machine screw	Drill Cl. hole for 8–32 in. machine screw
TT	13 mm	½ in.
UU	25 mm	1 in.
VV	30 mm	1-3/16 in.
WW	60 mm	2-⅜ in.
XX	12.5 mm	½ in.
YY	6-mm diameter steel rod	¼-in. diameter steel rod
ZZ	4.5–0.75 IMC × 16-mm machine screw	8–32 × ⅝-in. machine screw

6. Sampling

6.1 Take samples according to the applicable provisions of Practice C 192/C 192M from batches of hydraulic-cement mortar or concrete made in the laboratory (Note 2).

NOTE 2—When collecting samples in nonstandard conditions, such as field concrete, it is suggested that Practice C 172 be followed. Field cast specimens can show up to twice as much drying shrinkage as laboratory cast specimens from the same materials and proportions.

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7. Test Specimens

7.1 *Mortar*—The test specimen for mortar shall be a prism of 1-in. [25-mm] square cross-section and approximately 11¼ in. [285 mm] in length. Three specimens shall be prepared for each test condition.

7.2 *Concrete*—The test specimen for concrete, in which all of the aggregate passes a 2-in. [50-mm] sieve, shall be a prism of 4-in. [100-mm] square cross-section and approximately 11¼ in. [285 mm] long. However, a prism of 3-in. [75-mm] square cross-section shall be used if all of the aggregate passes a 1-in. sieve [25.0-mm]. Three specimens shall be prepared for each test condition. Since length change is capable of being influenced by the size of the specimen, specimens to be compared shall have the same dimensions, and any specification limit based upon this method shall be applied to a specified size of specimen.

8. Procedure for Mixing Mortars and Concrete

8.1 If the mortar or concrete to be tested is made in accordance with requirements other than those given in one of the following paragraphs, samples shall be taken and specimens molded as described in the sections on sampling and on molding specimens.

8.2 Bring all materials to a temperature between 65 and 75 °F [18 and 24 °C] before using to make mortar or concrete. Proportion solid materials by mass (that is, not by volume). It is permissible to batch water and liquid admixtures either by mass or by volume. For calculation of batch quantities, assume aggregates to be saturated and surface-dry; if they are not in this condition at the time of use, apply appropriate corrections, as necessary, to batch quantities to compensate for absorption or free moisture.

8.3 *Mortar*—Mix mortar in a mechanical mixer as described in Practice C 305. The clearances between paddle and bowl specified in Practice C 305 are suitable only for mortars made with fine aggregates that are finer than the 2.36 mm (No. 8) sieve. Mortars made with aggregates containing particles coarser than this sieve require special clearances or a different type of paddle to permit the mixer to operate freely and to avoid damage to the paddle and bowl. The sequence of mixing shall be in accordance with the applicable provisions of Practice C 305. Determine the flow of the mortar in accordance with the applicable provisions of Test Method C 1437, and use sufficient mixing water to produce a flow of 110 ± 5 %.

8.4 *Concrete*—Mix concrete in a suitable laboratory mixer in accordance with the applicable provisions of Practice C 192/C 192M. Determine the slump of the concrete using Test Method C 143/C 143M, and use sufficient mixing water to produce a slump of 3.5 ± ½ in. [90 ± 15 mm].

9. Procedure for Molding Specimens

9.1 *Mortar Specimens*—Place the mortar in the mold in two approximately equal layers. Compact each layer with the tamper. Work the mortar into the corners, around the gage studs, and along the surfaces of the mold with the tamper until a homogeneous specimen is obtained. After the top layer has been compacted, strike off the mortar flush with the top of the mold, and smooth the surface with a few strokes of a trowel. Immediately after completion of molding, loosen the device by holding the gage studs in position at each end of the mold in order to prevent any restraint of the gage studs during initial shrinkage of the specimen.

9.2 *Concrete Specimens*—Place the concrete in the mold in two approximately equal layers in accordance with the general instructions for placing concrete in specimens given in Practice C 192/C 192M. Consolidate each layer by rodding, except use external vibration if the slump is less than 3 in. [75 mm] in accordance with the instructions for consolidation of flexure test specimens given in Practice C 192/C 192M. The same method of consolidation is to be used for all specimens to be compared. In addition, as the top layer is being placed, work the concrete thoroughly around each gage stud with the fingers. The top layer shall slightly overfill the mold. After consolidation is complete, strike off the excess material with a straightedge. Immediately after completion of molding, loosen the device by holding the gage studs in position at each end of the mold in order to prevent any restraint of the gage studs before the test specimens are demolded.

10. Procedure for Curing of Specimens

10.1 Cure the test specimens in the molds in a moist cabinet or room in accordance with Specification C 511. Protect specimens from dripping water.

10.2 Remove specimens from the molds at an age of 23½ ± ½ h after the addition of water to the cement during the mixing operation. In order to avoid damage during removal from the molds, it is not permitted, especially in the case of certain slow-hardening cements, to allow specimens to remain in the molds for more than 24 h. When this is found necessary the moist curing schedule shall be extended, but all specimens that are to be directly compared with each other shall be subjected to the same conditions of moist-curing and shall have their initial comparator reading made within ±½ h of the same age. It is permitted to use the demolding device to remove specimens without striking or jarring and with particular care not to exert pressure directly against the gage studs. The gage stud holder shall remain attached to the stud during this operation. Marks placed on the specimens for identification or positioning are only to be made by graphite applied either by a soft pencil or as a liquid that deposits essentially graphite without binder or made with waterproof indelible ink. Upon removal of the specimens from the molds, place them in lime-saturated water maintained at 73 ± 1 °F [23 ± 0.5 °C] for a minimum of 15 min in the case of 1-in. [25-mm] square cross-section specimens, and for a minimum of 30 min in the case of 3-in. [75-mm] or 4-in. [100-mm] square cross section specimens before being measured for length. This is to minimize variation in length due to variation in temperature. At an age of 24 ± ½ h after the addition of water to the cement during the mixing operation, remove the specimens from water storage one at a time, wipe with a damp cloth, and immediately take the initial comparator reading.

10.3 After the initial comparator reading, store the specimens in lime-saturated water at 73 ± 3 °F [23 ± 2 °C] until they have reached an age of 28 days, including the period in the molds. At the end of the curing period, take a second comparator reading after the specimens have been brought to a

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more closely controlled temperature as was done prior to the earlier reading and in the manner described above.

NOTE 3—To determine the drying shrinkage of concrete subjected to elevated temperature curing in the laboratory, a modification of the previous method is necessary. Where concrete is cured with elevated (non-autoclave) temperatures, the curing cycle for this test method shall be that to be used for the project structural members. The elevated temperature curing cycle consists of pre-steam, steam cure, and post-steam periods. To avoid measuring thermal volume change, after the molds are stripped, cool drying-shrinkage specimens at laboratory temperature until they reach equilibrium (approximately 6 h for 4 by 4 by 11-in. [100 by 100 by 280-mm] bars). Then place them in lime-saturated water prior to the initial reading (see 10.2).

11. Procedure for Storage of Specimens

11.1 After measurement at the end of the curing period, store the specimens as described in either of the following:

11.1.1 *Water Storage*—Immerse the specimens in lime-saturated water storage in accordance with Specification C 511. Take comparator readings of each specimen when it has reached an age, including the curing period of 8, 16, 32, and 64 weeks. Make these readings immediately after the specimens have been subjected to storage in water at 73 ± 1 °F [23 ± 0.5 °C] for at least 15 min in the case of 1-in. [25-mm] specimens or 30 min in the case of 3-in. [75-mm] or 4-in. [100-mm] specimens.

11.1.2 *Air Storage*—Store the specimens in the drying room, so that the specimens have a clearance of at least 1 in. or 25 mm on all sides. Take comparator readings of each specimen after periods of air storage after curing of 4, 7, 14, and 28 days, and after 8, 16, 32, and 64 weeks. Preferably, take these readings in a room maintained at a relative humidity of 50 ± 4 % while the specimens are at a temperature of 73 ± 3 °F [23 ± 2 °C].

12. Procedure for Calculating Length Change

12.1 *Comparator Reading*—Read the comparator dial with the test specimen in the comparator; then read the comparator dial with the reference bar in the comparator. Calculate the difference between the two readings as described in Practice C 490.

12.2 *Length Change*—Calculate the length change of any specimen at any age after the initial comparator reading as follows:

$$\Delta L_x = \frac{CRD - \text{initial } CRD}{G} \times 100 \quad (1)$$

where:

ΔL_x = length change of specimen at any age, %,
CRD = difference between the comparator reading of the specimen and the reference bar at any age, and
G = the gage length (10 in. [250 mm]) (see Note 4).

NOTE 4—In Practice C 490, the comparator dial gage specified for use with 10-in. gage length specimens shall be graduated in fractions of an inch; the comparator dial gage specified for use with 250-mm gage length specimens shall be graduated in fractions of a millimetre.

13. Report

13.1 Report the following information:

13.1.1 Identification as mortar or concrete specimens, number of specimens for each condition, and date molded,

13.1.2 Source and identification of each material employed,

13.1.3 Type, maximum size, moisture condition, and grading of the aggregate,

13.1.4 Size of specimens,

13.1.5 Mortar or concrete mixture data at time of mixing, including flow or slump and temperature of mixture,

13.1.6 Description of consolidation of concrete, specifying whether rodding or external vibration was used,

13.1.7 Conditions and periods of moist curing prior and subsequent to removal of molds, if different from those specified,

13.1.8 Description of storage condition, including temperature and humidity, either by indicating whether the water or air storage was followed or by giving the details of any procedure not conforming to either of these conditions,

13.1.9 Total elapsed time of storage and total age of specimen, or total elapsed time of curing and storage if the same condition was used for both,

13.1.10 Length change data, reported as percent increase or decrease in linear dimension to the nearest 0.001 % of the gage length based on the initial measurement made at the time of removal from the molds, and

13.1.11 Any other pertinent information.

14. Precision and Bias

14.1 *Precision*:

14.1.1 When this test method was used for the purpose of determining drying shrinkage of mortar as affected by the choice of portland cement used in making it, the precision was found to be as reported in Test Method C 596.

14.1.1.1 The following single-laboratory, multiple-operator precision applies to concrete specimens measured at 180 days.

14.1.1.2 For specimens stored in water, the standard deviation (1s) among specimens is 0.0045 %. When three replicate specimens are tested, the maximum range among them is not expected to exceed 0.0266 % in 95 % of the sets tested. When a test result represents the mean of three specimens, the 1s is 0.0026 %. The difference between two such means is not expected to exceed 0.0074 % in 95 % of such duplicate tests performed.

14.1.1.3 For specimens stored in air, the standard deviation (1s) among specimens is 0.0084 %. When three replicate specimens are tested, the maximum range among them is not expected to exceed 0.0496 % in 95 % of the sets tested. When a test result represents the mean of 3 specimens, the 1s is 0.0048 %. The difference between two such means is not expected to exceed 0.0137 % in 95 % of such duplicate tests performed.

NOTE 5—These precision values were calculated from data taken on specimens described on p. 47 of STP 205,[4] representing 193 concrete mixtures; two specimens made from each of three batches made on separate days, one of each two specimens stored in water, the other stored at nominal 50 % relative humidity.

[4] Mather, Bryant, "The Partial Replacement of Portland Cement in Concrete," *Cement and Concrete, ASTM STP 205*, ASTM, 1958.

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14.2 *Bias*—No statement on bias is being made since there is no accepted reference material suitable for determining the bias of these procedures.

15. Keywords

15.1 length change; mortar concrete

SUMMARY OF CHANGES

Committee C09 has identified the location of selected changes to this test method since the last issue, C 157/C 157M – 06, that may impact the use of this test method. (Approved October 1, 2008)

(*1*) Revised Footnote 3.

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Designation: C 171 – 07

Standard Specification for Sheet Materials for Curing Concrete[1]

This standard is issued under the fixed designation C 171; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

This standard has been approved for use by agencies of the Department of Defense.

1. Scope*

1.1 This specification covers materials in sheet form used for covering the surfaces of hydraulic cement concrete to inhibit moisture loss during the curing period and, in the case of the white reflective type materials, to also reduce temperature rise in concrete exposed to radiation from the sun. The following types are included:

1.1.1 *Curing Paper*:

1.1.1.1 Regular.

1.1.1.2 White.

1.1.2 *Polyethylene Film*:

1.1.2.1 Clear.

1.1.2.2 White Opaque.

1.1.3 *White-Burlap-Polyethylene Sheet*.

1.2 The values stated in SI units are to be regarded as the standard. Inch-pound units are provided in parentheses for information only.

NOTE 1—This specification does not cover materials such as burlap, cotton mats, or rugs used with additional applications of water to maintain a water-saturated environment on such surfaces. Procedures employing these materials are discussed in ACI 308R. Sheet materials having additional characteristics such as insulating properties and the ability to carry additional water to the curing region are commercially available but are not currently addressed in this specification.

1.3 The text of this standard references notes and footnotes which provide explanatory material. These notes and footnotes shall not be considered as requirements of the standard.

2. Referenced Documents

2.1 *ASTM Standards:* [2]

C 156 Test Method for Water Retention by Liquid Membrane-Forming Curing Compounds for Concrete

D 829 Test Methods for Wet Tensile Breaking Strength of Paper and Paper Products

D 4397 Specification for Polyethylene Sheeting for Construction, Industrial, and Agricultural Applications

E 96/E 96M Test Methods for Water Vapor Transmission of Materials

E 1347 Test Method for Color and Color-Difference Measurement by Tristimulus Colorimetry

2.2 *ACI Standard:*

ACI 308R Standard Practice for Curing Concrete[3]

3. Terminology

3.1 *Definitions:*

3.1.1 *curing paper*, *n*—a composite consisting of two layers of kraft paper bonded together with a bituminous material and reinforced with fiber, used for covering the surface of fresh concrete to inhibit moisture loss during the curing period.

4. Ordering Information

4.1 The purchaser shall specify the type of curing material to be furnished under this specification.

4.2 Lengths and widths of the rolls or mats of the sheet materials furnished shall be as agreed upon between the purchaser and seller.

5. Performance Requirements

5.1 The sheet materials furnished under this specification shall be tough, strong, resilient, and capable of withstanding normal job use without puncturing or tearing.

5.2 The sheet material shall exhibit a water vapor transmission rate (WVTR) of no more than 10 g/m^2 in 24 h when tested according to Test Methods E 96/E 96M using the Water Method in the environment (test cabinet) specified in Test Method C 156.

5.3 The daylight reflectance of the white side of white curing paper shall be at least 50 % when measured by Test Method E 1347. The daylight reflectance of white polyethylene film and the polyethylene side of white burlap-polyethylene sheet shall be at least 70 % when measured according to Test Method E 1347.

NOTE 2—Daylight reflectance is total luminous reflectance factor, CIE

[1] This specification is under the jurisdiction of ASTM Committee C09 on Concrete and Concrete Aggregates and is the direct responsibility of Subcommittee C09.22 on Materials Applied to New Concrete Surfaces.

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[2] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

[3] Available from American Concrete Institute (ACI), P.O. Box 9094, Farmington Hills, MI 48333-9094, http://www.aci-int.org.

***A Summary of Changes section appears at the end of this standard.**

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tristimulus value Y for the CIE 1931 (2°) standard observer and CIE standard illuminant C or D65.

6. Physical Requirements

6.1 *Curing Paper* shall consist of two sheets of kraft paper cemented together with a bituminous material in which are embedded cords or strands of fiber running in both directions and not more than 32 mm (1¼ in.) apart. The paper shall be light in color, shall be free of visible defects, and shall have a uniform appearance. White paper shall have a white surface on at least one side.

6.1.1 The tensile strength of curing paper shall be no less than 5.25 kN/m of width (30 lbf/in. of width) in the machine direction and 2.62 kN/m of width (15 lbf/in. of width) in the cross direction when measured according to Test Methods D 829.

6.2 *Polyethylene Film* shall consist of a single sheet manufactured from polyethylene resins. It shall be free of visible defects and shall have a uniform appearance. The clear type shall be essentially transparent. The opaque film shall contain white pigment.

6.2.1 The nominal thickness of polyethylene film shall be no less than 0.10 mm (4 mil) as determined according to Specification D 4397 . Thickness at any point shall be no less than 0.075 mm (0.0030 in.).

6.2.2 The impact resistance and mechanical properties shall be as required in Specification D 4397.

6.3 *White Burlap-Polyethylene Sheeting* shall consist of burlap weighing not less than 305 g/m^2(9 oz./yd^2) extrusion coated on one side with white opaque polyethylene at least 0.10 mm (0.004 in.) thick and meeting the other requirements of 6.2. The polyethylene material shall be securely bonded to the burlap so that there will be no separation of the materials during handling and curing of the concrete.

7. Sampling

7.1 Samples of film or sheeting sufficient to determine conformance with this specification shall be taken at random.

8. Keywords

8.1 concrete curing materials; polyethylene film; sheet material for curing concrete; curing paper; white burlap-polyethylene sheet

SUMMARY OF CHANGES

Committee C09 has identified the location of selected changes to this specification since the last issue, C 171 – 03, that may impact the use of this specification. (Approved November 1, 2007)

(*1*) Revised 5.2 to clarify test conditions to be used for Test Methods E 96/E 96M.

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Designation: C 172 – 08

Standard Practice for Sampling Freshly Mixed Concrete[1]

This standard is issued under the fixed designation C 172; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

This standard has been approved for use by agencies of the Department of Defense.

1. Scope*

1.1 This practice covers procedures for obtaining representative samples of fresh concrete as delivered to the project site on which tests are to be performed to determine compliance with quality requirements of the specifications under which the concrete is furnished (Note 1). The practice includes sampling from stationary, paving and truck mixers, and from agitating and nonagitating equipment used to transport central-mixed concrete.

1.2 The values stated in SI units are to be regarded as standard. The values given in parentheses are mathematical conversions to inch-pound units that are provided for information only and are not considered standard.

NOTE 1—Composite samples are required by this practice, unless specifically excepted by procedures governing the tests to be performed such as tests to determine uniformity of consistency and mixer efficiency. Procedures used to select the specific test batches are not described in this practice, but it is recommended that random sampling be used to determine overall specification compliance.

1.3 This practice also covers the procedures to be used for preparing a sample of concrete for further testing where it is desirable or necessary to remove the aggregate larger than a designated size. This removal of larger aggregate particles is preferably accomplished by wet-sieving.

1.4 The text of this standard references notes and footnotes which provide explanatory material and shall not be considered as requirements of the practice.

1.5 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.* (**Warning**—Fresh hydraulic cementitious mixtures are caustic and may cause chemical burns to skin and tissue upon prolonged exposure.[2])

2. Referenced Documents

2.1 *ASTM Standards:* [3]

E 11 Specification for Wire Cloth and Sieves for Testing Purposes

3. Significance and Use

3.1 This practice is intended to provide standard requirements and procedures for sampling freshly mixed concrete from different containers used in the production or transportation of concrete. The detailed requirements as to materials, mixtures, air content, temperature, number of specimens, slump, interpretation of results, and precision and bias are in specific test methods.

4. Sampling

4.1 The elapsed time shall not exceed 15 min. between obtaining the first and final portions of the composite sample.

4.1.1 Transport the individual samples to the place where fresh concrete tests are to be performed or where test specimens are to be molded. They shall be combined and remixed with a shovel the minimum amount necessary to ensure uniformity and compliance with the maximum time limits specified in 4.1.2.

4.1.2 Start tests for slump, temperature, and air content within 5 min after obtaining the final portion of the composite sample. Complete these tests expeditiously. Start molding specimens for strength tests within 15 min after fabricating the composite sample. Expeditiously obtain and use the sample and protect the sample from the sun, wind, and other sources of rapid evaporation, and from contamination.

5. Procedure

5.1 *Size of Sample*—Make the samples to be used for strength tests a minimum of 28 L (1 ft^3). Smaller samples are not prohibited for routine air content, temperature, and slump tests. The size of the samples shall be dictated by the maximum aggregate size.

[1] This practice is under the jurisdiction of ASTM Committee C09 on Concrete and Concrete Aggregates and is the direct responsibility of Subcommittee C09.60 on Testing Fresh Concrete.

Current edition approved June 1, 2008. Published July 2008. Originally approved in 1942. Last previous edition approved in 2007 as C 172 – 07a.

[2] Section on Safety Precautions, Manual of Aggregate and Concrete Testing, *Annual Book of ASTM Standards*, Vol 04.02.

[3] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

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5.2 The procedures used in sampling shall include the use of every precaution that will assist in obtaining samples that are truly representative of the nature and condition of concrete sampled as follows:

NOTE 2—Sampling should normally be performed as the concrete is delivered from the mixer to the conveying vehicle used to transport the concrete to the forms; however, specifications may require other points of sampling, such as the discharge of a concrete pump.

5.2.1 *Sampling from Stationary Mixers, Except Paving Mixers*—Sample the concrete by collecting two or more portions taken at regularly spaced intervals during discharge of the middle portion of the batch. Obtain these portions within the time limit specified in Section 4. Combine into one composite sample for testing purposes. Do not obtain portions of the composite sample from the very first or last part of the batch discharge (Note 3). Perform sampling by passing a receptacle completely through the discharge stream, or by completely diverting the discharge into a sample container. If discharge of the concrete is too rapid to divert the complete discharge stream, discharge the concrete into a container or transportation unit sufficiently large to accommodate the entire batch and then accomplish the sampling in the same manner as given above. Take care not to restrict the flow of concrete from the mixer, container, or transportation unit so as to cause segregation. These requirements apply to both tilting and nontilting mixers.

NOTE 3—No samples should be taken before 10 % or after 90 % of the batch has been discharged. Due to the difficulty of determining the actual quantity of concrete discharged, the intent is to provide samples that are representative of widely separated portions, but not the beginning and the end of the load.

5.2.2 *Sampling from Paving Mixers*—Sample the concrete after the contents of the paving mixer have been discharged. Obtain samples from at least five different portions of the pile and then composite into one sample for test purposes. Avoid contamination with subgrade material or prolonged contact with and absorptive subgrade. To preclude contamination or absorption by the subgrade, sample the concrete by placing three shallow containers on the subgrade and discharging the concrete across the container. Combine the samples so obtained into one composite sample for test purposes. The containers shall be of a size sufficient to provide a composite sample size that is in agreement with the maximum aggregate size.

NOTE 4—In some instances, the containers may have to be supported above the subgrade to prevent displacement during discharge.

5.2.3 *Sampling from Revolving Drum Truck Mixers or Agitators*—Sample the concrete by collecting two or more portions taken at regularly spaced intervals during discharge of the middle portion of the batch. Take the samples so obtained within the time limit specified in Section 4 and combine them into one composite sample for test purposes. In any case do not obtain samples until after all of the water and any admixtures have been added to the mixer; also do not obtain samples from the very first or last portions of the batch discharge (Note 3). Sample by repeatedly passing a receptacle through the entire discharge stream or by completely diverting the discharge into a sample container. Regulate the rate of discharge of the batch by the rate of revolution of the drum and not by the size of the gate opening.

5.2.4 *Sampling from Open-Top Truck Mixers, Agitators, Nonagitating Equipment, or Other Types of Open-Top Containers*—Take samples by whichever of the procedures described in 5.2.1, 5.2.2, or 5.2.3 is most applicable under the given conditions.

6. Additional Procedure for Large Maximum Size Aggregate Concrete

6.1 When the concrete contains aggregate larger than that appropriate for the size of the molds or equipment to be used, wet-sieve the sample as described below except perform density (unit weight) tests for use in yield computations on the full mix.

NOTE 5—The effect of wet-sieving on the test results should be considered. For example, wet-sieving concrete causes the loss of a small amount of air due to additional handling. The air content of the wet-sieved fraction of concrete is greater than that of the total concrete because the larger size aggregate which is removed does not contain air. The apparent strength of wet-sieved concrete in smaller specimens is usually greater than that of the total concrete in larger appropriate size specimens. The effect of these differences may need to be considered or determined by supplementary testing for quality control or test result evaluation purposes.

6.2 *Definition*:

6.2.1 *wet-sieving concrete*—the process of removing aggregate larger than a designated size from the fresh concrete by sieving it on a sieve of the designated size.

6.3 *Apparatus*:

6.3.1 *Sieves*, as designated, conforming to Specification E 11.

6.3.2 *Receptacle*—A container of suitable size having a nonabsorbent surface.

6.3.3 *Wet-Sieving Equipment*—Equipment for wet-sieving concrete shall be a sieve as noted in 6.3.1 of suitable size and conveniently arranged and supported so that one can shake it rapidly by either hand or mechanical means. Generally, a horizontal back and forth motion is preferred. The equipment shall be capable of rapidly and effectively removing the designated size of aggregate.

6.3.4 *Hand Tools*—Shovels, hand scoops, plastering trowels, and rubber gloves as required.

6.4 *Procedure*:

6.4.1 *Wet-Sieving*—After sampling the concrete, pass the concrete over the designated sieve and remove and discard the aggregate retained. This shall be done before remixing. Shake or vibrate the sieve by hand or mechanical means until no undersize material remains on the sieve. Mortar adhering to the aggregate retained on the sieve shall not be wiped from it before it is discarded. Place only enough concrete on the sieve at any one time so that after sieving, the thickness of the layer of retained aggregate is not more than one particle thick. The concrete which passes the sieve shall fall into a batch pan of suitable size which has been dampened before use or onto a clean, moist, nonabsorbent surface. Scrape any mortar adhering to the sides of the wet-sieving equipment into the batch. After removing the larger aggregate particles by wet-sieving

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remix the batch with a shovel the minimum amount necessary to ensure uniformity and proceed testing immediately.

7. Keywords

7.1 air content; batch; composite sample; concrete; slump; temperature; wet-sieving

SUMMARY OF CHANGES

Committee C09 has identified the location of selected changes to this practice since the last issue, C 172 – 07a, that may impact the use of this practice. (Approved June 1, 2008)

(*1*) Added wording to 5.2.3 to make it clear that sampling should not be done until all admixtures have been added to the mixer.

Committee C09 has identified the location of selected changes to this practice since the last issue, C 172 – 07, that may impact the use of this practice. (Approved December 15, 2007)

(*1*) Changed "composite" to "combine" in 5.2.1, 5.2.2, and 5.2.3.

Committee C09 has identified the location of selected changes to this practice since the last issue, C 172 – 04, that may impact the use of this practice. (Approved July 15, 2007)

(*1*) Added a definition for receptacle as new 6.3.2 and renumbered subsequent paragraphs.

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Designation: C173/C173M – 10

Standard Test Method for Air Content of Freshly Mixed Concrete by the Volumetric Method[1]

This standard is issued under the fixed designation C173/C173M; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

This standard has been approved for use by agencies of the Department of Defense.

1. Scope*

1.1 This test method covers determination of the air content of freshly mixed concrete containing any type of aggregate, whether it be dense, cellular, or lightweight.

1.2 The values stated in either SI units or inch-pound units are to be regarded separately as standard. The SI units are shown in brackets. The values stated in each system may not be exact equivalents; therefore, each system shall be used independently of the other. Combining values from the two systems may result in non-conformance with the standard.

1.3 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*(**Warning**—Fresh hydraulic cementitious mixtures are caustic and may cause chemical burns to skin and tissue upon prolonged exposure.[2])

2. Referenced Documents

2.1 *ASTM Standards:*[3]

C29/C29M Test Method for Bulk Density ("Unit Weight") and Voids in Aggregate

C31/C31M Practice for Making and Curing Concrete Test Specimens in the Field

C138/C138M Test Method for Density (Unit Weight), Yield, and Air Content (Gravimetric) of Concrete

C143/C143M Test Method for Slump of Hydraulic-Cement Concrete

C172 Practice for Sampling Freshly Mixed Concrete

C173/C173M Test Method for Air Content of Freshly Mixed Concrete by the Volumetric Method

C231 Test Method for Air Content of Freshly Mixed Concrete by the Pressure Method

C670 Practice for Preparing Precision and Bias Statements for Test Methods for Construction Materials

3. Significance and Use

3.1 This test method covers the determination of the air content of freshly mixed concrete. It measures the air contained in the mortar fraction of the concrete, but is not affected by air that may be present inside porous aggregate particles.

3.1.1 Therefore, this is the appropriate test to determine the air content of concretes containing lightweight aggregates, air-cooled slag, and highly porous or vesicular natural aggregates.

3.2 This test method requires the addition of sufficient isopropyl alcohol, when the meter is initially being filled with water, so that after the first or subsequent rollings little or no foam collects in the neck of the top section of the meter. If more foam is present than that equivalent to 2 % air above the water level, the test is declared invalid and must be repeated using a larger quantity of alcohol. Addition of alcohol to dispel foam any time after the initial filling of the meter to the zero mark is not permitted.

3.3 The air content of hardened concrete may be either higher or lower than that determined by this test method. This depends upon the methods and amounts of consolidation effort applied to the concrete from which the hardened concrete specimen is taken; uniformity and stability of the air bubbles in the fresh and hardened concrete; accuracy of the microscopic examination, if used; time of comparison; environmental exposure; stage in the delivery, placement and consolidation processes at which the air content of the unhardened concrete is determined, that is, before or after the concrete goes through a pump; and other factors.

4. Apparatus

4.1 *Air Meter*—An air meter consisting of a bowl and a top section (Fig. 1) conforming to the following requirements:

[1] This test method is under the jurisdiction of ASTM Committee C09 on Concrete and Concrete Aggregates and is the direct responsibility of Subcommittee C09.60 on Testing Fresh Concrete.

Current edition approved Feb. 1, 2010. Published March 2010. Originally approved in 1942. Last previous edition approved in 2009 as C173/C173M–09 DOI: 10.1520/C0173_C0173M-10

[2] Section on Safety Precautions, Manual of Aggregate and Concrete Testing, *Annual Book of ASTM Standards*, Vol 04.02.

[3] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

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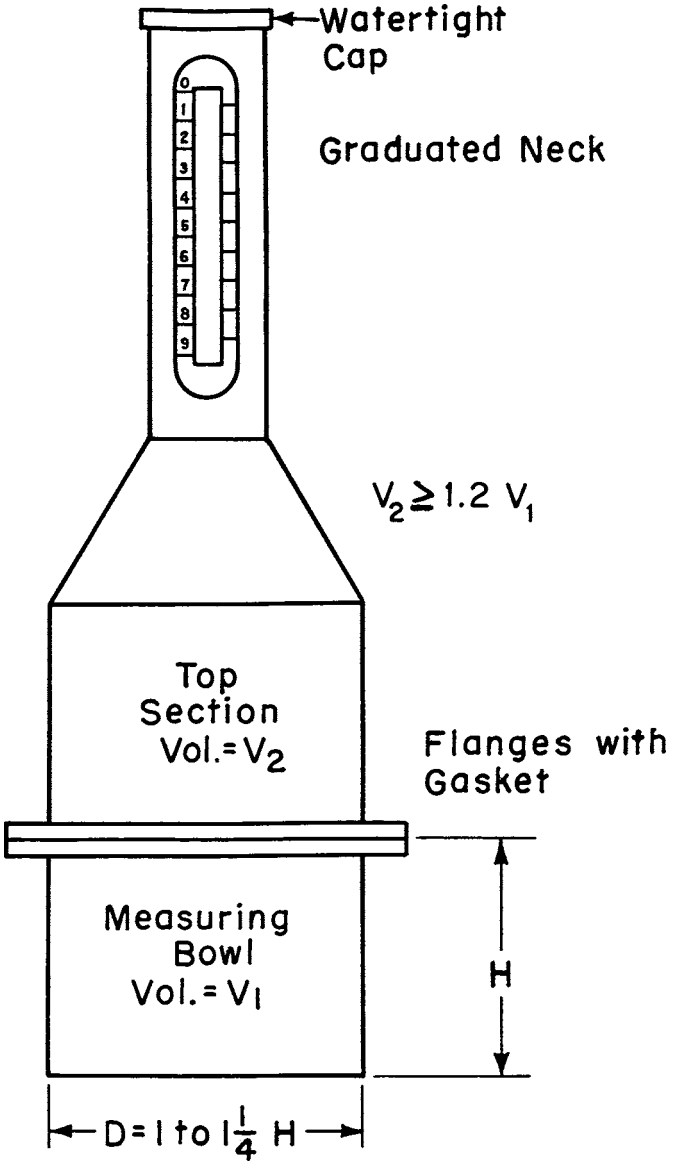

FIG. 1 Apparatus for Measuring Air Content of Fresh Concrete by Volumetric Method

4.1.1 The bowl and top sections shall be of sufficient thickness and rigidity to withstand rough field use. The material shall not be attacked by high pH cement paste, deform when stored at high temperatures in closed spaces, or become brittle or crack at low temperatures. A watertight seal must be obtained when the top section is attached to the bowl.

4.1.2 *Bowl*—The bowl shall have a diameter equal to 1 to 1.25 times the height and be constructed with a flange at or near the top surface. Bowls shall not have a capacity of less than 0.075 ft^3 [2.0 L].

4.1.3 *Top Section*—The top section shall have a capacity at least 20 % larger than the bowl and shall be equipped with a flexible gasket and a device to attach the top section to the bowl. The top section shall be equipped with a transparent scale, graduated in increments not greater than 0.5 % from 0 at the top to 9 %, or more, of the volume of the bowl. Graduations shall be accurate to ±0.1 % by volume of the bowl. The upper end of the neck shall have a watertight cap that will maintain a watertight seal when the meter is inverted and rolled.

4.2 *Funnel*—A funnel with a spout of a size permitting it to be inserted through the neck of the top section and long enough to extend to a point just above the bottom of the top section. The discharge end of the spout shall be so constructed that when water is added to the container there will be a minimum disturbance of the concrete.

4.3 *Tamping Rod*—A round, straight steel, high-density polyethylene, or other plastic rod of equal or greater abrasion resistance with a ⅝ in. [16 m] ± 1⁄16 in. [2 mm] diameter. The length of the tamping rod shall be at least 4 in. [100 mm] greater than the depth of the bowl in which rodding is being performed, but not greater than 24 in. [600 mm] in overall length (Note 1). The length tolerance for the tamping rod shall be ± ⅛ in. [4 mm]. The rod shall have the tamping end or both ends rounded to a hemispherical tip of the same diameter as the rod.

NOTE 1—A rod length of 16 in. [400 mm] to 24 in. [600 mm] meets the requirements of the following: Practice C31/C31M, Test Method C138/C138M, Test Method C143/C143M, Test Method C173/C173M, and Test Method C231.

4.4 *Strike-off Bar*—A flat, straight steel bar at least ⅛ by ¾ by 12 in. [3 by 20 by 300 mm] or a flat, straight high-density polyethylene bar, or other plastic of equal or greater abrasion resistance, at least ¼ by ¾ by 12 in. [6 by 20 by 300 mm].

4.5 *Calibrated Cup*—A metal or plastic cup either having a capacity of or being graduated in increments equal to 1.00 ± 0.04 % of the volume of the bowl of the air meter. The calibrated cup is only to be used to add water when the concrete air content exceeds 9 % or the calibrated range of the meter.

4.6 *Measuring Vessel for Isopropyl Alcohol*—A vessel with a minimum capacity of at least 1 pt [500 mL] with graduations not larger than 4 oz [100 mL] for measuring a quantity of isopropyl alcohol.

4.7 *Syringe*—A rubber syringe having a capacity of at least 2 oz [50 mL].

4.8 *Pouring Vessel for Water*—A container of approximately 1 qt [1 L] capacity.

4.9 *Scoop*—of a size large enough so each amount of concrete obtained from the sampling receptacle is representative and small enough so it is not spilled during placement in the bowl.

4.10 *Isopropyl Alcohol*—Use 70 % by volume isopropyl alcohol (approximately 65 % by weight) (Note 2). Other foam-dispersing agents are permitted if tests demonstrate that the use of the agent does not change the indicated air content, in the amounts being used, by more than 0.1 % or if correction factors are developed similar to those in Table 1. When other dispersing agents are used, a copy of the records documenting the testing or calculations shall be available in the laboratory.

NOTE 2—Seventy percent isopropyl alcohol is commonly available as rubbing alcohol. More concentrated grades can be diluted with water to the required concentration.

4.11 *Mallet*—A mallet (with a rubber or rawhide head) with a mass of approximately 1.25 ± 0.5 lb [600 ± 200 g].

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TABLE 1 Correction for the Effect of Isopropyl Alcohol on C173/C173M Air Meter Reading

70 % Isopropyl Alcohol Used			
Pints	Fluid Ounces	Litres	Correction, %[A]
≤ 2.0	≤ 32	≤ 1.0	0.0[B]
3.0	48	1.5	0.25
4.0	64	2.0	0.50
5.0	80	2.5	0.75

[A] Subtract from final meter reading.

[B] Corrections are applied only when 2.5 pt [1.25 L] or more of isopropyl alcohol is used. The values given are for air meters that have a bowl volume of 0.075 ft^3 [2.1 L] and a top section that is 1.2 times the volume of the bowl.

5. Calibration

5.1 Calibrate the meter and calibrated cup initially and annually or whenever there is reason to suspect damage or deformation of the meter or calibrated cup.

5.2 Determine the volume of the bowl with an accuracy of at least 0.1 % by determining the mass of water required to fill it at room temperature and dividing it by the density of the water at the same temperature. Follow the calibration procedure outlined in Test Method C29/C29M.

5.3 Determine the accuracy of the graduations on the neck of the top section of the air meter by filling the assembled measuring bowl and top section with water to the level of the mark for highest air content graduation.

5.3.1 Add water in increments of 1.0 % of the volume of the bowl to check accuracy throughout the graduated range of air content. The error at any point throughout the graduated range shall not exceed 0.1 % of air.

5.4 Determine the volume of the calibrated cup using water at 70 °F [21.1 °C] by the method outlined in 5.2. A quick check can be made by adding one or more calibrated cups of water to the assembled apparatus and observing the increase in the height of the water column after filling to a given level.

6. Sampling

6.1 Obtain the sample of freshly mixed concrete in accordance with Practice C172. If the concrete contains coarse aggregate particles that would be retained on a 1½-in. [37.5-mm] sieve, wet sieve a representative sample over a 1-in. [25-mm] sieve to yield somewhat more than enough material to fill the measuring bowl. The wet sieving procedure is described in Practice C172. Carry out the wet sieving operation with the minimum practicable disturbance of the mortar. Make no attempt to wipe adhering mortar from coarse aggregate particles retained on the sieve.

7. Procedure

7.1 *Rodding and Tapping*—Wet the inside of the bowl and dry it to a damp but not shiny appearance. Using the scoop described in 4.9, fill the bowl with freshly mixed concrete in two layers of equal depth. While placing the concrete in the bowl, move the scoop around the perimeter of the bowl opening to ensure an even distribution of the concrete with minimal segregation. Rod each layer 25 times uniformly over the cross section with the rounded end of the rod. Rod the bottom layer throughout its depth. In rodding this layer, use care not to damage the bottom of the bowl. For the upper layer, allow the rod to penetrate through the layer being rodded and into the layer below approximately 1 in. [25 mm]. After each layer is rodded, tap the sides of the bowl 10 to 15 times with the mallet to close any voids left by the tamping rod and to release any large bubbles of air that may have been trapped. After tapping the final layer, a slight excess of concrete, ⅛ in. [3 mm] or less, above the rim is acceptable. Add or remove a representative sample of concrete if necessary to obtain the required amount of concrete.

7.2 *Striking Off*—After rodding and tapping of the second layer, strike off the excess concrete with the strike-off bar until the surface is flush with the top of the bowl. Wipe the flange of the bowl clean.

7.3 *Adding Water and Alcohol*—Wet the inside of the top section of the meter, including the gasket. Attach the top section to the bowl and insert the funnel. Add at least 1 pt [0.5 L] of water followed by the selected amount (Note 3) of isopropyl alcohol. Record the amount of isopropyl alcohol added. Continue adding water until it appears in the graduated neck of the top section (Note 4). Remove the funnel. Adjust the liquid level until the bottom of the meniscus is level with the zero mark. A rubber syringe is useful for this purpose. Attach and tighten the watertight cap.

NOTE 3—The amount of isopropyl alcohol necessary to obtain a stable reading and a minimum of foam at the top of the water column will depend upon a number of factors. Many concretes made with less than 500 lb/yd^3 [300 kg/m^3] of cement and air contents less than 4 % may require less than 0.5 pt [200 mL] of alcohol. Some high-cement mixes made with silica fume that have air contents of 6 % or more may require more than 3 pt [1400 mL] of alcohol. The amount required will vary with the concrete air content, the amount and type of air-entraining admixture, the cement content and cement alkali content, and perhaps other factors. Generally, the amount of alcohol necessary can be established for given mixture proportions and should not change greatly during the course of a job.

NOTE 4—When, if ever, it is necessary to use more than 4 or 4.5 pt [2.0 L] of isopropyl alcohol, it may be necessary to restrict the amount of water added initially to avoid overfilling the meter. However, it is desirable to add at least some water initially to aid in mixing the alcohol and limit the contact of the concentrated alcohol with the top surface of the concrete.

7.4 *Displacing the Volume of Air in the Concrete Specimen Using These Procedures*:

7.4.1 *Free the Concrete from the Base*— Quickly invert the meter, shake the base horizontally, and return the meter to the upright position. To prevent the aggregate from lodging in the neck of the unit, do not keep it inverted for more than 5 s at a time. Repeat the inversion and shaking process for a minimum of 45 s and until the concrete has broken free and the aggregate can be heard moving in the meter as it is inverted.

7.4.2 *Rolling*—Place one hand on the neck of the meter and the other on the flange. Using the hand on the neck, tilt the top of the meter approximately 45° from the vertical position with the bottom edge of the base of the meter resting on the floor or on the work surface. Maintain this position through the procedures described in this section. Using the hand on the flange to rotate the meter, vigorously roll the meter ¼ to ½ turn forward and back several times, quickly starting and stopping the roll. Turn the base of the meter about ⅓ turn and repeat the rolling procedure as stated previously. Continue the turning

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and rolling procedures for approximately 1 min. The aggregate must be heard sliding in the meter during this process.

7.4.2.1 If, at any time, during the inversion and rolling procedures liquid is found to be leaking from the meter, the test is invalid and a new test shall be started as in 6.1.

7.4.2.2 Set the unit upright and loosen the top to allow any pressure to stabilize. Allow the meter to stand while the air rises to the top and until the liquid level stabilizes. The liquid level is considered stable when it does not change more than 0.25 % air within a 2-min period.

7.4.2.3 If it takes more than 6 min for the liquid level to stabilize or if there is more foam than that equivalent to 2 full percent air content divisions on the meter scale over the liquid level, discard the trial and start a new test as in 6.1. Use a larger addition of alcohol than was used in the initial trial.

7.4.2.4 If the level is stable without excessive foam, read the bottom of the meniscus to the nearest 0.25 % and record the *initial meter reading*.

7.4.2.5 If the air content is greater than the 9 % range of the meter, add a sufficient number of calibrated cups of water to bring the liquid level within the graduate range. Read the bottom of the meniscus to the nearest 0.25 %. Record the number of calibrated cups of water to be added to the final meter reading in 8.2.

7.5 *Confirmation of the Initial Meter Reading*:

7.5.1 When an initial meter reading is obtained as in 7.4.2.4, retighten the top and repeat the 1-min rolling as in 7.4.2, 7.4.2.2, and 7.4.2.3.

7.5.2 When the liquid level is stable as in 7.4.2.2 and the requirements of 7.4.2.3 are met, make a direct reading to the bottom of the meniscus and estimate to 0.25 % air. If this reading has not changed more than 0.25 % from the initial meter reading in 7.4.2.4, record it as the *final meter reading* of the sample tested.

7.5.2.1 If the reading has changed from the *initial meter reading* by more than 0.25 % air, record this reading as a new "*initial reading*" and repeat the 1-min rolling as in 7.4.2. Read the indicated air content. If this reading has not changed by more than 0.25 % air from the "*newest initial reading*" record it as the *final meter reading*.

7.5.2.2 If the reading has changed by more than 0.25 %, discard the test and start a new test on a new sample of concrete as in 6.1 using more alcohol.

7.6 Disassemble the apparatus. Dump the base and examine the contents to be sure that there are no portions of undisturbed, tightly packed concrete in the base. If portions of undisturbed concrete are found, the test is invalid.

8. Calculation

8.1 If more than 2.5 pt [1.25 L] of alcohol is used in 7.3, a correction to the final meter reading is required. Round the volume of alcohol used to the nearest pint [0.5 L] and select the correction factor from Table 1.

NOTE 5—When the top section is initially filled to the zero mark with water and isopropyl alcohol that mixture has a defined volume; however, when that solution is further mixed with the water present in the concrete, the concentration of alcohol changes and the new solution occupies a volume slightly smaller than it did when the meter was initially filled to the zero mark. For this reason, the meter tends to indicate a higher than actual air content when more than about 2.5 pt [1.2 L] of alcohol is used. Therefore, when large amounts of alcohol are used, the correction factors in Table 1 reduce the air content indicated by the meter.

8.2 *Air Content*—Calculate the air content of the concrete in the measuring bowl as follows:

$$A = A_R - C + W \quad (1)$$

where:

A = air content, %,
A_R = final meter reading, %,
C = correction factor from Table 1, %, and
W = number of calibrated cups of water added to the meter (See 7.4.2.5)

8.2.1 Report the air content to the nearest 0.25 %.

8.3 When the sample tested represents that portion of the mixture obtained by wet sieving over a 1-in. (25-mm) sieve, calculate the air content of the mortar or of the full mixture using the formulas given in Test Method C231. Use appropriate quantities coarser or finer than the 1-in. sieve instead of the 1½-in. (37.5-mm) sieve specified in Test Method C231.

9. Precision and Bias

9.1 The standard deviation is essentially proportional to the average for different levels of air content. The following precision statement is based on 979 tests made in 6 field experiments by the West Virginia D.O.T. The multi-operator coefficient of variation has been found to be 11 % of the measured air content. Therefore, results of tests by two different operators on specimens taken from a single concrete sample should not differ from each other by more than 32 % of their average air content (Note 6).

NOTE 6—These numbers represent, respectively, the 1s % and d2s % limits described in Practice C670. The data collected for the precision statement was obtained using procedures standard prior to the use of large amounts of isopropyl alcohol in Test Method C173/C173M-01.

9.2 This test method provides volumetric procedures for determining the air content of freshly mixed concrete. When conducted properly, this test method has no bias because the value of the air content can only be defined in terms of this test method.

10. Keywords

10.1 air content; calibration; concrete; correction factor; freshly mixed concrete; measuring bowl; meter; volumetric method

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APPENDIX

(Nonmandatory Information)

X1. A Check List for Performing the Volumetric Air Content Test Method

X1.1 The following outline (see Fig. X1.1) does not include all steps and precautions required to perform this test method properly. It is provided to help new users follow the sequence of the procedures.

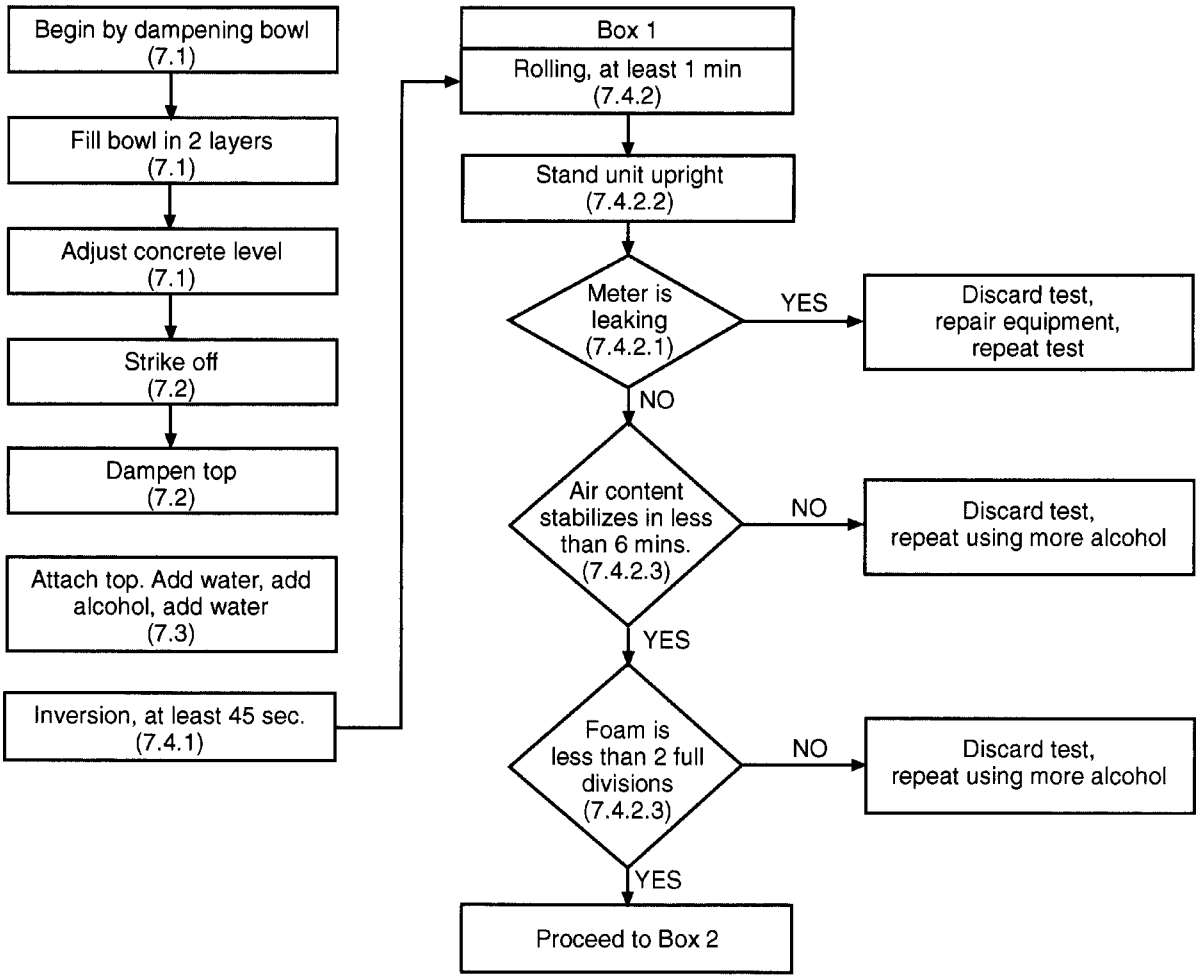

FIG. X1.1 Outline of Check List for Performing the Volumetric Air Content Test Method

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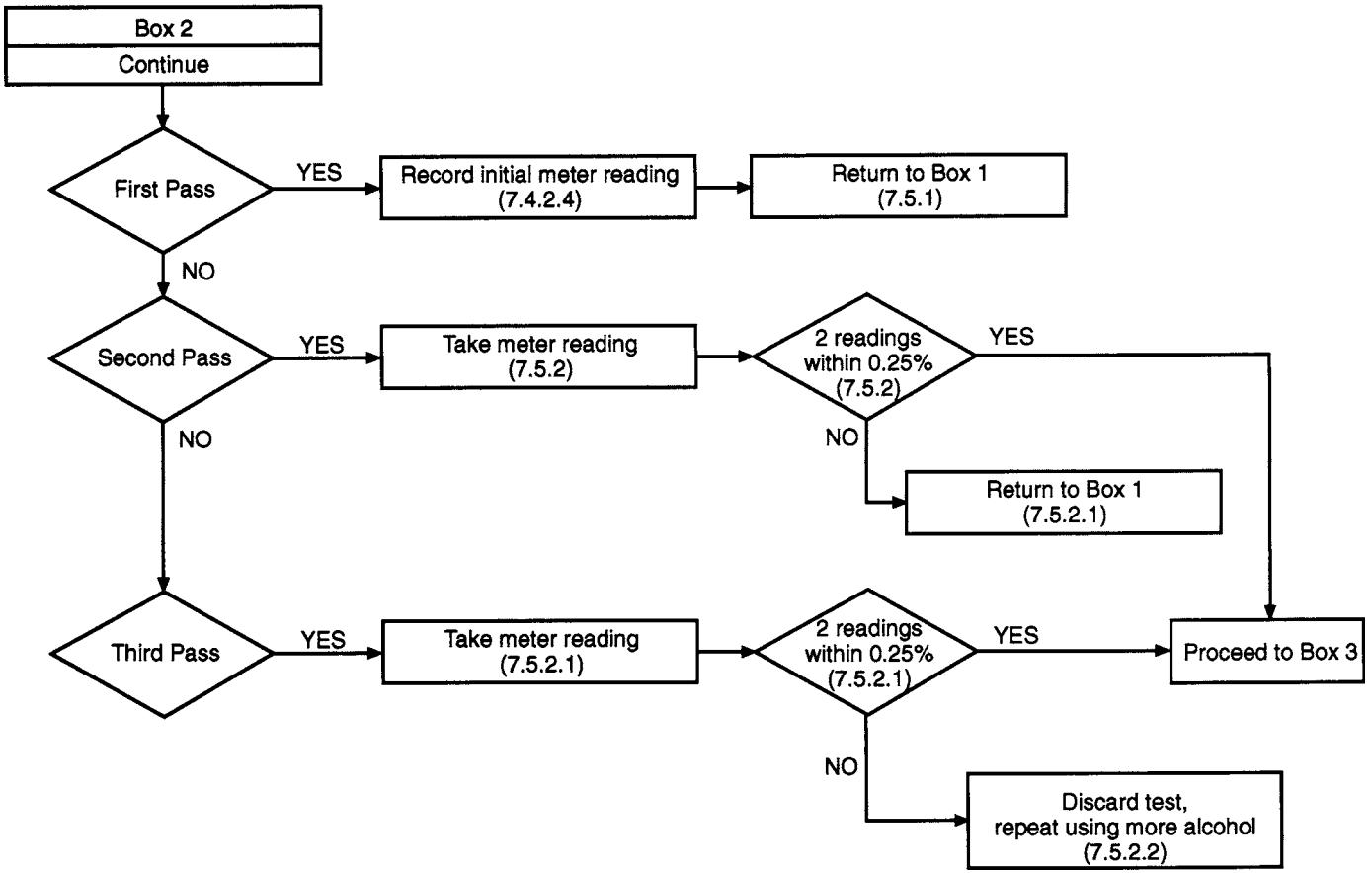

FIG. X1.1 Outline of Check List for Performing the Volumetric Air Content Test Method *(continued)*

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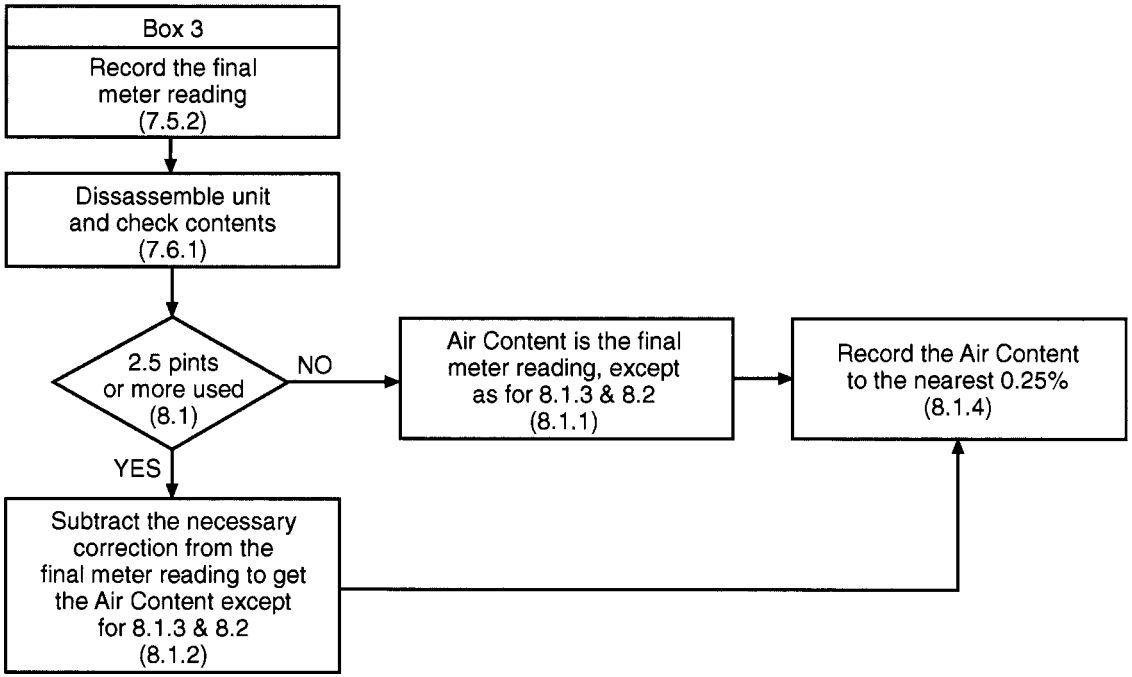

FIG. X1.1 Outline of Check List for Performing the Volumetric Air Content Test Method *(continued)*

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SUMMARY OF CHANGES

Committee C09 has identified the location of selected changes to this test method since the last issue, C173/C173M–09 that may impact the use of this test method. (Approved February 1, 2010)

(*1*) Revised 4.3 to alter requirements of tamping rod.

(*2*) Added new Note 1 describing acceptable tamping rod length and renumbered subsequent notes.

(*3*) Revised 7.1 to alter wording of tamping rod use.

Committee C09 has identified the location of selected changes to this test method since the last issue, C173/C173M–08a, that may impact the use of this test method. (Approved June 1, 2009)

(*1*) Revised Table 1, including Footnote B.

(*2*) Revised Section 8. Much of the text in Section 8 was removed and replaced by Eq 1 to clarify the calculation of air content.

Committee C09 has identified the location of selected changes to this test method since the last issue, C173/C173M–08, that may impact the use of this test method. (Approved December 15, 2008)

(*1*) Revised Table 1.

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Designation: C 174/C 174M – 06

American Association State
Highway and Transportation Officials Standard
AASHTO No.: T 148

Standard Test Method for Measuring Thickness of Concrete Elements Using Drilled Concrete Cores[1]

This standard is issued under the fixed designation C 174/C 174M; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope*

1.1 This test method covers the determination of the thickness of a concrete pavement, slab, or structural element by measuring the length of a core drilled from a concrete structure.

1.2 The values stated in either SI units or inch-pound units are to be regarded separately as standard. Within the text, the inch-pound units are shown in brackets. The values stated in each system are not exact equivalents; therefore, each system shall be used independently of the other.

1.3 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

2. Significance and Use

2.1 This test method is used to determine the compliance of concrete construction with design specifications. It is especially important in determining the thickness of pavements and other slab construction.

3. Apparatus

3.1 The apparatus shall consist of a 3-point calipering device that will measure the length of axial elements of the core. While the details of the mechanical design are not prescribed, the apparatus shall conform to the requirements of 3.2 to 3.6.[2] An example of the apparatus is illustrated in Fig. 1.[3]

FIG. 1 Core Measuring Apparatus

3.2 The apparatus shall be so designed that the specimen will be held with its axis in a vertical position by three symmetrically placed supports bearing against the lower end. These supports shall be short posts or studs of hardened steel, and the ends that bear against the surface of the specimen shall be rounded to a radius of not less than 6 mm [¼ in.] and not more than 13 mm [½ in.].

3.3 The apparatus shall provide for the accommodation of specimens of different nominal lengths over a range of at least 100 to 250 mm [4 to 10 in.].

3.4 The calipering device shall be so designed that it will be possible to make a length measurement at the center of the upper end of the specimen, and at eight additional points spaced at equal intervals along the circumference of a circle

[1] This test method is under the jurisdiction of ASTM Committee C09 on Concrete and Concrete Aggregates and is the direct responsibility of Subcommittee C09.69 on Miscellaneous Tests.

Current edition approved Feb. 1, 2006. Published February 2006. Originally approved in 1942. Last previous edition approved in 1997 as C 174/C 174M – 97.

[2] For further information relating to the development of this test method and apparatus, reference should be made to the "Project Report on a Study of Methods of Measurement of the Length of Cores Drilled from Concrete Structures," prepared by L. W. Teller for Subcommittee VII on Methods and Apparatus for Testing Concrete, of Committee C09, see *Proceedings*, Am. Soc. Testing Mats., ASTM, Vol 42, 1942.

[3] The sole source of supply of the apparatus known to the committee at this time is Humboldt Mfg. Co., 7300 West Agatite, Norridge, IL 80656-4704, Catalog No. H-2939. If you are aware of alternative suppliers, please provide this information to ASTM Headquarters. Your comments will receive careful consideration at a meeting of the responsible technical committee, which you may attend.

***A Summary of Changes section appears at the end of this standard.**

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whose center point coincides with that of the end area of the specimen and whose radius is not less than one half nor more than three fourths of the radius of the specimen.

3.5 The measuring rod or other device that makes contact with the end surface of the specimen for measurement shall be rounded to a radius of 3 mm [⅛ in.]. The scale on which the length readings are made shall be marked with clear, definite, accurately spaced graduations. The spacing of the graduations shall be 1.0 mm [0.10 in.] or a decimal part thereof.

3.6 The apparatus shall be stable and sufficiently rigid to maintain its shape and alignment without a distortion or deflection of more than 0.25 mm [0.01 in.] during all normal measuring operations.

4. Test Specimens

4.1 Cores used as specimens for length measurement shall be in every way representative of the concrete in the structure from which they are removed. The specimen shall be drilled with the axis normal to the surface of the structure, and the ends shall be free from all conditions not typical of the surfaces of the structure. Cores that show abnormal defects or that have been damaged appreciably in the drilling operation shall not be used. If a core drilled from a pavement or structure placed on dense-graded aggregate base course includes particles of the aggregate bonded to the bottom surface of the concrete, the bonded particles shall be removed by wedging or by chisel and hammer applied so as to expose the lower surface of the concrete. If the concrete is placed on an open-graded aggregate base course, the mortar in the concrete may penetrate into the base and surround some particles. Use sufficient force with a wedge or chisel and hammer to remove bonded particles but not such force as to fracture particles substantially surrounded by mortar. If during the removal of bonded aggregate the concrete is broken so that the instructions of 5.4 cannot be followed, the core shall not be used for length measurement.

5. Procedure

5.1 Before any measurements of the core length are made, calibrate the apparatus with suitable gages so that errors caused by mechanical imperfections in the apparatus are known. When these errors exceed 0.25 mm [0.01 in.], apply suitable corrections to the core length measurements.

5.2 Place the specimen in the measuring apparatus with the smooth end of the core, that is, the end that represents the upper surface of a pavement slab or a formed surface in the case of other structures, placed down so as to bear against the three hardened-steel supports. So place the specimen on the supports that the central measuring position of the measuring apparatus is directly over the midpoint of the upper end of the specimen.

5.3 Make nine measurements of the length on each specimen, one at the central position and one each at eight additional positions spaced at equal intervals along the circumference of the circle of measurement. Read each of these nine measurements to the nearest 1.0 mm [0.05 in.].

5.4 If, in the course of the measuring operation, it is discovered that at one or more of the measuring points the surface of the specimen is not representative of the general plane of the core end because of a small projection or depression, the specimen shall be rotated slightly about its axis and a complete set of nine measurements made with the specimen in the new position. With cores from pavements placed over open-graded aggregate bases the foregoing provisions frequently cannot be met because of the great number of projections or voids on the bottom surface.

6. Report

6.1 The individual observations shall be recorded to the nearest 1.0 mm [0.05 in.], and the average of the nine measurements expressed to the nearest 1.0 mm [0.1 in.] shall be reported as the length of the concrete core.

7. Precision and Bias

7.1 *Precision*:

7.1.1 *3-Point Caliper*—No statement is made about the precision of this test procedure. An interlaboratory test program for the determination of core length by this procedure is being studied by Subcommittee C09.69 and will be included in a later revision of this test method.

7.2 *Bias*—Since there are not acceptable reference cores suitable for determining the bias of these procedures, no statement on bias is being made.

8. Keywords

8.1 3-point caliper; concrete; cores; length measurement; thickness measurement

SUMMARY OF CHANGES

Committee C09 has identified the location of selected changes to this test method since the last issue, C 174/C 174M – 97, that may impact the use of this test method. (Approved February 1, 2006)

(*1*) Added Keywords.

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Designation: C 183 – 08

Standard Practice for Sampling and the Amount of Testing of Hydraulic Cement[1]

This standard is issued under the fixed designation C 183; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

This standard has been approved for use by agencies of the Department of Defense.

1. Scope*

1.1 This practice covers procedures for sampling and for the amount of testing of hydraulic cement after it has been manufactured and is ready to be offered for sale.

1.2 The values stated in SI units are to be regarded as the standard. The inch-pound units in parentheses are for information purposes only.

1.2.1 A ton as used in this practice is 907 kg (2000 lb).

1.2.2 Values in SI units shall be obtained by measurement in SI units or by appropriate conversion, using the Rules for Conversion and Rounding given in Standard IEEE/ASTM SI 10, of measurement made in other units.

1.3 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

2. Referenced Documents

2.1 *ASTM Standards:*[2]

C 91 Specification for Masonry Cement

C 109/C 109M Test Method for Compressive Strength of Hydraulic Cement Mortars (Using 2-in. or [50-mm] Cube Specimens)

C 114 Test Methods for Chemical Analysis of Hydraulic Cement

C 115 Test Method for Fineness of Portland Cement by the Turbidimeter

C 150 Specification for Portland Cement

C 151 Test Method for Autoclave Expansion of Hydraulic Cement

C 157/C 157M Test Method for Length Change of Hardened Hydraulic-Cement Mortar and Concrete

C 185 Test Method for Air Content of Hydraulic Cement Mortar

C 186 Test Method for Heat of Hydration of Hydraulic Cement

C 191 Test Methods for Time of Setting of Hydraulic Cement by Vicat Needle

C 204 Test Methods for Fineness of Hydraulic Cement by Air-Permeability Apparatus

C 227 Test Method for Potential Alkali Reactivity of Cement-Aggregate Combinations (Mortar-Bar Method)

C 265 Test Method for Water-Extractable Sulfate in Hydrated Hydraulic Cement Mortar

C 266 Test Method for Time of Setting of Hydraulic-Cement Paste by Gillmore Needles

C 451 Test Method for Early Stiffening of Hydraulic Cement (Paste Method)

C 452 Test Method for Potential Expansion of Portland-Cement Mortars Exposed to Sulfate

C 563 Test Method for Approximation of Optimum SO_3 in Hydraulic Cement Using Compressive Strength

C 595 Specification for Blended Hydraulic Cements

C 845 Specification for Expansive Hydraulic Cement

C 1012 Test Method for Length Change of Hydraulic-Cement Mortars Exposed to a Sulfate Solution

C 1157 Performance Specification for Hydraulic Cement

C 1328 Specification for Plastic (Stucco) Cement

C 1329 Specification for Mortar Cement

E 11 Specification for Wire Cloth and Sieves for Testing Purposes

IEEE/ASTM SI 10 Standard for Use of the International System of Units (SI): The Modern Metric System

2.2 *ACI Standard:*

225.1R Guide to the Selection and Use of Hydraulic Cements[3]

3. Terminology

3.1 *Definitions of Terms Specific to This Standard:*

3.1.1 *lot (of cement)*—specific quantity of cement offered for inspection at any one time. A lot may be one or more

[1] This practice is under the jurisdiction of ASTM Committee C01 on Cement and is the direct responsibility of Subcommittee C01.95 on Coordination of Standards.

Current edition approved Dec. 15, 2008. Published January 2009. Originally approved in 1944. Last previous edition approved in 2002 as C 183 – 02.

[2] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

[3] Detailed requirements for this sieve are given in Specification E 11.

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storage bins filled consecutively. A lot may also be the contents of one or more transport units representing cement drawn from the same storage bin.

3.1.2 *reduced testing rate*—test program that provides for the testing of only two samples from any given lot of samples obtained and prepared for testing at the normal rate as described herein. The program utilizes probability factors and is so designed that when results from the two samples fulfill the requirements of the program it may be said with 95 % confidence that less than 5 % of the samples would be outside the specification limits.

4. Significance and Use

4.1 The sampling procedures described are intended for use in the procurement of samples of hydraulic cement after it has been manufactured and is ready to be offered for sale. They are not intended as sampling procedures for quality control purposes during manufacturing. The testing procedures outlined cover the amount of testing to be done and provide guidance for reporting on conformance or non-conformance of cements with requirements of purchase specifications.

4.2 This practice is referenced as the procedure for sampling masonry cement (Specification C 91), portland cement (Specification C 150), blended hydraulic cement (Specification C 595), expansive hydraulic cement (Specification C 845), plastic stucco cement (Specification C 1328), mortar cement (Specification C 1329), and hydraulic cement based on a performance specification (Specification C 1157).

4.3 Most building codes and construction specifications require that hydraulic cement to be used in the work meet the applicable requirements of the relevant purchase specifications, such as Specifications C 91, C 150, C 595, C 1157, C 1328, C 1329, or C 845. If the code or specification requires sampling of the manufactured cement, the provisions given in 4.4 are applicable. Not much cement is sold on the basis of such sampling and testing. A useful discussion of sampling and testing cement is contained in ACI 225.1R.

4.4 The procedures covered in this practice should be done by or for purchasers of hydraulic cement who are using a code or specification that requires sampling and testing to determine if the samples conform to the relevant acceptance specifications. The testing is done using specified methods to determine whether the samples yield test results that conform to the specification, and the tests serve as a basis for acceptance or rejection of the lot of material sampled.

4.5 It is neither intended nor required that all cements be tested using all the test methods referenced in Section 2.

5. Kinds and Size of Samples and by Whom Taken

5.1 A cement sample secured from a conveyor, from bulk storage, or from a bulk shipment in one operation, shall be termed a "grab sample." A sample obtained during a 10-min interval using an automatic sampling device that continuously samples a cement stream may also be termed a grab sample. Grab samples taken at prescribed intervals over a period of time may be combined to form a "composite sample'' representative of the cement produced during that period of time.

5.2 All samples, whether grab or composite, shall have a mass of at least 5 kg (10 lb).

5.3 The purchaser may designate a representative to supervise the sampling, packing, and shipping of samples when it is so specified in the purchase contract.

5.4 Package the samples in moisture-proof, airtight containers numbered consecutively in the order in which the samples are taken. The purchase contract shall state who will pay for the costs of sampling, packaging, shipping and testing the samples.

NOTE 1—Polyvinyl chloride sample containers, upon occasion, have been found to affect the air-entraining potential of a cement sample. The same problem might be experienced with containers made from other plastics.

6. Testing-Time Requirements for the Completion of Tests

6.1 When tests of hydraulic cement are made at a laboratory other than that of the cement manufacturer, the cement sampling schedule, sample transportation time, and sample testing schedule must be coordinated among the purchaser, the manufacturer, and the testing laboratory so that the tests results will be available when required.

6.2 The manufacturer of the cement shall make the cement available to be sampled for testing early enough before the time the test results are needed so that at least the applicable time intervals listed in 6.3 exist.

6.3 When this has been done, the testing laboratory shall provide test results not later than the indicated number of days after sampling:

Test Methods	Time Interval, days
C 109/C 109M (1-day results), C 114, C 115, C 151, C 185, C 191, C 204, C 451, C 265, C 266, C 563	8
C 109/C 109M (3-day results)	10
C 109/C 109M and C 186 (7-day results)	14
C 227, C 452, and C 1012 (14-day results)	21
C 109/C 109M and C 186 (28-day results)	35
C 157/C 157M (34-day results)	41
C 227 (56-day results)	63
C 227 (91-day results)	98

7. Sampling

7.1 The cement may be sampled by any of the applicable methods described in this section.

7.1.1 *From the Conveyor Delivering to Bulk Storage*—Take one grab sample, having a mass of at least 5 kg (10 lb), at approximately 6-h intervals.

7.1.2 *Transfer Sampling*—Sample cement in storage while the cement is being transferred from one bin to another. Take one grab sample from the transfer stream for each 360 Mg (400 tons) of cement, or fraction thereof, but take no less than two grab samples and combine them to produce a composite sample.

7.1.3 *Other Sampling Methods*—When neither of the above sampling methods is applicable, samples may, when authorized by the purchaser, be taken by one of the following methods:

7.1.3.1 *From Bulk Storage at Points of Discharge*—Withdraw cement from the discharge openings in a steady stream until sampling is completed. Estimate the quantity of cement in Mg to be withdrawn from one discharge opening as $0.055\ d^3 \times 0.2$, where d is the depth in metres of cement above the discharge opening. If a high circular silo is being sampled, take all samples from one opening. If the quantity of the

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cement in the bin exceeds 1100 Mg (1200 tons) when low rectangular bins are being sampled, discharge openings employed in the sampling shall be such that for no opening shall the number of samples represent more than one half the contents of the bin or more than 1800 Mg (2000 tons). In sampling bulk storage at points of discharge, while the cement is flowing through the openings, take samples at such intervals so that at least two grab samples shall be secured for each 360 Mg (400 tons) in the bin or silo.

7.1.3.2 *From Bulk Storage and Bulk Shipment by Means of a Slotted Tube Sampler*—When the depth of the cement to be sampled does not exceed 2.1 m (7 ft), obtain samples using a slotted tube sampler similar to that shown in Fig. 1. It shall be between 1.5 and 1.8 m (5 and 6 ft) long and approximately 35 mm (1⅜ in.) in outside diameter and consist of two polished brass telescopic tubes with registering slots that are opened or closed by rotation of the inner tube, the outer tube being provided with a sharp point to facilitate penetration. Take samples from well-distributed points and various depths of the cement so that the samples taken will represent the cement involved.

7.1.3.3 *From Packaged Cement by Means of Tube Sampler*—Insert the sampler, shown in Fig. 2, diagonally into the valve of the bag and place the thumb over the air hole. Then withdraw the sampler. Take one sample from a bag in each 4.5 Mg (5 tons) or fraction thereof.

7.1.3.4 *From Bulk Shipment of Car or Truck*:

(a) (a) Single Shipment—If only one car or truck is being loaded and the loading is continuous and all from the same source, take a 5-kg (10-lb) sample. If not continuous or unknown, combine five or more portions from different points in the load to form the test sample.

(b) (b) Multiple Shipments—When the shipment consists of several cars or trucks loaded from the same source and on the same day, sample the shipment at the rate of one sample for each 90 Mg (100 tons) of cement or fraction thereof, but take not less than two samples. Consider cement represented by such samples as a lot, and test the samples in accordance with the procedure outlined in the section on Amount of Testing.

7.2 *Protection of Samples*—As samples are taken, place them directly in moisture-proof airtight containers to avoid moisture absorption and aeration of the sample. If the samples are placed in cans, fill the can completely and immediately seal. Use moisture-proof multiple-wall paper bags or plastic bags if they are strong enough to avoid breakage, and if they can be sealed immediately after filling in such a manner as to eliminate excess air in the sample and avoid moisture absorption and aeration of the sample. Samples shall be treated as described in the section on Preparation of Sample.

8. Preparation of Sample

8.1 Before testing, pass each sample through an 850-µm (No. 20) sieve,[6] or any other sieve having approximately the same size openings, in order to mix the sample, break up lumps, and remove foreign material. Discard the foreign materials and hardened lumps that do not break up on sieving or brushing. Store the cement in airtight moisture-proof containers to prevent aeration or absorption of moisture prior to test.

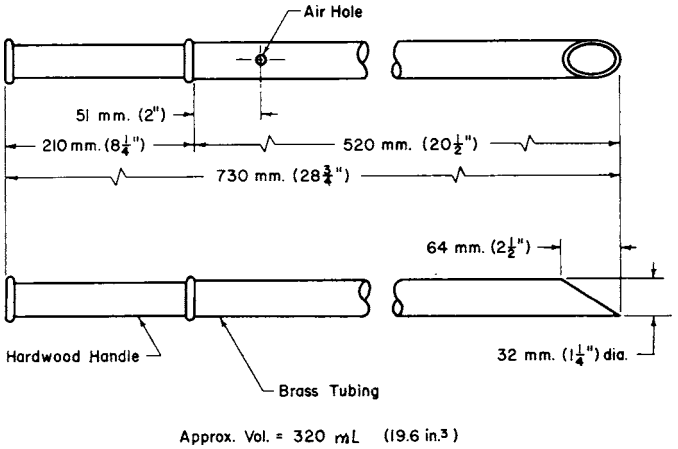

FIG. 2 Tube Sampler for Packaged Cement

9. Amount of Testing

9.1 *General*—When required, the purchaser shall specify the amount of testing for heat of hydration (Test Method C 186), alkali reactivity (Test Method C 227), and sulfate resistance (Test Method C 1012). Make all other tests on individual grab or composite samples chosen as specified herein under Selection of Samples for Testing. Do only those tests required by the applicable specification.

9.2 *Normal Testing*—Determine the number of samples to be tested in accordance with Table 1. The normal testing rate shall be used under the following conditions:

9.2.1 Before the quality history has been established,

9.2.2 When no samples from a particular mill have been tested within a year,

9.2.3 When the quality history is based entirely on data more than two years old, and

9.2.4 When it is deemed necessary to recalculate the critical limit because of indicated lack of control as shown by the control chart of the range.

NOTE 2—Random grab samples taken at inappropriate times, such as immediately following the repair or adjustment of manufacturing equipment, or from inappropriate places, such as from the top surface of the material in a car, will not suitably reflect the properties of a cement, and therefore should not be used as the basis for acceptance or rejection of a lot of cement.

9.3 *Reduced Testing*—After the quality history has been established, test at the reduced testing rate. If the results of these tests are within the critical range, make additional tests (total equal to the number of tests at the normal rate as shown in Table 1).

FIG. 1 Slotted Tube Sampler for Bulk Cement

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TABLE 1 Number of Samples for Test

Lot Size—Number of Samples	Number of Tests	
	Normal Rate	Reduced Rate
2	2	2
3	3	2
4 to 10	4	2
11 to 20	6	2
Over 20	8	2

NOTE 3—When the quality history indicates that the results for a given requirement will probably be within the critical range, and substantial delay in completion of the tests would result from making additional tests (for example, compressive strength), it may be desirable to make the tests at the normal rate, rather than the reduced testing rate.

9.4 *Selection of Samples for Testing*— Take samples to be tested from each lot by some random method. The following method is suggested: Place a group of consecutively numbered markers equal to the number of samples in a container and mix, then draw one marker at a time from the container until the number drawn is equal to the number of samples to be tested at the normal rate. If the testing is to be done at the reduced rate, mix the drawn markers and draw two to select the numbers of the samples to be tested.

9.5 *Establishing a Quality History and Control Charts*:

9.5.1 *Quality History*—The quality history shall represent cement from the same source as the cement to be tested, and shall be based on data not more than 2 years old. There shall be available test results for not less than 40 test samples representing not less than 7 lots of cement. The test samples shall conform to the applicable provisions of this practice. A pair shall be two test samples from the same lot, in numerical sequence. Several pairs from the same lot may be used where available. The number of paired samples representing a large lot may be reduced as follows: From the consecutively numbered group of tested samples representing the entire lot, select a subgroup by some random method. List the numbers identifying the subgroup in numerical sequence, and pair in the order of listing. Compute the range (difference between the test results of a pair) for each pair of test results. Total the ranges and divide their sum by the total number of ranges used to obtain the average range, $\bar{r}$. Compute the average range, $\bar{r}$, for each included physical and chemical property limited by specification requirements.

9.5.2 *Critical Limit*—Calculate the critical limit, *C*, for each included physical and chemical property limited by a specification requirement. First, multiply the average range, $\bar{r}$, by the probability factor, 2.49, this will yield a number that for convenience is called *d*. If the requirement has a maximum specification limit, obtain *C* by subtracting *d* from the specification limit and, if a minimum, add *d* to the specification limit. Maintain quality history charts.

NOTE 4—Improved estimates of the range $\bar{r}$, and consequently of *C*, will result if the test results are not rounded. For example, the test result of 21.78 % for SiO_2 is preferred to the rounded value of 21.8 %. For the fineness, the calculated value of 3243 is preferred to the rounded value of 3240.

9.5.3 *Control Chart of the Range*—Maintain a control chart of the range to indicate when the critical limit needs to be recomputed. Multiply the average range. $\bar{r}$, as obtained in 9.5.2, by the probability factor 3.267 to obtain the upper control limit for the range between each consecutive pair of test results. The horizontal scale of the chart will be successive groups of two, and the vertical scale will be the range. Where the range chart indicates lack of control (points beyond the upper control limit), the critical limit, *C*, may need to be recalculated. Consider the occurrence of two consecutive points beyond the upper control limit for the range, or the occurrence of three points beyond the upper control limit in any series of five consecutive points cause to recalculate the critical limit. Where it becomes necessary to recalculate the critical limit, discontinue reduced testing until a new quality history has been established.

NOTE 5—Examples of the calculation of $\bar{r}$, *d*, and quality history and control charts are shown in Table 2 and Fig. 3 and Fig. 4. The specification limits used in these examples are hypothetical.

9.5.4 When the hydraulic cement sampled is to conform to Specification C 150, and the manufacturer has chosen the optimized cement SO_3 option as described in Specification C 150 Table 1 footnote D, the critical limit described in paragraph 9.5.2 using the specification limit for SO_3 is not applicable. Paragraphs 9.5.2 and 9.5.3 dealing with the calculation of critical limit are not required for SO_3 in this case.

9.5.5 When the hydraulic cement sampled is to conform to Specification C 595, and the manufacturer has chosen the optimized cement SO_3 content option as described in Specification C 595 Table 1 footnote A, the critical limit described in paragraph 9.5.2 using the specification limit for SO_3 is not applicable. Paragraphs 9.5.2 and 9.5.3 dealing with the calculation of critical limit are not required for SO_3 in this case.

9.6 *Reporting for Normal Testing*—When the testing is done at the normal testing rate, report the cement as complying with the specification if it meets the specification requirements, and report it as failing to meet the specification requirements if it does not meet each of the requirements as specified.

9.7 *Reporting for Reduced Testing*— When the testing is done at the reduced testing rate, report the cement as complying with the specification if the average of the test results is further from the specified limit than the critical limit. If the average of the results for one or more requirements are between the critical limit and the specification limit, test additional samples (total equal to the number of tests at the normal rate) for that requirement, and if on completion of the additional tests, all of the results meet the specified requirements report the cement as complying with the specification. Report the cement as failing to meet the specification requirements if any test result does not conform to the respective requirements.

9.8 When a cement is reported as failing to meet the specification requirements, state in the report which requirement the cement failed and the applicable limit.

10. Noncompliance and Retest

10.1 If any test result fails to meet the specification requirement, the lot of cement shall not be reported as not complying with the specification unless noncompliance is confirmed by retest as described in 10.2.

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TABLE 2 Test Data, Type I Low-Alkali Cement[A]

Lot No.	Sample No.	Alkalies %	Range %	7-day Strength Average of 3 Specimens		Range	
				MPa	(psi)	MPa	(psi)
88	1	0.58		35.5	(5150)		
	13	0.61	0.03	37.0	(5358)	1.44	(208)
	17	0.57		32.2	(4675)		
	21	0.55	0.02	33.1	(4800)	0.86	(125)
91	1	0.55		32.0	(4633)		
	5	0.55	0.00	33.9	(4917)	1.95	(283)
	13	0.57		34.3	(4975)		
	21	0.54	0.03	35.2	(5108)	0.92	(133)
98	5	0.55		33.8	(4896)		
	13	0.56	0.01	34.2	(4957)	0.42	(61)
	17	0.56		35.4	(5133)		
	21	0.56	0.00	36.3	(5267)	0.92	(133)
106	5	0.42		35.6	(5158)		
	13	0.45	0.03	34.1	(4950)	1.44	(208)
	17	0.47		33.3	(4832)		
	21	0.39	0.08	32.6	(4728)	0.72	(104)
107	4	0.47		34.1	(4938)		
	8	0.46	0.01	34.8	(5042)	0.72	(104)
	12	0.40		32.3	(4683)		
	20	0.41	0.01	33.7	(4892)	1.44	(208)
111	4	0.45		36.1	(5233)		
	8	0.44	0.01	36.9	(5350)	0.80	(117)
	12	0.41		35.6	(5163)		
	20	0.40	0.01	36.2	(5246)	0.57	(83)
112	3	0.45		36.8	(5333)		
	7	0.48	0.03	34.2	(4958)	2.59	(375)
	15	0.48		34.5	(4996)		
	19	0.49	0.01	35.3	(5113)	0.80	(117)
113	2	0.49		34.0	(4937)		
	15	0.46	0.03	33.1	(4803)	0.92	(133)
	20	0.47		34.4	(4994)		
	24	0.49	0.02	34.0	(4925)	0.48	(69)
120	1	0.46		32.5	(4717)		
	6	0.46	0.00	33.2	(4814)	0.67	(98)
	11	0.46		32.2	(4675)		
	21	0.46	0.00	33.2	(4808)	0.92	(133)
123	6	0.46		36.6	(5304)		
	11	0.45	0.01	36.3	(5267)	0.26	(38)
	21	0.44		35.3	(5117)		
	26	0.44	0.00	35.8	(5196)	0.55	(79)
Total	40		0.34			19.39	2811

	Calculation of Critical Limit and Control Limit		
	Alkalies	Strength MPa	Strength psi
Specification limit	0.60	30.0	4350
$\bar{r}$	0.017	0.969	141
d = 2.49 $\bar{r}$	0.042	2.413	350
Critical limit	(0.60 – 0.042)	(30 + 2.4)	(4350 + 350)
	0.558	32.4	4700
3.267 $\bar{r}$	0.0555	3.17	459
Control limit	0.056	3.2	459

10.2 A retest is considered to be an additional test of a certain property that is made when the initial test of that property produces a result not complying with the specification requirements. A retest may consist of either a single determination or a set of replicate determinations.

10.3 Retests shall be conducted in accordance with the provisions, if given, of the applicable specification. If no provisions are given, the following procedure shall be used:

10.3.1 Make the retest on a portion of the same sample as was used for the initial test. Use referee methods whenever they are provided for determination of the property requiring retest and in such case use only the results obtained by referee methods. The retest shall consist of the same number of determinations required for the initial test, or, if a within-laboratory precision statement is given which is based on a specified number of replicates (that is, duplicate or triplicate determinations), the number of replicates used as the basis of such precision statement. If two or more determinations are required, the value reported shall be the average of all results that are within the limits of precision of the method at the 95 % confidence level, as stated in the applicable specification or as generally recognized.

11. Keywords

11.1 hydraulic cement; sampling; testing

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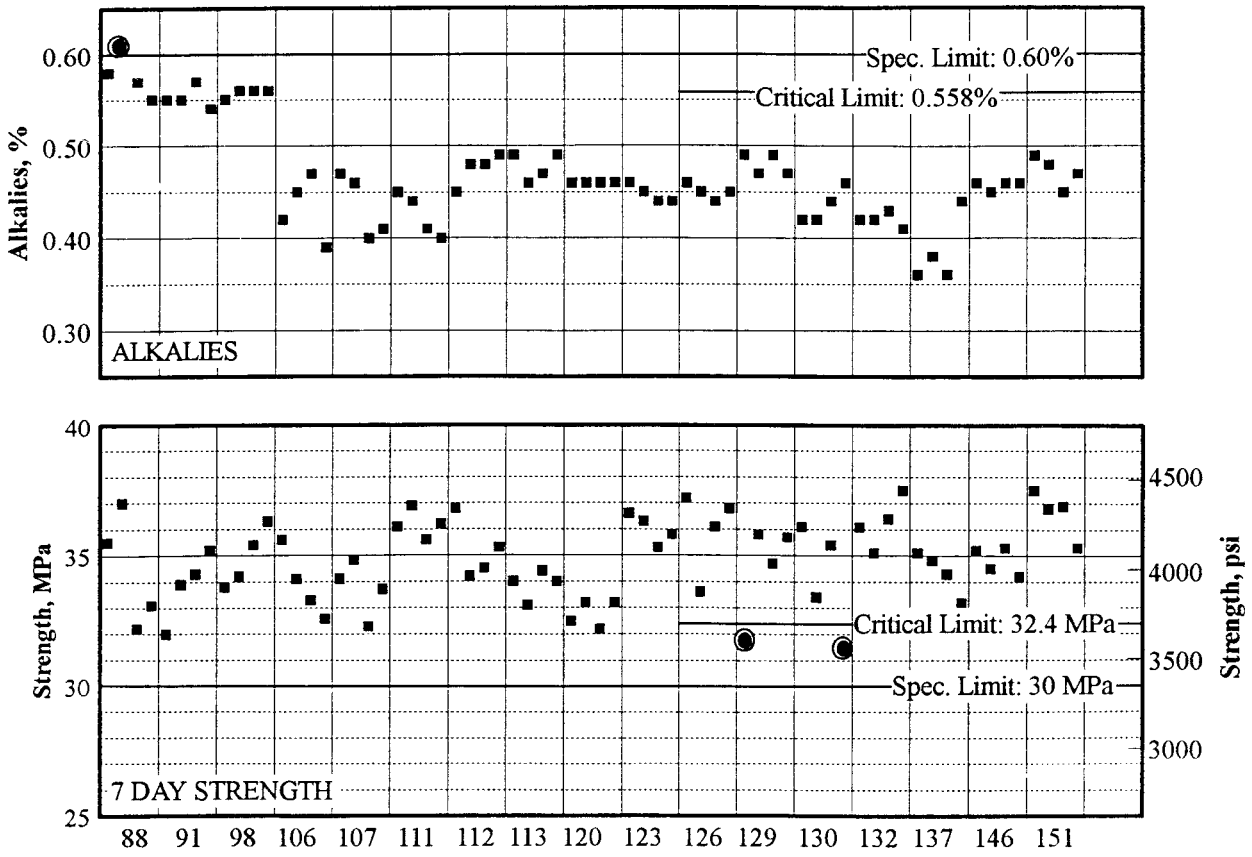

FIG. 3 Quality History Chart

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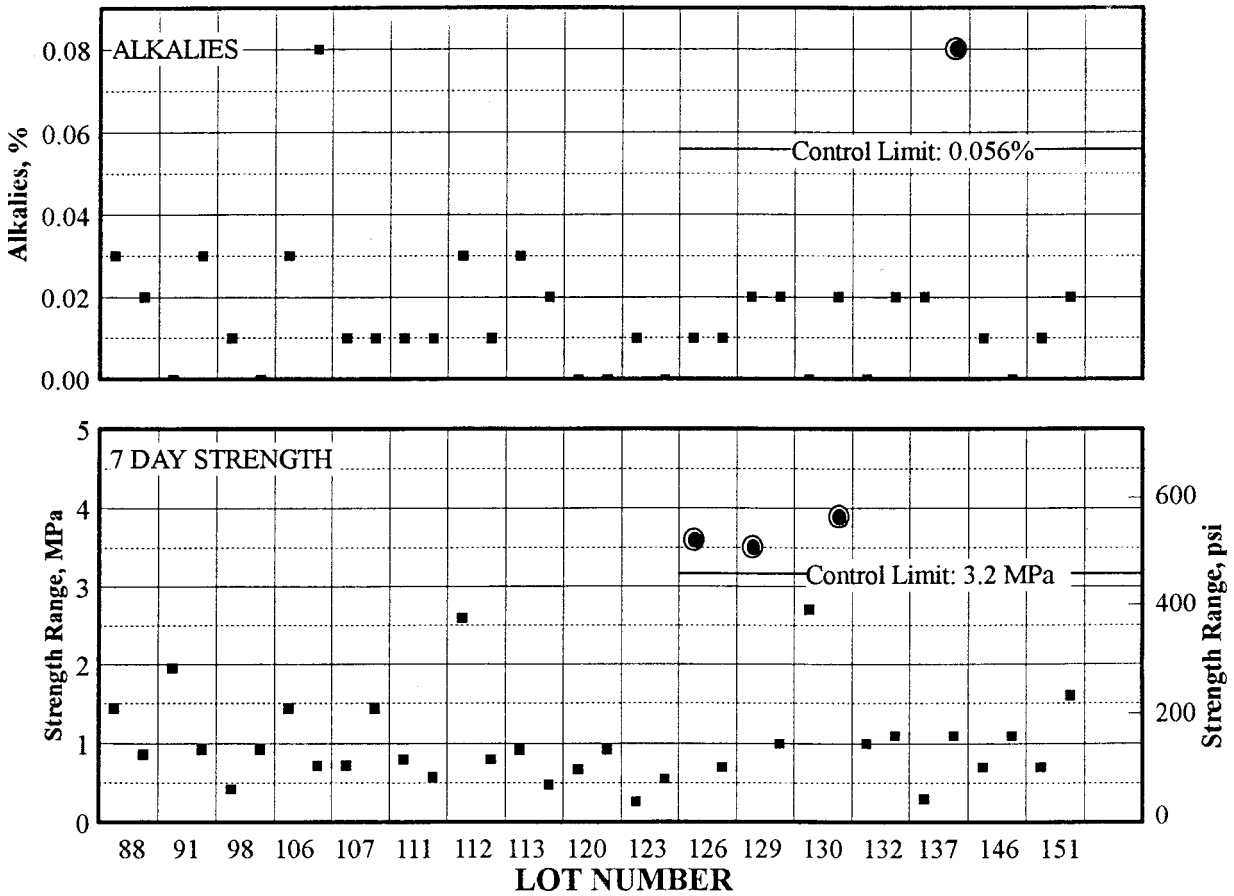

FIG. 4 Control Chart for Range

SUMMARY OF CHANGES

Committee C01 has identified the location of selected changes to this practice since the last issue, C 183 – 02, that may impact the use of this practice. (Approved December 15, 2008)

(*1*) Added new 9.5.4 and 9.5.5.

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Designation: C 185 – 08

American Association State
Highway and Transportation Officials Standard
AASHTO No.: T137

Standard Test Method for Air Content of Hydraulic Cement Mortar[1]

This standard is issued under the fixed designation C 185; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

This standard has been approved for use by agencies of the Department of Defense.

1. Scope*

1.1 This test method covers the determination of the air content of hydraulic cement mortar under the conditions hereinafter specified.

1.2 The values stated in SI units are to be regarded as standard. No other units of measurement are included in this standard.

1.3 Values in SI shall be obtained by measurement in SI units or by appropriate conversion, using the Rules for Conversion and Rounding in IEEE/ASTM SI 10, of measurements made in other units.

1.4 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

1.5 **Warning—** Fresh hydraulic cementitious mixtures are caustic and may cause chemical burns to skin and tissue upon prolonged exposure.[2]

2. Referenced Documents

2.1 *ASTM Standards:* [3]

C 91 Specification for Masonry Cement

C 109/C 109M Test Method for Compressive Strength of Hydraulic Cement Mortars (Using 2-in. or [50-mm] Cube Specimens)

C 150 Specification for Portland Cement

C 183 Practice for Sampling and the Amount of Testing of Hydraulic Cement

C 230/C 230M Specification for Flow Table for Use in Tests of Hydraulic Cement

C 305 Practice for Mechanical Mixing of Hydraulic Cement Pastes and Mortars of Plastic Consistency

C 511 Specification for Mixing Rooms, Moist Cabinets, Moist Rooms, and Water Storage Tanks Used in the Testing of Hydraulic Cements and Concretes

C 595 Specification for Blended Hydraulic Cements

C 778 Specification for Standard Sand

C 1005 Specification for Reference Masses and Devices for Determining Mass and Volume for Use in the Physical Testing of Hydraulic Cements

C 1157 Performance Specification for Hydraulic Cement

C 1328 Specification for Plastic (Stucco) Cement

C 1329 Specification for Mortar Cement

E 438 Specification for Glasses in Laboratory Apparatus

E 694 Specification for Laboratory Glass Volumetric Apparatus

IEEE/ASTM SI 10 Standard for Use of the International System of Units (SI): The Modern Metric System

3. Summary of Test Method

3.1 Prepare a mortar with standard sand and the cement to be tested, using a water content sufficient to give a required flow. Compact the mortar into a measure of known volume and determine mass. Calculate the air content from the measured density of the mortar, the known densities of the constituents, and the mixture proportions.

4. Significance and Use

4.1 The purpose of this test method is to determine whether or not the hydraulic cement under test meets the air-entraining or non-air-entraining requirements of the applicable hydraulic cement specification for which the test is being made. The air content of concrete is influenced by many factors other than the potential of the cement for air entrainment.

5. Apparatus

5.1 *Flow Table, Flow Mold, and Caliper*, shall conform to Specification C 230/C 230M.

5.2 *Measure*—A cylindrical measure having an inside diameter of 76 ± 2 mm and a depth (approximately 88 mm) adjusted by standardization with water to contain 400 ± 1 mL

[1] This test method is under the jurisdiction of ASTM Committee C01 on Cement and is the direct responsibility of Subcommittee C01.21 on Air Entrainment.

Current edition approved July 1, 2008. Published August 2008. Originally approved in 1944. Last previous edition approved in 2002 as C 185 – 02.

[2] Refer to the section on Safety Precautions, "Manual of Cement Testing," *Annual Book of ASTM Standards*, Vol 04.01.

[3] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

***A Summary of Changes section appears at the end of this standard.**

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at 23.0 ± 2.0 °C (Note 1). For the purposes of this test, the capacity of the measure in millilitres is the mass of the water content of the measure, in grams, divided by 0.9976, no correction in mass being made for the buoyant effect of air. The measure shall have a uniform wall thickness. The thickness of the wall and bottom shall not be less than 2.9 mm. The total mass of the empty measure shall not be more than 900 g. The measure shall be made of a metal not attacked by the cement mortar.

NOTE 1—Calibrate the 400-mL measure by filling with distilled water at 23.0± 2.0 °C to a point where the meniscus extends appreciably above the top of the measure, placing a clean piece of plate glass on the top of the measure, and allowing the excess water to be squeezed out. The absence of air bubbles as seen through the glass ensures that the measure is completely full. Care shall be taken that the excess water is wiped from the sides of the container before weighing.

5.3 *Mixer, Bowl, and Paddle*, shall conform to the apparatus section of Practice C 305.

5.4 *Straightedge*—A steel straightedge not less than 200 mm long and not less than 1.5 mm nor more than 3.5 mm in thickness.

5.5 *Weights and Weighing Devices*, shall conform to Specification C 1005. Evaluate the weighing device for precision and accuracy at a total load of 2 kg.

5.6 *Glass Graduates*—Glass graduates of 250-mL capacity, conforming to the requirements of Specifications E 438 and E 694.

5.7 *Tamper*, conforming to the requirements of Test Method C 109/C 109M. The tamping face of the tamper shall be flat and at right angles to the length of the tamper.

5.8 *Tapping Stick*, a piece of hard wood having a diameter of approximately 16 mm and a length of approximately 152 mm.

5.9 *Spoon*—A metal restaurant-type serving spoon not less than 230 mm in length and with a bowl approximately 100 mm in length.

6. Temperature and Humidity

6.1 Maintain the temperature of the room and dry materials at 23.0 ± 4.0 °C.

6.2 Condition the mixing water and the measure, if it is being calibrated at 23 ± 2 °C.

6.3 Maintain the relative humidity of the laboratory at not less than 50 %.

7. Standard Sand

7.1 Use sand conforming to the requirements of Specification C 778 for 20–30 sand.

8. Sampling

8.1 Sample the cement in accordance with Practice C 183.

NOTE 2—Polyvinyl chloride (PVC) sample containers, upon occasion, have been found to affect the air-entraining potential of a cement sample. The same problem might be experienced with containers made from other plastics.

9. Procedure

9.1 *Batch*—Proportion the standard mortar using 350 g cement to 1400 g 20–30 standard sand and sufficient water to give a flow of 87½ ± 7½ % when determined in accordance with 9.3.

NOTE 3—Test Method C 185 refers to hydraulic cements that comply under Specification C 150, Specification C 595, and Performance Specification C 1157. Masonry cements (see Specification C 91), mortar cements (see Specification C 1329), and plastic cements (see Specification C 1328) require different sand, mass, and flow. Refer to the applicable specification.

9.2 *Mixing of Mortar*—Mix the mortar in accordance with Practice C 305.

9.3 *Flow Determination*—Carefully wipe dry the flow-table top and place the flow mold at the center of it. Using the spoon, place a layer of mortar about 25 mm in thickness in the mold and tamp 20 times with the tamper. The tamping pressure shall be just sufficient to ensure uniform filling of the mold. Overfill the top of the mold approximately 20 mm with mortar and tamp as specified for the first layer. Then cut off the mortar to a plane surface, flush with the top of the mold, by drawing the straightedge with a sawing motion across the top of the mold. Wipe the flow table top clean and dry, being especially careful to remove any water from around the edge of the mold. Lift the mold away from the mortar 1 min after completing the mixing operation. Immediately drop the table 10 times in accordance with Specification C 230/C 230M. The flow is the resulting increase in average diameter of the mortar mass, as determined with the calipers, measured on at least four diameters at approximately equispaced intervals, expressed as a percentage of the original diameter. Make trial mortars with varying percentages of water until the specified flow is obtained. Make each trial with fresh mortar.

9.4 *Mass per 400 mL of Mortar*—When the quantity of mixing water has been found that produces a flow of 87½ ± 7½ %, immediately determine the mass per 400 mL of mortar, using the mortar remaining in the mixing bowl after the flow has been determined. In the determination of the mass per 400 mL, do not use the portion of the mortar used in the flow determination. Using the spoon, place the mortar gently into the 400–ml measure in three equal layers. Tamp each layer 20 times around the inner surface of the measure. For the final layer of mortar, overfill the 400–ml measure approximately 20 mm. The position of the tamper shall be that: the broad side of the tamper is parallel to the radius and is perpendicular to the inner surface of the measure. Each layer is tamped in one complete revolution (rotation) with only sufficient pressure to adequately fill the measure and eliminate voids within the mortar. After the measure has been filled and tamped in the above prescribed manner, tap the sides of the measure lightly with the side of the tapping stick, one each at five different points at approximately equal spacing around the outside of the measure, in order to preclude entrapment of extraneous air (Note 4). No obvious space shall be left between the mortar and the inner surface of the measure as a result of the tamping operation. Then cut the mortar off to a plane surface, flush with the top of the measure, by drawing the straightedge with a sawing motion across the top of the measure, making two

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passes over the entire surface, the second pass being made at right angles to the first. If, in the striking-off operation, loose sand grains cause the straightedge to ride above the top surface of the measure, these grains shall be removed, and the operation repeated. Complete the entire operation of filling and striking off the measure within 1½ min. Wipe off all mortar and water adhering to the outside of the measure. Determine the mass of the measure and its contents. Subtract the mass of the container, and record the mass of the mortar in grams.

NOTE 4—This operation may be facilitated by placing the measure on a steady flat-surfaced support of lesser diameter than the measure while filling and wiping.

10. Calculation

10.1 Calculate the air content of the mortar from the following formula which is based on the batch proportions given in 9.1, taking the specific gravity of portland cement as 3.15 and of 20–30 standard sand as 2.65. When the hydraulic cement is other than portland, the appropriate value for its specific gravity shall be substituted for the value of 3.15 and the formula rederived accordingly:

$$\text{Air content, volume \%} = 100 - W[(182.7 + P)/(2000 + 4P)] \quad (1)$$

where:

W = mass of 400 mL of mortar, g, and

P = percentage of mixing water, based on mass of cement used.

NOTE 5—This formula is derived as follows:

$$\text{Air content, volume \%} = 100[1 - (W_a/W_c)] \quad (2)$$

where:

W_a = actual mass per unit of volume as determined by this test method.

= W/400 g/mL, where W is the mass in grams of the specified 400 mL of mortar (9.4),

W_c = theoretical mass per unit of volume, calculated on an air-free basis as follows and using the values for quantities of materials and specific gravities as given in 9.1 and 10.1,

$$= \frac{350 + 1400 + 350 \times P \times 0.01}{\frac{350}{3.15} + \frac{1400}{2.65} + \frac{350 \times P \times 0.01}{1}}$$

$$= \frac{(5 + 0.01P)}{(1.827 + 0.01P)}, \text{ and}$$

P = percentage of mixing water, based on mass of cement.

Substituting for W_a and W_c we have:

$$\text{Air content, volume \%} = 100\left(1 - \frac{W}{400} \times \frac{1.827 + 0.01P}{5 + 0.01P}\right)$$

$$\text{Air content, volume \%} = 100 - \frac{W}{4} \times \frac{(1.827 + 0.01P)}{(5 + 0.01P)}$$

$$\text{Air content, volume \%} = 100 - 2.5W\frac{(182.7 + P)}{(5000 + 10P)}$$

$$\text{Air content, volume \%} = 100 - W\frac{(182.7 + P)}{(2000 + 4P)}$$

10.2 Make only one determination of air content on a batch.

NOTE 6—Difficulty has occasionally been experienced with this test method by some persons. These difficulties usually have taken the form of values for air content that are abnormally high and that may be greater than the specified maxima in specifications for hydraulic cement. The air-entraining potential of the sand may be reduced by washing in the laboratory with potable water by decantation until a clear, colorless supernatant liquid is obtained. In case of dispute, such freshly washed sand shall be used.

11. Report

11.1 When this test method is used for specific action in compliance testing, report the value for the air content to the nearest 1 %.

12. Precision and Bias

12.1 The single-operator, within-laboratory, standard deviation has been found to be 0.56 % air content throughout the range of 8 to 19 % air. Therefore, results of two properly conducted tests by the same operator on similar batches should not differ by more than 1.6 % air.

12.2 The multilaboratory standard deviation has been found to be 1.0 % air content throughout the range from 8 to 19 % air. Therefore, results of two different laboratories on similar batches should not differ from each other by more than 2.8 % air.

13. Keywords

13.1 air content; hydraulic cement mortar

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For additional useful information on details of cement tests methods, references may be made to the "Manual of Cement Testing," which appears in the *Annual Book of ASTM Standards,* **Vol 04.01.**

SUMMARY OF CHANGES

Committee C01 has identified the location of selected changes to this test method since the last issue, C 185 – 02, that may impact the use of this test method. (Approved July 1, 2008)

(*1*) Added new Note 2 and renumbered subsequent notes.

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Designation: C 186 – 05

Standard Test Method for Heat of Hydration of Hydraulic Cement[1]

This standard is issued under the fixed designation C 186; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope

1.1 This test method covers the determination of the heat of hydration of a hydraulic cement by measuring the heat of solution of the dry cement and the heat of solution of a separate portion of the cement that has been partially hydrated for 7 and for 28 days, the difference between these values being the heat of hydration for the respective hydrating period.

1.2 The results of this test method may be inaccurate if some of the components of the hydraulic cement are insoluble in the nitric acid/hydrofluoric acid solution.

1.3 The values stated in SI units are to be regarded as the standard. The values given in parentheses are for information only.

1.4 Values in SI units shall be obtained by measurement in SI units or by appropriate conversion, using the Rules for Conversion and Rounding given in Standard IEEE/ASTM SI 10, or measurements made in other units.

1.5 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability or regulatory limitations prior to use.*

2. Referenced Documents

2.1 *ASTM Standards:* [2]

C 109/C 109M Test Method for Compressive Strength of Hydraulic Cement Mortars (Using 2-in. or [50-mm] Cube Specimens)

C 114 Test Methods for Chemical Analysis of Hydraulic Cement

C 670 Practice for Preparing Precision and Bias Statements for Test Methods for Construction Materials

C 1005 Specification for Reference Masses and Devices for Determining Mass and Volume for Use in the Physical Testing of Hydraulic Cements

E 11 Specification for Wire-Cloth Sieves for Testing Purposes

IEEE/ASTM SI 10 Standard for Use of the International System of Units (SI): The Modern Metric System

3. Significance and Use

3.1 The purpose of this test is to determine if the hydraulic cement under test meets the heat of hydration requirement of the applicable hydraulic cement specification.

3.2 This test may also be used for research purposes when it is desired to determine the heat of hydration of hydraulic cement at any age.

NOTE 1—When tests are performed for research purposes, useful additional information can be obtained by determining fineness, chemical and compound compositions.

3.3 Determination of the heat of hydration of hydraulic cements provides information that is helpful for calculating temperature rise in mass concrete.

4. Apparatus

4.1 *Calorimetric Apparatus*:

4.1.1 *Calorimeter*—The calorimeter, such as that illustrated in Fig. 1 shall consist of a 0.5-L (1-pt), wide-mouth vacuum jar, with cork stopper, or other suitable non-reactive stopper held in a suitably insulated container (See 4.1.2) to keep the vacuum jar in position and to protect the jar from undue temperature fluctuations. The vacuum jar shall be coated on the interior with a material resistant to hydrofluoric acid, such as a baked phenolic resin, a baked vinyl chloride acetate resin, or beeswax. The acid-resistant coating shall be intact and free of cracks at all times; it shall be examined frequently and renewed whenever necessary. As another means of protecting the vacuum jar, a plastic liner of suitable size may be used instead of coating the interior of the jar. The contents of the vacuum jar shall not change more than 0.001 °C/min per degree difference from room temperature when filled with 425 g of the acid specified in 6.2, stoppered, and allowed to stand unstirred for 30 min. The temperature for this check shall approximate the starting temperatures to be used in making the determination.

4.1.2 *Insulated Container*—The container shall have an insulating layer of a material such as non-reactive foam, cotton,

[1] This test method is under the jurisdiction of ASTM Committee C01 on Cement and is the direct responsibility of Subcommittee C01.26 on Heat of Hydration.

Current edition approved July 1, 2005. Published August 2005. Originally approved in 1944. Last previous edition approved in 1998 as C 186 – 98.

[2] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

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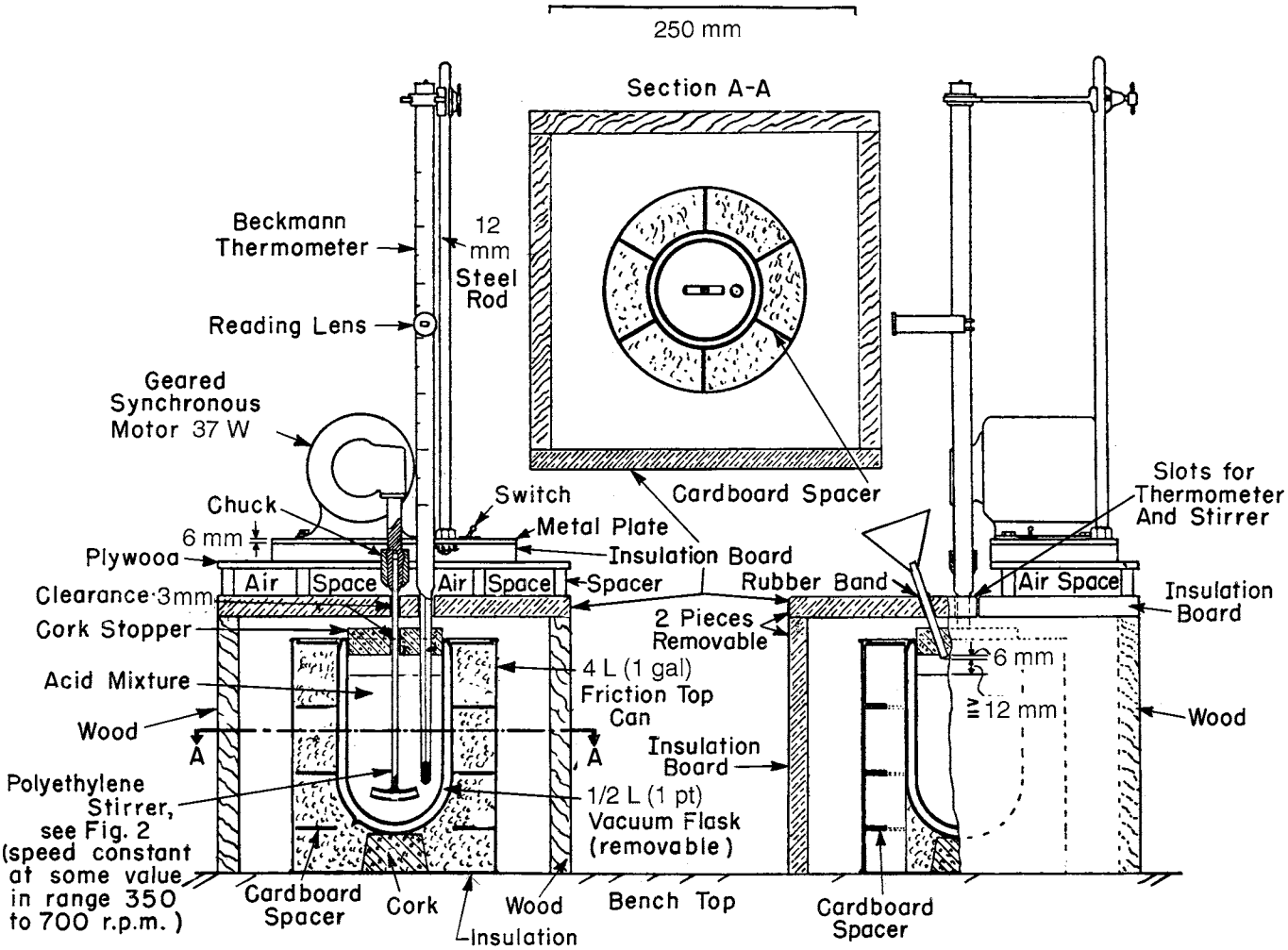

Metric Units	Inch-Pound Equivalents	Metric Units	Inch-Pound Equivalents
250 mm	10 in.	6 mm	1/4 in.
12 mm	1/2 in.	3 mm	1/8 in.
37 W	1/20 hp	0.47 litre	1 pt

FIG. 1 Calorimeter

or fiber-glass, which shall be at least 25 mm (1 in.) in thickness and shall encase the sides and bottom of the vacuum jar, but shall be so arranged as to permit easy removal of the jar.

4.1.3 *Thermometers*—Two thermometers are required. One is a high precision thermometer required to determine temperature rise associated with dissolution of cement during determinations. For purposes of this test method, this thermometer is called the *solution thermometer*. The other thermometer is used for measuring sample temperature before introduction into the calorimeter and air temperature during the determination. For purposes of this test method, it is called the *reference thermometer*.

4.1.3.1 *Solution thermometer*—The solution thermometer shall be readable to 0.001 °C. The solution thermometer may be either a Beckman type (See Note 2), which is a mercury-in-glass type that only outputs temperature differentials, or a digital type that gives actual temperature outputs. If a Beckman type is used, it shall be graduated to at least 0.01 °C, with readings to 0.001 °C that can be estimated by interpolation between these graduations. It shall also have a temperature range of at least 6 °C.

NOTE 2— If the part of the thermometer that will be in contact with the test solution is sensitive to the nitric and hydrofluoric acids in the test solution, then it is recommended that this part of the thermometer be coated with a resistant material to prolong the service life of the thermometer.

4.1.3.2 *Reference thermometer*—The reference thermometer shall be any type that reads to a precision of at least 0.1 °C.

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4.1.4 *Funnel*—The funnel through which the sample is introduced into the calorimeter shall be glass or plastic and shall have a stem inside diameter of at least 6 mm (See Note 3).

NOTE 3—The minimum diameter is to prevent clogging of the powdered cement sample. The length of the stem will need to be adjusted so that the sample is delivered without the tip becoming wet from the acid solution, which will cause the funnel to become clogged and necessitate aborting the determination. The angle of the stem will need to be adjusted so that sample is not delivered onto the rotating stirrer, which will cause sample to cake at the liquid line.

4.1.5 *Stirring Assembly*—The stirrer shall be a three-bladed polyethylene propeller having the dimensions shown in Fig. 2, and shall extend as closely as possible to the bottom of the calorimeter. The motor shall be of the constant-speed type, at least 37 W (1/20 hp), and shall be equipped with a geared speed reducer so that one speed, in the range of 350 to 700 r/min, can be maintained constant.

NOTE 4—The stirrer shown in Fig. 2 may be readily made from a commercially available three-bladed polyethylene propeller having a propeller diameter of 34 mm (1⅜ in.), shaft diameter of 6 mm (¼ in.), and a shaft length of approximately 455 mm (18 in.). The function of the stirrer is two-fold: to maintain uniform temperature throughout the liquid and to supply sufficient agitation to keep the solid in suspension in the acid mixture. Since a stirrer capable of keeping the solid in suspension generates considerable heat in the calorimeter, it is important that the stirrer speed, and hence the rate of heat generation, be maintained constant. Because such constancy is difficult to achieve with other types of motors, a synchronous motor with a geared speed reducer is recommended.

4.2 *Mixer*—A moderate-speed mechanical mixer, such as a milk-shake type stirrer, capable of intimately mixing the cement and water to a uniform paste.

4.3 *Storage*—Storage space with temperature controlled at 23.0 ± 2.0 °C (73.5 ± 3.5 °F).

4.4 *Mortar*, approximately 200 mm (8 in.) in diameter, and pestle for grinding the partially hydrated samples.

4.5 *Drying Oven*, maintained at 100 to 110 °C.

4.6 *Sieves*, 150-µm (No. 100) and 850-µm (No. 20), conforming to Specification E 11.

4.7 *Crucibles*, platinum, 30-mL capacity, with covers, for loss on ignition determination.

4.8 *Muffle Furnace*, or suitable burners capable of maintaining a temperature of 900 to 950 °C.

4.9 *Analytical Balance and Analytical Weights*, conforming to the requirements prescribed in Test Methods C 114 for weighing out calorimetric samples and for loss on ignition weighings.

4.10 *Weights and Weighing Devices*, conforming to the requirements of Specification C 1005. The weighing device shall be evaluated at a total load of 1000 g.

5. Reagents and Materials

5.1 *Purity of Reagents*—Reagent grade chemicals shall be used in all tests. Unless otherwise indicated, it is intended that all reagents shall conform to the specifications of the Committee on Analytical Reagents of the American Chemical Society,

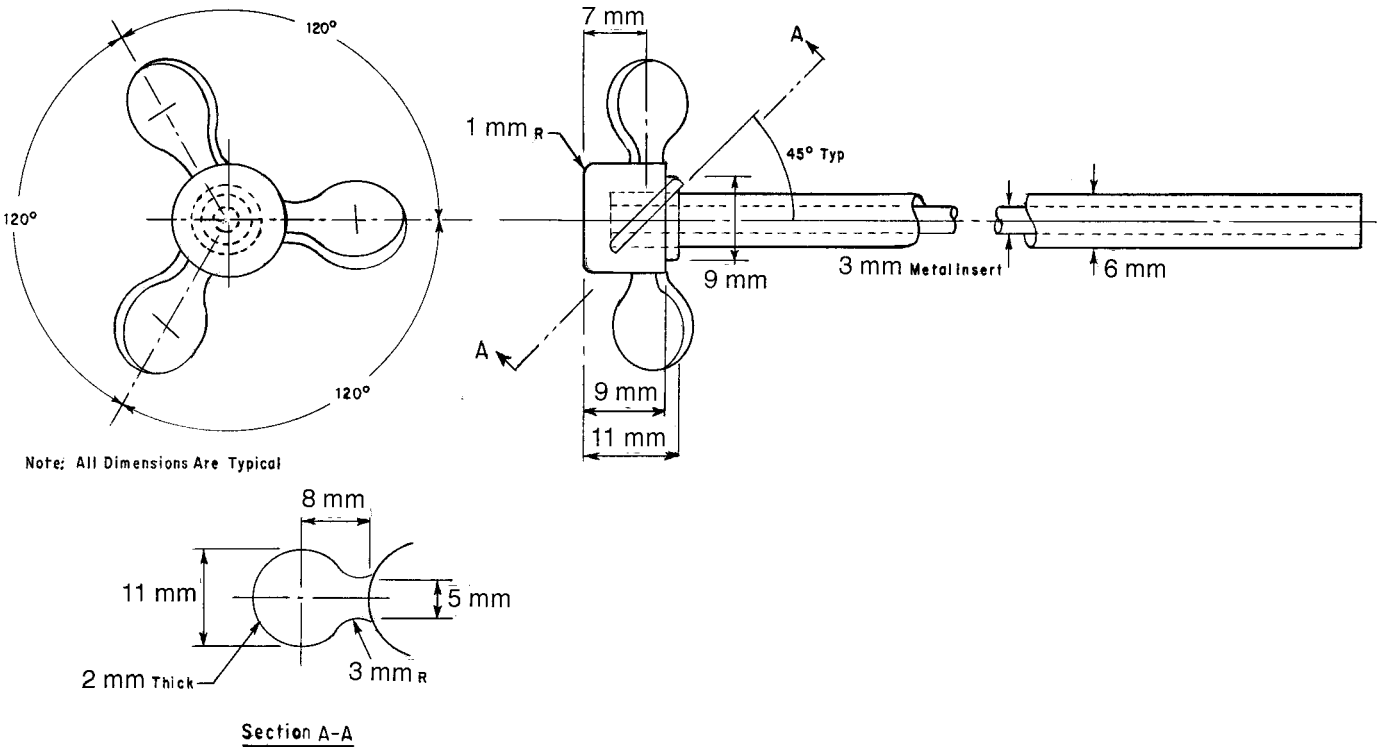

FIG. 2 Stirrer

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where such specifications are available.[3] Other grades may be used, provided it is first ascertained that the reagent is of sufficiently high purity to permit its use without lessening the accuracy of the determination.

5.2 *Hydrofluoric Acid (sp gr 1.15)*—Concentrated hydrofluoric acid (HF).

5.3 *Nitric Acid (2.00 N)*—The 2.00 *N* HNO_3, for use in the calorimeter, shall be prepared and standardized in large quantities. Optionally, the dilute HNO_3 may be made up with 127 mL of concentrated HNO_3(sp gr 1.42) per litre of solution, provided that heat capacity determinations are made with each batch of diluted HNO_3 so prepared.

5.4 *Wax*—Paraffin wax, or other suitable wax, for sealing vials.

5.5 *Zinc Oxide (ZnO)*—The ZnO shall be heated at 900 to 950 °C for 1 h, then cooled in a desiccator, ground to pass a 150-µm (No. 100) sieve, and stored. Immediately prior to a heat capacity determination, 7 g of the ZnO so prepared shall be heated for not more than 5 min at 900 to 950 °C, cooled to room temperature in a desiccator, and weighed accurately for introduction into the calorimeter.

NOTE 5—The rate of solution of the ZnO varies with the preliminary treatment. The procedure described results in a product which dissolves at about the same rate as the dry cement.

6. Determination of Heat Capacity of Apparatus

6.1 To determine the heat capacity of the system (that is, the number of joules or calories required to raise the temperature of the calorimeter and contents 1 °C), measure the corrected temperature rise obtained by dissolving 7 g of ignited ZnO in the specified acid mixture (See 6.2-6.7).

6.2 Transfer approximately 400 g of the 2.00 *N* HNO_3, which has been cooled to the temperature indicated by the lower range of the Beckmann thermometer (ordinarily about 4 to 5 °C below room temperature), into the vacuum jar, add 8.0 mL of HF (sp gr 1.15), weigh, and add sufficient additional 2.00 *N* HNO_3 to bring the total weight of the solution to 425.0 g. Then, assemble the calorimeter and start the stirring motor. Take care that the stirrer blades or shaft do not touch the thermometer, the sides or bottom of the jar, or the cork stopper. The lower end of the funnel stem shall extend approximately 6 mm (¼ in.) below the lower surface of the stopper and at least 12 mm (½ in.) above the level of the liquid. The upper end of the bulb of the Beckmann thermometer shall be at least 38 mm (1½ in.) below the surface of the liquid. Place it at the same depth in all determinations. After an initial stirring period of at least 20 min to allow the temperature of the system to become uniform, record the temperature of the room to the nearest 0.1 °C, the temperature of the acid to the nearest 0.001 °C, record the time, and then immediately introduce the prepared ZnO through the funnel at a uniform rate (See Note 6). Complete the introduction of the ZnO in not less than 1 or more than 2 min. Brush any ZnO clinging to the funnel stem into the acid mixture by means of a small "camel's-hair" brush.

NOTE 6—The temperature of the sample shall be identical with that of the room when the sample is introduced into the calorimeter.

6.3 Read the temperature, to the nearest 0.001 °C, at 20 min and again at 40 min after beginning the introduction of the sample. The temperature rise in the first 20 min includes temperature rise due to the heat of solution of the sample and any heat gain or heat loss to the environment. This is called the solution period. The temperature change during the second 20-min period is due to heat loss or gain to or from the environment. It is used to correct the temperature rise in the solution period to give the actual heat of solution of the sample. The second 20-min period is called the correction period.

6.4 Calculate the corrected temperature rise as follows:

$$R_o = \theta_{20} - \theta_0 \tag{1}$$

$$R = R_o - (\theta_{40} - \theta_{20})$$

where:

R_o = observed temperature rise, °C,
θ_{20} = calorimeter temperature at the end of the solution period,
θ_0 = calorimeter temperature when sample was introduced,
R = corrected temperature rise, °C, and
θ_{40} = calorimeter temperature at the end of the correction period.

6.5 Calculate the heat capacity of the calorimeter and contents as follows (See Note 7):

$$C = \frac{W[1072 + 0.4(30 - t) + 0.5(T - t)]}{R} \tag{2}$$

where:

C = heat capacity, kJ/°C,
W = mass of ZnO, g,
t = final temperature of the calorimeter, °C (θ_{20} plus temperature, °C, at which the Beckmann thermometer reading is zero),
T = temperature of the ZnO (room temperature), °C, when introduced into the calorimeter, and
R = corrected temperature rise, °C.

NOTE 7—The heat of solution of ZnO is 1072 kJ/kg (256.1 cal/g) at 30 °C. This value increases 0.4 kJ/kg (0.1 cal/g) for each degree decrease in temperature below 30 °C. The heat capacity of ZnO is 0.5 kJ/kg·K (0.12 cal/g·°C). The heat required to bring the ZnO to the final temperature of the calorimeter must be included in the effective heat of solution.

6.6 If more than a trace of ZnO is found adhering to the tip of the funnel or to the stopper when the calorimeter is opened, reject the test.

6.7 Redetermine the heat capacity at the following times:

6.7.1 When the Beckmann thermometer (if used) is reset,

6.7.2 When a new coating is applied to the solution thermometer, stirrer, or flask,

6.7.3 When a new solution thermometer, stirrer, or flask is put in service,

6.7.4 When a new batch of acid is used, and

[3] *Reagent Chemicals, American Chemical Society Specifications*, American Chemical Society, Washington, DC. For suggestions on the testing of reagents not listed by the American Chemical Society, see *Analar Standards for Laboratory Chemicals*, BDH Ltd., Poole, Dorset, U.K., and the *United States Pharmacopeia and National Formulary*, U.S. Pharmacopeial Convention, Inc. (USPC), Rockville, MD.

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6.7.5 At other times when, according to the judgment of the operator, the need is indicated.

7. Sampling and Test Specimens

7.1 *Preparation of Cement Paste*—Store the cement and the mixing water in a constant-temperature room at 23.0 ± 2.0 °C (73.5 ± 3.5 °F) until the materials are at ambient temperature before preparation of the paste. Mix 150 g of cement and 60 mL of distilled water by means of a spatula, and then vigorously stir the mixture with a mechanical stirrer for 5 min. Place approximately equal representative portions of the paste in four or more plastic vials, filling the vials to within about 13 mm (½ in.) of the top. Immediately after filling the vials, close them with tight-fitting stoppers or caps. (If there is any doubt regarding the tightness of the seal, the sealed ends of the vials should be dipped in molten paraffin wax.) Store the vials in an upright position in a water bath at 23 ± 2.0 °C until the time of test.

7.2 *Preparation of Partially Hydrated Sample for Heat of Solution Test*—At the specified age of test or age of interest, remove a vial of the partially hydrated sample from storage within the test time tolerances of Test Method C 109/C 109M, and, during a 20-min initial stirring period of the calorimeter, break the plastic away from the sample and rapidly crush the entire sample with a mortar and pestle so that all the material will pass through a 850-μm (No. 20) sieve; then quickly place the sample in a well-stoppered weighing bottle. Take care, particularly with the 7-day partially hydrated sample, to expose the sample to the air as little as possible, and thus minimize the action of CO_2 or the loss of moisture from the sample.

8. Procedure

8.1 *Calorimetric Procedure, Dry Cement*—Determine the heat of solution of the dry cement sample according to the procedure described for the heat capacity determination (See Section 6), but use a 3-g sample (weighed to the nearest 0.001 g) of the dry cement instead of the prepared ZnO (See Note 6). (Exercise care in securing a uniform and representative sample.) Calculate and report the results on the ignited mass basis (See 8.3).

8.2 *Calorimetric Procedure, Partially Hydrated Sample*—For the heat of solution of the partially hydrated sample follow the same procedure as for the dry cement described in 8.1, but use a 4.18 ± 0.05-g calorimetric sample of the partially hydrated cement, weighed to the nearest 0.001 g (See Note 6). Calculate the results on the ignited basis.

8.3 *Loss on Ignition*:

8.3.1 *Portland Cement*—Immediately before and after the calorimetric sample is being weighed out, weigh a sample of similar amount into a platinum crucible for determination of loss on ignition, the value to be used being the average of the two determinations. Ignite the dry cement at 950 ± 50 °C for at least 1½ h or to constant mass. Immediately place the crucible containing the sample in a desiccator and allow to cool to room temperature; then quickly weigh the crucible. When determining the loss on ignition of the hydrated cement, first dry the weighed sample in an oven at 100 to 110 °C for 1 h; then place the sample in a muffle furnace at 950 ± 50 °C overnight, or bring to constant mass. Reduce the mass of the cement sample that was introduced into the calorimeter to the ignited mass basis for use in the final calculations as follows:

$$W_i = (A/B)W \tag{3}$$

where:

W_i = mass of calorimetric sample, on ignited basis, g,
A = mass of ignited sample, g,
B = mass of sample before ignition, g, and
W = mass of calorimetric sample, g.

8.3.2 *Blended Hydraulic Cements*—In addition to the procedures described in 8.3.1, determine the loss on ignition by the reference method given in Test Methods C 114 for portland blast-furnace slag cement and slag cement.

8.3.2.1 Determine the SO_3 content by the reference method given in Test Methods C 114 (See Note 8). Also determine the SO_3 content of a portion of the same cement that has not been ignited, using the same procedure.

8.3.2.2 Calculate the percentage of mass gain from sulfide sulfur as follows:

$$G = 0.8\,(S_1 - S_2) \tag{4}$$

where:

G = percent mass gain in ignited sample,
S_1 = SO_3 determined on ignited sample, and
S_2 = SO_3 determined on unignited sample.
0.8 = molecular weight ratio of 4(0)/SO_3

NOTE 8—Some of the acid used for dissolving the sample may first be warmed in the platinum crucible to dissolve any adhering material.

8.3.2.3 Calculate the mass of the dry calorimetric sample on the ignited basis as follows:

$$W_i = \frac{\left(A - \frac{BG}{100}\right) W}{B} \tag{5}$$

where:

W_i = mass of dry calorimetric sample, on ignited basis, g,
A = mass of ignited dry sample, g,
B = mass of dry sample before ignition, g,
G = percentage mass gain from sulfide sulfur, and
W = mass of dry calorimetric sample, g.

Calculate the mass of the partially hydrated calorimetric sample on the ignited basis as follows: (See Note 9)

$$W_i = \frac{A\,W\left(1 - \frac{G}{100}\right)}{B} \tag{6}$$

where:

W_i = mass of calorimetric sample, on ignited basis, g,
A = mass of partially hydrated sample after ignition, g,
B = mass of partially hydrated sample before ignition, g,
G = percentage mass gain from sulfide sulfur, and
W = mass of partially hydrated calorimetric sample, g.

NOTE 9—An assumption is made in the calculation that the same percentage of sulfide sulfur is present prior to ignition in the partially hydrated sample as was determined in the cement. Tests have confirmed

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that the assumption is reasonably correct and will not alter the precision of the test method.

9. Calculation

9.1 *Heat of Solution of Dry Cement*—Calculate the corrected temperature rise as described in 6.3 and 6.4. Also, correct the heat of solution value if the final calorimeter temperature of the heat of solution test is different from the temperature of the calorimetric sample when introduced. Thus, for the dry cement, which has a specific heat of approximately 0.8 kJ/kg·K (0.2 cal/g·°C), if the final calorimeter temperature exceeds the temperature of the cement sample at the time it was introduced, add a correction of 0.8 kJ/kg·K (0.2 cal/g·°C) difference in those temperatures when calculating the heat of solution. Calculate the heat of solution of the dry cement as follows:

$$H_1 = (RC/W_i) - 0.8(T - t_d) \quad (7)$$

where:

H_1 = heat of solution of dry cement, kJ/kg,
R = corrected temperature rise, °C,
C = heat capacity, kJ/°C,
W_i = mass of sample on ignited basis, g,
T = room temperature, when sample is introduced, °C, and
t_d = final calorimeter temperature at end of determination on dry cement, °C.

9.2 *Heat of Solution of Partially Hydrated Sample*—Calculate the heat of solution of the partially hydrated sample in the same way as for the dry cement (See 9.1), except make additional corrections, as follows:

9.2.1 Since an increase of 1 °C in the temperature at which the heat of solution test occurs causes a decrease of approximately 1.3 kJ/kg (0.3 cal/g) in the heat of solution, if the temperature of the heat of solution test of the partially hydrated sample exceeds the temperature of the dry cement determination, a correction of 1.3 kJ/kg·K (°C) difference in temperature shall be added to the heat of solution value obtained for the partially hydrated sample (See Eq 8).

9.2.2 Also, correct the heat of solution value if the final calorimeter temperature of the solution test is different from the temperature of the calorimetric sample when introduced. Thus, for the partially hydrated sample, which has a specific heat of approximately 1.7 kJ/kg (0.4 cal/g) of ignited cement, if the final calorimeter temperature exceeds the temperature of the sample at the time it was introduced, add a correction of 1.7 kJ/kg·K (°C) difference in those temperatures when calculating the heat of solution (See Eq 8).

9.2.3 Calculate the heat of solution of the partially hydrated sample as follows:

$$H_2 = (RC/W_i) - 1.7(T - t_h) - 1.3(t_d - t_h) \quad (8)$$

where:

H_2 = heat of solution of partially hydrated sample, kJ/kg,
R, C, W_i, and T = the same definition as in 9.1 except that they relate to the partially hydrated sample,
t_d = the same numerical value as in 9.1, and
t_h = final calorimeter temperature at end of determination on partially hydrated sample, °C.

9.3 *Heat of Hydration*—A final calorimeter temperature of 25 °C shall be considered as the basis to which the heat of hydration shall be referred, and the effects of variation in that temperature should be kept in mind when considering test results. An increase in the final temperature raises the heat of hydration approximately 0.4 kJ/kg·K (0.1 cal/g·°C) of ignited cement. For example, if the final temperature is 27 °C, 0.8 kJ/kg (0.2 cal/g) should be subtracted from the observed heat of hydration in order to refer the results to 25 °C. In borderline cases, proper correction should be made for the effects of final calorimeter temperature. Calculate the heat of hydration of the cement to the nearest kilojoule, as follows:

$$H = H_1 - H_2 - 0.4(t_h - 25.0) \quad (9)$$

where:

H = heat of hydration of ignited cement, kJ/kg,
H_1 = heat of solution of dry cement (See 9.1),
H_2 = heat of solution of partially hydrated sample (See 9.2), and
t_h = the same numerical value as in 9.2.3

NOTE 10—To convert cal/g to kJ/kg multiply by 4.184 in accordance with Standard IEEE/ASTM SI 10.

10. Retests

10.1 In case of failure to meet the 28-day requirement for heat of hydration, a reserve sample of paste may be tested at a later age and a correction of 2.1 kJ/kg (0.5 cal/g) per day of excess age added to bring the retested heat of solution to a 28-day basis. The period over which this correction may be made shall be limited to 4 days. In case of failure to meet the 7-day requirement, a complete retest including mixing of the paste should be made.

11. Report

11.1 Report the following information:

11.1.1 Sample identification, which may include the source and type of hydraulic cement and sampling date, and

11.1.2 The heat of hydration results at each of the test ages required by the applicable specification.

12. Precision and Bias

12.1 *Precision*:

12.1.1 *Single-Operator Precision*—The single-operator standard deviations have been found to be 12.2 kJ/kg(1s) (2.91 cal/g)(1s) and 14.8 kJ/kg(1s) (3.54 cal/g)(1s) for the determinations of heat of solution and heat of hydration, respectively. Therefore, results of two properly conducted tests by the same operator on samples of the same cement should not differ from each other by more than 34 kJ/kg (8 cal/g) in the determination of heat of solution or 42 kJ/kg (10 cal/g) in the determination of heat of hydration.[4]

[4] These numbers represent, respectively the (1s) and (d2s) limits as described in Practice C 670.

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12.1.2 *Multilaboratory Precision*—The multilaboratory standard deviations have been found to be 18.5 kJ/kg(1s) (4.42 cal/g)(1s) and 16.9 kJ/kg(1s) (4.03 cal/g)(1s) for the determinations of heat of solution and heat of hydration respectively. Therefore, results of two properly conducted tests from two different laboratories on samples of the same cement should not differ from each other by more than 52 kJ/kg (13 cal/g) in the determination of heat of solution or 48 kJ/kg (11 cal/g) in the determination of heat of hydration.[4]

12.2 *Bias*—Since there is no accepted reference material, no statement on bias is being made.

13. Keywords

13.1 blended cement; heat of hydration; heat of solution; hydraulic cements; portland cement

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Designation: C 187 – 04

American Association State
Highway and Transportation Officials Standard
AASHTO No.: T 129

Standard Test Method for Normal Consistency of Hydraulic Cement[1]

This standard is issued under the fixed designation C 187; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope

1.1 This test method covers the determination of the normal consistency of hydraulic cement.

1.2 The values stated in SI units are to be regarded as the standard. The values given in parentheses are for information only.

1.3 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.* See 1.4 for a specific warning statement.

1.4 **Warning**—Fresh hydraulic cementitious mixtures are caustic and may cause chemical burns to skin and tissue upon prolonged exposure. The use of gloves, protective clothing, and eye protection is recommended. Wash contact area with copious amounts of water after contact. Wash eyes for a minimum of 15 min. Avoid exposure of the body to clothing saturated with the liquid phase of the unhardened material. Remove contaminated clothing immediately after exposure.[2]

2. Referenced Documents

2.1 *ASTM Standards:* [3]

C 305 Practice for Mechanical Mixing of Hydraulic Cement Pastes and Mortars of Plastic Consistency

C 490 Practice for Use of Apparatus for the Determination of Length Change of Hardened Cement Paste, Mortar, and Concrete

C 1005 Specification for Reference Masses and Devices for Determining Mass and Volume for Use in the Physical Testing of Hydraulic Cements

D 1193 Specification for Reagent Water

E 177 Practice for Use of the Terms Precision and Bias in ASTM Test Methods

3. Significance and Use

3.1 This test method is intended to be used to determine the amount of water required to prepare hydraulic cement pastes for testing.

4. Apparatus

4.1 *Reference Masses and Devices for Determining Mass*, conforming to the requirements of Specification C 1005. The devices for determining mass shall be evaluated for precision and bias at a total load of 1000 g.

4.2 *Glass Graduates*, 200 or 250-mL capacity, and conforming to the requirements of Practice C 490.

4.3 *Vicat Apparatus*—The Vicat apparatus shall consist of a frame *A* (Fig. 1) bearing a movable rod *B,* weighing 300 g, one end *C,* the plunger end, being 10 mm in diameter for a distance of at least 50 mm, and the other end having a removable needle *D,* 1 mm in diameter and 50 mm in length. The rod *B* is reversible, and can be held in any desired position by a set screw *E,* and has an adjustable indicator *F,* which moves over a scale (graduated in millimetres) attached to the frame *A*. The paste is held in a rigid conical ring *G,* resting on a plane nonabsorptive square base plate *H,* about 100 mm on each side. The rod *B* shall be made of stainless steel having a hardness of not less than 35 HRC (See Note 1), and shall be straight with the plunger end which is perpendicular to the rod axis. The ring shall be made of a noncorroding, nonabsorbent material, and shall have an inside diameter of 70 mm at the base and 60 mm at the top, and a height of 40 mm. In addition to the above, the Vicat apparatus shall conform to the following requirements:

Weight of movable rod	300 ± 0.5 g (0.661 lb ± 8 grains) in
Diameter of plunger end of rod	10 ± 0.05 mm (0.394 ± 0.002 in.)
Diameter of needle	1 ± 0.05 mm (0.039 ± 0.002 in.)
Inside diameter of ring at bottom	70 ± 3 mm (2.75 ± 0.12 in.)
Inside diameter of ring at top	60 ± 3 mm (2.36 ± 0.12 in.)
Height of ring	40 ± 1 mm (1.57 ± 0.04 in.)
Graduated scale	The graduated scale, when compared with a standard scale accurate to within 0.1 mm at all points, shall not show a deviation at any point greater than 0.25 mm.

NOTE 1—The requirement that the rod be made of stainless steel shall apply only to new Vicat apparatus or replacement rods and not to equipment in use which meets the other requirements of this test method.

[1] This test method is under the jurisdiction of ASTM Committee C01 on Cement and is the direct responsibility of Subcommittee C01.22 on Workability.

Current edition approved Dec. 1, 2004. Published December 2004. Originally approved in 1944. Last previous edition approved in 1998 as C 187 – 98.

[2] Section on Safety, Manual of Cement Testing, *Annual Book of ASTM Standards,* Vol 04.01.

[3] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

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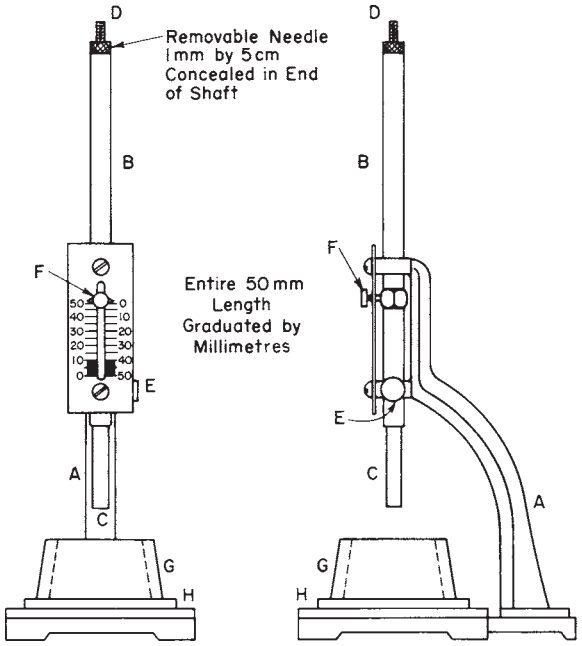

FIG. 1 Vicat Apparatus

4.4 *Flat Trowel*, having a sharpened straight-edged steel blade 100 to 150 mm in length.

5. Temperature and Humidity

5.1 The temperature of the air in the vicinity of the mixing slab, the dry cement, molds, and base plates shall be maintained between 20 and 27.5 °C (68 and 81.5 °F). The temperature of the mixing water shall not vary from 23.0 °C (73.5 °F) by more than ±2.0 °C (3.5 °F).

5.2 The relative humidity of the laboratory shall be not less than 50 %.

6. Procedure

6.1 *Preparation of Cement Paste*—Mix 650 g of cement with a measured quantity of water following the procedure prescribed in the Procedure for Mixing Pastes of Practice C 305. The water shall conform to the numerical limits of Specification D 1193 for Type III or Type IV grade of reagent water.

6.2 *Molding Test Specimen*—Quickly form the cement paste, prepared as described in 6.1, into the approximate shape of a ball with gloved hands. Then toss six times through a free path of about 150 mm (6 in.) from one hand to another so as to produce a nearly spherical mass that may be easily inserted into the Vicat ring with a minimum amount of additional manipulation. Press the ball, resting in the palm of one hand, into the larger end of the conical ring *G,* Fig. 1, held in the other hand, completely filling the ring with paste. Remove the excess at the larger end by a single movement of the palm of the hand. Place the ring on its larger end on the base plate *H,* and slice off the excess paste at the smaller end at the top of the ring by a single oblique stroke of a sharp-edged trowel held at a slight angle with the top of the ring, and smooth the top, if necessary, with a few light touches of the pointed end of the trowel. During these operations of cutting and smoothing, take care not to compress the paste.

6.3 *Consistency Determination*—Center the paste confined in the ring, resting on the plate, under the rod *B,* Fig. 1, the plunger end *C* of which shall be brought in contact with the surface of the paste, and tighten the set-screw *E.* Then set the movable indicator *F* to the upper zero mark of the scale, or take an initial reading, and release the rod immediately. This must not exceed 30 s after completion of mixing. The apparatus shall be free of all vibrations during the test. The paste shall be of normal consistency when the rod settles to a point 10 ± 1 mm below the original surface in 30 s after being released. Make trial pastes with varying percentages of water until the normal consistency is obtained. Make each trial with fresh cement.

7. Calculation

7.1 Calculate the amount of water required for normal consistency to the nearest 0.1 % and report it to the nearest 0.5 % of the weight of the dry cement.

8. Precision and Bias

8.1 The single operator-instrument precision has been found to be 0.25 (1S), and the multilaboratory precision has been found to be 0.35 (1S) as defined in Practice E 177; therefore, the results of two properly conducted tests by the same operator in a laboratory should agree within 0.7 percentage point, and test results between two laboratories should agree with 1.0 percentage point 95 % of the time.

9. Keywords

9.1 consistency; normal consistency; Vicat needles

For additional useful information on details of cement test methods, reference may be made to the "Manual of Cement Testing," which appears in the *Annual Book of ASTM Standards,* **Vol 04.01.**

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Designation: C188 – 09

American Association State
Highway and Transportation Officials Standard
AASHTO No.: T133

Standard Test Method for Density of Hydraulic Cement[1]

This standard is issued under the fixed designation C188; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

This standard has been approved for use by agencies of the Department of Defense.

1. Scope*

1.1 This test method covers the determination of the density of hydraulic cement. Its particular usefulness is in connection with the design and control of concrete mixtures.

1.2 The density of hydraulic cement is defined as the mass of a unit volume of the solids.

1.3 The values stated in SI units are to be regarded as standard. No other units of measurement are included in this standard.

1.4 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

2. Referenced Documents

2.1 *ASTM Standards:*[2]

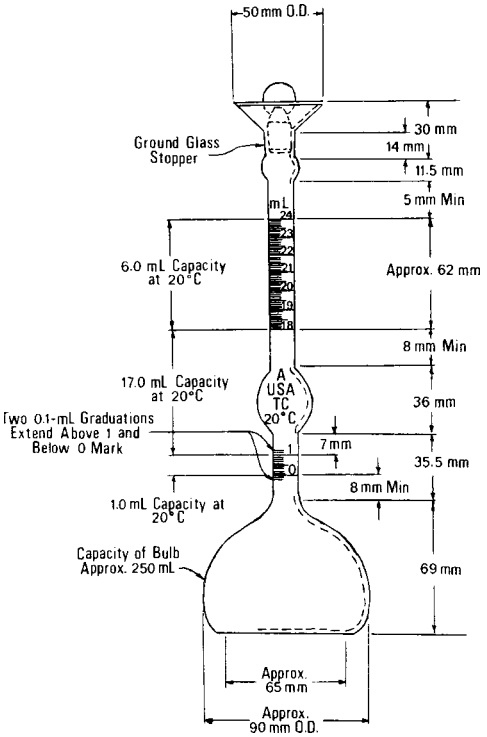
C114 Test Methods for Chemical Analysis of Hydraulic Cement

C670 Practice for Preparing Precision and Bias Statements for Test Methods for Construction Materials

3. Apparatus

3.1 *Le Chatelier flask*—The standard flask, which is circular in cross section, with shape and dimensions conforming essentially to Fig. 1 (Note 1). The requirements in regard to tolerance, inscription and length, spacing, and uniformity of graduation will be rigidly observed. There shall be a space of at least 10 mm between the highest graduation mark and the lowest point of grinding for the glass stopper.

3.1.1 The material of construction shall be excellent quality glass, transparent and free of striae. The glass shall be chemically resistant and shall have small thermal hysteresis. The flasks shall be thoroughly annealed before being graduated. They shall be of sufficient thickness to ensure reasonable resistance to breakage.



NOTE—Variations of a few millimetres in such dimensions as total height of flask, diameter of base, and so forth, are to be expected and will not be considered sufficient cause for rejection. The dimensions of the flask shown in Fig. 1 apply only to new flasks and not to flasks in use which meet the other requirements of this test method.

FIG. 1 Le Chatelier Flask for Density Test

3.1.2 The neck shall be graduated from 0 to 1 mL and from 18 to 24 mL in 0.1-mL graduations. The error of any indicated capacity shall not be greater than 0.05 mL.

3.1.3 Each flask shall bear a permanent identification number and the stopper, if not interchangeably ground, shall bear the same number. Interchangeable ground-glass parts shall be marked on both members with the standard-taper symbol, followed by the size designation. The standard temperature shall be indicated, and the unit of capacity shall be shown by the letters "mL" placed above the highest graduation mark.

[1] This test method is under the jurisdiction of ASTM Committee C01 on Cement and is the direct responsibility of Subcommittee C01.25 on Fineness.

Current edition approved Dec. 1, 2009. Published January 2010. Originally approved in 1944. Last previous edition approved in 2003 as C188 – 95(2003). DOI: 10.1520/C0188-09.

[2] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

***A Summary of Changes section appears at the end of this standard.**

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3.2 Kerosine, free of water, or naphtha, having a density greater than 0.73 g/mL at 23 ± 2° C shall be used in the density determination.

3.3 The use of alternative equipment or methods for determining density is permitted provided that a single operator can obtain results within ± 0.03 Mg/m^3 of the results obtained using the flask method.

NOTE 1—The design is intended to ensure complete drainage of the flask when emptied, and stability of standing on a level surface, as well as accuracy and precision of reading.

4. Procedure

4.1 Determine the density of cement on the material as received, unless otherwise specified. If the density determination on a loss-free sample is required, first ignite the sample as described in the test for loss on ignition in section 16.1 on Portland Cement of Test Methods C114.

4.2 Fill the flask (Note 2) with either of the liquids specified in 3.2 to a point on the stem between the 0 and the 1-mL mark. Dry the inside of the flask above the level of the liquid, if necessary, after pouring. Record the first reading after the flask has been immersed in the water bath (Note 3) in accordance with 4.4.

NOTE 2—It is advisable to use a rubber pad on the table top when filling or rolling the flask.

NOTE 3—Before the cement has been added to the flask, a loose-fitting, lead-ring weight around the stem of the flask will be helpful in holding the flask in an upright position in the water bath, or the flask may be held in the water bath by a buret clamp.

4.3 Introduce a quantity of cement, weighed to the nearest 0.05 g, (about 64 g for portland cement) in small increments at the same temperature as the liquid (Note 2). Take care to avoid splashing and see that the cement does not adhere to the inside of the flask above the liquid. A vibrating apparatus may be used to accelerate the introduction of the cement into the flask and to prevent the cement from sticking to the neck. After all the cement has been introduced, place the stopper in the flask and roll the flask in an inclined position (Note 2), or gently whirl it in a horizontal circle, so as to free entrapped air from the cement until no further air bubbles rise to the surface of the liquid. If a proper amount of cement has been added, the level of the liquid will be in its final position at some point of the upper series of graduations. Take the final reading after the flask has been immersed in the water bath in accordance with 4.4.

4.4 Immerse the flask in a constant-temperature water bath for sufficient periods of time in order to avoid flask temperature variations greater than 0.2°C between the initial and the final readings.

5. Calculation

5.1 The difference between the first and the final readings represents the volume of liquid displaced by the mass of cement used in the test.

5.2 Calculate the cement density, ρ, as follows:

$$\rho(Mg/m^3) = \rho(g/cm^3) = \text{mass of cement, g/displaced volume, } cm^3$$

NOTE 4—The displaced volume in millilitres is numerically equal to the displaced volume in cubic centimetres.

NOTE 5—Density in megagrams per cubic metre (Mg/m^3) is numerically equal to grams per cubic centimetre (g/cm^3). Calculate the cement density, ρ, to three decimal places and round to the nearest 0.01 Mg/m^3.

NOTE 6—In connection with proportioning and control of concrete mixtures, density may be more usefully expressed as specific gravity, the latter being a dimensionless number. Calculate the specific gravity as follows: Sp gr = cement density/water density at 4°C (at 4°C the density of water is 1 Mg/m^3($1 g/cm^3$)).

6. Precision and Bias

6.1 The single-operator standard deviation for portland cements has been found to be 0.012.[3] Therefore, the results of two properly conducted tests by the same operator on the same material should not differ by more than 0.03.

6.2 The multilaboratory standard deviation for portland cements has been found to be 0.037.[3] Therefore, the results of two properly conducted tests from two different laboratories on samples of the same cement should not differ by more than 0.10.[3]

6.3 Since there is no accepted reference material suitable for determining any bias that might be associated with this test method, no statement on bias is being made.

7. Keywords

7.1 density; hydraulic cement; specific gravity

[3] These numbers represent the 1s and d2s limits described in Practice C670.

SUMMARY OF CHANGES

Committee C01 has identified the location of selected changes to this test method since the last issue, C188 – 95(2003), that may impact the use of this test method. (Approved December 1, 2009)

(*1*) Revised 4.3.

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Designation: C 191 – 08

American Association State
Highway and Transportation Officials Standard
AASHTO No.: T131

Standard Test Methods for Time of Setting of Hydraulic Cement by Vicat Needle[1]

This standard is issued under the fixed designation C 191; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope*

1.1 These test methods determine the time of setting of hydraulic cement by means of the Vicat needle. Two test methods are given; Method A is the Reference Test Method using the manually operated standard Vicat apparatus, while Method B permits the use of an automatic Vicat machine that has, in accordance with the qualification requirements of this method, demonstrated acceptable performance.

1.2 The values stated in SI units are to be regarded as standard. No other units of measurement are included in this standard.

1.3 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.* See 1.4 for a specific warning statement.

1.4 **Warning**—Fresh hydraulic cementitious mixtures are caustic and may cause chemical burns to skin and tissue upon prolonged exposure. The use of gloves, protective clothing, and eye protection is recommended. Wash contact area with copious amounts of water after contact. Wash eyes for a minimum of 15 min. Avoid exposure of the body to clothing saturated with the liquid phase of the unhardened material. Remove contaminated clothing immediately after exposure.[2]

1.5 The text of this standard references notes and footnotes which provide explanatory material. These notes and footnotes (excluding those in tables and figures) shall not be considered as requirements of the standard.

NOTE 1—For the method for determining the time of setting by Gillmore needles, see Test Method C 266.

2. Referenced Documents

2.1 *ASTM Standards:* [3]

C 150 Specification for Portland Cement

C 151 Test Method for Autoclave Expansion of Hydraulic Cement

C 183 Practice for Sampling and the Amount of Testing of Hydraulic Cement

C 187 Test Method for Normal Consistency of Hydraulic Cement

C 219 Terminology Relating to Hydraulic Cement

C 266 Test Method for Time of Setting of Hydraulic-Cement Paste by Gillmore Needles

C 305 Practice for Mechanical Mixing of Hydraulic Cement Pastes and Mortars of Plastic Consistency

C 511 Specification for Mixing Rooms, Moist Cabinets, Moist Rooms, and Water Storage Tanks Used in the Testing of Hydraulic Cements and Concretes

C 595 Specification for Blended Hydraulic Cements

C 1005 Specification for Reference Masses and Devices for Determining Mass and Volume for Use in the Physical Testing of Hydraulic Cements

C 1157 Performance Specification for Hydraulic Cement

D 1193 Specification for Reagent Water

3. Terminology

3.1 *Definitions*—The terms used in this test method are defined in accordance with Terminology C 219.

4. Summary of Test Method

4.1 A paste that is proportioned and mixed to normal consistency, as described in the Test Method C 187, is molded and placed in a moist cabinet and allowed to start setting. Periodic penetration tests are performed on this paste by allowing a 1-mm Vicat needle to settle into this paste. The Vicat initial time of setting is the time elapsed between the initial contact of cement and water and the time when the penetration is measured or calculated to be 25 mm. The Vicat final time of setting is the time elapsed between initial contact of cement and water and the time when the needle does not leave a complete circular impression in the paste surface.

5. Significance and Use

5.1 This test method provides a means of determining compliance with a specification limit for Vicat time of setting. Refer to the appropriate specification for the cement to determine if this test method is used for specification compliance.

[1] These test methods are under the jurisdiction of ASTM Committee C01 on Cement and is the direct responsibility of Subcommittee C01.30 on Time of Set.

Current edition approved June 1, 2008. Published July 2008. Originally approved in 1944. Last previous edition approved in 2007 as C 191 – 07.

[2] Section on Safety, Manual of Cement Testing, *Annual Book of ASTM Standards,* Vol 04.01.

[3] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

***A Summary of Changes section appears at the end of this standard.**

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5.2 Time of setting measured by this method will not necessarily provide the same results as the time of setting of hydraulic cement paste measured by other methods, or the time of setting of mortar or concrete.

6. Apparatus

6.1 *Vicat Apparatus*—See Annex A1.1 and Fig. A1.1. The Vicat apparatus for this test method shall have a movable rod, B, of mass 300 ± 0.5g.

6.1.1 The end of the rod used for measuring penetration shall have a straight steel removable needle with a diameter of 1.00 ± 0.05 mm and length no less than 50 mm.

6.1.2 The needle end that contacts the specimen shall be flat, plane, and at right angles to the axis of the rod.

6.2 *Reference Masses and Devices for Determining Mass*, conforming to the requirements of Specification C 1005. The devices for determining mass shall be evaluated for precision and accuracy at a total load of 1000 g.

6.3 *Glass Graduates*, 200 or 250-mL capacity, and conforming to the requirements of Specification C 1005.

6.4 *Plane non-adsorptive plate*, 100 ± 5 mm square of similar planeness, corrosivity, and absorptivity to that of glass (see Annex A1.1, Fig. A1.1, H).

6.5 *Flat trowel*, having a sharpened straight-edged steel blade 100 to 150 mm in length. The edges when placed on a plane surface shall not depart from straightness by more than 1 mm.

6.6 *Conical ring*, made of a rigid, non-corroding, non-absorbent material and having a height of 40 ± 1 mm, an inside diameter at the bottom of 70 ± 3 mm, and an inside diameter at the top of 60 ± 3 mm (see Annex A1.1, Fig. A1.1, G).

6.7 *Mixer, bowl, and paddle*, conforming to Practice C 305.

6.8 *Automatic Vicat Needle Apparatus for Method B*—The apparatus shall be equipped with a Vicat needle as described in 6.1.1 and 6.1.2. The total mass supported by the needle tip at the time of measurement shall be 300 ± 0.5 g. The instrument shall be capable of automatically completing and recording penetration measurements of a test specimen at predetermined time intervals not exceeding 10 min and make each penetration test at least 5 mm away from any previous penetration and at least 10 mm away from the inner side of the mold.

6.9 *Specimen Mold for Method B*—The cement paste is held in a conical ring with the height of 40 ± 1 mm and a removable base plate. The test surface shall have a minimum diameter of 60 ± 3 mm.

6.10 Inspect and document Section 6 apparatus for conformance to the requirements of this test method at least every 2 ½ years.

7. Reagents and Materials

7.1 *Mixing Water*—Potable water is satisfactory for routine tests. Use water conforming to the requirements of Specification D 1193 for Type III or Type IV grade reagent water for all referee and cooperative tests.

8. Sampling

8.1 When the test is required for acceptance testing, sample cement in accordance with Practice C 183.

9. Conditioning

9.1 Maintain the temperature of the air in the vicinity of the mixing slab, the dry cement, molds, and base plates at 23.0 ± 3.0 °C.

9.2 Maintain the temperature of the mixing water at 23.0 ± 2.0 °C.

9.3 The relative humidity of the mixing room shall be not less than 50 %.

9.4 The moist cabinet or moist room shall be in accordance with Specification C 511.

10. Preparation of Cement Paste[4]

10.1 The cement paste used for the determination of the time of setting is obtained from one of the following methods:

10.1.1 Prepare a new batch of paste by mixing 650 g of cement with the percentage of mixing water required for normal consistency (Test Method C 187), following the procedure described in Practice C 305.

10.1.2 For method A, at the option of the tester, use the test specimen used for determining normal consistency (see Note 2).

10.1.3 At the option of the tester, use the paste remaining from the batch used for the autoclave specimen (Test Method C 151) or from the normal consistency determination (Test Method C 187).

NOTE 2—The specimen used for the determination of the normal consistency will have an irregular surface, making it unsuitable for method B.

11. Calculation

11.1 Calculate the Vicat time of setting to the nearest 1 min as follows:

$$\left(\left(\frac{(H-E)}{(C-D)}\right)\times(C-25)\right)+E \qquad (1)$$

where:

E = time in minutes of last penetration greater than 25 mm,
H = time in minutes of first penetration less than 25 mm,
C = penetration reading at time E, and
D = penetration reading at time H.

11.2 Calculate the Vicat final time of setting by determining the elapsed time between the time of the initial contact between cement and water and the time when the needle does not sink visibly into the paste, rounded to the nearest 5 min.

12. Report

12.1 Report the time of setting and the method used as follows:

Vicat time of setting (*A* or *B*) _____ min
Vicat final time of setting (*A* or *B*) _____ min

Method A—Manual Vicat Needle Apparatus

13. Manual Vicat Apparatus

13.1 Refer to the Apparatus section, paragraphs 6.1, 6.4, and 6.6, and Annex A1 for a description of the Vicat apparatus.

[4] See Test Method C 187.

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14. Procedure A

14.1 *Molding Test Specimen*—Quickly form the cement paste, prepared as described in the section on preparation of cement paste, into a ball with gloved hands and toss six times from one hand to the other, maintaining the hands about 150 mm (6 in.) apart. Press the ball, resting in the palm of the hand, into the larger end of the conical ring, *G*, Fig. A1.1, held in the other hand, completely filling the ring with paste. Remove the excess at the larger end by a single movement of the palm of the hand. Place the ring on its larger end onto the non-absorptive plate, *H*, and slice off the excess paste at the smaller end at the top of the ring by a single oblique stroke of the trowel held at a slight angle with the top of the ring. Smooth the top of the specimen, if necessary, with one or two light touches of the pointed end of the trowel. During the operation of cutting and smoothing, take care not to compress the paste. Immediately after molding, place the test specimen in the moist cabinet or moist room and allow it to remain there except when penetration measurements are being made. The specimen shall remain in the conical mold, supported by the non-absorptive plate throughout the test period.

14.2 *Time of Setting Determination*—Allow the time of setting specimen to remain in the moist cabinet or moist room for 30 min after molding without being disturbed. Determine the penetration of the 1-mm needle at this time and every 15 min thereafter (every 10 min for Type III cements) until a penetration of 25 mm or less is obtained. Perform the penetration test by lowering the needle *D* of the rod *B* until it rests on the surface of the cement paste. Tighten the setscrew, *E*, and set the indicator, *F*, at the upper end of the scale, or take an initial reading. Release the rod quickly by releasing the set screw, *E*, and allow the needle to settle for 30 s; then take the reading to determine the penetration. At the option of the tester, if the paste is obviously quite soft on the early readings, retard the fall of the rod to avoid bending the 1-mm needle, but when actual penetration measurements to determine the time of setting are made, release the rod only by the setscrew. Make each penetration test at least 5 mm away from any previous penetration and at least 10 mm away from the inner side of the mold. Record the results of all penetration tests and, by interpolation, determine the time when a penetration of 25 mm is obtained. The elapsed time between the initial contact of cement and water and the penetration of 25 mm is the Vicat time of setting or Vicat initial time of setting.

14.3 Determine the Vicat final time of setting end point to be the first penetration measurement that does not mark the specimen surface with a complete circular impression. Verify final set by performing two additional penetration measurements on different areas of the specimen surface. Obtain verification measurements within 90 s of the first "final set" measurement. The elapsed time between the initial contact of cement and water and the end point determination above is the Vicat final time of setting.

14.4 *Precautions*—Keep all the apparatus free from vibration during the penetration test. Keep the 1-mm needle straight and clean. The needle must be kept clean to prevent cement from adhering to the sides of the needle and decreasing penetration, and to prevent cement from adhering to the point and increasing penetration.

15. Precision and Bias

15.1 *Precision*:

15.1.1 The single-operator (within-laboratory) standard deviation has been found to be 12 min for the initial time of setting, throughout the range of 49 to 202 min, and 20 min for the final time of settings throughout the range of 185 to 312 min. Therefore, results of two properly conducted tests by the same operator on Vicat initial time of setting of similar paste should not differ from each other by more than 34 min and on Vicat final time of setting of similar pastes should not differ from each other by more than 56 min.

15.1.2 The multilaboratory (between-laboratory) standard deviation has been found to be 16 min for the initial time of setting throughout the range of 49 to 207 min, and 43 min for the final time of setting throughout the range of 185 to 312 min. Therefore, results of two properly conducted tests from two different laboratories on Vicat initial time of setting of similar pastes should not differ from each other by more than 45 min, and on Vicat final time of setting of similar pastes should not differ from each other by more than 122 min.

15.2 *Bias*—Since there are no accepted reference materials suitable for determining the bias for the procedure in this test method, no statement on bias is presented.

Method B—Automatic Vicat

16. Automatic Vicat Apparatus

16.1 *Automatic Vicat Needle Apparatus*—Refer to the Apparatus section, paragraphs 6.8 and 6.9, for a description of the Automatic Vicat needle apparatus.

17. Procedure

17.1 *Molding the Specimen*—Quickly form the cement paste, prepared as described in the section on preparation of cement paste, into a ball with gloved hands and toss six times from one hand to the other, maintaining the hands about 150 mm apart. Press the ball, resting in the palm of the hand, into the larger end of the conical ring, held in the other hand, completely filling the ring with paste. Remove the excess at the larger end by a single movement of the palm of the hand. Place the ring on its larger end on the base plate. Use a trowel to remove the excess paste at the top of the mold. Holding the trowel at about a 30° incline with the leading edge raised and starting near the center of the mold, level the paste by drawing the trowel across the top of the mold using a sawing motion; repeat the procedure for the other half of the surface. Then smooth the surface level to the top of the mold making steady and complete strokes across the entire surface with the trailing edge of the trowel. Repeat the cutting and smoothing steps but at 90° from the previous cut. Repeat the steps as required to produce a surface level with the top of the mold. Usually the paste is level within two cycles, but occasionally three will be required. Avoid excessive strokes and compaction. Since the automatic Vicat device references to the top edge of the mold, it is imperative that the top surface of the paste be uniform and level with the top of the mold.

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17.2 *Time of Setting Determinations*—Follow the manufacturer's instructions and complete the required instrument calibration and zero procedures. Set the instrument to measure no less frequently than every 10 min (see Note 3). Position the molded specimen in the automatic Vicat apparatus and initiate the measurements (see Note 4).

NOTE 3—Automatic devices are usually capable of measurement more frequently than once every 10 min and more frequent measurement minimizes interpolation.

NOTE 4—The initial time of setting according to Method A is determined as the elapsed time required to achieve a penetration of 25 mm and the final time of setting as the total time elapsed until the needle does not leave a complete circular impression in the paste surface. The end points established by a qualified automatic Vicat test method may deviate significantly from end points specified in Method A, and require standardization to correct bias.

17.3 Determine the range of applicability of the method from the range of the average time of setting of the cements used for qualification and standardization, and limit that range to 30 min greater than the maximum, and 30 min less than the minimum.

17.4 *Performance Requirement (Qualification) for Automatic Vicat Instrument*:

17.4.1 When time of setting results from the automatic Vicat apparatus are to be used for acceptance or rejection of cement, the method used shall comply with the qualification requirements covered in Annex A2.

18. Performance Requirement (Qualification) for Automatic Vicat Instrument

18.1 *Scope*—When time of setting results from the automatic Vicat apparatus are to be used for acceptance or rejection of cement, the method used shall comply with the qualification requirements of this section. A method is considered to consist of the specific instrument and the molding procedure meeting the requirements of this standard, and used in a consistent manner by a given laboratory.

18.2 *Hydraulic Cement Samples Required*—Select three cements that comply with requirements of Specifications C 150, C 595, or C 1157, and that when tested in accordance with Method A, shall include the following:

18.2.1 One cement that has an initial time of setting of less than 110 min,

18.2.2 One cement with an initial time of setting of greater than 150 min,

18.2.3 One cement with a final time of setting of less than 180 min, and

18.2.4 One cement with a final time of setting of greater than 210 min (see Note 5).

NOTE 5—Laboratories are advised to reserve sufficient cement for future qualification and standardization.

18.3 *Tests*—Using the method to be qualified and including the standardization formula described in the section on standardization, make single determinations of the times of initial and final setting on each of the three cements. On the same day, conduct companion time of setting determinations according to Method A. Make single determinations of the normal consistency on each cement, and use that amount of water for all replicate batches. Complete three rounds of tests on different days, repeating all the steps of the methods. Conduct the qualification tests on specimens prepared separately from the standardization testing.

18.4 *Calculations*—Calculate the three–round averages for initial and final time of setting for each cement and method. A method complies with the initial time of setting qualification requirements if the difference between the initial time of setting average values for Method A and the corresponding average values of Method B is not greater than 25 min for any sample, and the range for any three replicate tests by Method B does not exceed 30 min. Likewise, a method complies with the final time of setting qualification requirements if the difference between the final time of setting average values for Method A and corresponding average values for Method B is not greater than 45 min for any sample, and the range for any three replicate tests by Method B does not exceed 30 min. Example qualification data are given in Appendix X1.

18.5 *Standardization*—When standardization is required in order to achieve agreement between Method A and Method B, it can be applied to either the initial time of setting, final time of setting, or both. A standardization formula shall be based on a comparison of test results obtained using Method A and the chosen method using the automatic instrument (Method B). Results of tests from at least five different hydraulic cements shall be required for standardization. The cements shall have a minimum range of 60 min initial time of setting, and a minimum range of 90 min final time of setting when tested in accordance with Method A. If desired, the three cements used for instrument qualification may be used, but make new determinations. Use the same method as used for instrument qualification, including all the same steps. Valid standardization formulas shall be mathematically derived and applied to all samples (see Note 6).

NOTE 6—Generally, the automatic instruments are computer operated and easily adapted to standardization calculations.

19. Requalification of a Method

19.1 Requalify the method at least once per year and when any of the following conditions occur:

19.1.1 The instrument has been significantly modified.

19.1.2 The instrument has been substantially repaired.

19.1.3 Substantial evidence indicates that the method is not providing data meeting the performance requirements.

19.1.4 The average of a Cement and Concrete Reference Laboratory (CCRL) sample differs from the value obtained by the method by more than 45 min for either the initial or final time of setting.

20. Precision and Bias

20.1 *Precision*—Since Method B represents procedures specific to a laboratory that have been qualified in comparison to Method A, no statement on precision is being made.

20.2 *Bias*—Since there are no accepted reference materials suitable for determining the bias for the procedure in this test method, no statement on bias is presented.

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21. Keywords

21.1 automatic vicat; hydraulic-cement paste; time of setting; vicat; vicat needle

ANNEXES

(Mandatory Information)

A1. VICAT APPARATUS

A1.1 The Vicat apparatus shall consist of a frame, A, Fig. A1.1, bearing a movable rod, B, with a mass as specified by the method referencing this apparatus, one end, C, the plunger end, with a diameter as specified by the method referencing this apparatus, and the other end having a mass or a removable steel needle, D, as specified by the method referencing this apparatus. The rod, B, is reversible, and can be held in any desired position by a setscrew, E, and has an adjustable indicator, F, which moves over a scale graduated in millimetres and attached to the frame, A. The gradations on the graduated scale, when compared to a scale accurate to within 0.1 mm at all points, shall not show a variance from the reference scale greater than 0.25 mm.

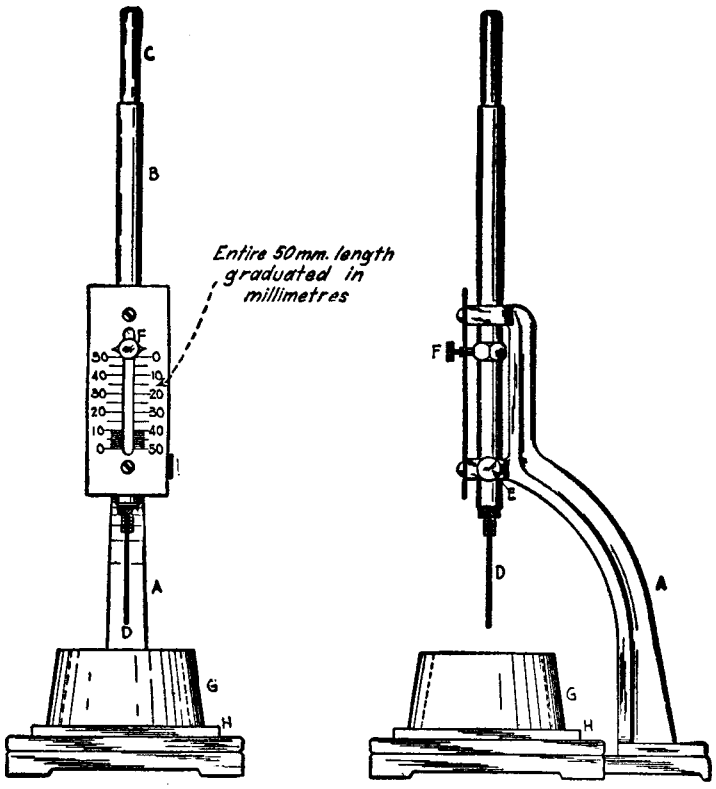

FIG. A1.1 Vicat Apparatus

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A2. PERFORMANCE REQUIREMENT (QUALIFICATION) FOR AUTOMATIC VICAT INSTRUMENT

A2.1 When time of setting results from the automatic Vicat apparatus are to be used for acceptance or rejection of cement, the method used shall comply with the qualification requirements covered in this section. A method is considered to consist of the specific instrument and the molding procedure meeting the requirements of this test method, and used in a consistent manner by a given laboratory.

A2.2 *Hydraulic Cement Samples Required*—Select three cements that comply with requirements of Specifications C 150, C 595, or C 1157, and that when tested in accordance with Method A, shall include the following:

A2.2.1 One cement that has an initial time of setting of less than 110 min,

A2.2.2 One cement with an initial time of setting of greater than 150 min,

A2.2.3 One cement with a final time of setting of less than 180 min, and

A2.2.4 One cement with a final time of setting of greater than 210 min (see Note A2.1).

NOTE A2.1—Laboratories are advised to reserve sufficient cement for future qualification and standardization.

A2.3 *Tests*—Using the method to be qualified and including the standardization formula described in the section on standardization, make single determinations of the times of initial and final setting on each of the three cements. On the same day, conduct companion time of setting determinations according to Method A. Make single determinations of the normal consistency on each cement, and use that amount of water for all replicate batches. Complete three rounds of tests on different days, repeating all the steps of the methods. Conduct the qualification tests on specimens prepared separately from the standardization testing.

A2.4 *Calculations*—Calculate the three-round averages for initial and final time of setting for each cement and method. A method complies with the initial time of setting qualification requirements if the difference between the initial time of setting average values for Method A and the corresponding average values of Method B is not greater than 25 min for any sample, and the range for any three replicate tests by Method B does not exceed 30 min. Likewise, a method complies with the final time of setting qualification requirements if the difference between the final time of setting average values for Method A and corresponding average values for Method B is not greater than 45 min for any sample, and the range for any three replicate tests by Method B does not exceed 30 min. Example qualification data are given in Appendix X1.

A2.5 *Standardization*—When standardization is required in order to achieve agreement between Method A and Method B, it can be applied to either the initial time of setting, final time of setting, or both. A standardization formula shall be based on a comparison of test results obtained using Method A and the chosen method using the automatic instrument (Method B). Results of tests from at least five different hydraulic cements shall be required for standardization. The cements shall have a minimum range of 60 min initial time of setting, and a minimum range of 90 min final time of setting when tested in accordance with Method A. If desired, the three cements used for instrument qualification may be used, but make new determinations. Use the same method as used for instrument qualification, including all the same steps. Valid standardization formulas shall be mathematically derived and applied to all samples (see Note A2.2).

NOTE A2.2—Generally, the automatic instruments are computer operated and easily adapted to standardization calculations.

A3. REQUALIFICATION OF A METHOD

A3.1 Requalify the method at least once per year and when any of the following conditions occur:

A3.2 The instrument has been significantly modified.

A3.3 The instrument has been substantially repaired.

A3.4 Substantial evidence indicates that the method is not providing data meeting the performance requirements.

A3.5 The average of a Cement and Concrete Reference Laboratory (CCRL) sample differs from the value obtained by the method by more than 45 min for either the initial or final time of setting.

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APPENDIX

(Nonmandatory Information)

X1. SAMPLE QUALIFICATION RESULTS

TABLE X1.1 Time of Initial Setting, min

Cement	Round No.	Initial C 191 Method A	Initial Auto Method B	Diff. Avg. (Spec. 25 Max.)
A	1	95	105	. . .
A	2	90	105	. . .
A	3	95	90	. . .
Range (Spec. 30 Max.)		5	15	. . .
Average		93.3	100.0	6.7
B	1	100	120	. . .
B	2	105	95	. . .
B	3	85	95	. . .
Range (Spec. 30 Max.)		20	25	. . .
Average		96.7	103.3	6.7
C	1	155	170	. . .
C	2	155	160	. . .
C	3	145	155	. . .
Range (Spec. 30 Max.)		10	15	. . .
Average		151.7	161.7	10.0

TABLE X1.2 Time of Final Setting, min

Cement	Round No.	Final C 191 Method A	Final Auto Method B	Diff. Avg. (Spec. 45 Max.)
A	1	150	150	. . .
A	2	145	150	. . .
A	3	170	125	. . .
Range (Spec. 30 Max.)		25	25	. . .
Average		155.0	141.7	13.3
B	1	185	180	. . .
B	2	200	180	. . .
B	3	185	155	. . .
Range (Spec. 30 Max.)		15	25	. . .
Average		190.0	171.7	18.3
C	1	235	225	. . .
C	2	240	220	. . .
C	3	240	215	. . .
Range (Spec. 30 Max.)		5	10	. . .
Average		238.3	220.0	18.3

For additional useful information on details of cement test methods, reference may be made to the "Manual of Cement Testing," which appears in the *Annual Book of ASTM Standards*, **Vol 04.01.**

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SUMMARY OF CHANGES

Committee C01 has identified the location of selected changes to these test methods since the last issue, C 191 – 07, that may impact the use of these test methods. (Approved June 1, 2008)

(*1*) Revised 6.2 and 6.5.

Committee C01 has identified the location of selected changes to these test methods since the last issue, C 191 – 04b, that may impact the use of these test methods. (Approved July 15, 2007)

(*1*) Added new 6.10.

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Designation: C 192/C 192M – 07

Standard Practice for Making and Curing Concrete Test Specimens in the Laboratory[1]

This standard is issued under the fixed designation C 192/C 192M; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

This standard has been approved for use by agencies of the Department of Defense.

1. Scope*

1.1 This practice covers procedures for making and curing test specimens of concrete in the laboratory under accurate control of materials and test conditions using concrete that can be consolidated by rodding or vibration as described herein.

1.2 The values stated in either inch-pound units or SI units shall be regarded separately as standard. The SI units are shown in brackets. The values stated in each system are not exact equivalents; therefore, each system shall be used independently of each other. Combining values from the two systems may result in nonconformance.

1.3 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.* (**Warning**—Fresh hydraulic cementitious mixtures are caustic and may cause chemical burns to exposed skin and tissue upon prolonged exposure.[2])

2. Referenced Documents

2.1 *ASTM Standards:* [3]

C 70 Test Method for Surface Moisture in Fine Aggregate
C 125 Terminology Relating to Concrete and Concrete Aggregates
C 127 Test Method for Density, Relative Density (Specific Gravity), and Absorption of Coarse Aggregate
C 128 Test Method for Density, Relative Density (Specific Gravity), and Absorption of Fine Aggregate
C 138/C 138M Test Method for Density (Unit Weight), Yield, and Air Content (Gravimetric) of Concrete
C 143/C 143M Test Method for Slump of Hydraulic-Cement Concrete
C 172 Practice for Sampling Freshly Mixed Concrete
C 173/C 173M Test Method for Air Content of Freshly Mixed Concrete by the Volumetric Method
C 231 Test Method for Air Content of Freshly Mixed Concrete by the Pressure Method
C 330 Specification for Lightweight Aggregates for Structural Concrete
C 403/C 403M Test Method for Time of Setting of Concrete Mixtures by Penetration Resistance
C 470/C 470M Specification for Molds for Forming Concrete Test Cylinders Vertically
C 494/C 494M Specification for Chemical Admixtures for Concrete
C 511 Specification for Mixing Rooms, Moist Cabinets, Moist Rooms, and Water Storage Tanks Used in the Testing of Hydraulic Cements and Concretes
C 566 Test Method for Total Evaporable Moisture Content of Aggregate by Drying
C 617 Practice for Capping Cylindrical Concrete Specimens
C 1064/C 1064M Test Method for Temperature of Freshly Mixed Hydraulic-Cement Concrete
C 1077 Practice for Laboratories Testing Concrete and Concrete Aggregates for Use in Construction and Criteria for Laboratory Evaluation

2.2 *American Concrete Institute Publications:* [4]

211.3 Practice for Selecting Proportions for No-Slump Concrete
309 Guide for Concrete Consolidation

3. Significance and Use

3.1 This practice provides standardized requirements for preparation of materials, mixing concrete, and making and curing concrete test specimens under laboratory conditions.

3.2 If specimen preparation is controlled as stipulated herein, the specimens may be used to develop information for the following purposes:

[1] This practice is under the jurisdiction of ASTM Committee C09 on Concrete and Concrete Aggregates and is the direct responsibility of Subcommittee C09.61 on Testing for Strength.

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[2] See section on Safety Precautions, *Manual of Aggregate and Concrete Testing*, *Annual Book of ASTM Standards*, Vol. 04.02.

[3] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

[4] Available from American Concrete Institute (ACI), P.O. Box 9094, Farmington Hills, MI 48333-9094, http://www.aci-int.org.

***A Summary of Changes section appears at the end of this standard.**

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3.2.1 Mixture proportioning for project concrete,
3.2.2 Evaluation of different mixtures and materials,
3.2.3 Correlation with nondestructive tests, and
3.2.4 Providing specimens for research purposes.

NOTE 1—The concrete test results for concrete specimens made and cured using this practice are widely used. They may be the basis for acceptance testing for project concrete, research evaluations, and other studies. Careful and knowledgeable handling of materials, mixing concrete, molding test specimens, and curing test specimens is necessary. Many laboratories performing this important work are independently inspected or accredited. Practice C 1077 identifies and defines duties, responsibilities, including minimum responsibilities of the laboratory personnel and minimum technical requirements for laboratory equipment used. Many laboratories ensure qualified technicians by participating in national certification programs such as the American Concrete Institute Laboratory Technician Program or an equivalent program.

4. Apparatus

4.1 *Molds, General*—Molds for specimens or fastenings thereto in contact with the concrete shall be made of steel, cast iron, or other nonabsorbent material, nonreactive with concrete containing portland or other hydraulic cements. Molds shall conform to the dimensions and tolerances specified in the method for which the specimens are required. Molds shall hold their dimensions and shape under all conditions of use. Watertightness of molds during use shall be judged by their ability to hold water poured into them. Test procedures for watertightness are given in the section on Test Methods for Elongation, Absorption, and Watertightness of Specification C 470/C 470M. A suitable sealant, such as heavy grease, modeling clay, or microcrystalline wax, shall be used where necessary to prevent leakage through the joints. Positive means shall be provided to hold base plates firmly to the molds. Reusable molds shall be lightly coated with mineral oil or a suitable nonreactive release material before use.

4.2 *Cylinder Molds:*

4.2.1 *Molds for Casting Specimens Vertically* shall conform to the requirements of 4.1 and Specification C 470/C 470M.

4.2.2 *Horizontal Molds for Creep Test Cylinders* shall conform to the requirements of 4.1 and to the requirements for symmetry and dimensional tolerance in the section on General Requirements except for verticality requirements of Specification C 470/C 470M. The use of horizontal molds is intended only for creep specimens that contain axially embedded strain gages. Molds for creep cylinders to be filled while supported in a horizontal position shall have a filling slot parallel to the axis of the mold which extends the full length to receive the concrete. The width of the slot shall be one half the diameter of the specimen. If necessary the edges of the slot shall be reinforced to maintain dimensional stability. Unless specimens are to be capped or ground to produce plane ends, the molds shall be provided with two machined metal end plates at least 1 in. [25 mm] thick and the working surfaces shall comply with the requirements for planeness and surface roughness given in the section on Capping Plates of Practice C 617. Provision shall be made for fixing both end plates firmly to the mold. The inside surface of each end plate shall be provided with at least three lugs or studs approximately 1 in. [25 mm] long, firmly fastened to the plate for embedment in the concrete. One base plate shall be drilled from the inside at an angle to permit the lead wire from the strain gage to exit the specimen through the edge of the plate. Provision shall be made for accurately positioning the strain gage. All necessary holes shall be as small as possible to minimize disturbance to subsequent strain measurements and shall be sealed to prevent leakage.

4.3 *Beam and Prism Molds* shall be rectangular in shape (unless otherwise specified) and of the dimensions required to produce the desired specimen size. The inside surfaces of the molds shall be smooth and free from indentations. The sides, bottom, and ends shall be at right angles to each other and shall be straight and true and free of warpage. Maximum variation from the nominal cross section shall not exceed ⅛ in. [3 mm] for molds with depth or breadth of 6 in. [150 mm] or more, or 1⁄16 in. [2 mm] for molds of smaller depth or breadth. Except for flexure specimens, molds shall not vary from the nominal length by more than 1⁄16 in. [2 mm]. Flexure molds shall not be shorter than 1⁄16 in. [2 mm] of the required length, but may exceed it by more than that amount.

4.4 *Tamping Rods*—Two sizes are specified in ASTM methods. Each shall be a round, straight steel rod with at least the tamping end rounded to a hemispherical tip of the same diameter as the rod. Both ends may be rounded, if preferred.

4.4.1 *Larger Rod*, ⅝ in. [16 mm] in diameter and approximately 24 in. [600 mm] long.

4.4.2 *Smaller Rod*, ⅜ in. [10 mm] in diameter and approximately 12 in. [300 mm] long.

4.5 *Mallets*—A mallet with a rubber or rawhide head weighing 1.25 ± 0.50 lb [0.6 ± 0.20 kg] shall be used.

4.6 *Vibrators*:

4.6.1 *Internal Vibrators*—The vibrator frequency shall be at least 7000 vibrations per minute [115 Hz] while the vibrator is operating in the concrete. The diameter of a round vibrator shall be no more than one fourth the diameter of the cylinder mold or one fourth the width of the beam or prism mold. Other shaped vibrators shall have a perimeter equivalent to the circumference of an appropriate round vibrator. The combined length of the vibrator shaft and vibrating element shall exceed the depth of the section being vibrated by at least 3 in. [75 mm].

NOTE 2—For information on size and frequency of various vibrators and method to periodically check vibrator frequency, see ACI 309.

4.6.2 *External Vibrators*—The two types of external vibrators permitted are either table or plank. The external vibrator frequency shall be 3600 vibrations per minute [60 Hz] or higher.

4.6.3 Provisions shall be made for clamping the mold securely to the apparatus for both types of vibrators.

NOTE 3—Vibratory impulses are frequently imparted to a table or plank vibrator through electromagnetic means, or by use of an eccentric weight on the shaft of an electric motor or on a separate shaft driven by a motor.

4.7 *Small Tools*—Tools and items such as shovels, pails, trowels, wood float, blunted trowels, straightedge, feeler gage, scoops, rulers, rubber gloves, and metal mixing bowls shall be provided.

4.8 *Slump Apparatus*—The apparatus for measurement of slump shall conform to the requirements of Test Method C 143/C 143M.

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4.9 *Sampling and Mixing Pan*—The pan shall be flat-bottom and of heavy-gage metal, watertight, of convenient depth, and of sufficient capacity to allow easy mixing by shovel or trowel of the entire batch; or, if mixing is by machine, to receive the entire batch on discharge of the mixer and allow remixing in the pan by trowel or shovel.

4.10 *Wet-Sieving Equipment*—If wet-sieving is required, the equipment shall conform to the requirements of Practice C 172.

4.11 *Air Content Apparatus*—The apparatus for measuring air content shall conform to the requirements of either Test Methods C 231 or C 173.

4.12 *Scales*—Scales for determining the mass of batches of materials and concrete shall be accurate within 0.3 % of the test load at any point within the range of use.

NOTE 4—In general the mass of small quantities should not be determined on large capacity scales. In many applications the smallest mass determined on a scale should be greater than about 10 % of the maximum capacity of the scale; however, this will vary with the performance characteristics of the scale and the required accuracy of the determination. Acceptable scales used for determining the mass for concrete materials preferably should determine mass accurately to about 0.1 % of total capacity and the foregoing precaution is applicable. However, certain analytical and precision balances are exceptions to this rule and should weigh accurately to 0.001 %. Particular care must be exercised in measuring small quantities of material by determining the difference between two much larger masses.

4.13 *Temperature Measuring Device*—The temperature measuring device shall conform to the requirements of Test Method C 1064.

4.14 *Concrete Mixer*—A power-driven concrete mixer shall be a revolving drum, tilting mixer, or suitable revolving pan or revolving-paddle mixer capable of thoroughly mixing batches of the prescribed sizes at the required slump.

NOTE 5—A pan mixer is usually more suitable for mixing concrete with less than 1-in. [25 mm] slump than a revolving drum mixer. The rate of rotation, degree of tilt, and rated capacity of tilting mixers are not always suitable for laboratory mixed concrete. It may be found desirable to reduce the rate of rotation, decrease the angle of tilt from the horizontal, and use the mixer at somewhat less than the manufacturer's rated capacity.

5. Specimens

5.1 *Cylindrical Specimens*—Cylinder dimensions shall be as stipulated in the specification, test method or practice for the laboratory studies being performed and shall meet the requirements of 5.4. If dimensions are not stipulated in a specification, test method, or practice, the specimen selected shall have a length that is twice the diameter and meet the requirements of 5.4.

NOTE 6—The same cylinder size should be used for the reference (control) concrete mixture and test concrete mixtures when conducting comparative studies such as those required in Specification C 494/C 494M. For mixture proportioning of project concrete, it is preferable for the cylinder size in the laboratory to be the same as that specified for acceptance testing.

NOTE 7—When molds in SI units are required and not available, equivalent inch-pound unit size mold should be permitted.

5.1.1 Cylindrical specimens for tests other than creep shall be molded and allowed to harden with the axis of the cylinder vertical.

5.1.2 Cylindrical creep specimens may be cast with the cylindrical axis either vertical or horizontal and allowed to harden in the position in which cast.

5.2 *Prismatic Specimens*—Beams for flexural strength, prisms for freezing and thawing, bond, length change, volume change, etc., shall be formed with their long axes horizontal, unless otherwise required by the method of test in question, and shall conform in dimension to the requirements of the specific test method.

5.3 *Other Specimens*—Other shapes and sizes of specimens for particular tests may be molded as desired following the general procedures set forth in this practice.

5.4 *Specimen Size versus Aggregate Size*—The diameter of a cylindrical specimen or minimum cross-sectional dimension of a rectangular section shall be at least three times the nominal maximum size of the coarse aggregate in the concrete as defined in Terminology C 125. When the nominal maximum size of the coarse aggregate exceeds 2 in. [50 mm], the sample shall be treated by wet sieving through a 2-in. [50-mm] sieve as described in Practice C 172, unless otherwise stipulated.

5.5 *Number of Specimens*—The number of specimens and the number of test batches are dependent on established practice and the nature of the test program. Guidance is usually given in the test method or specification for which the specimens are made. Usually three or more specimens are molded for each test age and test condition unless otherwise specified (Note 8). Specimens involving a given variable should be made from three separate batches mixed on different days. An equal number of specimens for each variable should be made on any given day. When it is impossible to make at least one specimen for each variable on a given day, the mixing of the entire series of specimens should be completed in as few days as possible, and one of the mixtures should be repeated each day as a standard of comparison.

NOTE 8—Test ages often used are 7 and 28 days for compressive strength tests, or 14 and 28 days for flexural strength tests. Specimens containing Type III cement are often tested at 1, 3, 7, and 28 days. For later test ages, 3 months, 6 months, and 1 year are often used for both compressive and flexural strength tests. Other test ages may be required for other types of specimens.

6. Preparation of Materials

6.1 *Temperature*—Before mixing the concrete, bring the concrete materials to room temperature in the range from 68 to 86 °F [20 to 30 °C], except when the temperature of the concrete is stipulated. When a concrete temperature is stipulated, the method proposed to obtain the concrete temperature needs approval of the stipulator.

6.2 *Cement*—Store the cement in a dry place, in moisture-proof containers, preferably made of metal. The cement shall be thoroughly mixed to provide a uniform supply throughout the tests. It shall be passed through a 850-μm [No. 20] or finer sieve to remove all lumps, remixed on a plastic sheet, and returned to sample containers.

6.3 *Aggregates*—In order to preclude segregation of a coarse aggregate, separate into individual size fractions and for each batch recombine in the proper proportions to produce the desired grading.

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NOTE 9—Only rarely is a coarse aggregate batched as a single size fraction. The number of size fractions will generally be between 2 and 5 for aggregate smaller than 2½ in. [60 mm]. When a size fraction to be batched is present in amounts in excess of 10 %, the ratio of the opening of the larger to the smaller sieve should not exceed 2.0. More closely sized groups are sometimes advisable.

6.3.1 Unless fine aggregate is separated into individual size fractions, maintain it in a damp condition or restore to a damp condition until use, to prevent segregation, unless material uniformly graded is subdivided into batch size lots using a sample splitter with proper size openings. If unusual gradings are being studied, the fine aggregate may need to be dried and separated into individual sizes. In this instance, if the total quantity of fine aggregate required is larger than can be efficiently blended in a single unit, then the individual size fractions should be determined in a mass required for each individual batch. When the total quantity of fine aggregate needed for the complete investigation is such that it can be thoroughly mixed, blended, and maintained in a damp condition, then it should be handled in that manner. Determine the specific gravity and absorption of aggregates in accordance with either Test Methods C 127 or C 128.

6.3.2 Before incorporating in concrete, prepare the aggregate to ensure a definite and uniform condition of moisture. Determine the weight of aggregate to be used in the batch by one of the following procedures:

6.3.2.1 Determine the mass of low-absorption aggregates (absorption less than 1.0 %) in the room-dry condition with allowance made for the amount of water that will be absorbed from the unset concrete (Note 10). This procedure is particularly useful for coarse aggregate which must be batched as individual sizes; because of the danger of segregation it can be used for fine aggregate only when the fine aggregate is separated into individual size fractions.

NOTE 10—When using aggregates with low absorption in room-dry condition the amount of water that will be absorbed by the aggregates before the concrete sets may be assumed to be 80 % of the difference between the 24-h absorption of the aggregates determined by Test Methods C 127 or C 128, and the amount of water in the pores of the aggregates in their room-dry state, as determined by Test Method C 566.

6.3.2.2 Individual size fractions of aggregate may be weighed separately, recombined into a tared container in the amounts required for the batch, and immersed in water for 24 h prior to use. After immersion the excess water is decanted and the combined weight of aggregate and mixing water determined. Allowance shall be made for the amount of water absorbed by the aggregate. The moisture content of the aggregates may be determined in accordance with Test Methods C 70 and C 566.

6.3.2.3 The aggregate may be brought to and maintained in a saturated condition, with surface moisture contained in sufficiently small amounts to preclude loss by draining, at least 24 h prior to use. When this method is used, the moisture content of the aggregate must be determined to permit calculation of proper quantities of the damp aggregate. The quantity of surface moisture present must be counted as a part of the required amount of mixing water. Surface moisture in fine aggregate may be determined in accordance with Test Methods C 70 and C 566, making due allowance for the amount of water absorbed. The method outlined here (moisture content slightly exceeding absorption) is particularly useful for fine aggregate. It is used less frequently for coarse aggregate because of the difficulty of accurately determining the moisture content, but if used, each size fraction must be handled separately to ensure that the proper grading is obtained.

6.3.2.4 Aggregates, fine or coarse, may be brought to and maintained in a saturated surface-dry condition until batched for use. This method is used primarily to prepare material for batches not exceeding ¼ ft^3 [0.007 m^3] in volume. Care must be taken to prevent drying during weighing and use.

6.4 *Lightweight Aggregates*—The procedures for specific gravity, absorption, and preparation of aggregates mentioned in this practice pertain to materials with normal absorption values. Lightweight aggregates, air-cooled slag, and certain highly porous or vesicular natural aggregate may be so absorptive as to be difficult to treat as described. The moisture content of lightweight aggregate at the time of mixing may have important effects on properties of freshly mixed and hardened concretes such as slump loss, compressive strength, and resistance to freezing and thawing.

6.5 *Admixtures*—Powdered admixtures that are entirely or largely insoluble, that do not contain hygroscopic salts and are to be added in small quantities, should be mixed with a portion of the cement before introduction into the batch in the mixer so as to ensure thorough distribution throughout the concrete. Essentially insoluble materials which are used in amounts exceeding 10 % by mass of cement, such as pozzolans, should be handled and added to the batch in the same manner as cement. Powdered admixtures which are largely insoluble but contain hygroscopic salts may cause balling of cement and should be mixed with the sand. Water-soluble and liquid admixtures should be added to the mixer in solution in the mixing water. The quantity of such solution used shall be included in the calculation of the water content of the concrete. Admixtures, incompatible in concentrated form, such as solutions of calcium chloride and certain air-entraining and set-retarding admixtures, should not be intermixed prior to their addition to concrete. The time, sequence, and method of adding some admixtures to a batch of concrete can have important effects on concrete properties such as time of set and air content. The method selected must remain unchanged from batch to batch.

NOTE 11—The mixing apparatus and accessories shall be thoroughly cleaned to ensure that chemical additions or admixtures used in dissimilar batches of concrete do not affect subsequent batches.

7. Procedure

7.1 *Mixing Concrete:*

7.1.1 *General*—Mix concrete in a suitable mixer or by hand in batches of such size as to leave about 10 % excess after molding the test specimens. Hand-mixing procedures are not applicable to air-entrained concrete or concrete with no measurable slump. Hand mixing should be limited to batches of ¼ ft^3 [0.007 m^3] volume or less. Mixing procedures are given in 7.1.2 and 7.1.3. However, other procedures may be used when it is desired to simulate special conditions or practices, or when the procedures specified are impracticable. A machine-mixing

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procedure suitable for drum-type mixers is described. It is important not to vary the mixing sequence and procedure from batch to batch unless the effect of such variation is under study.

7.1.2 *Machine Mixing*—Prior to starting rotation of the mixer add the coarse aggregate, some of the mixing water, and the solution of admixture, when required, in accordance with 6.5. When feasible, disperse the admixture in the mixing water before addition. Start the mixer, then add the fine aggregate, cement, and water with the mixer running. If it is impractical for a particular mixer or for a particular test to add the fine aggregate, cement, and water while the mixer is running, these components may be added to the stopped mixer after permitting it to turn a few revolutions following charging with coarse aggregate and some of the water (Note 12). Mix the concrete, after all ingredients are in the mixer, for 3 min followed by a 3-min rest, followed by a 2-min final mixing. Cover the open end or top of the mixer to prevent evaporation during the rest period. Take precautions to compensate for mortar retained by the mixer so that the discharged batch, as used, will be correctly proportioned (Note 13). To eliminate segregation, deposit machine-mixed concrete in the clean, damp mixing pan and remix by shovel or trowel until it appears to be uniform.

NOTE 12—An experienced operator may add water incrementally during mixing to adjust to the desired slump.

NOTE 13—It is difficult to recover all of the mortar from mixers. To compensate for this difficulty one of the following procedures may be used to ensure the correct final proportions in the batch:

(1) "*Buttering*" *the Mixer*—Just prior to mixing the test batch, the mixer is "buttered" by mixing a batch proportioned to simulate closely the test batch. The mortar adhering to the mixer after discharging is intended to compensate for loss of mortar from the test batch.

(2) "*Over-Mortaring*" *the Mix*—The test mix is proportioned by the use of an excess mortar, the amount established in advance, to compensate for that which, on the average, adheres to the mixer. In this case the mixer is cleaned before mixing the test batch.

7.1.3 *Hand Mixing*—Mix the batch in a watertight, clean (Note 11), damp, metal pan or bowl, with a bricklayer's blunted trowel, using the following procedure when aggregates have been prepared in accordance with 6.3.2.1, 6.3.2.3, and 6.3.2.4.

7.1.3.1 Mix the cement, powdered insoluble admixture, if used, and fine aggregate without addition of water until they are thoroughly blended.

7.1.3.2 Add the coarse aggregate and mix the entire batch without addition of water until the coarse aggregate is uniformly distributed throughout the batch.

7.1.3.3 Add water, and the admixture solution if used, and mix the mass until the concrete is homogeneous in appearance and has the desired consistency. If prolonged mixing is necessary because of the addition of water in increments while adjusting the consistency, discard the batch and make a new batch in which the mixing is not interrupted to make trial consistency tests.

7.1.4 *Mixed Concrete*—Select the portions of the batch of mixed concrete to be used in tests for molding specimens so as to be representative of the actual proportions and condition of the concrete. When the concrete is not being remixed or sampled cover it to prevent evaporation.

7.2 *Slump, Air Content, Yield, and Temperature:*

7.2.1 *Slump*—Measure the slump of each batch of concrete immediately after mixing in accordance with Test Method C 143/C 143M.

NOTE 14—The slump test is unsuitable for concrete so dry that it slumps less than ¼ in. [6 mm]. No-slump concrete may be tested by one of several means described in ACI 211.3.

7.2.2 *Air Content*—Determine the air content, when required, in accordance with either Test Methods C 173 or C 231. Test Method C 231 should not be used with concretes made with lightweight aggregates, air-cooled blast-furnace slag, or aggregates of high porosity. Discard the concrete used for the determination of air content.

7.2.3 *Yield*—Determine the yield of each batch of concrete, if required, in accordance with Test Method C 138. Concrete used for slump and yield tests may be returned to the mixing pan and remixed into the batch.

7.2.4 *Temperature*—Determine the temperature of each batch of concrete in accordance with Test Method C 1064.

7.3 *Making Specimens:*

7.3.1 *Place of Molding*—Mold specimens as near as practicable to the place where they are to be stored during the first 24 h. If it is not practicable to mold the specimens where they will be stored, move them to the place of storage immediately after being struck off. Place molds on a rigid surface free from vibration and other disturbances. Avoid jarring, striking, tilting, or scarring of the surface of the specimens when moving the specimens to the storage place.

7.3.2 *Placing*—Place the concrete in the molds using a scoop, blunted trowel, or shovel. Select each scoopful, trowelful, or shovelful of concrete from the mixing pan to ensure that it is representative of the batch. It may be necessary to remix the concrete in the mixing pan with a shovel or trowel to prevent segregation during the molding of specimens. Move the scoop or trowel around the top edge of the mold as the concrete is discharged in order to ensure a symmetrical distribution of the concrete and to minimize segregation of coarse aggregate within the mold. Further distribute the concrete by use of a tamping rod prior to the start of consolidation. In placing the final layer the operator shall attempt to add an amount of concrete that will exactly fill the mold after compaction. Do not add nonrepresentative samples of concrete to an underfilled mold.

7.3.2.1 *Number of Layers*—Make specimens in layers as indicated in Table 1.

7.4 *Consolidation:*

7.4.1 *Methods of Consolidation*—Preparation of satisfactory specimens requires different methods of consolidation. The methods of consolidation are rodding, and internal or external vibration. Base the selection of the method on the slump, unless the method is stated in the specifications under which the work is being performed. Rod or vibrate concrete with slump greater than or equal to 1 in. [25 mm]. Vibrate concrete with slump less than 1 in. (Note 15). Do not use internal vibration for cylinders with a diameter less than 4 in. [100 mm], and for beams or prisms with breath or depth less than 4 in.

NOTE 15—Concrete of such low water content that it cannot be properly consolidated by the methods described herein is not covered by

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TABLE 1 Number of Layers Required for Specimens

Specimen Type and Size	Mode of Consolidation	Numbers of Layers of Approximate Equal Depth
Cylinders: Diameter, in. [mm]		
3 or 4 [75 to 100]	rodding	2
6 [150]	rodding	3
9 [225]	rodding	4
up to 9 [225]	vibration	2
Prisms and horizontal creep Cylinders: Depth, in. [mm]		
up to 8 [200]	rodding	2
over 8 [200]	rodding	3 or more
up to 8 [200]	vibration	1
over 8 [200]	vibration	2 or more

this practice. Provisions for specimens and methods of testing will be found in the standards concerned. There are concretes that can be consolidated by external vibration, but additional forces on the surface are required to embed the coarse aggregate thoroughly and consolidate the mixture. For such mixtures the following procedures may be followed: using external vibration fill 6 by 12-in. [150 by 300-mm] cylinder molds in 3 in. [75 mm] lifts using a 10-lb [4.5-kg] cylindrical surcharge, or 3 by 6-in. [75 by 150-mm] cylinder molds in 2 in. [50 mm] lifts using a 2.5-lb [1-kg] cylindrical surcharge. The surcharge should have a diameter ¼ in. [6 mm] less than the inside of the mold. Simultaneously each lift should be compacted by external vibration with the surcharge on the top surface of the concrete, until the mortar begins to ooze around the bottom of the surcharge.

7.4.2 *Rodding*—Place the concrete in the mold, in the required number of layers of approximately equal volume. Rod each layer with the rounded end of the rod using the number of strokes and size of rod specified in Table 2. Rod the bottom layer throughout its depth. Distribute the strokes uniformly over the cross section of the mold and for each upper layer allow the rod to penetrate through the layer being rodded and into the layer below about 1 in. [25 mm]. After each layer is rodded, tap the outsides of the mold lightly 10 to 15 times with the mallet to close any holes left by rodding and to release any large air bubbles that may have been trapped. Use an open hand to tap light-gage single-use molds which are susceptible to damage if tapped with a mallet. After tapping, spade the concrete along the sides and ends of beam and prism molds with a trowel or other suitable tool.

7.4.3 *Vibration*—Maintain a uniform duration of vibration for the particular kind of concrete, vibrator, and specimen mold involved. The duration of vibration required will depend upon the workability of the concrete and the effectiveness of the vibrator. Usually sufficient vibration has been applied as soon as the surface of the concrete becomes relatively smooth and large air bubbles cease to break through the top surface. Continue vibration only long enough to achieve proper consolidation of the concrete (see Note 16). Overvibration may cause segregation. Fill the molds and vibrate in the required number of approximately equal layers (Table 2). Place all the concrete for each layer in the mold before starting vibration of that layer. When placing the final layer, avoid overfilling by more than ¼ in. [6 mm]. When the finish is applied after vibration, add only enough concrete with a trowel to overfill the mold about ⅛ in. [3 mm], work it into the surface and then strike it off.

NOTE 16—Generally, no more than 5 s of vibration should be required for each insertion to adequately consolidate the concrete with a slump greater than 3 in. [75 mm]. Longer times may be required for lower slump concrete, but the vibration time should rarely have to exceed 10 s per insertion.

7.4.3.1 *Internal Vibration*—In compacting the specimen insert the vibrator slowly and do not allow the vibrator to rest on or touch the bottom or sides of the mold or strike embedded items such as strain meters. Slowly withdraw the vibrator so that no large air pockets are left in the specimen.

7.4.3.2 *Cylinders*—The number of insertions of the vibrator is given in Table 3. When more than one insertion per layer is required, distribute the insertions uniformly within each layer. Allow the vibrator to penetrate into the layer below about 1 in. [25 mm]. After each layer is vibrated, tap the outside of the mold at least 10 times with the mallet to close the holes that remain and to release entrapped air voids. Use an open hand to tap cardboard or single-use metal molds that are susceptible to damage if tapped with a mallet.

7.4.3.3 *Beams, Prisms, and Horizontal Creep Cylinders*—Insert the vibrator at intervals not exceeding 6 in. [150 mm] along the center line of the long dimension of the specimen, or along both sides but not in contact with the strain gage in the case of creep cylinders. For specimens wider than 6 in. [150 mm], use alternating insertions along two lines. Allow the shaft of the vibrator to penetrate into the bottom layer about 1 in. [25 mm]. After each layer is vibrated, tap the outsides of the mold

TABLE 2 Diameter of Rod and Number of Roddings to be Used in Molding Test Specimens

Cylinders		
Diameter of Cylinder, in. [mm]	Diameter of Rod in. [mm]	Number of Strokes/Layer
3 [75] to < 6 [150]	⅜ [10]	25
6 [150]	⅝ [16]	25
8 [200]	⅝ [16]	50
10 [250]	⅝ [16]	75
Beams and Prisms		
Top Surface Area of Specimen, in.^{2}[cm^2]	Diameter of Rod in. (mm)	Number of Roddings/Layer
25 [160] or less	⅜ [10]	25
26 to 49 [165 to 310]	⅜ [10]	one for each 1 in.^{2}[7 cm^2] of surface
50 [320] or more	⅝ [16]	one for each 2 in.^{2}[14 cm^2] of surface
Horizontal Creep Cylinders		
Diameter of Cylinder in. [mm]	Diameter of Rod in. [mm]	Number of Roddings/Layer
6 [150]	⅝ [16]	50 total, 25 along both sides of axis

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TABLE 3 Number of Vibrator Insertions per Layer

Specimen Type and Size	Number of Insertions per Layer
Cylinder: Diameter, in. [mm]	
4 in. [200 mm]	1
6 in. [150 mm]	2
9 in. [225 mm]	4

sharply at least 10 times with the mallet to close holes left by vibrating and to release entrapped air voids.

7.4.4 *External Vibration*—When external vibration is used, take care to ensure that the mold is rigidly attached to or securely held against the vibrating element or vibrating surface (Note 15).

7.5 *Finishing*—After consolidation by any of the methods, strike off the surface of the concrete and float or trowel it in accordance with the method concerned. If no finish is specified, finish the surface with a wood or magnesium float. Perform all finishing with the minimum manipulation necessary to produce a flat even surface that is level with the rim or edge of the mold and which has no depressions or projections larger than ⅛ in. [3 mm].

7.5.1 *Cylinders*—After consolidation finish the top surfaces by striking them off with the tamping rod where the consistency of the concrete permits, or with a wood float or trowel. If desired, cap the top surface of freshly made cylinders with a thin layer of stiff portland cement paste which is permitted to harden and cure with the specimen. See the section on Capping Materials of Practice C 617.

7.5.2 *Horizontally Cast Creep Cylinders*—After consolidation strike off the specimen with a trowel or float, then trowel the minimum amount required to form the concrete in the opening concentrically with the rest of the specimen. Use a screed curved to the radius of the specimen to more precisely shape and finish the concrete in the opening.

8. Curing

8.1 *Initial Curing*—To prevent evaporation of water from unhardened concrete, cover the specimens immediately after finishing, preferably with a nonabsorptive, nonreactive plate or a sheet of tough, durable impervious plastic. Specimens shall be stored immediately after finishing until the removal of the molds to prevent loss of moisture from the specimens. Select an appropriate procedure or combination of procedures that will prevent moisture loss and is nonabsorptive and nonreactive with the concrete. When wet burlap is used for covering, the burlap must not be in contact with the fresh concrete surface and care must be exercised to keep the burlap wet until the specimens are removed from the molds. Placing a sheet of plastic over the burlap will facilitate keeping it wet. To prevent damage to specimens, protect the outside of cardboard molds from contact with wet burlap or other sources of water until the molds are removed. Record the maximum and minimum ambient temperatures during the initial curing.

8.2 *Removal from Molds*—Remove the specimens from the molds 24 ± 8 h after casting. For concrete with prolonged setting time, molds shall not be removed until 20 ± 4 h after final set. If needed, determine the setting times in accordance with Test Method C 403/C 403M.

8.3 *Curing Environment*—Unless otherwise specified all specimens shall be moist cured at 73.5 ± 3.5 °F [23.0 ± 2.0 °C] from the time of molding until the moment of test (Note 17). Storage during the first 48 h of curing shall be in a vibration-free environment. As applied to the treatment of demolded specimens, moist curing means that the test specimens shall have free water maintained on the entire surface area at all times. This condition is met by using water storage tanks or a moist room in accordance with the requirements of Specification C 511. Cure structural lightweight concrete cylinders in accordance with Specification C 330.

NOTE 17—The temperature within damp sand and under wet burlap or similar materials will always be lower than the temperature in the surrounding atmosphere if evaporation takes place.

8.4 *Flexural Strength Test Specimens*—Cure the flexural strength test specimens in accordance with 8.1 and 8.2 except that while in storage for a minimum period of 20 h immediately prior to testing they shall be immersed in water saturated with calcium hydroxide at 73 ± 3 °F [23 ± 2 °C]. At the end of the curing period, between the time the specimen is removed from curing until testing is completed, drying of the surfaces shall be prevented.

NOTE 18—Relatively small amounts of drying of the surface of flexural strength specimens will induce tensile stresses in the extreme fibers that will markedly reduce the indicated flexural strength.

9. Precision and Bias

9.1 Data to establish precision statements for various testing required by this standard were obtained in the Concrete Proficiency Sample Program of the Cement and Concrete Reference Laboratory.

9.2 The single-operator standard deviations for slump, unit weight, air content, and 7-day compressive strength of trial batches have been found to be 0.7 in., 0.9 lb/ft^3, 0.3 %, and 203 psi, respectively; therefore the results of properly conducted tests on two trial batches made in the same laboratory should not differ by more than 2.0 in., 2.5 lb/ft^3, 0.8 %, and 574 psi, respectively. This precision statement is considered applicable to laboratory trial batches proportioned to contain prescribed quantities of materials and to have a constant water-cement ratio. The values should be used with caution for air-entrained concrete, concrete with slump less than 2 in. [50 mm] or over 6 in. [150 mm], or concrete made with other than normal weight aggregate or aggregate larger than 1 in. [25 mm] nominal maximum size.

9.3 The multilaboratory standard deviations for slump, unit weight, air content, and 7-day compressive strength of trial batches have been found to be 1.0 in., 1.4 lb/ft^3 0.4 %, and 347 psi, respectively; therefore, the results of properly conducted tests on single trial batches made in two different laboratories should not differ by more than 2.8 in., 4.0 lb/ft^3, 1.1 %, and 981 psi, respectively. This precision statement is considered applicable to laboratory trial batches proportioned to contain prescribed quantities of materials and to have a prescribed water-cement ratio. The values should be used with caution for air-entrained concrete, concrete with slump less than 2 in. [50 mm] or over 6 in. [150 mm], or concrete made with other than

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normal weight aggregate or aggregate larger than 1 in. [25 mm] nominal maximum size.

9.4 *Bias*—The procedures for the test methods in 9.3 have no bias because the values obtained from each of those test methods are defined only in terms of the test method.

10. Keywords

10.1 concrete; cylinders; laboratory; prisms; strength testing

SUMMARY OF CHANGES

Committee C09 has identified the location of selected changes to this practice since the last issue, C 192/C 192M – 06, that may impact the use of this practice. (Approved August 1, 2007)

(*1*) Revised 5.4.

(*2*) Revised Diameter of Cylinder in Table 2.

Committee C09 has identified the location of selected changes to this practice since the last issue, C 192/C 192M – 05, that may impact the use of this practice. (Approved June 1, 2006)

(*1*) Revised 1.3.

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Designation: C 204 – 07

American Association State
Highway and Transportation Officials Standard
AASHTO No.: T 153

Standard Test Methods for Fineness of Hydraulic Cement by Air-Permeability Apparatus[1]

This standard is issued under the fixed designation C 204; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope*

1.1 This test method covers determination of the fineness of hydraulic cement, using the Blaine air-permeability apparatus, in terms of the specific surface expressed as total surface area in square centimetres per gram, or square metres per kilogram, of cement. Two test methods are given: Test Method A is the Reference Test Method using the manually operated standard Blaine apparatus, while Test Method B permits the use of automated apparatus that has in accordance with the qualification requirements of this test method demonstrated acceptable performance. Although the test method may be, and has been, used for the determination of the measures of fineness of various other materials, it should be understood that, in general, relative rather than absolute fineness values are obtained.

1.1.1 This test method is known to work well for portland cements. However, the user should exercise judgement in determining its suitability with regard to fineness measurements of cements with densities, or porosities that differ from those assigned to Standard Reference Material No. 114.

1.2 The values stated in SI units are to be regarded as the standard.

1.3 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

2. Referenced Documents

2.1 *ASTM Standards:* [2]

A 582/A 582M Specification for Free-Machining Stainless Steel Bars

C 670 Practice for Preparing Precision and Bias Statements for Test Methods for Construction Materials

E 832 Specification for Laboratory Filter Papers

2.2 *Other Document:*

No. 114 National Institute of Standards and Technology Standard Reference Material[3]

BS 4359: 1971 British Standard Method for the Determination of Specific Surface of Powders: Part 2: Air Permeability Methods[4]

TEST METHOD A: REFERENCE METHOD

3. Apparatus

3.1 *Nature of Apparatus*—The Blaine air-permeability apparatus consists essentially of a means of drawing a definite quantity of air through a prepared bed of cement of definite porosity. The number and size of the pores in a prepared bed of definite porosity is a function of the size of the particles and determines the rate of airflow through the bed. The apparatus, illustrated in Fig. 1, shall consist specifically of the parts described in 3.2-3.8.

3.2 *Permeability Cell*—The permeability cell shall consist of a rigid cylinder 12.70 ± 0.10 mm in inside diameter, constructed of austenitic stainless steel. The interior of the cell shall have a finish of 0.81 µm (32 µin.). The top of the cell shall be at right angles to the principal axis of the cell. The lower portion of the cell must be able to form an airtight fit with the upper end of the manometer, so that there is no air leakage between the contacting surfaces. A ledge ½ to 1 mm in width shall be an integral part of the cell or be firmly fixed in the cell 55 ± 10 mm from the top of the cell for support of the perforated metal disk. The top of the permeability cell shall be fitted with a protruding collar to facilitate the removal of the cell from the manometer.

NOTE 1—Specification A 582/A 582M Type 303 stainless steel (UNS designation S30300) has been found to be suitable for the construction of the permeability cell and the plunger.

3.3 *Disk*—The disk shall be constructed of noncorroding metal and shall be 0.9 ± 0.1 mm in thickness, perforated with 30 to 40 holes 1 mm in diameter equally distributed over its area. The disk shall fit the inside of the cell snugly. The center

[1] This test method is under the jurisdiction of ASTM Committee C01 on Cement and is the direct responsibility of Subcommittee C01.25 on Fineness.

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[2] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

[3] Available from National Institute of Standards and Technology (NIST), 100 Bureau Dr., Stop 1070, Gaithersburg, MD 20899-1070, http://www.nist.gov.

[4] Available from British Standards Institute (BSI), 389 Chiswick High Rd., London W4 4AL, U.K., http://www.bsi-global.com.

***A Summary of Changes section appears at the end of this standard.**

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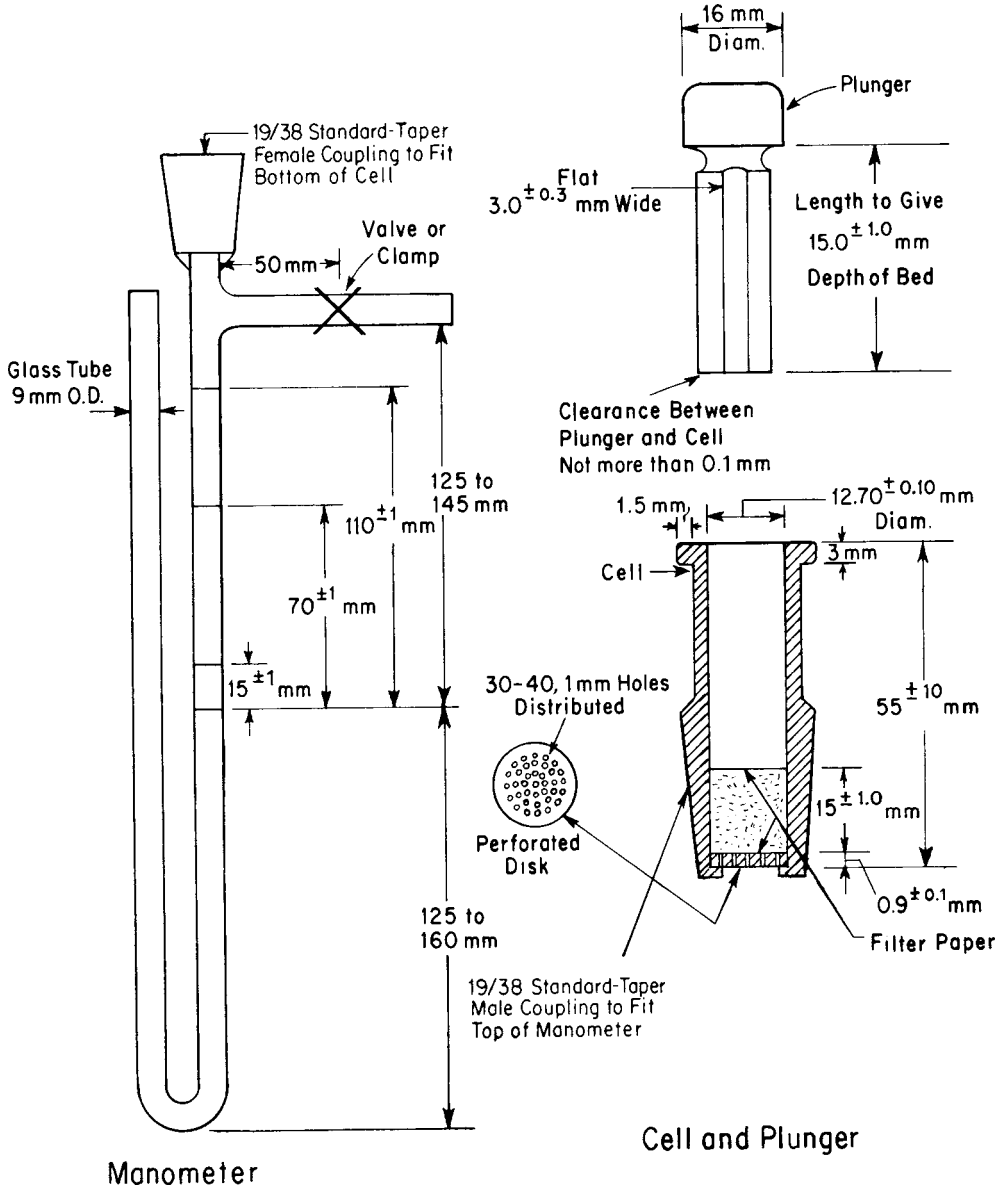

FIG. 1 Blaine Air-Permeability Apparatus

portion of one side of the disk shall be marked or inscribed in a legible manner so as to permit the operator always to place that side downwards when inserting it into the cell. The marking or inscription shall not extend into any of the holes, nor touch their peripheries, nor extend into that area of the disk that rests on the cell ledge.

3.4 *Plunger*—The plunger shall be constructed of austenitic stainless steel and shall fit into the cell with a clearance of not more than 0.1 mm. The bottom of the plunger shall sharply meet the lateral surfaces and shall be at right angles to the principal axis. An air vent shall be provided by means of a flat 3.0 ± 0.3 mm wide on one side of the plunger. The top of the plunger shall be provided with a collar such that when the plunger is placed in the cell and the collar brought in contact with the top of the cell, the distance between the bottom of the plunger and the top of the perforated disk shall be 15 ± 1 mm.

3.5 *Filter Paper*—The filter paper shall be medium retentive, corresponding to Type 1, Grade B, in accordance with Specification E 832. The filter paper disks shall be circular, with smooth edges, and shall have the same diameter (Note 2) as the inside of the cell.

NOTE 2—Filter paper disks that are too small may leave part of the sample adhering to the inner wall of the cell above the top disk. When too large in diameter, the disks have a tendency to buckle and cause erratic results.

3.6 *Manometer*—The U-tube manometer shall be constructed according to the design indicated in Fig. 1, using nominal 9-mm outside diameter, standard-wall, glass tubing. The top of one arm of the manometer shall form an airtight connection with the permeability cell. The manometer arm connected to the permeability cell shall have a midpoint line etched around the tube at 125 to 145 mm below the top side outlet and also others at distances of 15 ± 1 mm, 70 ± 1 mm, and 110 ± 1 mm above that line. A side outlet shall be provided at 250 to 305 mm above the bottom of the manometer for use

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in the evacuation of the manometer arm connected to the permeability cell. A positive airtight valve or clamp shall be provided on the side outlet not more than 50 mm from the manometer arm. The manometer shall be mounted firmly and in such a manner that the arms are vertical.

3.7 *Manometer Liquid*—The manometer shall be filled to the midpoint line with a nonvolatile, nonhygroscopic liquid of low viscosity and density, such as dibutyl phthalate (dibutyl 1,2-benzene-dicarboxylate) or a light grade of mineral oil. The fluid shall be free of debris.

3.8 *Timer*—The timer shall have a positive starting and stopping mechanism and shall be capable of being read to the nearest 0.5 s or less. The timer shall be accurate to 0.5 s or less for time intervals up to 60 s, and to 1 % or less for time intervals of 60 to 300 s.

4. Calibration of Apparatus

4.1 *Sample*—The calibration of the air permeability apparatus shall be made using the current lot of NIST Standard Reference Material No. 114. The sample shall be at room temperature when tested.

4.2 *Bulk Volume of Compacted Bed of Powder*—Determine the bulk volume of the compacted bed of powder by the mercury displacement method as follows:

4.2.1 Place two filter paper disks in the permeability cell, pressing down the edges, using a rod having a diameter slightly smaller than that of the cell, until the filter disks are flat on the perforated metal disk; then fill the cell with mercury, ACS reagent grade or better, removing any air bubbles adhering to the wall of the cell. Use tongs when handling the cell. If the cell is made of material that will amalgamate with mercury, the interior of the cell shall be protected by a very thin film of oil just prior to adding the mercury. Level the mercury with the top of the cell by lightly pressing a small glass plate against the mercury surface until the glass is flush to the surface of the mercury and rim of the cell, being sure that no bubble or void exists between the mercury surface and the glass plate. Remove the mercury from the cell and measure and record the mass of the mercury. Remove one of the filter disks from the cell. Using a trial quantity of 2.80 g of cement (Note 3) compress the cement (Note 4) in accordance with 4.5 with one filter disk above and one below the sample. Into the unfilled space at the top of the cell, add mercury, remove entrapped air, and level off the top as before. Remove the mercury from the cell and measure and record the mass of the mercury.

4.2.2 Calculate the bulk volume occupied by the cement to the nearest 0.005 cm^3 as follows:

$$V = (W_A - W_B)/D \quad (1)$$

where:

V = bulk volume of cement, cm^3,
W_A = grams of mercury required to fill the cell, no cement being in the cell,
W_B = grams of mercury required to fill the portion of the cell not occupied by the prepared bed of cement in the cell, and
D = density of mercury at the temperature of test, Mg/m^3 (see Table 1).

4.2.3 Make at least two determinations of bulk volume of cement, using separate compactions for each determination. The bulk volume value used for subsequent calculations shall be the average of two values agreeing within ± 0.005 cm^3. Note the temperature in the vicinity of the cell and record at the beginning and end of the determination.

NOTE 3—It is not necessary to use the standard sample for the bulk volume determination.

NOTE 4—The prepared bed of cement shall be firm. If too loose or if the cement cannot be compressed to the desired volume, adjust the trial quantity of cement used.

4.3 *Preparation of Sample*—Enclose the contents of a vial of the standard cement sample in a jar, approximately 120 cm^3 (4 oz), and shake vigorously for 2 min to fluff the cement and break up lumps or agglomerates. Allow the jar to stand unopened for a further 2 min, then remove the lid and stir gently to distribute throughout the sample the fine fraction that has settled on the surface after fluffing.

4.4 *Mass of Sample*—The mass of the standard sample used for the calibration test shall be that required to produce a bed of cement having a porosity of 0.500 ± 0.005, and shall be calculated as follows:

$$W = \rho V(1 - \epsilon) \quad (2)$$

where:

W = grams of sample required,
ρ = density of test sample (for portland cement a value of 3.15 Mg/m^3 or 3.15 g/cm^3 shall be used),
V = bulk volume of bed of cement, cm^3, as determined in accordance with 4.2, and
ϵ = desired porosity of bed of cement (0.500 ± 0.005) (Note 5).

NOTE 5—The porosity is the ratio of volume of voids in a bed of cement to the total or bulk volume of the bed, V.

4.5 *Preparation of Bed of Cement*—Seat the perforated disk on the ledge in the permeability cell, inscribed or marked face down. Place a filter paper disk on the metal disk and press the edges down with a rod having a diameter slightly smaller than that of the cell. Measure the mass to the nearest 0.001 g the quantity of cement determined in accordance with 4.4 and place in the cell. Tap the side of the cell lightly in order to level the bed of cement. Place a filter paper disk on top of the cement and compress the cement with the plunger until the plunger collar is in contact with the top of the cell. Slowly withdraw the

TABLE 1 Density of Mercury, Viscosity of Air (η), and $\sqrt{\eta}$ at Given Temperatures

Room Temperature, °C	Density of Mercury, Mg/m^3	Viscosity of Air, η μPa·s	$\sqrt{\eta}$
18	13.55	17.98	4.24
20	13.55	18.08	4.25
22	13.54	18.18	4.26
24	13.54	18.28	4.28
26	13.53	18.37	4.29
28	13.53	18.47	4.30
30	13.52	18.57	4.31
32	13.52	18.67	4.32
34	13.51	18.76	4.33

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plunger a short distance, rotate about 90°, repress, and then slowly withdraw. Use of fresh paper filter disks is required for each determination.

4.6 *Permeability Test*:

4.6.1 Attach the permeability cell to the manometer tube, making certain that an airtight connection is obtained (Note 6) and taking care not to jar or disturb the prepared bed of cement.

4.6.2 Slowly evacuate the air in the one arm of the manometer U-tube until the liquid reaches the top mark, and then close the valve tightly. Start the timer when the bottom of the meniscus of the manometer liquid reaches the second (next to the top) mark and stop when the bottom of the meniscus of liquid reaches the third (next to the bottom) mark. Note the time interval measured and record in seconds. Note the temperature of test and record in degrees Celsius.

4.6.3 In the calibration of the instrument, make at least three determinations of the time of flow on each of three separately prepared beds of the standard sample (Note 7). The calibration shall be made by the same operator who makes the fineness determination.

NOTE 6—A little stopcock grease should be applied to the standard taper connection. The efficiency of the connection can be determined by attaching the cell to the manometer, stoppering it, partially evacuating the one arm of the manometer, then closing the valve. Any continuous drop in pressure indicates a leak in the system.

NOTE 7—The sample may be refluffed and reused for preparation of the test bed, provided that it is kept dry and all tests are made within 4 h of the opening of the sample.

4.7 *Recalibration*—The apparatus shall be recalibrated (Note 8):

4.7.1 At periodic intervals, the duration of which shall not exceed 2½ years, to correct for possible wear on the plunger or permeability cell, or upon receipt of evidence that the test is not providing data in accordance with the precision and bias statement in Section 8.

4.7.2 If any loss in the manometer fluid occurs, recalibrate starting with 4.5, or

4.7.3 If a change is made in the type or quality of the filter paper used for the tests.

NOTE 8—It is suggested that a secondary sample be prepared and used as a fineness standard for the check determinations of the instrument between regular calibrations with the standard cement sample.

5. Procedure

5.1 *Temperature of Cement*—The cement sample shall be at room temperature when tested.

5.2 *Size of Test Sample*—The weight of sample used for the test shall be the same as that used in the calibration test on the standard sample, with these exceptions: When determining the fineness of Type III or other types of fine-ground portland cement whose bulk for this mass is so great that ordinary thumb pressure will not cause the plunger collar to contact the top of the cell, the weight of the sample shall be that required to produce a test bed having a porosity of 0.530 ± 0.005. When determining the fineness of materials other than portland cement, or if for a portland cement sample one of the required porosities cannot be attained, the mass of the sample shall be adjusted so that a firm, hard bed is produced by the compacting process. In no case, however, shall more than thumb pressure be used to secure the proper bed, nor shall such thumb pressure be used that the plunger "rebounds" from the cell top when pressure is removed.

5.3 *Preparation of Bed of Cement*—Prepare the test bed of cement in accordance with the method described in 4.5.

5.4 *Permeability Tests*—Make the permeability tests in accordance with the method described in 4.6, except that only one time-of-flow determination need be made on each bed.

6. Calculation

6.1 Calculate the specific surface values in accordance with the following equations:

$$S = \frac{S_s\sqrt{T}}{\sqrt{T_s}} \tag{3}$$

$$S = \frac{S_s\sqrt{\eta_s}\sqrt{T}}{\sqrt{T_s}\sqrt{\eta}} \tag{4}$$

$$S = \frac{S_s(b-\epsilon_s)\sqrt{\epsilon^3}\sqrt{T}}{\sqrt{\epsilon_s^3}\sqrt{T_s}(b-\epsilon)} \tag{5}$$

$$S = \frac{S_s(b-\epsilon_s)\sqrt{\epsilon^3}\sqrt{\eta}\sqrt{T}}{\sqrt{\epsilon_s^3}\sqrt{T_s}\sqrt{\eta}(b-\epsilon)} \tag{6}$$

$$S = \frac{S_s\rho_s(b_s-\epsilon_s)\sqrt{\epsilon^3}\sqrt{T}}{\rho(b-\epsilon)\sqrt{\epsilon_s^3}\sqrt{T_s}} \tag{7}$$

$$S = \frac{S_s\rho_s(b_s-\epsilon_s)\sqrt{\eta_s}\sqrt{\epsilon^3}\sqrt{T}}{\rho(b-\epsilon)\sqrt{\epsilon_s^3}\sqrt{T_s}\sqrt{\eta}} \tag{8}$$

where:

S = specific surface of the test sample, m^2/kg,
S_s = specific surface of the standard sample used in calibration of the apparatus, m^2/kg (Note 9),
T = measured time interval, s, of manometer drop for test sample (Note 10),
T_s = measured time interval, s, of manometer drop for standard sample used in calibration of the apparatus (Note 10),
η = viscosity of air, micro pascal seconds (μPa·s), at the temperature of test of the test sample (Note 10),
η_s = viscosity of air, micro pascal seconds (μPa·s), at the temperature of test of the standard sample used in calibration of the apparatus (Note 10),
ϵ = porosity of prepared bed of test sample (Note 10),
$\epsilon\epsilon_s$ = porosity of prepared bed of standard sample used in calibration of apparatus (Note 10),
ρ = density of test sample (for portland cement a value of 3.15 Mg/m^3 or 3.15 g/cm^3 shall be used),
ρ_s = density of standard sample used in calibration of apparatus (assumed to be 3.15 Mg/m^3 or 3.15 g/cm^3),
b = a constant specifically appropriate for the test sample (for hydraulic cement a value of 0.9 shall be used), and
b_s = 0.9, the appropriate constant for the standard sample.

NOTE 9—Upon purchase of SRM 114 series samples, a certificate comes with them that indicates the proper specific surface value.

NOTE 10—Values for $\sqrt{\eta}$, $\sqrt{\epsilon 3}$, and $\sqrt{T}$ may be taken from Tables 1-3, respectively.

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TABLE 2 Values for Porosity of Cement Bed

Porosity of Bed, ϵ	$\sqrt{\epsilon^3}$
0.496	0.349
0.497	0.350
0.498	0.351
0.499	0.352
0.500	0.354
0.501	0.355
0.502	0.356
0.503	0.357
0.504	0.358
0.505	0.359
0.506	0.360
0.507	0.361
0.508	0.362
0.509	0.363
0.510	0.364
0.525	0.380
0.526	0.381
0.527	0.383
0.528	0.384
0.529	0.385
0.530	0.386
0.531	0.387
0.532	0.388
0.533	0.389
0.534	0.390
0.535	0.391

6.1.1 Eq 3 and 4 shall be used in calculations of fineness of portland cements compacted to the same porosity as the standard fineness sample. Eq 3 is used if the temperature of test of the test sample is within ± 3 °C of the temperature of calibration test, and Eq 4 is used if the temperature of test of the test sample is outside of this range.

6.1.2 Eq 5 and 6 shall be used in calculation of fineness of portland cements compacted to some porosity other than that of the standard fineness sample used in the calibration test. Eq 5 is used if the temperature of test of the test sample is within ± 3 °C of the temperature of calibration test of the standard fineness sample, and Eq 6 is used if the temperature of test of the test sample is outside of this range.

6.1.3 Eq 7 and 8 shall be used in calculation of fineness of materials other than portland cement. Eq 7 shall be used when the temperature of test of the test sample is within ± 3 °C of the temperature of calibration test, and Eq 8 is used if the temperature of test of the test sample is outside of this range.

6.1.4 It is recommended that values of b be determined on no less than three samples of the material in question. Test each sample at a minimum of four different porosities over a porosity range of at least 0.06. Correlation coefficients should exceed 0.9970 for the correlation of $\sqrt{\epsilon^3 T}$ versus ϵ on each sample tested (see Appendix X1).

6.2 To calculate the specific surface values in square metres per kilogram, multiply the surface area in cm^2/g by the factor of 0.1.

6.3 Round values in cm^2/g to the nearest 10 units (in m^2/kg to the nearest unit). Example: 3447 cm^2/g is rounded to 3450 cm^2/g or 345 m^2/kg.

7. Report

7.1 For portland cements and portland cement-based materials, report results on a single determination on a single bed.

7.2 For very high fineness materials with long time intervals, report the average fineness value of two permeability tests, provided that the two agree within 2 % of each other. If they do not agree, discard the values and repeat the test (Note 11) until two values so agreeing are obtained.

NOTE 11—Lack of agreement indicates a need for checks of procedure and apparatus. See also the "Manual of Cement Testing."

8. Precision and Bias

8.1 *Single-Operator Precision*—The single-operator coefficient of variation for portland cements has been found to be 1.2 % (Note 12). Therefore, results of two properly conducted tests, by the same operator, on the same sample, should not differ by more than 3.4 % (Note 12) of their average.

8.2 *Multilaboratory Precision*—The multilaboratory coefficient of variation for portland cements has been found to be 2.1 % (Note 12). Therefore, results of two different laboratories on identical samples of a material should not differ from each other by more than 6.0 % (Note 12) of their average.

NOTE 12—These numbers represent, respectively, the 1s % and d2s % limits as described in Practice C 670.

8.3 Since there is no accepted reference material suitable for determining any bias that may be associated with Test Method C 204, no statement is being made.

TEST METHOD B: AUTOMATED APPARATUS

9. Apparatus

9.1 The automated test method shall employ apparatus designed either on the principles of the Blaine air-permeability method (See Note 13) or apparatus based on the air-permeability principles of the Lea and Nurse method (See Note 14).

NOTE 13—Automated apparatus is generally equipped with a microprocessor capable of operating the measuring devices, calculating and displaying the test results. Commercially available units may have significantly different dimensions for manometer and cement bed than those specified by standard methods.

NOTE 14—The Lea and Nurse constant flow rate air permeability method is described in BS 4359: 1971.

10. Calibration of Apparatus

10.1 Follow the manufacturer's directions for calibrating the apparatus (See Note 15). If the apparatus is equipped with more than one cell, each cell will require a separate calibration. The manufacturer's procedure shall detail the method for bed preparation and the steps required to initiate the automated measurement. It is essential that the procedure be followed precisely and consistently for all tests.

NOTE 15—The manufacturer of the apparatus will generally provide standard samples that can be used for calibration.

11. Procedure

11.1 *Temperature of Cement*—The cement sample shall be at room temperature when tested.

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TABLE 3 Time of Airflow

T = time of airflow in seconds; $\sqrt{T}$ = the factor for use in the equations

T	$\sqrt{T}$	T	$\sqrt{T}$	T	$\sqrt{T}$	T	$\sqrt{T}$	T	$\sqrt{T}$	T	$\sqrt{T}$
26	5.10	51	7.14	76	8.72	101	10.05	151	12.29	201	14.18
26½	5.15	51½	7.18	76½	8.75	102	10.10	152	12.33	202	14.21
27	5.20	52	7.21	77	8.77	103	10.15	153	12.37	203	14.25
27½	5.24	52½	7.25	77½	8.80	104	10.20	154	12.41	204	14.28
28	5.29	53	7.28	78	8.83	105	10.25	155	12.45	205	14.32
28½	5.34	53½	7.31	78½	8.86	106	10.30	156	12.49	206	14.35
29	5.39	54	7.35	79	8.89	107	10.34	157	12.53	207	14.39
29½	5.43	54½	7.38	79½	8.92	108	10.39	158	12.57	208	14.42
30	5.48	55	7.42	80	8.94	109	10.44	159	12.61	209	14.46
30½	5.52	55½	7.45	80½	8.97	110	10.49	160	12.65	210	14.49
31	5.57	56	7.48	81	9.00	111	10.54	161	12.69	211	14.53
31½	5.61	56½	7.52	81½	9.03	112	10.58	162	12.73	212	14.56
32	5.66	57	7.55	82	9.06	113	10.63	163	12.77	213	14.59
32½	5.70	57½	7.58	82½	9.08	114	10.68	164	12.81	214	14.63
33	5.74	58	7.62	83	9.11	115	10.72	165	12.85	215	14.66
33½	5.79	58½	7.65	83½	9.14	116	10.77	166	12.88	216	14.70
34	5.83	59	7.68	84	9.17	117	10.82	167	12.92	217	14.73
34½	5.87	59½	7.71	84½	9.19	118	10.86	168	12.96	218	14.76
35	5.92	60	7.75	85	9.22	119	10.91	169	13.00	219	14.80
35½	5.96	60½	7.78	85½	9.25	120	10.95	170	13.04	220	14.83
36	6.00	61	7.81	86	9.27	121	11.00	171	13.08	222	14.90
36½	6.04	61½	7.84	86½	9.30	122	11.05	172	13.11	224	14.97
37	6.08	62	7.87	87	9.33	123	11.09	173	13.15	226	15.03
37½	6.12	62½	7.91	87½	9.35	124	11.14	174	13.19	228	15.10
38	6.16	63	7.94	88	9.38	125	11.18	175	13.23	230	15.17
38½	6.20	63½	7.97	88½	9.41	126	11.22	176	13.27	232	15.23
39	6.24	64	8.00	89	9.43	127	11.27	177	13.30	234	15.30
39½	6.28	64½	8.03	89½	9.46	128	11.31	178	13.34	236	15.36
40	6.32	65	8.06	90	9.49	129	11.36	179	13.38	238	15.43
40½	6.36	65½	8.09	90½	9.51	130	11.40	180	13.42	240	15.49
41	6.40	66	8.12	91	9.54	131	11.45	181	13.45	242	15.56
41½	6.44	66½	8.15	91½	9.57	132	11.49	182	13.49	244	15.62
42	6.48	67	8.19	92	9.59	133	11.53	183	13.53	246	15.68
42½	6.52	67½	8.22	92½	9.62	134	11.58	184	13.56	248	15.75
43	6.56	68	8.25	93	9.64	135	11.62	185	13.60	250	15.81
43½	6.60	68½	8.28	93½	9.67	136	11.66	186	13.64	252	15.87
44	6.63	69	8.31	94	9.70	137	11.70	187	13.67	254	15.94
44½	6.67	69½	8.34	94½	9.72	138	11.75	188	13.71	256	16.00
45	6.71	70	8.37	95	9.75	139	11.79	189	13.75	258	16.06
45½	6.75	70½	8.40	95½	9.77	140	11.83	190	13.78	260	16.12
46	6.78	71	8.43	96	9.80	141	11.87	191	13.82	262	16.19
46½	6.82	71½	8.46	96½	9.82	142	11.92	192	13.86	264	16.25
47	6.86	72	8.49	97	9.85	143	11.96	193	13.89	266	16.31
47½	6.89	72½	8.51		9.87	144	12.00	194	13.93	268	16.37
48	6.93	73	8.54		9.90	145	12.04	195	13.96	270	16.43
48½	6.96	73½	8.57	98½	9.92	146	12.08	196	14.00	272	16.49
49	7.00	74	8.60	99	9.95	147	12.12	197	14.04	274	16.55
49½	7.04	74½	8.63	99½	9.97	148	12.17	198	14.07	276	16.61
50	7.07	75	8.66	100	10.00	149	12.21	199	14.11	278	16.67
50½	7.11	75½	8.69	100½	10.02	150	12.25	200	14.14	280	16.73

11.2 *Size of the Test Sample*—The mass of the sample used for the test shall be the same as used in the calibration test unless cements of different density or porosity are to be tested and then follow the manufacturer's guidelines for adjusting mass.

11.3 *Permeability Tests*—Make permeability tests using the same procedure used for the calibration tests. Only one determination need be made for each bed preparation.

12. Performance Requirement (Qualification) for the Automated Apparatus

12.1 *Scope*—When the specific surface values determined by an automated apparatus are to be used for acceptance or rejection of cement, the method used shall comply with the qualification requirements of this section. A method is considered to consist of the specific instrument and testing procedure

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meeting the requirements of this standard and used in a consistent manner by a given laboratory.

12.2 *Samples*—Select two cement samples that have surface area and density that bracket the desired test range. The range of the surface area shall not exceed 2000 cm^2/g (200 m^2/kg) and shall have densities that differ no more than 0.06 g/cm^3 (60 Mg/m^3).

12.3 *Tests*—Make triplicate determinations on each cement sample following Test Method A (Reference Method). On the same day, complete a second round of triplicate tests using the method to be qualified (Test Method B) and including the standardization formula described in this section. Prepare a new cell bed and repeat all the steps of the test procedures for each determination. Report values to the nearest 10 cm^2/g (1 m^2/kg).

12.4 *Calculations*—Calculate the range and the mean of the three replicate tests for each method and each cement. A method complies with the qualification requirements if the absolute difference between the average value of Test Method A and the corresponding average value for Test Method B (each with three replicates) is not greater than 2.7 % of the Test Method A average (See Note 16) and the range for any three replicate tests does not exceed 4.0 % of the average (See Note 17). The method is qualified only if both cement samples shall meet the above requirements. Example qualification data are given in Appendix X2.

NOTE 16—This value represents the least-significant-difference (lsd) for 95 % confidence as applied to the coefficient of variation of 1.2 % (Single-Operator-Precision) for Test Method A, given in section 8.1. The equation is:

$$1sd\ (95\ \%) = t_{0.05,\,df}[(2CV^2/n)]^{\frac{1}{2}} \qquad (9)$$

where:

df	=	4, degree of freedom, two from each of the two sets of results
n	=	3, the number of replicates
CV	=	1.2 %, the Single-Operator-Precision, and
$t_{0.05,\,4}$	=	2.776, Students-t statistic for a 5 % probability with a df = 4.

NOTE 17— This value represents the d2s % calculation for 3 replicates in accordance with Table 1 of Practice C 670 and applied to the coefficient of variation of 1.2 % (Single-Operator-Precision) for Test Method A, given in section 8.1.

12.5 *Standardization*:

12.5.1 When standardization is required in order to achieve agreement between Test Method A and Test Method B, standardize the apparatus as follows:

12.5.1.1 Prepare a separate standardization for each type of cement to be tested, using reference samples of density within 0.06 g/cm^3(60 Mg/m^3) of the cement to be tested, and packed to the same bed porosity.

12.5.1.2 For each standardization, obtain five reference samples with a minimum air permeability fineness range of 800 cm^2/g (80 m^2/kg) and a minimum difference between samples of 50 cm^2/g (5 m^2/kg). If cements samples used for qualification are used, make new determinations. Use the same method as used for the instrument qualification and follow all the steps. Valid standardization formulas shall be mathematically derived and applied to all samples.

13. Requalification of a Method

13.1 Requalify the method at least once per year and when any of the following conditions occur:

13.1.1 The instrument has been significantly modified.

13.1.2 The instrument has been substantially repaired.

13.1.3 Substantial evidence indicates that the method is not providing data meeting the performance requirements.

13.1.4 The average of a Cement and Concrete Reference Laboratory (CCRL) proficiency test sample differs from the value obtained by the method by more than 6 %.

14. Precision and Bias

14.1 *Precision*—No precision data are available at this time. Based on qualification requirements, the precision of the method should not be greater than that of Test Method A

14.2 *Bias*—Since there are no acceptable reference materials suitable for determining any bias that may be associated with Test Methods C 204, no statement on bias is presented.

15. Keywords

15.1 air-permeability; apparatus; fineness

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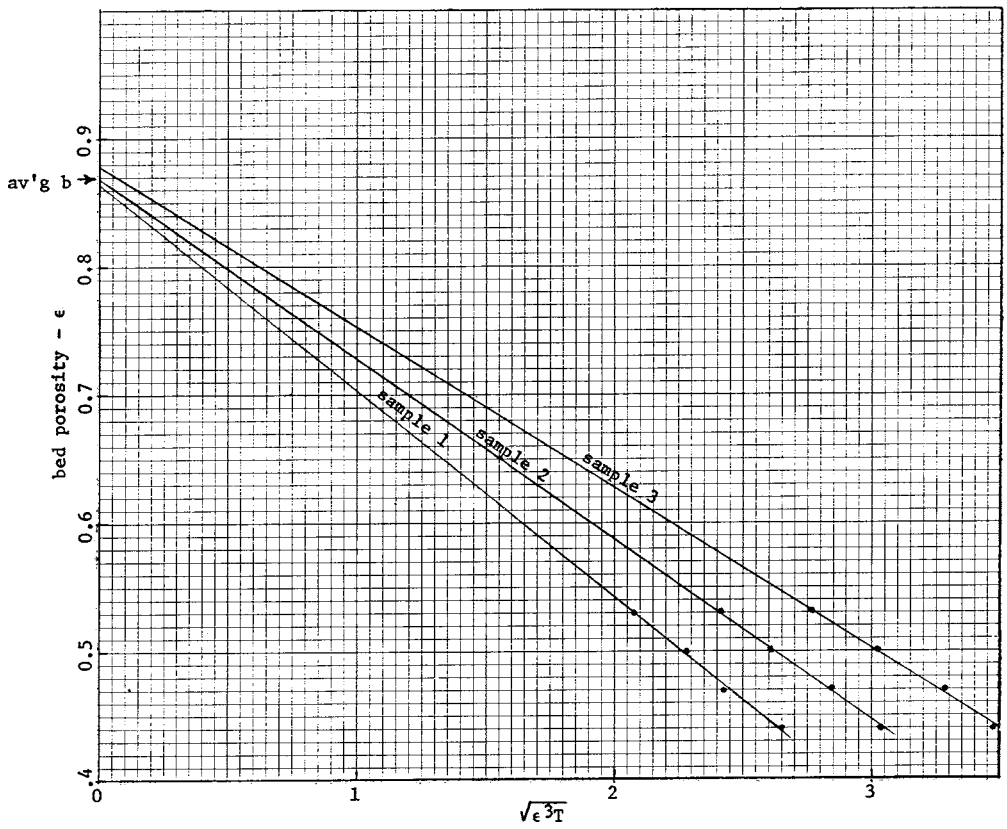
APPENDIXES

(Nonmandatory Information)

X1. ILLUSTRATIVE METHOD FOR THE DETERMINATION OF THE VALUE FOR THE CONSTANT *b*



Material: Silica flour
ρ = density of test sample = 2.65 Mg/m^3
V = bulk volume of sample bed = 1.887 cm^3
ϵ = desired porosity of test
W = grams of sample required = $\rho V(1 - \epsilon)$
T = measured test time interval, seconds

Computed values of b by linear regression:
Sample 1 b = 0.863 (correlation coefficient = 0.9980)
Sample 2 b = 0.869 (correlation coefficient = 0.9993)
Sample 3 b = 0.879 (correlation coefficient = 0.9973)
Average b = 0.870

ϵ	W	T	$\sqrt{\epsilon^3 T}$
		Sample 1	
0.530	2.350	29.0	2.078
0.500	2.500	42.0	2.291
0.470	2.650	57.5	2.443
0.440	2.800	82.5	2.651
		Sample 2	
0.530	2.350	39.0	2.410
0.500	2.500	55.5	2.634
0.470	2.650	79.0	2.864
0.440	2.800	108.5	3.040
		Sample 3	
0.530	2.350	51.5	2.769
0.500	2.500	73.0	3.021
0.470	2.650	104.0	3.286
0.440	2.800	141.5	3.472

FIG. X1.1 Illustrative Method for the Determination of the Value for the Constant *b* (for use in fineness calculations of materials other than portland cement)

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X2. SAMPLE QUALIFICATION RESULTS

TABLE X2.1 Sample Qualification Results

Cement	Tests	Test Method A cm^2/g (m^2/kg)	Test Method B cm^2/g (m^2/kg)	Difference
A	1	3120 (312)	3130 (313)	
A	2	3130 (313)	3160 (316)	
A	3	3090 (309)	3140 (314)	
	Avg.	3113 (311.3)	3143 (314.3)	30
	Range Max.	40 (4)	30 (3)	
	4.0 % of Avg.	1.3 % (Pass)	1.0 % (Pass)	
	Max. Difference		(30 × 100)/3113 =	
	2.7 % of Test Method A Avg.		or	
			3 × 100)/311.3 =	0.9 % (Pass)

Cement	Tests	Test Method A cm^2/g (m^2/kg)	Test Method B cm^2/g (m^2/kg)	Difference
B	1	4180 (418)	4160 (416)	
B	2	4030 (403)	4150 (415)	
B	3	4060 (406)	4210 (421)	
	Avg.	4090 (409.0)	4173 (417.3)	83
	Range Max.	150	60	
	4.0 % of Avg.	3.7 % (Pass)	1.4 % (Pass)	
	Max. Difference		(83 × 100)/4090 =	2.0 % (Pass)
	2.7 % of Test Method A Avg.		or	
			(8.3 × 100)/409 =	

SUMMARY OF CHANGES

Committee C01 has identified the location of selected changes to these test methods since the last issue, C 204 – 05, that may impact the use of these test methods. (Approved August 1, 2007)

(*1*) Revised 3.6 and 3.7.

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Designation: C 206 – 03

Standard Specification for Finishing Hydrated Lime[1]

This standard is issued under the fixed designation C 206; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

This standard has been approved for use by agencies of the Department of Defense.

1. Scope

1.1 This specification covers two types of finishing hydrated lime that are suitable for use in the scratch, brown, and finish coats of plaster, for stucco, for mortar, and as an addition to portland-cement concrete. The two types of lime sold under this specification shall be designated as follows:

1.1.1 *Type N*—Normal hydrated lime for finishing purposes, and

1.1.2 *Type S*—Special hydrated lime for finishing purposes.

NOTE 1—Type N, normal finishing hydrated lime, is differentiated from Type S, special finishing hydrated lime, in that no limitation on the amount of unhydrated oxides is specified for Type N hydrate, and the plasticity requirement for Type N hydrate shall be determined after soaking for 16 to 24 h.

NOTE 2—For lime putty, refer to Specification C 1489.

2. Referenced Documents

2.1 *ASTM Standards:*

C 25 Test Methods for Chemical Analysis of Limestone, Quicklime, and Hydrated Lime[2]

C 50 Methods of Sampling, Inspection, Packing, and Marking of Lime and Limestone Products[2]

C 51 Terminology Relating to Lime and Limestone (As Used by the Industry)[2]

C 110 Test Methods for Physical Testing of Quicklime, Hydrated Lime, and Limestone[2]

C 842 Specification for Application of Interior Gypsum Plaster[2]

C 1489 Specification of Lime Putty for Structural Purposes[2]

3. Terminology

3.1 *Definitions*—For definitions of terms relating to hydrated lime, refer to Terminology C 51.

4. Chemical Composition

4.1 Hydrated lime for finishing purposes shall conform to the following requirements as to chemical composition:

	Type N	Type S
Calcium and magnesium oxides (nonvolatile basis), min, %	95	95
Carbon dioxide (as-received basis), max, %		
If sample is taken at the place of manufacture	5	5
If sample is taken at any other place	7	7
Unhydrated oxides (as-received basis), max, %	...	8

5. Residue

5.1 The percentage residue of finishing hydrated lime shall conform to the following requirements:

Residue retained on No. 30 (600-μm) sieve, max, %	0.5
Residue retained on No. 200 (75-μm) sieve, max, %	15

6. Popping and Pitting

6.1 Finishing hydrated lime shall show no pops or pits when tested in accordance with the method prescribed in 10.1.2.

7. Plasticity

7.1 The putty made from Type N, normal finishing hydrated lime, shall have a plasticity figure of not less than 200 when soaked for a period of not less than 16 h nor more than 24 h.

7.2 The putty made from Type S, special finishing hydrated lime, shall have a plasticity figure of not less than 200 when tested commencing within 30 min after mixing with water.

8. Application of Interior Gypsum Plaster

8.1 For recommended application procedures refer to Specification C 842.

9. Sampling, Inspection, etc.

9.1 The sampling, inspection, rejection, retesting, packing, and marking shall be conducted in accordance with Methods C 50.

10. Test Methods

10.1 The properties enumerated in this specification shall be determined in accordance with the following methods:

10.1.1 *Chemical Analysis*—Test Methods C 25.

10.1.2 *Physical Tests*—Test Methods C 110.

11. Package Marking

11.1 Type N hydrated lime, in bags, conforming to this specification, shall be soaked for a minimum of 16 h prior to use.

[1] This specification is under the jurisdiction of ASTM Committee C07 on Lime and is the direct responsibility of Subcommittee C07.02 on Structural Lime.

Current edition approved May 10, 2003. Published July 2003. Originally approved in 1946. Replaces C 6 – 49 (1974). Last previous edition approved in 1997 as C 206 – 84 (1997).

[2] *Annual Book of ASTM Standards*, Vol 04.01.

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12. Keywords

12.1 finishing lime; masonry; plaster; plasticity; popping and pitting; residue; Type N; Type S; unhydrated oxides

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Designation: C 207 – 06

Standard Specification for Hydrated Lime for Masonry Purposes[1]

This standard is issued under the fixed designation C 207; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

This standard has been approved for use by agencies of the Department of Defense.

1. Scope

1.1 This specification covers four types of hydrated lime. Types N and S are suitable for use in mortar, in scratch and brown coats of cement plaster, for stucco, and for addition to portland-cement concrete. Types NA and SA are air-entrained hydrated limes that are suitable for use in any of the above uses where the inherent properties of lime and air-entrainment are desired. The four types of lime sold under this specification shall be designated as follows:

1.1.1 *Type N*—Normal hydrated lime for masonry purposes.

1.1.2 *Type S*—Special hydrated lime for masonry purposes.

1.1.3 *Type NA*—Normal air-entraining hydrated lime for masonry purposes.

1.1.4 *Type SA*—Special air-entraining hydrated lime for masonry purposes.

NOTE 1—Type S, special hydrated lime, and Type SA, special air-entraining hydrated lime, are differentiated from Type N, normal hydrated lime, and Type NA, normal air-entraining hydrated lime, principally by their ability to develop high, early plasticity and higher water retentivity, and by a limitation on their unhydrated oxide content.

NOTE 2—For normal (Type N) and special (Type S) finishing hydrated lime, refer to Specification C 206.

NOTE 3—Some building codes prohibit the use of air-entraining materials in mortar, because of the accompanying reduction in bond and compressive strength. Where increased freeze-thaw resistance is important, air-entraining may be beneficial. Air-entraining lime should not be used as a finishing lime.

NOTE 4—For lime putty, refer to Specification C 1489.

1.2 This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.

2. Referenced Documents

2.1 *ASTM Standards:* [2]

C 25 Test Methods for Chemical Analysis of Limestone, Quicklime, and Hydrated Lime

C 50 Practice for Sampling, Sample Preparation, Packaging, and Marking of Lime and Limestone Products

C 110 Test Methods for Physical Testing of Quicklime, Hydrated Lime, and Limestone

C 206 Specification for Finishing Hydrated Lime

C 226 Specification for Air-Entraining Additions for Use in the Manufacture of Air-Entraining Hydraulic Cement

C 778 Specification for Sand

C 1489 Specification for Lime Putty for Structural Purposes

3. Terminology

3.1 *Definitions:*

3.1.1 *standard mortar*, *n*—a mortar containing only hydrated lime and sand meeting the requirements of Specification C 778. The mortar proportions are one part hydrated lime to three parts of sand by volume as indicated in Table 4 of Test Methods C 110.

4. Additions

4.1 Types NA and SA hydrated lime covered by this specification shall contain additives for the purpose of entraining air, and such additives shall conform to the requirements of Specification C 226.

5. Manufacturer's Statement

5.1 At the request of the purchaser, the manufacturer shall state in writing the nature, amount, and identity of the air-entraining agent used and of any processing addition that may have been used, and also, if requested, shall supply test data showing compliance of such air-entraining addition with the provisions of Specification C 226.

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[1] This specification is under the jurisdiction of ASTM Committee C07 on Lime and is the direct responsibility of Subcommittee C07.02 on Structural Lime.

Current edition approved Jan. 1, 2006. Published January 2006. Originally approved in 1946. Last previous edition approved in 2005 as C 207 – 05.

[2] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

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6. Chemical Composition

6.1 Hydrated lime for masonry purposes shall conform to the following requirements as to chemical composition:

	Hydrate Types:			
	N	NA	S	SA
Calcium and magnesium oxides (nonvolatile basis), min, %	95	95	95	95
Carbon dioxide (as-received basis), max, %:				
If sample is taken at place of manufacture	5	5	5	5
If sample is taken at any other place	7	7	7	7
Unhydrated oxides (as-received basis), max, %	···	···	8	8

7. Residue, Popping, and Pitting

7.1 The four types of hydrated lime for masonry purposes shall conform to one of the following requirements:

7.1.1 The residue retained on a No. 30 (600-µm) sieve shall not be more than 0.5 %, or

7.1.2 If the residue retained on a No. 30 (600-µm) sieve is over 0.5 %, the lime shall show no pops or pits when tested in accordance with the method prescribed in 12.1.2.

8. Plasticity

8.1 The putty made from Type S, special hydrate, or Type SA, special air-entraining hydrate, shall have a plasticity figure of not less than 200 Elmey units when tested within 30 min after mixing with water using Test Methods C 110.

9. Water Retention

9.1 Hydrated lime mortar made with Type N (normal hydrated lime) or Type NA (normal air-entraining hydrated lime), after suction for 60 s, shall have a water retention value of not less than 75 % when tested in a standard mortar made from the dry hydrate or from putty made from the hydrate which has been soaked for a period of 16 to 24 h.

9.2 Hydrated lime mortar made with Type S (special hydrated lime) or Type SA (special air-entraining hydrated lime), tested in accordance with Section 10 of Test Methods C 110, shall have a water retention value of not less than 85 % when tested in a standard mortar made from the dry hydrate using Test Methods C 110.

10. Air-Entrainment

10.1 The hydrated lime covered by Types N or S in this specification shall contain no additives for the purpose of entraining air. The air content of a standard mortar made with Types N or S shall not exceed 7 % as determined in accordance with the requirements of Section 13 of Test Methods C 110. The air content of standard mortar made with Types NA or SA shall have a minimum of 7 % and a maximum of 12 % when tested in accordance with the requirements of Section 13 of Test Methods C 110.

11. Sampling and Inspection

11.1 The sampling, inspection, rejection, retesting, packaging, and marking shall be conducted in accordance with Practice C 50.

12. Test Methods

12.1 Determine the properties enumerated in this specification in accordance with the following methods:

12.1.1 *Chemical Analysis*— Test Methods C 25.

12.1.2 *Physical Tests*—Test Methods C 110.

13. Special Package Marking

13.1 When Types NA or SA air-entraining hydrated lime are delivered in packages, the name and brand of the manufacturer, the type under this specification, and the words "AIR-ENTRAINING" shall be plainly indicated thereon or in case of bulk shipments, so indicated on shipping notices.

14. Keywords

14.1 hydrated lime; masonry; mortar; plasticity; popping and pitting; residue; stucco; Type N; Type NA; Type S; Type SA; unhydrated oxides; water retention; air entraining

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Designation: C 215 – 08

Standard Test Method for Fundamental Transverse, Longitudinal, and Torsional Resonant Frequencies of Concrete Specimens[1]

This standard is issued under the fixed designation C 215; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

This standard has been approved for use by agencies of the Department of Defense.

1. Scope*

1.1 This test method covers measurement of the fundamental transverse, longitudinal, and torsional resonant frequencies of concrete prisms and cylinders for the purpose of calculating dynamic Young's modulus of elasticity, the dynamic modulus of rigidity (sometimes designated as "the modulus of elasticity in shear"), and dynamic Poisson's ratio.

1.2 The values stated in SI units are to be regarded as standard. No other units of measurement are included in this standard.

1.3 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

2. Referenced Documents

2.1 *ASTM Standards:*[2]

C 31/C 31M Practice for Making and Curing Concrete Test Specimens in the Field

C 42/C 42M Test Method for Obtaining and Testing Drilled Cores and Sawed Beams of Concrete

C 125 Terminology Relating to Concrete and Concrete Aggregates

C 192/C 192M Practice for Making and Curing Concrete Test Specimens in the Laboratory

C 469 Test Method for Static Modulus of Elasticity and Poisson's Ratio of Concrete in Compression

C 670 Practice for Preparing Precision and Bias Statements for Test Methods for Construction Materials

E 1316 Terminology for Nondestructive Examinations

3. Terminology

3.1 *Definitions*—Refer to Terminology C 125 and the section related to ultrasonic examination in Terminology E 1316 for definitions of terms used in this test method.

4. Summary of Test Method

4.1 The fundamental resonant frequencies are determined using one of two alternative procedures: (*1*) the forced resonance method or (*2*) the impact resonance method. Regardless of which testing procedure is selected, the same procedure is to be used for all specimens of an associated series.

4.2 In the forced resonance method, a supported specimen is forced to vibrate by an electro-mechanical driving unit. The specimen response is monitored by a lightweight pickup unit on the specimen. The driving frequency is varied until the measured specimen response reaches a maximum amplitude. The value of the frequency causing maximum response is the resonant frequency of the specimen. The fundamental frequencies for the three different modes of vibration are obtained by proper location of the driver and the pickup unit.

4.3 In the impact resonance method, a supported specimen is struck with a small impactor and the specimen response is measured by a lightweight accelerometer on the specimen. The output of the accelerometer is recorded. The fundamental frequency of vibration is determined by using digital signal processing methods or counting zero crossings in the recorded waveform. The fundamental frequencies for the three different modes of vibration are obtained by proper location of the impact point and the accelerometer.

5. Significance and Use

5.1 This test method is intended primarily for detecting significant changes in the dynamic modulus of elasticity of laboratory or field test specimens that are undergoing exposure

[1] This test method is under the jurisdiction of ASTM Committee C09 on Concrete and Concrete Aggregates and is the direct responsibility of Subcommittee C09.64 on Nondestructive and In-Place Testing.

Current edition approved Oct. 1, 2008. Published November 2008. Originally approved in 1947. Last previous edition approved in 2002 as C 215 – 02.

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***A Summary of Changes section appears at the end of this standard.**

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to weathering or other types of potentially deteriorating influences. The test method may also be used to monitor the development of dynamic elastic modulus with increasing maturity of test specimens.

5.2 The value of the dynamic modulus of elasticity obtained by this test method will, in general, be greater than the static modulus of elasticity obtained by using Test Method C 469. The difference depends, in part, on the strength level of the concrete.

5.3 The conditions of manufacture, the moisture content, and other characteristics of the test specimens (see section on Test Specimens) materially influence the results obtained.

5.4 Different computed values for the dynamic modulus of elasticity may result from widely different resonant frequencies of specimens of different sizes and shapes of the same concrete. Therefore, it is not advisable to compare results from specimens of different sizes or shapes.

6. Apparatus

6.1 *Forced Resonance Apparatus (Fig. 1)*:

6.1.1 *Driving Circuit*—The driving circuit shall consist of a variable frequency audio oscillator, an amplifier, and a driving unit. The oscillator shall be calibrated to read within ±2 % of the true frequency over the range of use (about 100 to 10 000 Hz). The combined oscillator and amplifier shall be capable of delivering sufficient power output to induce vibrations in the test specimen at frequencies other than the fundamental and shall be provided with a means for controlling the output. The driving unit for creating the vibration in the specimen shall be capable of handling the full power output of the oscillator and amplifier. The driving unit is used in contact with the test specimen or separated from the specimen by an air gap. When the test specimen is contact-driven, the vibrating parts of the driving unit shall be small in mass compared with that of the specimen. The oscillator and amplifier shall be capable of producing a voltage that does not vary more than ±20 % over the frequency range and, in combination with the driving unit, shall be free from spurious resonances that will be indicated in the output.

NOTE 1—It is recommended that the calibration of the variable frequency audio oscillator be checked periodically against signals transmitted by the National Institute of Standards and Technology radio station WWV, or against suitable electronic equipment such as a frequency counter, the calibration of which has been previously checked and found to be adequate.

6.1.2 *Pickup Circuit*—The pickup circuit shall consist of a pickup unit, an amplifier, and an indicator. The pickup unit shall generate a voltage proportional to the displacement, velocity, or acceleration of the test specimen, and the vibrating parts shall be small in mass compared with the mass of the test specimen. The pickup unit shall be free from spurious resonances in the normal operating range. Either a piezoelectric or magnetic pickup unit meeting these requirements is acceptable. The amplifier shall have a controllable output of sufficient magnitude to actuate the indicator. The indicator shall consist of a voltmeter, milliammeter, or a real-time graphic display such as an oscilloscope or a data acquisition system with monitor (see Note 2).

NOTE 2—For routine testing of specimens whose fundamental frequency may be anticipated within reasonable limits, a meter-type indicator is satisfactory and may be more convenient to use than an oscilloscope or computer monitor. It is, however, strongly recommended that whenever feasible a graphic display be provided for supplementary use or to replace the meter-type indicator. The use of a graphic display as an indicator may be necessary when specimens are to be tested for which the fundamental frequency range is unpredictable. The graphic display is valuable also for checking the equipment for drift and for use in the event that it should be desired to use the equipment for certain other purposes than those specifically contemplated by this test method.

6.1.3 *Specimen Support*—The support shall permit the specimen to vibrate freely (Note 3). The location of the nodal points for the different modes of vibration are described in Notes 4, 5, and 6. The support system shall be dimensioned so that its resonant frequency falls outside the range of use (from 100 to 10 000 Hz).

NOTE 3—This may be accomplished by placing the specimen on soft rubber supports located near the nodal points or on a thick pad of sponge rubber.

6.2 *Impact Resonance Apparatus (Fig. 2)*:

6.2.1 *Impactor*—The impactor shall be made of metal or rigid plastic and shall produce an impact duration that is sufficiently short to excite the highest resonant frequency to be measured. The manufacturer shall indicate the maximum resonant frequency that can be excited when the impactor strikes a concrete specimen with surfaces formed by a metal or plastic mold.

NOTE 4—A 19 mm diameter solid steel ball mounted on a thin rod to produce a hammer is capable of exciting resonant frequencies up to about 10 kHz when impacting a smooth concrete surface. A 110 g steel ball peen hammer may act similarly. Larger steel balls will reduce the maximum

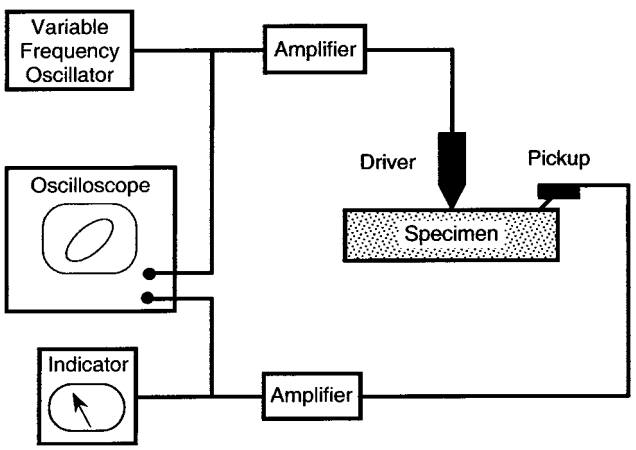

FIG. 1 Schematic of Apparatus for Forced Resonance Test

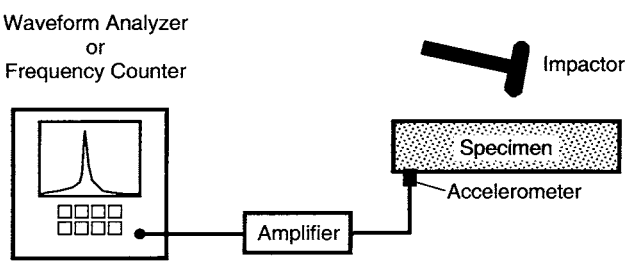

FIG. 2 Schematic of Apparatus for Impact Resonance Test

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resonant frequencies that can be excited.

6.2.2 *Sensor*—The sensor shall be a piezoelectric accelerometer with a mass less than 30 g and having an operating frequency range from 100 to 10 000 Hz. The resonant frequency of the accelerometer shall be at least two times the maximum operating frequency.

6.2.3 *Frequency Analyzer*—Determine the frequency of the specimen vibration by using either a digital waveform analyzer or a frequency counter to analyze the signal measured by the sensor. The waveform analyzer shall have a sampling rate of at least 20 kHz and shall record at least 1024 points of the waveform. The frequency counter shall have an accuracy of ±1 % over the range of use.

6.2.4 *Specimen Support*—Support shall be provided as specified in 6.1.3 for the forced resonance method.

7. Test Specimens

7.1 *Preparation*—Make the cylindrical or prismatic test specimens in accordance with Practice C 192/C 192M, Practice C 31/C 31M, Test Method C 42/C 42M, or other specified procedures.

7.2 *Measurement of Mass and Dimensions*—Determine the mass and average length of the specimens within ±0.5 %. Determine the average cross-sectional dimensions within ±1 %.

7.3 *Limitations on Dimensional Ratio*—Specimens having either small or large ratios of length to maximum transverse direction are frequently difficult to excite in the fundamental mode of vibration. Best results are obtained when this ratio is between 3 and 5. For application of the formulas in this test method, the ratio must be at least 2.

8. Determination of Resonant Frequencies—Forced Resonance Method

8.1 *Transverse Frequency*:

8.1.1 Support the specimen so that it is able to vibrate freely in the transverse mode (Note 5). Position the specimen and driver so that the driving force is perpendicular to the surface of the specimen. Locate the driving unit at the approximate middle of the specimen. Place the pickup unit on the specimen so that the direction of pickup sensitivity coincides with the vibration direction, that is, the transverse direction (see Fig. 3a). Position the pickup near one end of the specimen. It is permissible to position the driver on the vertical face so that the specimen vibrates perpendicular to the direction shown in Fig. 3a.

8.1.2 Force the test specimen to vibrate at varying frequencies. At the same time, observe the indication of the amplified output of the pickup. Record the fundamental transverse frequency of the specimen, which is the frequency at which the indicator shows the maximum reading and observation of nodal points indicates fundamental transverse vibration (Note 5). Adjust the amplifiers in the driving and pickup circuits to

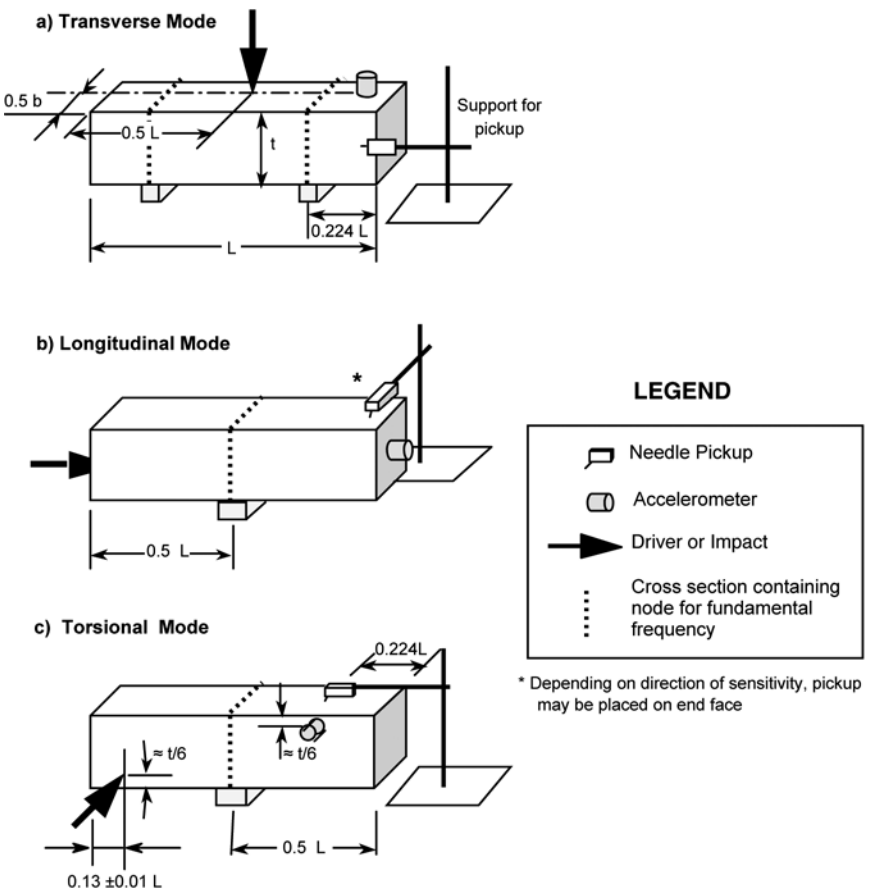

FIG. 3 Locations of Driver (or Impact) and Needle Pickup (or Accelerometer)

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provide a satisfactory indication. To avoid distortion, maintain the driving force as low as is feasible for good response at resonance.

NOTE 5—For fundamental transverse vibration, the nodal points are located 0.224 of the length of the specimen from each end (approximately the quarter points). Vibrations are a maximum at the ends, approximately three fifths of the maximum at the center, and zero at the nodal points; therefore, movement of the pickup along the length of the specimen will inform the operator whether the vibrations observed in the indicator are from the specimen vibrating in its fundamental transverse mode. An oscilloscope may also be used to determine whether the specimen is vibrating in its fundamental transverse mode. The driver signal is connected to the horizontal sweep and the pickup signal is connected to the vertical sweep of the oscilloscope. When the pickup is located at the end of the specimen, which is vibrating in its fundamental transverse mode, the oscilloscope will display an inclined elliptical pattern. When the pickup is placed at a node, the oscilloscope displays a horizontal line. When the pickup is placed at the center of the specimen, the display will be an elliptical pattern but inclined in the opposite direction to when the pickup was placed at the end of the specimen. The oscilloscope can also be used to verify that the driving frequency is the fundamental resonant frequency. Resonance can occur when the driving frequency is a fraction of the fundamental frequency. In this case, however, the oscilloscope pattern will not be an ellipse.

8.2 *Longitudinal Frequency*:

8.2.1 Support the specimen so that it is able to vibrate freely in the longitudinal mode (Note 6). Position the specimen and driver so that the driving force is perpendicular to and approximately at the center of one end surface of the specimen. Place the pickup unit on the specimen so that the direction of pickup sensitivity coincides with the vibration direction, that is, the longitudinal axis of the specimen (see Fig. 3b).

8.2.2 Force the test specimen to vibrate at varying frequencies. At the same time, observe the indication of the amplified output of the pickup. Record the fundamental longitudinal frequency of the specimen, which is the frequency at which the indicator shows the maximum reading and observation of the nodal point indicates fundamental longitudinal vibration (Note 6).

NOTE 6—For the fundamental longitudinal mode, there is one node at the center of length of the specimen. Vibrations are a maximum at the ends.

8.3 *Torsional Frequency*:

8.3.1 Support the specimen so that it is able to vibrate freely in the torsional mode (Note 7). Position the specimen and driver so that the driving force is perpendicular to the surface of the specimen. For prismatic specimens, locate the driving unit near the upper or lower edge of the specimen at a distance from the end that is 0.13 ± 0.01 of the length of the specimen and approximately ⅙ of the depth of the specimen from the edge (see Fig. 3c). For cylindrical specimens, locate the driving unit above or below the mid-line of the cylinder. Place the pickup unit on the surface of the specimen at a position on the opposite end that coincides with the node point for fundamental transverse vibration (see Fig. 3a). Position the pickup so that the direction of pickup sensitivity coincides with the vibration direction, that is, perpendicular to the longitudinal axis of the specimen.

8.3.2 Force the test specimen to vibrate at varying frequencies. At the same time, observe the indication of the amplified output of the pickup. Record the fundamental torsional frequency of the specimen, which is the frequency at which the indicator shows the maximum reading and observation of the nodal point indicates fundamental torsional vibration (Note 7).

NOTE 7—For the fundamental torsional mode, there is one node at the center of the specimen. Vibrations are maximum at the ends. Locating the driving unit and pickup as shown in Fig. 3c minimizes interferences from transverse vibrations that can occur simultaneously with torsional vibration.

9. Determination of Resonant Frequencies—Impact Resonance Method

9.1 *Transverse Frequency*:

9.1.1 Support the specimen so that it is able to vibrate freely in the transverse mode (Note 5). Attach the accelerometer near the end of the specimen as shown in Fig. 3a.

NOTE 8—The accelerometer may be attached to the specimen using soft wax or other suitable materials, such as glue or grease. If the specimen is wet, an air jet may be used to surface dry the region where the accelerometer is to be attached. Alternatively, the accelerometer may be held in position with a rubber band, but a coupling material should still be used to ensure good contact with the specimen.

9.1.2 Prepare the waveform analyzer or frequency counter for recording data. Set the digital waveform analyzer to a sampling rate of 20 kHz (Note 9) and a record length of 1024 points. Use the accelerometer signal to trigger data acquisition. Using the impactor, strike the specimen perpendicular to the surface and at the approximate middle of the specimen.

NOTE 9—The sampling frequency must be at least twice the resonant frequency of the specimen. A sampling frequency of 20 kHz is applicable to specimens with a resonant frequency less than 10 kHz, which is typical of the usual laboratory specimens. When higher resonant frequencies are involved, increase the sampling frequency accordingly.

9.1.3 Record the resonant frequency indicated by the waveform analyzer (Note 10) or frequency counter. Repeat the test two more times, and record the average transverse resonant frequency. If a frequency measurement deviates from the average value by more than 10 %, disregard that measurement and repeat the test. When using a frequency counter based on zero crossings, delay the start of recording until approximately the first 10 cycles of transverse vibration have occurred (Note 11).

NOTE 10—When using a waveform analyzer, the resonant frequency is the frequency with the highest peak in the amplitude spectrum or the power spectrum obtained from the fast Fourier transform of the recorded accelerometer signal. The fundamental resonant frequency can be verified by impacting the specimen at one of the nodal points. The amplitude spectrum should show a small or no peak at the value of the fundamental frequency.

NOTE 11—Care should be exercised when using a test instrument based on the zero-crossing method to evaluate the resonant frequency of a specimen that is undergoing degradation, such as by cycles of freezing and thawing. As the specimen degrades, the damping value increases and the amplitude of vibration after impact decays more rapidly compared with an undamaged specimen. For accurate determination of frequency, the duration of the sampling time must be compatible with the decay time of the specimen. In addition, a lower number of cycles of delay prior to starting the sampling record may be acceptable.

9.2 *Longitudinal Frequency*:

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9.2.1 Support the specimen so that it is able to vibrate freely in the longitudinal mode (Note 6). Attach the accelerometer (Note 8) at the approximate center of one end surface of the specimen as shown in Fig. 3b.

9.2.2 Prepare the waveform analyzer or frequency counter for recording data. Set the digital waveform analyzer to a sampling rate of 20 kHz (Note 10) and a record length of 1024 points. Use the accelerometer signal to trigger data acquisition. Using the impactor, strike the specimen perpendicular to and at the approximate center of the end surface without the accelerometer.

9.2.3 Record the resonant frequency indicated by the waveform analyzer (Note 10) or frequency counter. Repeat the test two more times, and record the average longitudinal resonant frequency. If a frequency measurement deviates from the average value by more than 10 %, disregard that measurement and repeat the test. When using a frequency counter based on zero crossings, delay the start of recording until approximately the first 30 cycles of longitudinal vibration have occurred, and ensure a perpendicular impact with the surface (Note 11).

9.3 *Torsional Frequency*:

9.3.1 Support the specimen so that it is able to vibrate freely in the torsional mode (Note 7). For a prismatic specimen, attach the accelerometer near an edge of the specimen at a cross section that contains a node point for fundamental transverse vibration as shown in Fig. 3c. For a cylindrical specimen, mount the accelerometer so that its direction of sensitivity is tangential to a circular cross section that contains a node point for fundamental transverse vibration.

NOTE 12—One approach is to attach the accelerometer to a tab glued to the cylinder as shown in Fig. 4.

9.3.2 Prepare the waveform analyzer or frequency counter for recording data. Set the digital waveform analyzer to a sampling rate of 20 kHz (Note 10) and a record length of 1024 points. Use the accelerometer signal to trigger data acquisition. For prismatic specimens, strike the specimen with the impactor at a point near the upper or lower edge of the specimen at a distance from the end that is 0.13 ± 0.01 of the length of the specimen and approximately 1⁄6 of the depth of the specimen from the edge (see Fig. 3c). For cylindrical specimens, strike the specimen tangentially to the surface at a similar distance from the end as shown in Fig. 4.

9.3.3 Record the resonant frequency indicated by the waveform analyzer (Note 10) or frequency counter. Repeat the test two more times, and record the average torsional resonant frequency. If a frequency measurement deviates from the average value by more than 10 %, disregard that measurement and repeat the test. When using a frequency counter based on zero crossings, delay the start of recording until approximately the first 10 cycles of torsional vibration have occurred (Note 11).

10. Calculation

10.1 Calculate dynamic Young's modulus of elasticity, E, in pascals from the fundamental transverse frequency, mass, and dimensions of the test specimen as follows:

$$\text{Dynamic } E = CMn^2 \quad (1)$$

where:

M = mass of specimen, kg,
n = fundamental transverse frequency, Hz,
C = $1.6067\ (L^3T/d^4)$, m^{-1} for a cylinder, or
= $0.9464\ (L^3T/bt^3)$, m^{-1} for a prism,
L = length of specimen, m,
d = diameter of cylinder, m,
t, b = dimensions of cross section of prism, m, t being in the direction in which it is driven, and
T = correction factor that depends on the ratio of the radius of gyration, K (the radius of gyration for a cylinder is $d/4$ and for a prism is $t/3.464$), to the length of the specimen, L, and on Poisson's ratio. Table 1 gives values of T for various values of K/L and Poisson's ratio.

10.2 Calculate dynamic Young's modulus of elasticity, E, in pascals from the fundamental longitudinal frequency, mass, and dimensions of the test specimen as follows:

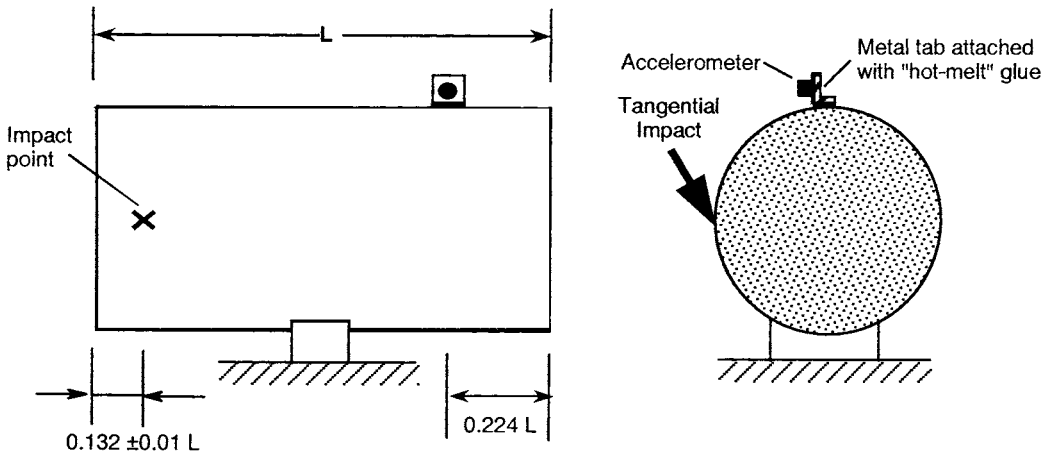

FIG. 4 Locations of Impact and Accelerometer for Torsional Mode of a Cylinder

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TABLE 1 Values of Correction Factor, *T*

K/L	Value of T^A			
	μ = 0.17	μ = 0.20	μ = 0.23	μ = 0.26
0.00	1.00	1.00	1.00	1.00
0.01	1.01	1.01	1.01	1.01
0.02	1.03	1.03	1.03	1.03
0.03	1.07	1.07	1.07	1.07
0.04	1.13	1.13	1.13	1.14
0.05	1.20	1.20	1.21	1.21
0.06	1.28	1.28	1.29	1.29
0.07	1.38	1.38	1.39	1.39
0.08	1.48	1.49	1.49	1.50
0.09	1.60	1.61	1.61	1.62
0.10	1.73	1.74	1.75	1.76
0.12	2.03	2.04	2.05	2.07
0.14	2.36	2.38	2.39	2.41
0.16	2.73	2.75	2.77	2.80
0.18	3.14	3.17	3.19	3.22
0.20	3.58	3.61	3.65	3.69
0.25	4.78	4.84	4.89	4.96
0.30	6.07	6.15	6.24	6.34

[A]Values of *T* for Poisson's ratio of 0.17 are derived from Fig. 1 of the paper by Gerald Pickett, "Equations for Computing Elastic Constants from Flexural and Torsional Resonant Frequencies of Vibration of Prisms and Cylinders," *Proceedings*, ASTEA, Am. Soc. Testing Mats., Vol 45, 1945, pp. 846–863.

Poisson's ratio for water-saturated concrete may be higher than 0.17. The correction factor, *T′*, for other values of Poisson's ratio, μ, and given *K/L*, are calculated from the following relationship:

$$T' = T\left[\frac{1 + (0.26\mu + 3.22\mu^2)K/L}{1 + 0.1328\ K/L}\right]$$

where *T* is the value for μ = 0.17 shown in the second column of Table 1 for the given *K/L*.

$$\text{Dynamic } E = DM(n')^2 \tag{2}$$

where:

n' = fundamental longitudinal frequency, Hz, and
D = 5.093 (L/d^2), m^{-1} for a cylinder, or
= 4 (L/bt), m^{-1} for a prism.

10.3 Calculate dynamic modulus of rigidity, *G*, in pascals from the fundamental torsional frequency, mass, and dimensions of the test specimen as follows:

$$\text{Dynamic } G = BM(n'')^2 \tag{3}$$

where:

n'' = fundamental torsional frequency, Hz,
B = $(4LR/A)$, m^{-1},
R = shape factor,
= 1 for a circular cylinder,
= 1.183 for a square cross-section prism,
= $(a/b + b/a)/[4a/b - 2.52(a/b)^2 + 0.21(a/b)^6]$ for a rectangular prism whose cross-sectional dimensions are *a* and *b*, m, with *a* less than *b*, and
A = cross-sectional area of test specimen, m^2.

10.4 Calculate the dynamic Poisson's ratio, the ratio of lateral to longitudinal strain for an isotropic solid, μ, as follows:

$$\mu = (E/2G) - 1 \tag{4}$$

NOTE 13—Values for Poisson's ratio for concrete normally vary between about 0.10 for dry specimens and 0.25 for saturated specimens. Higher values are expected for concrete tested at early ages.

11. Report

11.1 Report the following for each specimen:
11.1.1 Identification number,
11.1.2 Cross-sectional dimensions within 0.1 %,
11.1.3 Length within 0.5 %,
11.1.4 Mass within 0.5 %,
11.1.5 Description of any defects that were present, and
11.1.6 Mode of vibration and corresponding resonant frequency to the nearest 10 Hz.

11.2 If the dynamic Young's modulus of elasticity or dynamic modulus of rigidity are calculated, report to the nearest 0.5 GPa.

11.3 If the dynamic Poisson's ratio is calculated, report to the nearest 0.01.

12. Precision and Bias

12.1 The data used to develop the precision statements were obtained using an earlier inch-pound version of this test method.

12.2 *Precision of Forced Resonance Method*—The following precision statements are for fundamental transverse frequency only, determined on concrete prisms as originally cast. They do not necessarily apply to concrete prisms after they have been subjected to freezing-and-thawing tests. At the present time, data appropriate for determining precision of fundamental torsional and longitudinal frequencies are not available.

12.2.1 *Single-Operator Precision*—Criteria for judging the acceptability of measurements of fundamental transverse frequency obtained by a single operator in a single laboratory on concrete specimens made from the same materials and subjected to the same conditions are given in Table 2. These limits apply over the range of fundamental transverse frequency from 1400 to 3300 Hz. The different specimen sizes represented by the data include the following (the first dimension is the direction of vibration):

76 by 102 by 406 mm
102 by 76 by 406 mm
89 by 114 by 406 mm
76 by 76 by 286 mm
102 by 89 by 406 mm
76 by 76 by 413 mm

NOTE 14—The coefficients of variation for fundamental transverse frequency have been found to be relatively constant over the range of frequencies given for a range of specimen sizes and age or condition of the concrete, within limits.

TABLE 2 Test Results for Single Operator in a Single Laboratory

	Coefficient of Variation, %[A]	Acceptable Range of Two Results, % of Average[A]
Within-batch single specimen	1.0	2.8
Within-batch average of 3 specimens[B]	0.6	1.7
Between-batch, average of 3 specimens per batch	1.0	2.8

[A]These numbers represent, respectively, the 1s % and d2s % limits as described in Practice C 670.
[B]Calculated as described in Practice C 670.

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12.2.2 *Multilaboratory Precision*—The multilaboratory coefficient of variation for averages of three specimens from a single batch of concrete has been found to be 3.9 % for fundamental transverse frequencies over the range from 1400 to 3300 Hz (Note 15). Therefore, two averages of three specimens from the same batch tested in different laboratories should not differ by more than 11.0 % of their common average (see Note 15).

NOTE 15—These numbers represent, respectively, the 1s % and d2s % limits as described in Practice C 670.

12.3 *Precision of Impact Resonance Method*—The precision of this test method has yet to be determined. Experience, however, has shown that, when a frequency analyzer is used, replicate tests on the same specimen result in resonant frequency values that are within ± 1 digital step of each other (Note 16).

NOTE 16—The digital step in the amplitude spectrum equals the sampling frequency divided by number of points in the time domain waveform. For example, for a sampling frequency of 20 kHz (50-μs sample interval) and 1024 points in the waveform, the digital step is 20 000/1024 = 19.5 Hz.

12.4 *Bias*—The bias of either the forced resonance method or the impact resonance method has not been determined because there are no reference samples available.

13. Keywords

13.1 dynamic modulus of rigidity; dynamic Poisson's ratio; dynamic Young's modulus of elasticity; forced resonance; fundamental resonant frequency; impact resonance; nondestructive testing

SUMMARY OF CHANGES

Committee C09 has identified the location of selected changes to this test method since the last issue, C 215 – 02, that may impact the use of this test method. (Approved October 1, 2008)

(*1*) Simplified the units for the factors B, C, and D.
(*2*) Clarified that the values of *T* in Table 1 are for different values of Poisson's ratio in 10.1.
(*3*) Added the adjective "dynamic" in 10.4 and deleted 10.4.1.
(*4*) Revised the requirement of a suitable impactor in 6.2.1 so that it is performance based and added a requirement that the manufacturer needs to indicate the maximum resonant frequency that can be excited by the impactor.
(*5*) Added new Note 4 to illustrate an example of a suitable impactor.
(*6*) Revised 8.3.1, 9.3.2, and Fig. 3 to indicate that the point of excitation for the torsional mode should be near an edge of a prismatic specimen.
(*7*) Moved the last sentence of 9.3.1 into new Note 12.
(*8*) Revised 5.1 by adding that the test method can be used to monitor the development of elastic modulus.

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Designation: C 219 – 07a

Standard Terminology Relating to Hydraulic Cement[1]

This standard is issued under the fixed designation C 219; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope*

1.1 This terminology defines terms relating to hydraulic cements, their components, characteristics, properties, and the testing thereof. Some terms may have wider application than just to hydraulic cement.

1.2 See individual standards for terms applicable primarily therein, including meanings that may be more restrictive than those given here, and for explanations and descriptions of terms as they apply to those standards.

1.3 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

2. Referenced Documents

2.1 *ASTM Standards:* [2]

C 11 Terminology Relating to Gypsum and Related Building Materials and Systems

C 51 Terminology Relating to Lime and Limestone (as used by the Industry)

C 125 Terminology Relating to Concrete and Concrete Aggregates

C 294 Descriptive Nomenclature for Constituents of Concrete Aggregates

C 1328 Specification for Plastic (Stucco) Cement

C 1329 Specification for Mortar Cement

2.2 *ACI Standard:*

ACI 116R Cement and Concrete Terminology[3]

3. Significance and Use

3.1 In definitions of cements, ingredients are cited only when they are inherent to the definition, for example portland-pozzolan cement. For ingredients and their quantity limits, if any, that are permitted or prohibited by a specification for a particular cement, see the applicable specification for that cement.

3.2 In definitions of materials including cements, the method of production is included only if it is inherent to the definition.

3.3 Related terms may be found in other terminology documents such as Terminology C 11, Terminology C 51, Terminology C 125, and ACI 116R.

4. Terminology

addition, *n*—a material that is interground or blended in limited amounts into a hydraulic cement during manufacture.

DISCUSSION—Two classes of additions are recognized as defined below.

functional addition, *n*—an addition introduced to modify one or more properties of a hydraulic cement.

air-entraining addition, *n*—a functional addition that will entrain air in mortar or concrete.

processing addition, *n*—an addition introduced to aid in the manufacture or handling, or both, of a hydraulic cement.

air-entraining addition, *n*—see **addition; functional addition; air-entraining addition**

air content, *n*—of freshly mixed mortar the volume of air (and other gases) in mortar, expressed as a percentage of total volume of mortar.

air-entraining hydraulic cement, *n*—a hydraulic cement containing an air-entraining addition in such amount as to cause air to be entrained in mortar within specified limits when measured by the prescribed method.

alkali equivalent, *n*—deprecated term; see **equivalent alkalies**.

aluminous cement, *n*—deprecated term.

anhydrite, *n*—see **calcium sulfate**.

blast-furnace slag, *n*—the nonmetallic product, consisting essentially of silicates and aluminosilicates of calcium and other bases, that is developed in a molten condition simultaneously with iron in a blast furnace.

blended hydraulic cement, *n*—a hydraulic cement consisting of two or more inorganic constituents (at least one of which

[1] This terminology is under the jurisdiction of ASTM Committee C01 on Cement and is the direct responsibility of Subcommittee C01.91 on Terminology.

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[2] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

[3] Available from American Concrete Institute (ACI), P.O. Box 9094, Farmington Hills, MI 48333-9094, http://www.aci-int.org.

***A Summary of Changes section appears at the end of this standard.**

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is not portland cement or portland cement clinker) which separately or in combination contribute to the strength-gaining properties of the cement, (made with or without other constituents, processing additions and functional additions, by intergrinding or other blending).

portland blast-furnace slag cement, n—a hydraulic cement consisting of an intimately interground mixture of portland cement clinker and granulated blast-furnace slag or an intimate and uniform blend of portland cement and fine granulated blast-furnace slag in which the amount of the slag constituent is within specified limits.

portland-pozzolan cement, n—a hydraulic cement consisting of an intimate and uniform blend of portland cement or portland blast-furnace slag cement and fine pozzolan produced by intergrinding portland cement clinker and pozzolan, by blending portland cement or portland blast-furnace slag cement and finely divided pozzolan, or a combination of intergrinding and blending, in which the amount of the pozzolan constituent is within specified limits.

blending, *n—in hydraulic cement manufacture,* a process in which two or more ingredients are combined into an intimate and uniform product of finely divided dry material, as by intergrinding or mixing, or both.

calcium sulfate, *n*—in cement manufacture, a material composed essentially of calcium sulfate in one or more of its hydration states: **anhydrite** ($CaSO_4$), **gypsum** ($CaSO_4 \cdot 2H_2O$), or **calcium sulfate hemihydrate** ($CaSO_4 \cdot ½ H_2O$).

cementitious material, (*hydraulic***),** *n*—an inorganic material or a mixture of inorganic materials that sets and develops strength by chemical reaction with water by formation of hydrates and that is capable of doing so underwater.

cement paste, *n*—an unhardened or hardened mixture of finely divided hydraulic cementious material and water.

early stiffening, *n*—rapid loss of plasticity or rapid development of rigidity in freshly mixed hydraulic cement paste, mortar, or concrete.

false set, n—with little evolution of heat, which can be dispelled by further mixing without the addition of water.

flash set, n—with evolution of considerable heat, which cannot be dispelled by further mixing without the addition of water.

equivalent alkalies, Na_2Oeq**,** *n—in hydraulic cement*, the total of sodium and potassium oxides as calculated from the chemical analysis, and using the formula:
$Na_2Oeq = \% Na_2O + 0.658 \times \% K_2O$.

DISCUSSION—Used to indicate the levels of alkalies in a material when only Na_2O and K_2O are considered. The value, 0.658, is the molecular ratio of Na_2O to K_2O. Alkali equivalent, soda equivalent, and sodium equivalent are deprecated terms.

expansive hydraulic cement, *n*—a hydraulic cement that forms a paste when mixed with water, and increases in volume a controlled amount during the early hardening period occurring after setting.

DISCUSSION—Expansive hydraulic cements are used to compensate for volume decrease due to shrinkage or to induce tensile stress in concrete reinforcement.

false set—see **early stiffening**

flash set—see **early stiffening**

fog room, *n*—a moist room in which the humidity is controlled by atomization of water.

gage length, *n—in cement testing*, the nominal length between the innermost ends of metal studs that are molded into a test specimen with the axis of the stud in each end of the test specimen coincident with the longitudinal axis of the test specimen and with each other.

granulated blast-furnace slag, *n*—the glassy, granular material formed when molten blast-furnace slag is rapidly chilled, as by immersion in water.

gypsum, *n*—see **calcium sulfate**.

hydration, *n*—the chemical reaction between hydraulic cement and water forming new compounds most of which have strength-producing properties.

hydraulic cement, *n*—a cement that sets and hardens by chemical reaction with water and is capable of doing so under water.

hydraulic mortar, *n*—deprecated term; see mortar.

length change, *n—in cement testing*, an increase or decrease in linear dimension due to causes other than applied load, usually measured along the longitudinal axis of a test specimen and expressed as a percentage of a gage length.

lime-saturated water, *n—for curing test specimens*, water containing calcium hydroxide at saturation and in contact with solid calcium hydroxide so that saturation is maintained.

lot, *n*—a quantity of a single material that is considered as a unit, such as that manufactured during a single production run, offered at one time for sale, or offered at one time for inspection, or the contents of one or more transport containers drawn from one or more bins of material from a single production run, sequentially packaged from one or more bins, or a group of samples secured from one of the above.

masonry cement, *n*—a hydraulic cement manufactured for use in mortars for masonry construction or in plasters, or both, which contains a plasticizing material and, possibly, other performance-enhancing addition(s).

moist room, *n*—an enclosed room for storage and curing of paste, mortar, and concrete specimens in which temperature and high relative humidity can be controlled within specified limits.

mortar, *n*—a mixture of finely divided hydraulic cementitious material, fine aggregate, and water in either the unhardened or hardened state; hydraulic mortar.

mortar cement, *n*—a hydraulic cement manufactured for use in masonry mortar designed for specific bond and air content criteria.

DISCUSSION—Mortar cement is similar to masonry cement but must meet bond strength and air content criteria. See Specification C 1329 for limitations.

natural cement, *n*—a hydraulic cement produced by calcining a naturally occurring argillaceous limestone at a temperature below the sintering point and then grinding to a fine powder.

DISCUSSION—Argillaceous limestone is described in Standard C 294.

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normal consistency, *n*—a degree of plasticity of a hydraulic-cement paste that is appropriate for testing as measured by a stipulated method.

DISCUSSION—The result of tests for normal consistency is reported as the mass of water required to achieve this plasticity divided by the mass of hydraulic cement, expressed as a percentage.

plaster, *n*—*hydraulic cement,* a mixture of hydraulic cement, fine aggregate and water that hardens; used for coating surfaces, such as ceilings, walls and partitions.

plastic cement, *n*—a hydraulic cement used in plaster or stucco.

DISCUSSION—See Specification C 1328 for limitations on materials or properties pertaining to cement under that specification.

portland cement, *n*—a hydraulic cement produced by pulverizing clinker, consisting essentially of crystalline hydraulic calcium silicates, and usually containing one or more of the following: water, calcium sulfate, up to 5 % limestone, and processing additions.

portland-cement clinker, *n*—a clinker, partially fused by pyroprocessing, consisting predominantly of crystalline hydraulic calcium silicates.

pozzolan, *n*—a siliceous or siliceous and aluminous material, which in itself possesses little or no cementitious value but will, in finely divided form and in the presence of moisture, chemically react with calcium hydroxide at ordinary temperatures to form cementitious hydrates.

saturated-lime water, *n*—see **lime-saturated water**.

slag cement, *n*—a hydraulic cement consisting predominantly of ground, granulated blast-furnace slag.

stucco, *n*—a hydraulic cement plaster containing fine aggregate, used for coating exterior surfaces.

5. Keywords

5.1 cement terminology; definitions; hydraulic cement terminology; terminology; terms

SUMMARY OF CHANGES

Committee C01 has identified the location of selected changes to this terminology since the last issue, C 219 – 07, that may impact the use of this terminology. (Approved December 1, 2007)

(*1*) Revised the term **lime-saturated water**.

Committee C01 has identified the location of selected changes to this terminology since the last issue, C 219 – 03$^{\epsilon 1}$, that may impact the use of this terminology. (Approved February 1, 2007)

(*1*) Revised the term **equivalent alkalies**.

(*2*) Revised the term **portland cement**.

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Designation: C 226 – 07

Standard Specification for Air-Entraining Additions for Use in the Manufacture of Air-Entraining Hydraulic Cement[1]

This standard is issued under the fixed designation C 226; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

This standard has been approved for use by agencies of the Department of Defense.

1. Scope*

1.1 This specification covers the requirements and methods for establishing the suitability of a material for use as an air-entraining addition to be interground with the clinker in the manufacture of air-entraining hydraulic cement conforming to Specifications C 150, C 595, and C 1157.

1.2 The values stated in SI units are to be regarded as the standard.

1.3 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use. (***Warning—**Fresh hydraulic cementitious mixtures are caustic and may cause chemical burns to skin and tissue upon prolonged exposure.[2])

2. Referenced Documents

2.1 *ASTM Standards:* [3]

C 33 Specification for Concrete Aggregates

C 39/C 39M Test Method for Compressive Strength of Cylindrical Concrete Specimens

C 109/C 109M Test Method for Compressive Strength of Hydraulic Cement Mortars(Using 2-in. or [50-mm] Cube Specimens)

C 114 Test Methods for Chemical Analysis of Hydraulic Cement

C 115 Test Method for Fineness of Portland Cement by the Turbidimeter

C 138/C 138M Test Method for Density (Unit Weight), Yield, and Air Content (Gravimetric) of Concrete

C 143/C 143M Test Method for Slump of Hydraulic-Cement Concrete

C 150 Specification for Portland Cement

C 151 Test Method for Autoclave Expansion of Hydraulic Cement

C 175 Discontinued 1971; Specification for Air-Entraining Portlant Cement; Replaced by C 150[4]

C 185 Test Method for Air Content of Hydraulic Cement Mortar

C 187 Test Method for Normal Consistency of Hydraulic Cement

C 191 Test Methods for Time of Setting of Hydraulic Cement by Vicat Needle

C 192/C 192M Practice for Making and Curing Concrete Test Specimens in the Laboratory

C 204 Test Methods for Fineness of Hydraulic Cement by Air-Permeability Apparatus

C 231 Test Method for Air Content of Freshly Mixed Concrete by the Pressure Method

C 293 Test Method for Flexural Strength of Concrete (Using Simple Beam With Center-Point Loading)

C 595 Specification for Blended Hydraulic Cements

C 596 Test Method for Drying Shrinkage of Mortar Containing Hydraulic Cement

C 666/C 666M Test Method for Resistance of Concrete to Rapid Freezing and Thawing

C 1157 Performance Specification for Hydraulic Cement

2.2 *ACI Standards:*[5]

ACI 211.1-77 Recommended Practice for Selecting Proportions for Normal and Heavyweight Concrete

3. Materials

3.1 *Cements*:

3.1.1 In cases where it is desired that the proposed air-entraining addition be accepted for general use in portland cement, tests shall be made on six lots of cement ground at cement plants, using commercial grinding equipment. From each of three different samples of clinkers, two lots of cement shall be ground, representing respectively: a Type I portland cement containing not less than 9 % tricalcium aluminate

[1] This specification is under the jurisdiction of ASTM Commitee C01 on Cement and is the direct responsibility of Subcommittee C01.20 on Additions.

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[2] See the section on Safety, Manual of Cement Testing, *Annual Book of ASTM Standards*, Vol 04.01.

[3] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

[4] Withdrawn.

[5] Available from the American Concrete Institute, P.O. Box 19150, Detroit, MI 48219.

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(C_3A), calculated as specified in Table 1 of Specification C 150 and a Type II and a Type III portland cement all conforming to Specification C 150. One lot, the "control" shall be ground without the proposed air-entraining addition; the proposed addition shall be interground with the other lot, using the addition in such amounts as to produce the air/entrainment required in Specification C 150. Not more than two of the three clinkers shall be produced by or ground at the same mill.

3.1.2 In cases where it is desired that the proposed air-entraining addition be limited in use to specific types of cement in specific cement manufacturing plants, either or both less in number than required in 3.1.1, the tests and test procedure shall be as specified in 3.1.1, except that the number of cements to be tested shall be limited to those under specific consideration.

3.1.3 The two companion cements made from any one clinker shall be ground to the same fineness (within 5 m^2/kg when tested in accordance with Test Method C 115) as measured by the turbidimeter test (7.1.3) or (within 10 m^2/kg when tested in accordance with Test Method C 204) as measured by the air permeability apparatus, and the sulfur trioxide (SO_3) content expressed as a percentage of the cement weight and reported to the nearest 0.01 %, shall differ by no more than 0.3 for all types of cement. Each "control" cement shall comply with all of the requirements in the specification applicable to that type of cement, and shall not contain the proposed addition when tested by the method furnished by the producer or seller of the addition.

3.1.4 The percentage of each of the following constituents shall be determined for each lot of cement tested: silicon dioxide (SiO_2), aluminum oxide (Al_2O_3), iron oxide (Fe_2O_3), calcium oxide (CaO), magnesium oxide (MgO), SO_3, ignition loss, insoluble residue, sodium oxide (Na_2O), and potassium oxide (K_2O). There shall also be calculated the potential percentages of the following compounds: tricalcium silicate, dicalcium silicate, tricalcium aluminate, and tetracalcium aluminoferrite. Determinations for the percentage of addition shall be made on the cements containing the addition, using the method proposed therefore by the maker or seller of the addition.

3.2 *Aggregates*:

3.2.1 The fine and coarse aggregates used in the tests shall conform to the requirements of Specification C 33, except that the grading of the aggregates shall conform to the requirements given in Table 1.

TABLE 1 Grading Requirements of Aggregates

Sieve	Percentage Passing
Fine Aggregate	
4.75-mm (No. 4)	100
1.18-mm (No.16)	65 to 75
300-µm (No. 50)	15 to 20
150-µm (No. 100)	2 to 5
Coarse Aggregate	
25.0-mm (1-in.)	100
19.0-mm (¾-in.)	75
12.5-mm (½-in.)	50
9.5-mm (⅜-in.)	25
4.75-mm (No.4)	0

3.2.2 The coarse aggregate shall be carefully separated on the 25.0-mm (1-in.), 19.0-mm (¾-in.), 12.5-mm (½-in.), 9.5-mm (⅜-in.), and 4.75-mm (No. 4) sieves, and then recombined, using equal quantities by weight of each of the resulting four sizes.

3.2.3 The fine and coarse aggregates used in the tests of any two companion cements (that is, a cement containing the addition and the corresponding "control" cement) shall each come from a single lot of such aggregate.

3.3 *Reference Addition*:

3.3.1 The reference addition used in the concrete mixture specified in Section 8, from which specimens will be made for tests for resistance to freezing and thawing as specified in 10.2.3, shall be any one of the four materials (Vinsol resin, Darex, N-TAIR, or Airalon) that have been declared acceptable by ASTM under the former Specifications C 175 – 48 T.

3.3.2 The reference addition to be used will be designated by the person or agency for whom the testing will be performed. If no reference addition is designated, the material known commercially as "Vinsol resin" shall be used. The Vinsol resin used shall be neutralized with 15 percent by mass of sodium hydroxide (NaOH). The air contents of the concrete containing the reference addition and the concrete containing the proposed addition shall agree within 0.5 percentage points.

3.3.3 The reference addition, used as an admixture, is intended for use with control cements only in concrete for freezing-and-thawing tests to establish the durability factor by means of which the concretes containing the addition under test may be evaluated.

3.3.4 *Preparation of Standard Reference Solutions*:

3.3.4.1 Place 50 g (total solids in the case of solution or pastes) of the designated reference addition in 500 mL of freshly distilled water in a 1000-mL flask and mix thoroughly until the solids are completely dissolved or the paste or solution is uniformly diluted. After surface foam has been dissipated, dilute to 1000 mL and mix thoroughly.

3.3.4.2 In the case of Vinsol resin, the neutralized solution shall be made as follows: Dissolve 7.50 g of cp NaOH in 100 mL of distilled water. Add a few drops of this solution to 300 to 350 mL of distilled water contained in a 600-mL beaker. Add 50.00 g of dry, unneutralized Vinsol resin in pulverized form to the beaker and stir until all of the resin is wetted and well dispersed. Then add all of the NaOH solution to this suspension and stir until all of the resin is in solution. Transfer to a measuring flask, dilute to 1000 mL and mix thoroughly. From this stock standard solution prepare a dilute standard solution by diluting 100 mL of the stock solution to 1000 mL.

4. General Requirements

4.1 Air-entraining additions shall conform to the respective requirements prescribed in this specification.

4.2 The trade name, source, and character of the material, and means for the quantitative identification of the proposed addition in the finished cement, shall be furnished by the maker or seller of the addition, and that information shall form a part of the record of tests of the addition.

4.3 Air-entraining additions shall be evaluated by testing cements ground with and without the additions. The cements

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ground without the additions shall be referred to in this specification as "control" cements.

4.4 An air-entraining addition under this specification, when interground with hydraulic cement, shall produce a cement that complies with the appropriate Specifications C 150, C 595, or C 1157 and when evaluated by the results of tests made according to the procedures herein described, shall also comply with the following requirements as to the effect of the addition on the properties of the cement:

4.4.1 The time of setting of cement containing the addition shall not vary from the time of setting of the respective "control" cement by more than 50 %.

4.4.2 The percentage autoclave expansion for cement containing the addition shall not exceed the percentage autoclave expansion for the corresponding" control" cement by more than 0.1.

4.4.3 The compressive strength of standard mortar cubes made with cement containing the addition shall be not less than 80 % of the compressive strength of similar cubes made with the corresponding "control" cement.

4.4.4 The percentage length change of air-stored mortar bars made with cement containing the addition, based on an initial measurement at the age of 7 days, and expressed as a percentage change in length, shall be not more than 0.01 greater than that of similar mortar bars made with the corresponding "control" cement and similarly tested.

4.4.5 The percentage of air entrained in the concrete made with cement containing the addition shall exceed by at least 2.5 the percentage air in similar concrete prepared with the corresponding "control" cement. (See 3.1.1 for the limitation of air-entraining properties of the "control" cement.)

4.4.6 The compressive strength of the concrete made with cement containing the addition shall be not less than 80 % of the compressive strength of similar concrete made with the corresponding "control" cement.

4.4.7 The flexural strength of concrete made with cement containing the addition shall be not less than 85 % of the flexural strength of corresponding concrete made with the "control" cement.

4.4.8 In the freezing and thawing test, the durability factor of the concrete made with the cement containing the proposed addition shall be not less than 80 % of the durability factor of similar concrete made with the corresponding "control" cement and containing the reference addition as specified in 3.3. (See 11.1.3 for the method of calculating the durability factor.)

5. Sampling Cement

5.1 Samples of the plant-ground cements shall be obtained during grinding. Prior to the commencement of the sampling of a given lot of cement, the mill shall have run for approximately 4 h to establish equilibrium. Notes shall be kept as to the rate and continuity of the feed of the addition, the form in which the addition is used, strength of the solution, and the mill temperature. Fineness of the grinding should be checked during the grinding.

5.2 The quantity of sample shall be not less than 272 kg (600 lb) for the cement containing the proposed addition and for the corresponding control cement.

5.3 As the cement samples are secured, they shall be placed in metal drums provided with gasket-fitted lids. The drums shall be tightly closed at the end of the sampling period. Prior to use, the samples of a given lot of cement shall be well blended to form a uniform, representative composite.

6. Test Methods

6.1 Determine the properties enumerated in this specification in accordance with the methods prescribed in Sections 7-11.

7. Tests on Cement

7.1 Test the cement samples in accordance with the following methods:

7.1.1 *Chemical Analysis of Cement*—Test Methods C 114.

7.1.2 *Determination of Addition in the Finished Cement*—Determine the percentage of the addition in the finished cement by the method furnished by the manufacturer or seller of the proposed addition. The method shall be adequate for the qualitative and quantitative determination of the addition in the finished cement, and shall be fully described in the report of the tests on the addition.

7.1.3 *Fineness of Cement*—Test Method C 115 or C 204.

7.1.4 *Normal Consistency*—Test Method C 187.

7.1.5 *Time of Setting*—Determine the time of setting with the Vicat needle, in accordance with Test Method C 191.

7.1.6 *Autoclave Expansion*—Test Method C 151.

7.1.7 *Air Content of Mortar*—Test Method C 185.

7.1.8 *Compressive Strength of Mortar*—Test Method C 109/C 109M.

7.1.9 *Length Change of Mortar*—For each lot of cement, determine the length change of mortar bars according to Test Method C 596 except, after demolding, cure the specimens in saturated lime water for 6 days (7 days total age) and measure the length of each specimen at 7 days of age. Then, place the specimens in air storage for the remainder of the test period. Obtain a length comparator reading for each specimen at 28 days, 180 days, and 365 days of total age. Report the length change for each bar as a percentage of its length at 7 days of age.

8. Concrete Mixtures

8.1 *Preparation and Weighing*—Prepare all materials used in preparing the concrete mixtures, and make all weighings, as prescribed in Practice C 192/C 192M. Report the amount of mixing water on the basis of saturated surface-dry aggregates.

8.2 *Proportions*—Design one concrete mixture, having an actual cement content of 307 ± 3 kg/m^3 (517± 5 lb/yd^3), and use this mixture in all of the concrete tests specified herein. Adjust the water content of the mixture to provide concrete having a consistency equal to a 64 ± 13-mm (2½ ± ½-in.) slump. Adjust the ratio of fine aggregate to total aggregate to the optimum for concrete to be consolidated by hand-rodding (suggested trial values[6] for the percentage of fine aggregate in the total aggregate, by absolute volume, are shown in Table 2).

[6] Values for concrete without entrained air are based on the ACI Standard Recommended Practice for Selecting Proportions for Normal and Heavyweight Concrete (ACI 211.1-77).

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TABLE 2 Fine Aggregate in Total Aggregate, percent

Coarse Aggregate, Maximum Size 25 mm (1 in.)	Concrete Without Entrained Air	Concrete With Entrained Air
Angular	45	41
Rounded	40	36

8.3 *Mixing of Concrete*—Mix the concrete in accordance with Practice C 192/C 192M except as follows: Hand mixing shall not be permitted. The rated capacity of the mixer shall be not more than twice the size of the batch used. Use a preliminary (buttering) batch of the same proportions as the test batch to coat the mixer and discard it just prior to receiving the batch of the test concrete, which shall be mixed continuously for 2 min following the addition of the mixing water. Do not scrape the mixer after buttering. At the end of the mixing period dump the concrete without scraping from the mixer into a metal wheelbarrow or pan, and then turn with a shovel before making the slump, unit weight, and air determinations, and also before being placed in the test specimen molds.

9. Tests on Plastic Concrete

9.1 Test samples of the plastic concrete in accordance with the following methods:

9.1.1 *Consistency*—Test Method C 143/C 143M.

9.1.2 *Unit Weight and Air Content*—Make a determination of the unit weight, yield, and air content for each batch, in accordance with Test Method C 138/C 138M, except that the air content of the concrete may be determined in accordance with Test Method C 231.

10. Test Specimens of Hardened Concrete

10.1 *Number of Specimens*—Make six test specimens from each condition of concrete to be compared for each test and age. Make test specimens representing each test and each condition of concrete from at least three separate batches. An equal number of specimens for each variable should be made on any given day. When it is impossible to make at least one specimen for each variable on a given day, complete the mixing of the entire series of specimens in as few days as possible and repeat one of the mixes each day as a standard of comparison.

10.2 *Types of Specimens*:

10.2.1 *Compressive Strength*—Compressive strength test specimens shall be 152- by 305-mm (6- by 12-in.) cylinders, and shall be made and cured as prescribed in Practice C 192/C 192M.

10.2.2 *Flexural Strength*—Make and cure flexural strength test specimens as specified in Practice C 192/C 192M, except that the size of the beams shall be 76 by 101 by 406 mm (3 by 4 by 16 in.).

10.2.3 *Resistance to Freezing and Thawing*—Make and cure test specimens for resistance to freezing and thawing as specified in Practice C 192/C 192M, except that the size of the beams shall be 76 by 101 by 406 mm (3 by 4 by 16 in.).

11. Tests on Hardened Concrete

11.1 Test specimens of hardened concrete, as specified in Section 10, in accordance with the following methods, and at the ages herein specified.

11.1.1 *Compressive Strength*—Use Test Method C 39/C 39M, and test specimens at ages of 3, 7, and 28 days, and 3 months, except that for Type III cement a test shall be made also at 1 day.

11.1.2 *Flexural Strength*—Test Method C 293. Test flexural strength specimens at the ages of 3, 7, and 28 days, 3 months, and 1 year, except that for Type III cement a test shall be made also at 1 day.

11.1.3 *Resistance to Freezing and Thawing*—Use Test Method C 666/C 666M, except that the specimens shall be tested at the end of the 28-day curing period.

12. Report

12.1 The report covering the results of the evaluation of a material proposed as an air-entraining addition under this specification shall include the following information:

12.1.1 Trade name, source, and character of the material and means for the quantitative identification of the proposed addition in the finished cement—all as furnished by the manufacturer or seller of the addition.

12.1.2 Identification of the cements as to their type. General geographical location of mills where the test lots of cements were ground. (Company and brand names need not be given.)

12.1.3 Detailed results of all analyses and tests prescribed in this specification, as well as pertinent information required.

12.1.4 Comparison of test results to determine compliance with the requirements prescribed in 4.4.

12.1.5 Name and location of the laboratory or laboratories that made the tests covered by the report.

12.1.6 A statement indicating whether the evaluation was made to establish acceptability of the addition for general use (3.1.1), or whether the evaluation was made to establish acceptability for use with specific types of cement in specific cement mills (3.1.2). In the latter case, the type or types of cement and the brand names and location of mills that are covered by the tests shall be given.

13. Keywords

13.1 addition; air entraining; hydraulic cement

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SUMMARY OF CHANGES

Committee C01 has identified the location of selected changes to this specification since the last issue, C 226 – 02, that may impact the use of this specification. (Approved June 1, 2007)

(*1*) Revised 3.1.1 and 3.1.3.

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Designation: C 227 – 03

Standard Test Method for Potential Alkali Reactivity of Cement-Aggregate Combinations (Mortar-Bar Method)[1]

This standard is issued under the fixed designation C 227; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

This standard has been approved for use by agencies of the Department of Defense.

1. Scope

1.1 This test method covers the determination of the susceptibility of cement-aggregate combinations to expansive reactions involving hydroxyl ions associated with the alkalies (sodium and potassium) by measurement of the increase (or decrease) in length of mortar bars containing the combination during storage under prescribed conditions of test.

1.2 Alkalies participating in the expansive reactions usually are derived from the cement; under some circumstances they may be derived from other constituents of the concrete or from external sources. Two types of alkali reactivity of aggregates are recognized: *(1)* an alkali-silica reaction involving certain siliceous rocks, minerals, and natural or artificial glasses and *(2)* an alkali-carbonate reaction involving dolomite in certain calcitic dolomites and dolomitic limestones (see Standard C 294). The method is not recommended as a means to detect the latter reaction because expansions produced in the mortar-bar test by the alkali-carbonate reaction (see Test Method C 586) are generally much less than those produced by the alkali-silica reaction for combinations having equally harmful effects in service.

1.3 The values stated in SI units are to be regarded as standard. The non-SI values, shown in parentheses, are for informational purposes only.

1.4 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

2. Referenced Documents

2.1 *ASTM Standards:*

C 33 Specification for Concrete Aggregates[2]

C 109/C 109M Test Method for Compressive Strength of Hydraulic Cement Mortars (Using 2-in. or [50-mm] Cube Specimens)[3]

C 289 Test Method for Potential Alkali-Silica Reactivity of Aggregates (Chemical Method)[2]

C 294 Standard Descriptive Nomenclature for Constituents of Concrete Aggregates[2]

C 295 Guide for Petrographic Examination of Aggregates for Concrete[2]

C 305 Practice for Mechanical Mixing of Hydraulic Cement Pastes and Mortars of Plastic Consistency[3]

C 490 Practice for Use of Apparatus for the Determination of Length Change of Hardened Cement Paste, Mortar, and Concrete[2,3]

C 511 Specification for Moist Cabinets, Moist Rooms, and Water Storage Tanks Used in Testing of Hydraulic Cements and Concretes[2,3]

C 586 Test Method for Potential Alkali Reactivity of Carbonate Rocks for Concrete Aggregates (Rock Cylinder Method)[2]

C 856 Practice for Petrographic Examination of Hardened Concrete[2]

C 1437 Test Method for Determining Flow of Hydraulic Cement Mortar[3]

E 11 Specification for Wire Cloth and Sieves for Testing Purposes[4]

3. Significance and Use

3.1 Data correlating the results of tests performed using this test method with performance of cement-aggregate combinations in concrete in service, results of petrographic examination of aggregates (Guide C 295), and results of tests for potential reactivity of aggregates by chemical methods have been published in Test Method C 289 and should be consulted in connection with the use of results of tests performed using this

[1] This test method is under the jurisdiction of ASTM Committee C09 on Concrete and Concrete Aggregates and is the direct responsibility of Subcommittee C09.26 on Chemical Reactions of Materials.

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[2] *Annual Book of ASTM Standards*, Vol 04.02.

[3] *Annual Book of ASTM Standards*, Vol 04.01.

[4] *Annual Book of ASTM Standards*, Vol 14.02.

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test method as the basis for conclusions and recommendations concerning the use of cement-aggregate combinations in concrete.

3.2 The results of tests performed using this method furnish information on the likelihood that a cement-aggregate combination is potentially capable of harmful alkali-silica reactivity with consequent deleterious expansion of concrete. Criteria to determine potential deleterious alkali-silica reactivity of cement-aggregate combinations from the results of this test method have been given in the Appendix of Specification C 33.

3.3 Insignificant expansion may result when potentially deleteriously reactive siliceous rocks are present in comparatively high proportion even when a high-alkali cement is used. This may occur because the alkali-silica reaction products are characterized by an alkali to silica ratio that is so low as to minimize uptake of water and swelling, or because of alkali leaching from the bars (see section on containers). Dolomitic aggregates that are deleteriously affected by the alkali-carbonate reaction when employed as course aggregate in concrete may not produce notable expansion in this test method. Also, significant expansion may occur rarely in the test for reasons other than alkali-aggregate reaction, particularly the presence of sulfates in the aggregate that produce a sulfate attack upon the cement paste, ferrous sulfides (pyrite, marcasite, or pyrrhotite) that oxidize and hydrate with the release of sulfate, and materials such as free lime (CaO) or free magnesia (MgO) in the cement or aggregate that progressively hydrate and carbonate.

3.4 When expansions in excess of those given in the Appendix of Specification C 33 are shown in results of tests performed using this test method, it is strongly recommended that supplementary information be developed to confirm that the expansion is actually due to alkali reactivity. Sources of such supplementary information include: *(1)* petrographic examination of the aggregate to determine if known reactive constituents are present; *(2)* examination of the specimens after tests to identify the products of alkali reactivity; and *(3)* tests of the aggregate for potential reactivity by chemical methods (Test Method C 289).

3.5 When it has been concluded from the results of tests performed using this test method and supplementary information as outlined that a given cement-aggregate combination should be considered potentially deleteriously reactive, additional studies may be appropriate to develop information on the potential reactivity of other combinations containing the same cement with other aggregates, the same aggregate with other cements, or the same cement-aggregate combination with a mineral admixture.

4. Apparatus

4.1 The apparatus shall conform to Specification C 490, except as follows:

4.2 *Sieves*—Square hole, woven-wire cloth sieves, shall conform to Specification E 11.

4.3 *Mixer, Paddle, and Mixing Bowl*— Mixer, paddle, and mixing bowl shall conform to the requirements of Method C 305, except that the clearance between the lower end of the paddle and the bottom of the bowl shall be 5 to 6 mm (0.20 to 0.24 in.) .

4.4 *Tamper and Trowel*—The tamper and trowel shall conform to Test Method C 109/C 109M.

4.5 *Containers*—Covered containers for storing the test specimens shall be constructed of material that is resistant to corrosion under the test conditions. The wall thickness of the container and cover shall be less than 6 mm (3⁄16 in.) to reduce the insulating effect and provide a rapid heat transfer for the initial 14-day test period. The cover shall be constructed in a manner to maintain a tight seal between the cover and top of the container wall (Note 1). The container shall be arranged to provide every surface of each specimen with approximately an equal exposure to an absorbent wicking material. The specimens shall not be in direct contact with the wicking material but every surface shall be within 30 mm (1¼ in.) or less of the the wicking. A typical arrangement of such a container is shown in Fig. 1 (Note 2). The inner sides and the center core of the containers are to be lined with an absorbent material, such as blotting or filter paper, to act as a wick and to ensure that the atmosphere in the container is quickly saturated with water vapor when it is sealed after the specimens are placed therein (Note 2). The wicking liners will extend into the top of the water in the bottom of the container and above the tops of the specimens. Make provisions to support the bars in a vertical position with the lower end of the bars approximately 25 mm (1 in.) above the surface of the water in the containers. The weight of the specimens shall not be supported on the metal gage studs. A supporting rack shall be provided to ensure that the specimens do not touch the wicking material or each other. The supporting rack shall be constructed of brass wire or other material that is resistant to corrosion under the test conditions and shall not act as a vapor barrier but provide free movement of vapors within the container. Provisions shall be made to prevent water from splashing and dripping onto the specimens (Notes 3-5). If required to prevent the growth of mold on the wicking, add a suitable fungicide to the water in the container. The container size and internal arrangement of the specimens and wicking may be varied at the users discretion, providing expansion data for all specimens can be shown to be equivalent to that developed with the container herein described.

NOTE 1—This seal may be achieved by a double wrap of vinyl tape 38 mm (1½ in.) or greater in width, overlaying the lid and container wall along its full circumference.

NOTE 2—A covered container that has been found acceptable for this purpose is sold by the United States Plastic Corp., 1390 Neubrecht Rd., Lima, OH 45801, as a PVC plating, photo, and chemical tank, stock No. 10062, 6-in. diameter x 17 in. high, with cover.

NOTE 3—The shape and spacing of the center wicking material may be maintained during the test by the use of rubber bands or hardware cloth.

NOTE 4—If concern exists for adequately preventing dripping or splashing, the water should be tested for pH and alkali content.

NOTE 5—The container described in 4.5 and in Fig. 1 has been shown to produce large and reproducible expansions with cement-aggregate combinations such as borosilicate glass: high-alkali cement combination called for by ASTM C 441. However, recent work, at a few laboratories, suggests that the same factors that are responsible for the success with the C 441 mixtures, that is, high, constant, uniform internal relative humidity, will, under certain testing regimes permitted by this test method, promote leaching of alkali from the specimens and result in little or no expansion from some known deleteriously alkali-reactive aggregate: high-alkali cement combinations. Each laboratory should evaluate its containers with a known deleteriously alkali-reactive aggregate (not borosilicate glass

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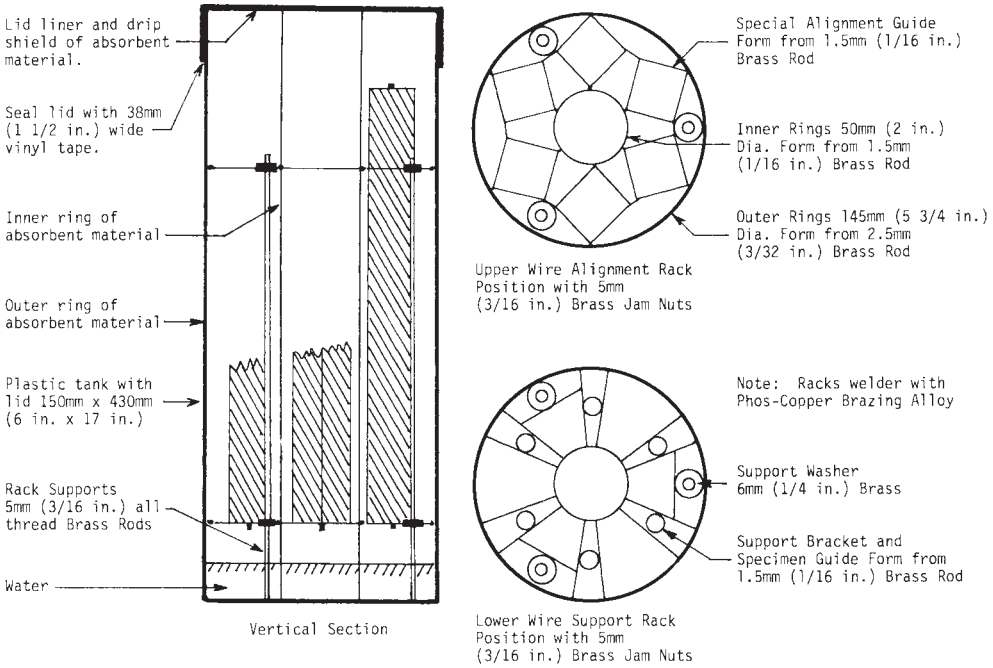

FIG. 1 Diagram of an Acceptable Assembled Container

which releases alkali) and a high-alkali cement, to establish that the expected level of expansion is obtained. If not, try removing the wicking to reduce the condensation and leaching. Minimizing the temperature variation within the storage room and the room in which the bars are read may also reduce condensation on and leaching from the bars.

5. Temperature and Humidity

5.1 The temperature of the molding room and dry materials shall be maintained at not less than 20°C (68°F) and not more than 27.5°C (81.5°F). The temperature of the mixing water, of the moist closet or moist room, and of the room in which the measurements are made shall not vary from 23°C (73.4°F) by more than 2.0°C (3°F).

5.2 The relative humidity of the molding room shall be not less than 50 %. The moist closet or room shall conform to Specification C 511.

5.3 The storage room in which the specimens in containers are stored shall be maintained at a temperature that shall not vary from 38.0°C (100°F) by more than 2.0°C (3°F).

6. Selection and Preparation of Materials

6.1 *Selection of Aggregate*—Materials proposed for use as fine aggregate in concrete shall be processed as described in 6.2 with a minimum of crushing. Materials proposed for use as coarse aggregate in concrete shall be processed by crushing to produce as nearly as practical a graded product from which a sample can be obtained. The sample shall have the grading as prescribed in 6.2 and be representative of the composition of the coarse aggregate as proposed for use.

6.1.1 When a given quarried material is proposed for use, both as coarse and as fine aggregate, it will be tested only by selection of an appropriate sample crushed to the fine aggregate sizes, unless there is reason to expect that the coarser size fractions have a different composition than the finer sizes and that these differences might significantly affect expansion due to reaction with the alkalies in cement. In this case the coarser size fractions should be tested in a manner similar to that employed in testing the fine aggregate sizes.

6.1.2 Coarse aggregate crushed to sand size may give increased expansion, owing to the increased surface exposed upon crushing. Therefore, if coarse aggregate tested by this method produces an excessive amount of expansion, the material shall not be classed as objectionably reactive with alkali unless tests of concrete specimens confirm the findings of the tests of the mortar.

6.2 *Preparation of Aggregate*—Fine aggregate shall be tested in a grading meeting the requirements of the specifications for the project except that any material retained on the 4.75-mm (No. 4) sieve shall be removed. Fine aggregates being tested for reasons other than to determine compliance with individual specifications, and all coarse aggregates to which this method is applied shall be graded in accordance with the requirements prescribed in Table 1. Aggregates in which sufficient quantities of the sizes specified in Table 1 do not exist shall be crushed until the required material has been produced. In the case of aggregates containing insufficient amounts of one or more of the larger sizes listed in Table 1, and if no larger material is available for crushing, the first size in which sufficient material is available shall contain the cumulative percentage of material down to that size as determined from the

TABLE 1 Grading Requirements

Sieve Size		Mass %
Passing	Retained on	
4.75-mm (No. 4)	2.36-mm (No. 8)	10
2.36-mm (No. 8)	1.18-mm (No. 16)	25
1.18-mm (No. 16)	600-µm (No. 30)	25
600-µm (No. 30)	300-µm (No. 50)	25
300-µm (No. 50)	150-µm (No. 100)	15

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grading specified in Table 1. When such procedures are required, special note shall be made thereof in the test report. After the aggregate has been separated into the various sieve sizes, each size shall be washed with a water spray over the sieve to remove adhering dust and fine particles from the aggregate. The portions retained on the various sieves shall then be dried and, unless used immediately, each such portion shall be stored individually in a clean container provided with a tight-fitting cover.

6.3 *Selection and Preparation of Cement*:

6.3.1 *Job Cement*—When it is desired to evaluate a particular cement-aggregate combination for use in particular work, the cement or cements used shall meet the requirements for the work and shall be from the source or sources expected to be used in the work. If several cements may be used in the work, tests desirably should be made using each of these; in any case, the cement or cements whose alkali content exceeds 0.60 %, calculated as Na_2O, should be used.

6.3.2 *Reference Cements*—When it is desired to evaluate aggregates for general use or to compare aggregates for investigational purposes, the cement used shall be of the highest alkali content representative of the general use intended, or available to the laboratory making the tests. The cement or cements selected should comply with applicable specifications. Additional information of value may be obtained by conducting tests in parallel with cements of different alkali content, different Na_2O:K_2O ratio, or using pozzolans.

6.3.3 *Preparation of Cement*—Cement for use in this test shall be passed through a 850-µm (No. 20) sieve to remove lumps before use.

7. Procedure

7.1 *Preparation of Test Specimens*:

7.1.1 *Number of Specimens*—Make at least four test specimens, two from each of two batches, for each cement-aggregate combination.

7.1.2 *Preparation of Molds*—Prepare the molds in accordance with the requirements of Specification C 490.

7.1.3 *Proportioning of Mortar*—Proportion the dry materials for the test mortar using 1 part of cement to 2.25 parts of graded aggregate by mass. The quantities of dry materials to be mixed at one time in the batch of mortar for making two specimens shall be 300 g of cement and 675 g of aggregate made up by recombining the portions retained on the various sieves (see 6.2) in the grading prescribed in Table 1 or of aggregate in a grading meeting the requirements of the specifications for the project. The amount of mixing water, measured in millimetres, shall be such as to produce a flow of 105 to 120 (as determined in accordance with Test Method C 1437) except that the flow table shall be given 10 drops in approximately 6 s. Express the amount of mixing water used as a percent by mass of the cement.

7.1.4 *Mixing of Mortar*—Mix the mortar in accordance with the requirements of Method C 305.

7.1.5 *Molding of Test Specimens*—Immediately following completion of the flow test return the mortar from the flow table to the mixing bowl. Mix the entire batch for a period of 15 s. Start molding specimens with a total elapsed time of not more than 2 min and 15 s after completion of the original mixing of the mortar batch. Fill the molds with two approximately equal layers, each layer being compacted with the tamper. Work the mortar into the corners, around the gage studs, and along the surfaces of the mold with the tamper until a homogeneous specimen is obtained. After the top layer has been compacted, cut off the mortar flush with the top of the mold and smooth the surface with a few strokes of the trowel.

7.1.5.1 When a duplicate batch of mortar is to be made immediately for additional specimens, a second flow test is not required, in which case allow the mortar to stand in the mixing bowl for 90 s and then remixed for 15 s before starting the molding of the specimens.

7.1.6 *Sequence of Making Batches of Mortar*—When more than one cement-aggregate combination is to be tested as part of a single investigation, make the total number of batches of mortar (two per cement-aggregate combination) in random order, except that in no case shall the two batches representing a single cement-aggregate combination be made consecutively. When the making of all of the specimens for a single investigation requires that batches be made on 2 working days, each cement-aggregate combination shall be represented by one batch made on each day, and the order in which the combinations are represented by batches shall be different on the 2 days. When more than 2 days are required, one cement-aggregate combination shall be represented by a batch made on each of the working days.

7.2 *Storage and Measurement of Test Specimens*:

7.2.1 *Initial Storage and Measurement*—After each mold has been filled, place the mold immediately in the moist cabinet or room. The specimens shall remain in the molds for 24 ± 2 h. Then remove them from the molds and, while being protected from loss of moisture, properly identify and measure for initial length. The initial and all subsequent measurements shall be made and recorded to the nearest 0.002 mm (0.0001 in.).

7.2.2 *Subsequent Storage and Measurement*—Stand the specimens on end over, but not in contact with, water in the storage container. Seal and place the container for 12 days in a cabinet or room maintained at a temperature of 38.0 ± 2.0°C (100 ± 3°F). When the specimens are 14 days old measure their length after removal of the container and contents from the storage room or cabinet, and after the container and contents have been stored at 23.0 ± 2.0°C (73.4 ± 3°F) for at least 16 h before opening the container and making the 14-day measurement. Additional measurements shall be made at later ages as required.

7.2.3 Additional information of value may often be obtained by returning the specimens to the 38.0°C (100°F) storage after the 14-day test and making additional measurements at later ages. Measurements at ages of 1, 2, 3, 4, 6, 9, and 12 months and, if necessary, at least every 6 months thereafter are suggested.

7.2.4 After each length measurement specimens may be examined, in the same manner described in Section 9, to provide supplemental information on their condition.

7.2.5 All specimens placed in a given container after the initial length measurement at 24 ± 2 h shall have been made on the same day and shall be placed in the container at the same

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time so that all specimens in a given container shall be due for measurement at the same time. Each time length measurements are made, clean the container and change the water.

7.2.6 Always place the specimens in the comparator with the same end uppermost and after measurement replace the specimens in the container in inverted position as compared with the previous period.

8. Calculation

8.1 Calculate the difference between the initial length of the specimen and the length at each period of measurement to the nearest 0.001 % of the effective gage length and record as the expansion of the specimen for that period. Report the average of the expansion of the four specimens of a given cement-aggregate combination to the nearest 0.01 % as the expansion for the combination for a given period.

9. Examination at End of Test

9.1 After the final length change measurements have been made, each specimen shall be tested for warping and shall be examined (see Note 6).

9.1.1 *Warping*—The warping, if any, that each specimen has manifested during the test period, shall be determined by placing the specimen on a plane surface and measuring the maximum separation between the specimen and the surface. The specimen shall be placed so that its ends curve down to the reference surface and the measurement made to the nearest 0.3 mm (0.01 in.).

9.1.2 *Examination*—Items to be noted in the examination include:

9.1.2.1 Presence, location, and type of pattern of cracking,

9.1.2.2 Appearance of surfaces, surface mottling, and

9.1.2.3 Surficial deposits or exudations, their nature, thickness and continuity.

NOTE 6—When it is believed that additional features of noteworthy importance are likely to be revealed thereby, a further examination of the interior of the specimen may be made, following Practice C 856. In such cases, the presence of gel-filled pores and fissures, evidence of reaction with aggregate particles of specific types and the nature of such evidence and the properties of the reaction products are among the items to be noted.

10. Report

10.1 Report the following information:

10.1.1 Type and source of aggregate,

10.1.2 Type and source of portland cement,

10.1.3 Alkali content of cement as percent potassium oxide (K_2O), sodium oxide (Na_2O), and calculated sodium oxide (Na_2O) equivalent,

10.1.4 Average length change in percent at each reading of the specimens,

10.1.5 Any relevant information concerning the preparation of aggregates, including the grading of the aggregate when it differs from that given in 6.2,

10.1.6 Any significant features revealed by examination of the specimens during and after test,

10.1.7 Amount of mixing water expressed as percent by mass of cement, and

10.1.8 Type, source, proportions, and chemical analyses, including Na_2O and K_2O, of any pozzolans employed in the tests.

11. Precision and Bias

11.1 Precision shall be considered satisfactory if the differences in the value for percentage expansion of any given specimen in a group from the average value for percentage expansion of the group does not exceed 0.003, except that, if the average expansion exceeds 0.020 %, the repeatability shall be considered satisfactory if the percentage expansion of each specimen molded from the same cement-aggregate combination is within 15 % of the average.

11.2 Interlaboratory test data for the determination of revisions to this section in accordance with Practice C 670 are being evaluated by Subcommittee C09.02.02 and will be included in a later revision of this test method.

12. Keywords

12.1 aggregate; alkali-silica reaction; cement; length change; mortar

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Designation: C 230/C 230M – 08

Standard Specification for Flow Table for Use in Tests of Hydraulic Cement[1]

This standard is issued under the fixed designation C 230/C 230M; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope*

1.1 This specification covers requirements for the flow table and accessory apparatus (Note 1) used in making flow tests for consistency of mortars in tests of hydraulic cement, such as but not limited to Test Method C 1437.

NOTE 1—To help clarify the design of the flow table and accessory apparatus see the drawing in Fig. 1 [Fig. 2] . This drawing is for informational purposes only.

1.2 The values stated in either SI units or inch-pound units are to be regarded separately as standard. The values stated in each system may not be exact equivalents; therefore, each system shall be used independently of the other. Combining values from the two systems may result in non-conformance with the standard. It is permissible to use an inch-pound caliper and mold with a SI flow table or a SI caliper and mold with an inch-pound flow table. It is not permissible to mix a SI mold with an inch-pound caliper or an inch-pound mold with a SI caliper.

1.3 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

2. Referenced Documents

2.1 *ASTM Standards:*[2]

C 1437 Test Method for Flow of Hydraulic Cement Mortar

3. Flow Table and Frame

3.1 The flow table apparatus shall consist of an integrally cast rigid iron frame and a circular rigid table top 10 ± 0.1 in. [255 ± 2.5 mm] in diameter, with a shaft attached perpendicular to the table top by means of a screw thread. The table top and shaft with contact shoulder shall be mounted on a frame in such a manner that it can be raised and dropped vertically through the specified height of 0.500 ± 0.005 in. [12.7± 0.13 mm] for new tables and of 0.500 ± 0.015 in. [12.7 ± 0.38 mm] for tables in use, by means of a rotated cam. The table top shall have a fine machined plane surface, free of blowholes and surface defects. The top shall be scribed with eight equidistant lines 2⅝ in. [68 mm] long, extending from the outside circumference toward the center of the table. Each line shall end with a scribed arc, ¼ in. [6 mm] long, whose center point is the center of the table top with a radius of 2⅜ in. [59.5 mm]. The scribe lines shall be made with a 60° tool to a depth of 0.01 in. [0.25 mm]. The table top shall be of cast brass or bronze having a Rockwell hardness number not less than 25 HRB with an edge thickness of 0.3 in. [7.5 mm], and shall have six integral radial stiffening ribs. The table top and attached shaft shall weigh 9 ± 0.1 lb [4.08 ± 0.05 kg] and the weight shall be symmetrical around the center of the shaft.

3.2 The cam and vertical shaft shall be of medium carbon machinery steel, hardened on the end of the shaft contacting the cam and the tip of the cam contacting the shaft. The shaft shall be straight and the difference between the diameter of the shaft and the diameter of the bore of the frame shall be not less than 0.002 in. [0.05 mm] and not more than 0.003 in. [0.08 mm] for new tables and shall be maintained at 0.002 to 0.010 in. [0.05 to 0.25 mm] for tables in use. The end of the shaft shall not fall upon the cam at the end of the drop, but shall make contact with the cam not less than 120° from the point of drop. The face of the cam shall be a smooth spiraled curve of uniformly increasing radius from ½ to 1¼ in. [13 to 32 mm] in 360° and there shall be no appreciable jar as the shaft comes into contact with the cam. The cam shall be so located and the contact faces of the cam and shaft shall be such that the table does not rotate more than one revolution in 25 drops. The surfaces of the frame and of the table that come into contact at the end of the drop shall be maintained smooth, plane, and horizontal and parallel with the upper surface of the table and shall make continuous contact over a full 360°.

3.3 The supporting frame of the flow table shall be integrally cast of fine-grained, high-grade cast iron. The frame casting shall have three integral stiffening ribs extending the full height of the frame and located 120° apart. The top of the frame shall be chilled to a depth of approximately ¼ in. [6

[1] This specification is under the jurisdiction of ASTM Committee C01 on Cement and is the direct responsibility of Subcommittee C01.22 on Workability.

Current edition approved July 1, 2008. Published August 2008. Originally approved in 1949. Last previous edition approved in 2003 as C 230/C 230M – 03.

[2] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

***A Summary of Changes section appears at the end of this standard.**

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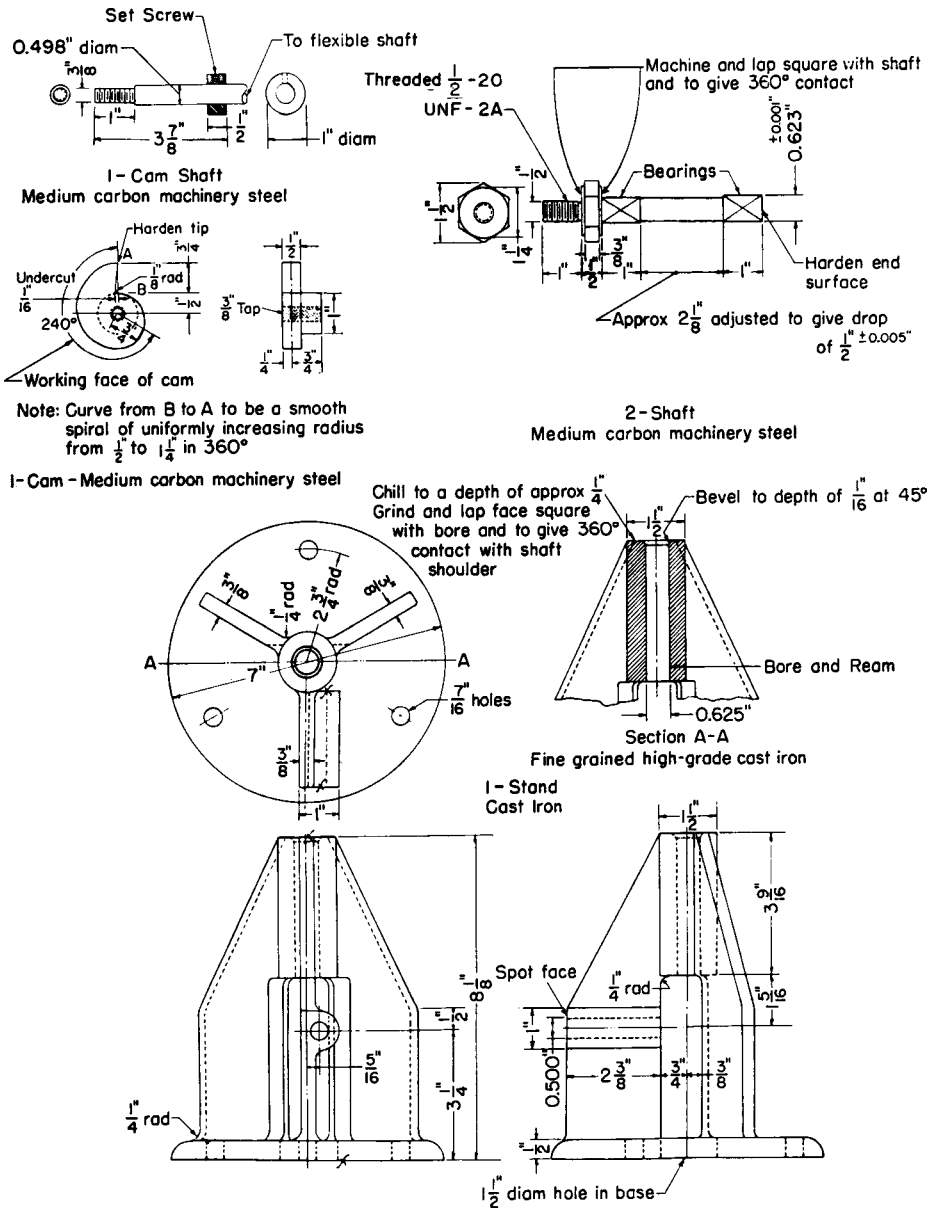

FIG. 1 Flow Table and Accessory Apparatus (Partial) (In./Lb)

mm], and the face shall be ground and lapped square with the bore to give 360° contact with the shaft shoulder. The underside of the base of the frame shall be ground to secure a complete contact with the steel plate beneath.

3.4 The flow table shall be driven by a motor (Note 2), connected to the cam shaft through an enclosed worm gear speed reducer and flexible coupling. The speed of the cam shaft shall be approximately 100 r/min. The motor drive mechanism shall not be fastened or mounted on the table base plate or frame.

NOTE 2—A 1/20-hp [40-W] motor has been found adequate.

3.5 The performance of a flow table shall be considered satisfactory if, in calibration tests, the table gives a flow value that does not differ by more than 5 percentage points from flow values obtained with a suitable calibration material.[3,4] (See Note 3)

[3] Such a material can be obtained from the Cement and Concrete Reference Laboratory at the National Institute of Standards and Technology, Gaithersburg, MD 20899.

[4] Supporting data have been filed at ASTM International Headquarters and may be obtained by requesting Research Report RR: C01–1006.

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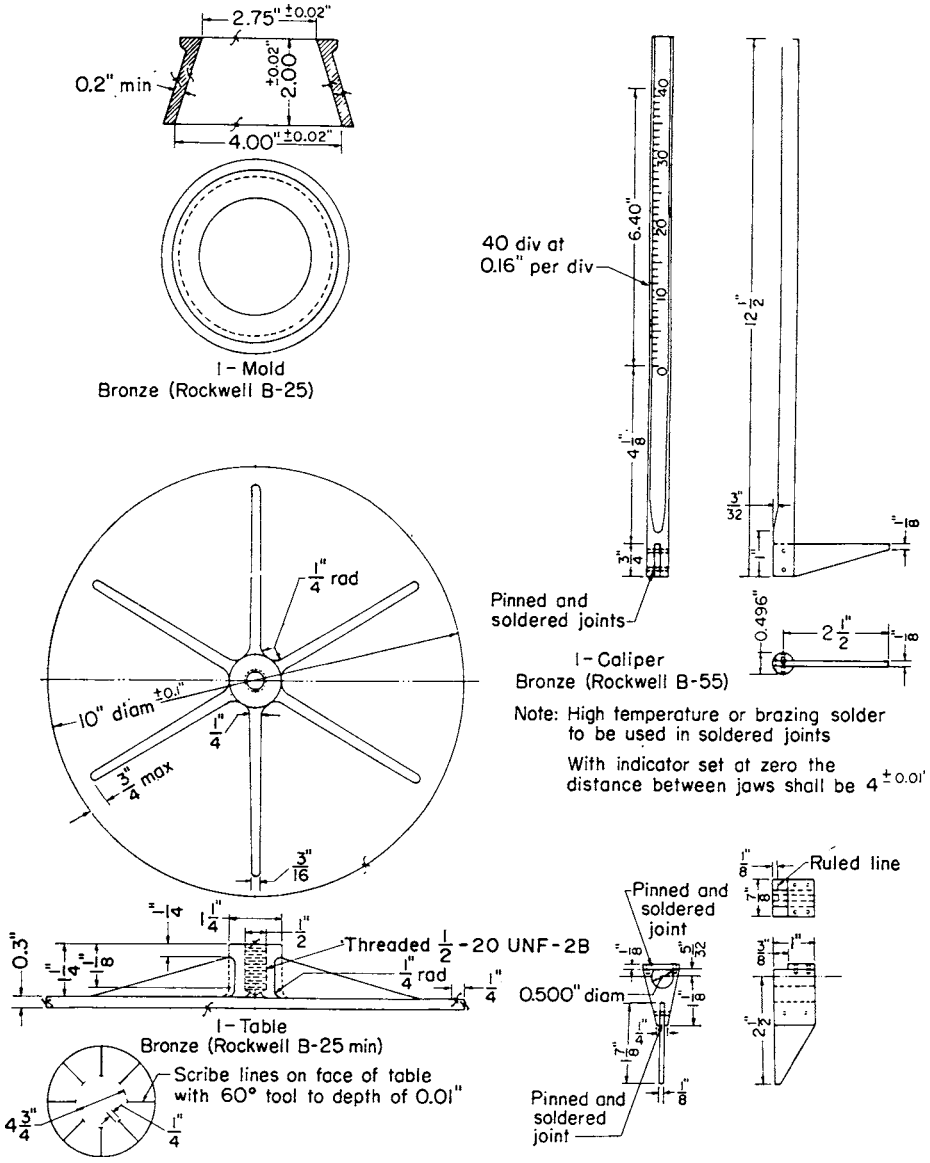

FIG. 1 Flow Table and Accessory Apparatus (Partial) (In./Lb) *(continued)*

NOTE 3—Some causes of and solutions to unsatisfactory performance of the flow table may be found in the section on flow tables in the *ASTM Manual of Cement Testing*.

4. Flow Table Mounting

4.1 The flow table frame shall be tightly bolted to a cast iron or steel plate at least 1 in. [25 mm] thick and 10 in. [250 mm] square. The top surface of this plate shall be machined to a smooth plane surface. The plate shall be anchored to the top of a concrete pedestal by four ½-in. [13-mm] bolts that pass through the plate and are imbedded at least 6 in. [150 mm] in the pedestal. The pedestal shall be cast inverted on the base plate. A positive contact between the base plate and the pedestal shall be obtained at all points. No nuts or other such leveling devices shall be used between the plate and the pedestal. Leveling shall be effected by suitable means under the base of the pedestal.

4.2 The pedestal shall be 10 to 11 in. [250 to 275 mm] square at the top, and 15 to 16 in. [375 to 400 mm] square at the bottom, 25 to 30 in. [625 to 750 mm] in height, and shall be of monolithic construction, cast from concrete weighing at least 140 lb/ft^3 [2240 kg/m ^{3}]. A stable gasket cork padding, ½ in. [13 mm] thick and the same size as the pedestal bottom or four pieces of padding ½ in. [13 mm] thick and approximately 4 in. [100 mm] square, shall be inserted under the pedestal or the four corners, respectively. The flow table shall be checked frequently for levelness of the table top, stability of the pedestal, and tightness of the bolts and nuts in the table base and the pedestal table. (A torque of 20 lb·ft [27 N·m] is recommended when tightening those fastenings.)

4.3 The table top, after the frame has been mounted on the pedestal, shall be level along two diameters at right angles to each other, in both the raised and lowered positions.

5. Flow Table Lubrication

5.1 The vertical shaft of the table shall be kept clean and shall be lightly lubricated (See Note 4) with a light oil

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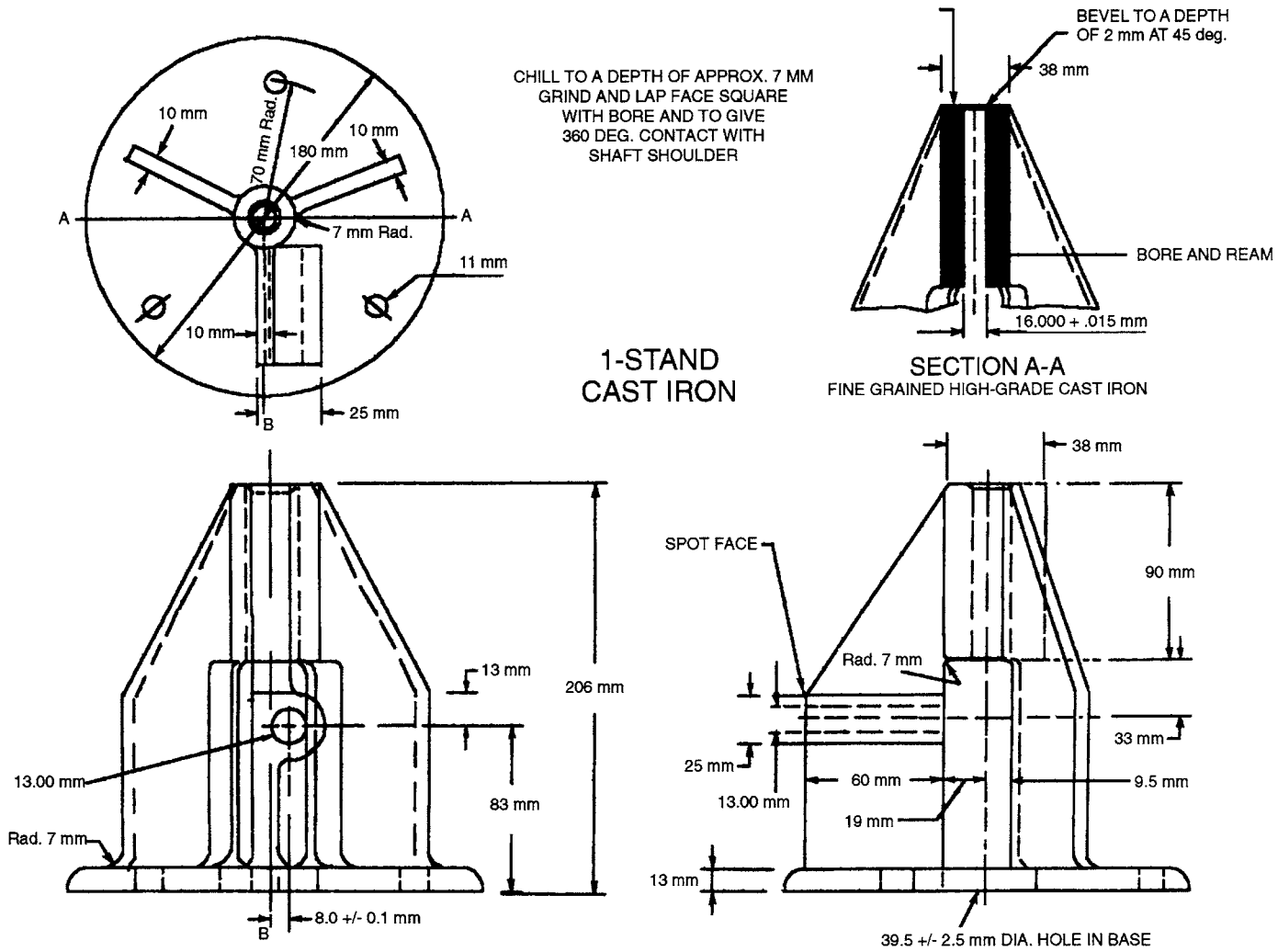

FIG. 2 Flow Table and Accessory Apparatus (Partial) [SI]

(SAE-10). Oil shall not be present between the contact faces of the table top and the supporting frame. Oil on the cam face will lessen wear and promote smoothness of operation. The table should be raised and permitted to drop a dozen or more times just prior to use if it has not been operated for some time.

NOTE 4—It has been demonstrated that an absence of lubrication on the table shaft will significantly reduce the flow reading.

6. Mold and Caliper

6.1 The conical mold for casting the flow specimen shall be of cast bronze or brass. The Rockwell hardness number of the metal shall be not less than 25 HRB. The height of the mold shall be 2.00 ± 0.02 in. [50.0 ± 0.5 mm]. The diameter of the top opening shall be 2.75± 0.02 in. [70.0 ± 0.5 mm] for new molds and 2.75 + 0.05 in. [70.0 + 1.3 mm] and –0.02 in. [–0.5 mm] for molds in use. The diameter of the bottom opening shall be 4.00 ± 0.02 in. [100.0 ± 0.5 mm] for new molds and 4.00 + 0.05 in. [+ 1.3 mm] and –0.02 in. [–0.5 mm] for molds in use. The surfaces of the base and top shall be parallel and at right angles to the vertical axis of the cone. The mold shall have a minimum wall thickness of 0.2 in. [5 mm]. The outside of the top edge of the mold shall be shaped so as to provide an integral collar for convenient lifting of the mold. All surfaces shall be machined to a smooth finish. A circular shield approximately 10 in. [255 mm] in diameter, with a center opening approximately 4 in. [100 mm] in diameter, made of nonabsorbing material not attacked by the cement, shall be used with the flow mold to prevent mortar from spilling on the table top.

6.2 A caliper consisting of one fixed jaw and one jaw movable along a permanent scale shall be provided for measuring the diameter of the mortar after it has been spread by the operation of the table. The scale shall be machine divided into 40 increments with 0.16 in. [4.0 mm] between divisions with major division lines every 5 divisions and the increment number every 10 divisions (Note 5). The construction and accuracy of the caliper shall be such that the distance between the jaws shall be 4 ± 0.01 in. [100 ± 0.25 mm] when the indicator is set at zero.

NOTE 5—The caliper is graduated to indicate one fourth of the actual flow percentage, so that the readings of four measurements on the caliper may be added to give the flow value without the necessity of calculating the average of four individual measurements of the total flow.

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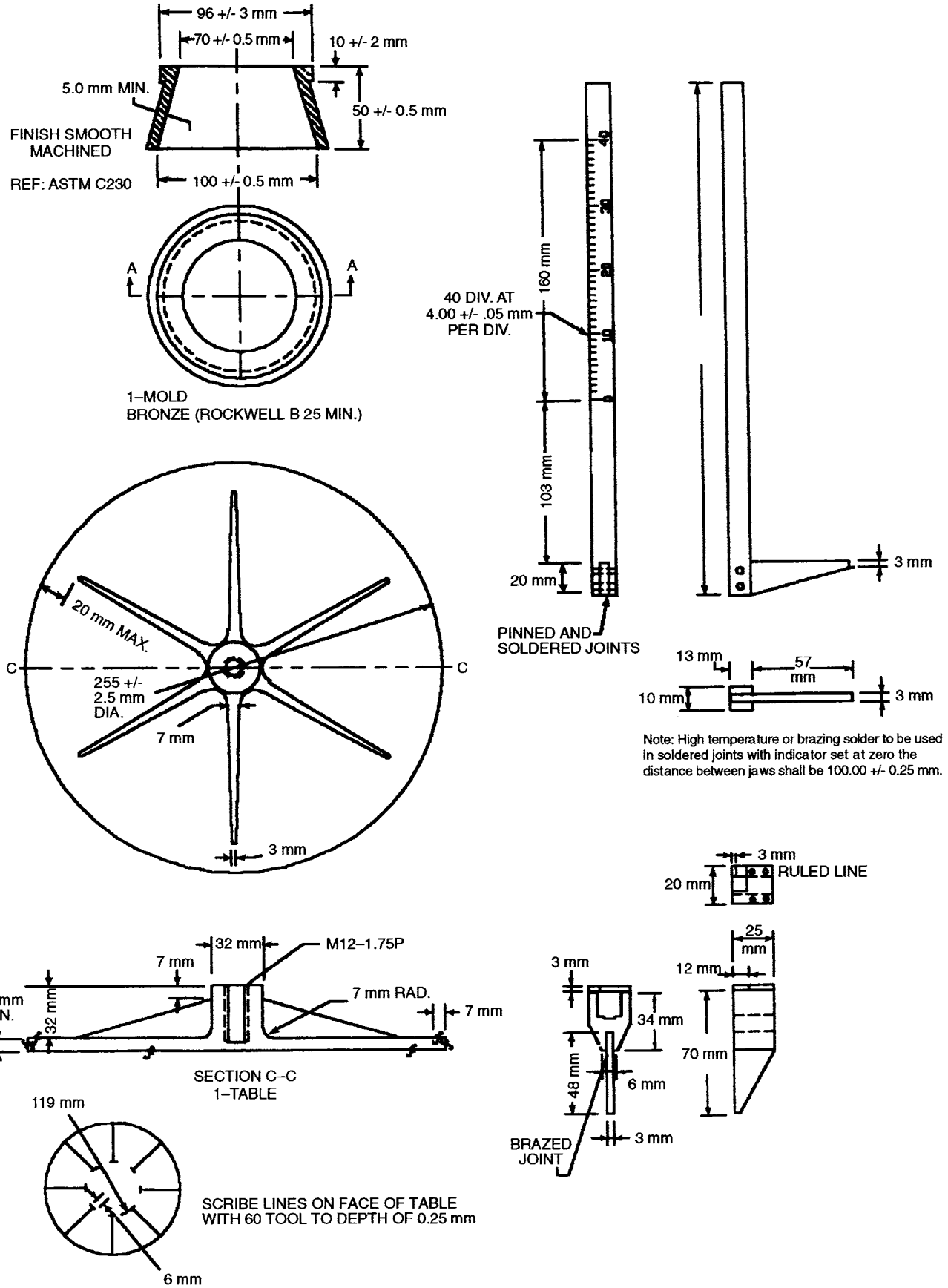

FIG. 2 Flow Table and Accessory Apparatus (Partial) [SI] *(continued)*

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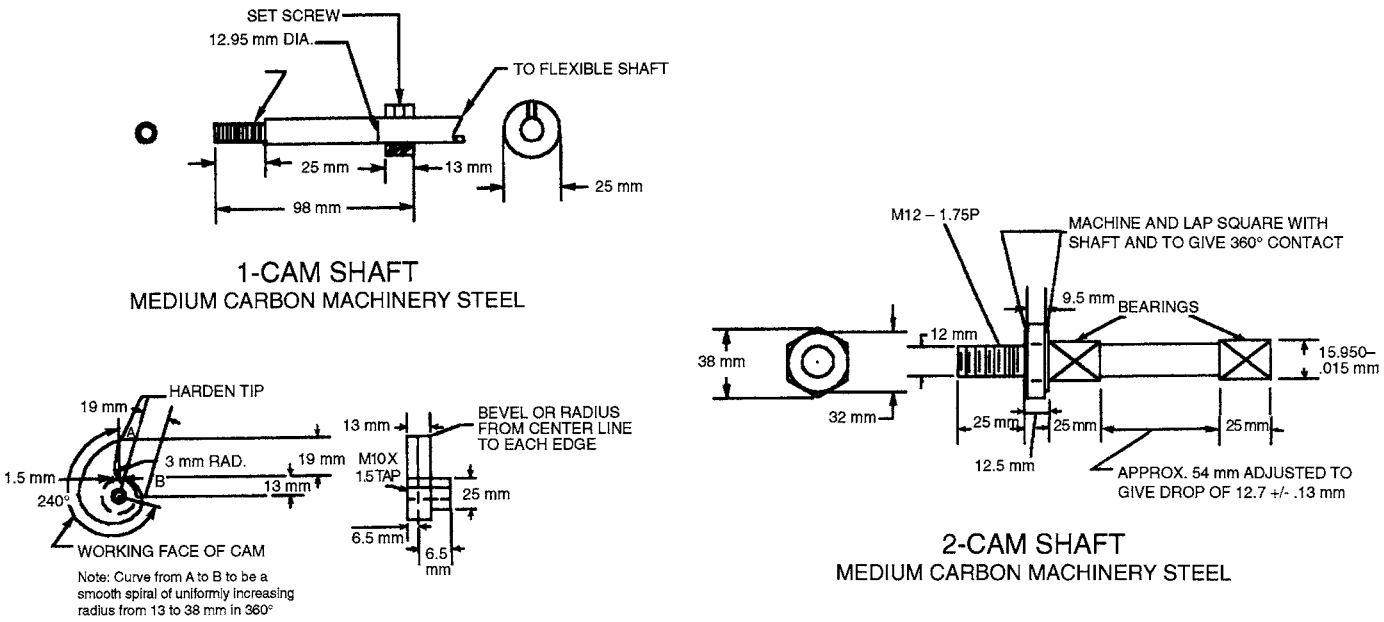

FIG. 2 Flow Table and Accessory Apparatus (Partial) [SI] *(continued)*

SUMMARY OF CHANGES

Committee C01 has identified the location of selected changes to this specification since the last issue, C 230/C 230M – 03, that may impact the use of this specification. (Approved July 1, 2008)

(*1*) Revised 1.1 and added new 1.3.

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Designation: C231/C231M – 09b

Standard Test Method for Air Content of Freshly Mixed Concrete by the Pressure Method[1]

This standard is issued under the fixed designation C231/C231M; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

This standard has been approved for use by agencies of the Department of Defense.

1. Scope*

1.1 This test method covers determination of the air content of freshly mixed concrete from observation of the change in volume of concrete with a change in pressure.

1.2 This test method is intended for use with concretes and mortars made with relatively dense aggregates for which the aggregate correction factor can be satisfactorily determined by the technique described in Section 6. It is not applicable to concretes made with lightweight aggregates, air-cooled blast-furnace slag, or aggregates of high porosity. In these cases, Test Method C173/C173M should be used. This test method is also not applicable to nonplastic concrete such as is commonly used in the manufacture of pipe and concrete masonry units.

1.3 The text of this test method references notes and footnotes that provide explanatory information. These notes and footnotes (excluding those in tables and figures) shall not be considered as requirements of this standard.

1.4 The values stated in either SI units or inch-pound units are to be regarded separately as standard. The values stated in each system may not be exact equivalents; therefore, each system shall be used independently of the other. Combining values from the two systems may result in non-conformance with the standard.

1.5 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.* (**Warning**—Fresh hydraulic cementitious mixtures are caustic and may cause chemical burns to skin and tissue upon prolonged exposure.)[2]

2. Referenced Documents

2.1 *ASTM Standards:*[3]

C31/C31M Practice for Making and Curing Concrete Test Specimens in the Field

C138/C138M Test Method for Density (Unit Weight), Yield, and Air Content (Gravimetric) of Concrete

C143/C143M Test Method for Slump of Hydraulic-Cement Concrete

C172 Practice for Sampling Freshly Mixed Concrete

C173/C173M Test Method for Air Content of Freshly Mixed Concrete by the Volumetric Method

C192/C192M Practice for Making and Curing Concrete Test Specimens in the Laboratory

C670 Practice for Preparing Precision and Bias Statements for Test Methods for Construction Materials

E177 Practice for Use of the Terms Precision and Bias in ASTM Test Methods

3. Significance and Use

3.1 This test method covers the determination of the air content of freshly mixed concrete. The test determines the air content of freshly mixed concrete exclusive of any air that may exist inside voids within aggregate particles. For this reason, it is applicable to concrete made with relatively dense aggregate particles and requires determination of the aggregate correction factor (see 6.1 and 9.1).

3.2 This test method and Test Method C138/C138M and C173/C173M provide pressure, gravimetric, and volumetric procedures, respectively, for determining the air content of freshly mixed concrete. The pressure procedure of this test method gives substantially the same air contents as the other two test methods for concretes made with dense aggregates.

3.3 The air content of hardened concrete may be either higher or lower than that determined by this test method. This

[1] This test method is under the jurisdiction of ASTM Committee C09 on Concrete and Concrete Aggregates and is the direct responsibility of Subcommittee C09.60 on Testing Fresh Concrete.

Current edition approved Dec. 15, 2009. Published February 2010. Originally approved in 1949. Last previous edition approved in 2009 as C231 – 09a. DOI: 10.1520/C0231_C0231M-09b.

[2] Section on Safety Precautions, Manual of Aggregate and Concrete Testing, *Annual Book of ASTM Standards*, Vol 04.02.

[3] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

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depends upon the methods and amount of consolidation effort applied to the concrete from which the hardened concrete specimen is taken; uniformity and stability of the air bubbles in the fresh and hardened concrete; accuracy of the microscopic examination, if used; time of comparison; environmental exposure; stage in the delivery, placement and consolidation processes at which the air content of the unhardened concrete is determined, that is, before or after the concrete goes through a pump; and other factors.

4. Apparatus

4.1 *Air Meters*—There are available satisfactory apparatus of two basic operational designs employing the principle of Boyle's law. For purposes of reference herein these are designated Meter Type A and Meter Type B.

4.1.1 *Meter Type A*—An air meter consisting of a measuring bowl and cover assembly (see Fig. 1) conforming to the requirements of 4.2 and 4.3. The operational principle of this meter consists of introducing water to a predetermined height above a sample of concrete of known volume, and the application of a predetermined air pressure over the water. The determination consists of the reduction in volume of the air in the concrete sample by observing the amount the water level is lowered under the applied pressure, the latter amount being calibrated in terms of percent of air in the concrete sample.

4.1.2 *Meter Type B*—An air meter consisting of a measuring bowl and cover assembly (see Fig. 2) conforming to the requirements of 4.2 and 4.3. The operational principle of this meter consists of equalizing a known volume of air at a known pressure in a sealed air chamber with the unknown volume of air in the concrete sample, the dial on the pressure gauge being calibrated in terms of percent air for the observed pressure at which equalization takes place. Working pressures of 50 to 205 kPa [7.5 to 30.0 psi] have been used satisfactorily.

4.2 *Measuring Bowl*—The measuring bowl shall be essentially cylindrical in shape, made of steel, hard metal, or other hard material not readily attacked by the cement paste, having a minimum diameter equal to 0.75 to 1.25 times the height, and a capacity of at least 6.0 L [0.20 ft^3]. It shall be flanged or otherwise constructed to provide for a pressure tight fit between measuring bowl and cover assembly. The interior surfaces of the measuring bowl and surfaces of rims, flanges, and other component fitted parts shall be machined smooth. The measuring bowl and cover assembly shall be sufficiently rigid to limit the expansion factor, *D*, of the apparatus assembly (Annex A1.5) to not more than 0.1 % of air content on the indicator scale when under normal operating pressure.

4.3 *Cover Assembly*:

4.3.1 The cover assembly shall be made of steel, hard metal, or other hard material not readily attacked by the cement paste. It shall be flanged or otherwise constructed to provide for a pressure-tight fit between measuring bowl and cover assembly and shall have machined smooth interior surfaces contoured to provide an air space above the level of the top of the measuring bowl. The cover shall be sufficiently rigid to limit the expansion factor of the apparatus assembly as prescribed in 4.2.

4.3.2 The cover assembly shall be fitted with a means of direct reading of the air content. The cover for the Type A meter shall be fitted with a standpipe, made of a transparent graduated tube or a metal tube of uniform bore with a glass water gauge attached. In the Type B meter, the dial of the pressure gauge shall be calibrated to indicate the percent of air. Graduations shall be provided for a range in air content of at least 8 % readable to 0.1 % as determined by the proper air pressure calibration test.

4.3.3 The cover assembly shall be fitted with air valves, air bleeder valves, and petcocks for bleeding off or through which water may be introduced as necessary for the particular meter design. Suitable means for clamping the cover to the measuring bowl shall be provided to make a pressure-tight seal without entrapping air at the joint between the flanges of the cover and measuring bowl. A suitable hand pump shall be provided with the cover either as an attachment or as an accessory.

4.4 *Calibration Vessel*—A measure having an internal volume equal to a percent of the volume of the measuring bowl corresponding to the approximate percent of air in the concrete to be tested; or, if smaller, it shall be possible to check calibration of the meter indicator at the approximate percent of air in the concrete to be tested by repeated filling of the measure. When the design of the meter requires placing the calibration vessel within the measuring bowl to check calibration, the measure shall be cylindrical in shape.

NOTE 1—A satisfactory calibration vessel to place within the measuring bowl may be machined from No. 16 gauge brass tubing, of a diameter to provide the volume desired, to which a brass disk 13 mm [½ in.] in thickness is soldered to form an end. When design of the meter requires withdrawing of water from the water-filled measuring bowl and cover assembly, to check calibration, the measure may be an integral part of the cover assembly or may be a separate cylindrical measure similar to the above-described cylinder.

4.5 The designs of various available types of air meters are such that they differ in operating techniques; therefore, all of the items described in 4.6-4.16 may not be required. The items required shall be those necessary for use with the particular design of apparatus used to satisfactorily determine air content in accordance with the procedures prescribed herein.

4.6 *Coil Spring or Other Device for Holding Calibration Cylinder in Place*.

4.7 *Spray Tube*—A brass tube of appropriate diameter, which may be an integral part of the cover assembly, or which may be provided separately. It shall be so constructed that when water is added to the container, it is sprayed to the walls of the cover in such a manner as to flow down the sides causing a minimum of disturbance to the concrete.

4.8 *Trowel*—A standard brick mason's trowel.

4.9 *Tamping Rod*—A round, straight steel rod, with a 16 mm [⅝ in.] ± 2 mm [1⁄16 in.] diameter. The length of the tamping rod shall be at least 100 mm [4 in.] greater than the depth of the measuring bowl in which rodding is being performed, but not greater than 600 mm [24 in.] in overall length (See Note 2). The length tolerance for the tamping rod shall be ± 4 mm [⅛ in.]. The rod shall have the tamping end or both ends rounded to a hemispherical tip of the same diameter as the rod.

NOTE 2—A rod length of 400 mm [16 in.] to 600 mm [24 in.] meets the requirements of the following: Practice C31/C31M, Test Method C138/C138M, Test Method C143/C143M, Test Method C173/C173M, and Test Method C231/C231M.

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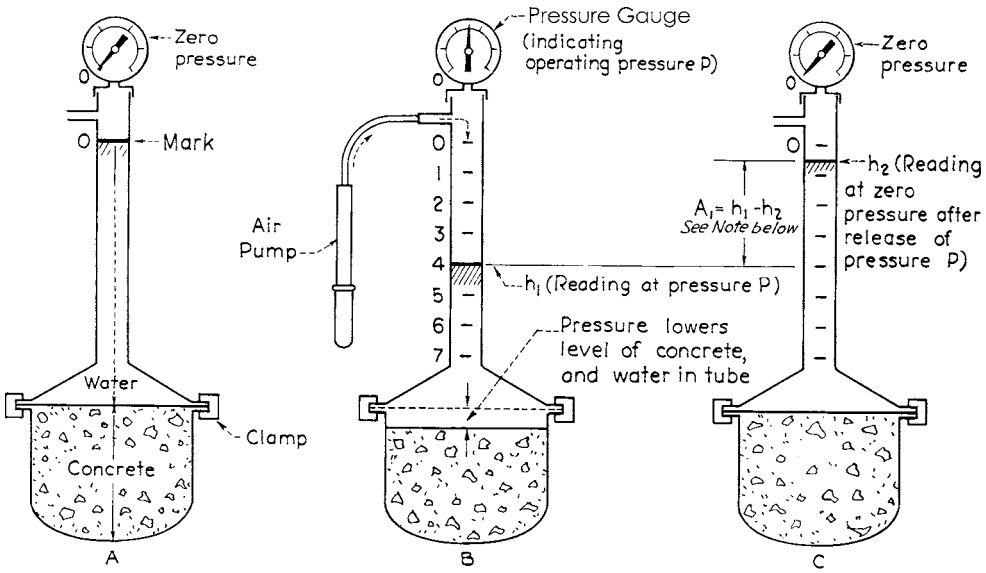

Note: $A_1 = h_1 - h_2$ when measuring bowl contains concrete as shown in this figure; when measuring bowl contains only aggregate and water, $h_1 - h_2 = G$ (aggregate correction factor). $A_1 - G = A$ (entrained air content of concrete)

FIG. 1 Illustration of the Pressure Method for Air Content—Type-A Meter

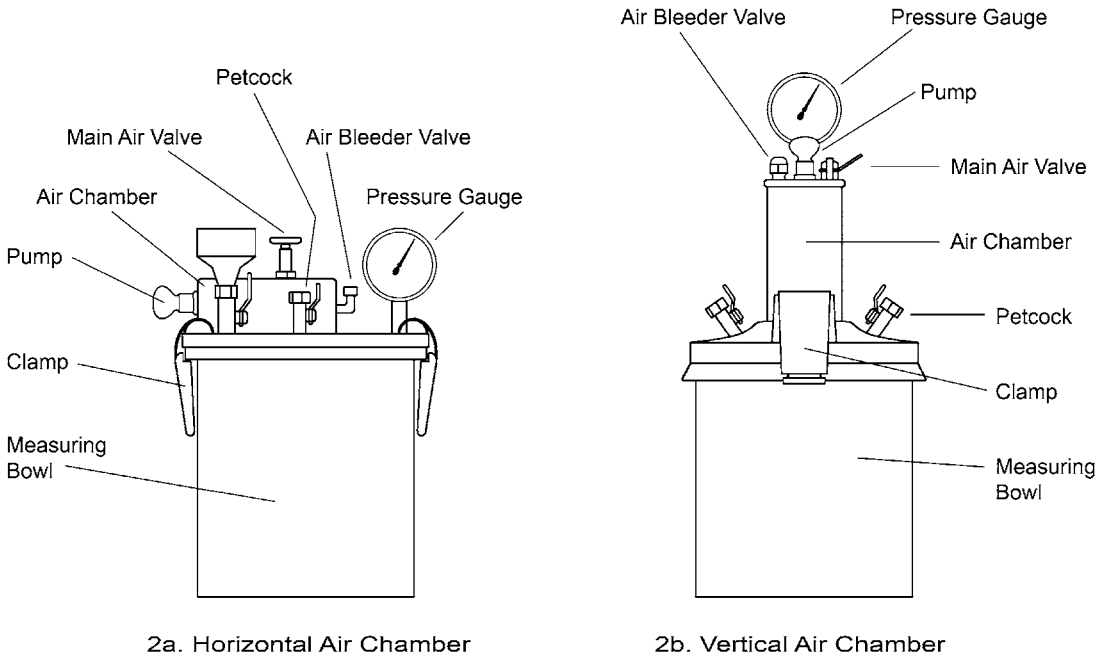

FIG. 2 Schematic Diagram—Type-B Meter

4.10 *Mallet*—A mallet (with a rubber or rawhide head) weighing approximately 0.60 ± 0.25 kg [1.25 ± 0.50 lb] for use with measures of 14 L [0.5 ft^3] or smaller, and a mallet weighing approximately 1.0 ± 0.25 kg [2.25 ± 0.50 lb] for use with measures larger than 14 L [0.5 ft^3].

4.11 *Strike-Off Bar*—A flat straight bar of steel or other suitable metal at least 3 mm [⅛ in.] thick and 20 mm [¾ in.] wide by 300 mm [12 in.] long.

4.12 *Strike-Off Plate*—A flat rectangular metal plate at least 6 mm [¼ in.] thick or a glass or acrylic plate at least 13 mm [½ in.] thick with a length and width at least 50 mm [2 in.] greater than the diameter of the measure with which it is to be used. The edges of the plate shall be straight and smooth within a tolerance of 1.5 mm [1⁄16 in.].

4.13 *Funnel*, with the spout fitting into spray tube.

4.14 *Measure for Water*, having the necessary capacity to fill the indicator with water from the top of the concrete to the zero mark.

4.15 *Vibrator*, as described in Practice C192/C192M.

4.16 *Sieves*, 37.5-mm (1½-in.) with not less than 0.2 m^2 [2 ft^2] of sieving area.

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4.17 *Scoop*—of a size large enough so each amount of concrete obtained from the sampling receptacle is representative and small enough so it is not spilled during placement in the measuring bowl.

5. Calibration of Apparatus

5.1 Make calibration tests in accordance with procedures prescribed in the annex. Rough handling will affect the calibration of both Types A and B meters. Changes in barometric pressure will affect the calibration of Type A meter but not Type B meter. The steps described A1.2-A1.6, as applicable to the meter type under consideration, are prerequisites for the final calibration test to determine the operating pressure, *P*, on the pressure gauge of the Type A meter as described in A1.7, or to determine the accuracy of the graduations indicating air content on the dial face of the pressure gauge of the Type B meter as described in A1.9. The steps in A1.2-A1.6 need be made only once (at the time of initial calibration), or only occasionally to check volume constancy of the calibration cylinder and measuring bowl. The calibration test described in A1.7 and A1.9, as applicable to the meter type being checked, must be made as frequently as necessary and at intervals not to exceed three months to ensure that the proper gauge pressure, *P*, is being used for the Type A meter or that the correct air contents are being indicated on the pressure gauge air content scale for the Type B meter. A change in elevation of more than 180 m [600 ft] from the location at which a Type A meter was last calibrated will require recalibration in accordance with A1.7.

5.2 *Calibration Records*—Information to be maintained in the records shall include determination of expansion factor; size of the calibration vessel used; and the reading of the meter at the calibration test point(s).

6. Determination of Aggregate Correction Factor

6.1 *Procedure*—Determine the aggregate correction factor on a combined sample of fine and coarse aggregate as directed in 6.2 to 6.4. It is determined independently by applying the calibrated pressure to a sample of inundated fine and coarse aggregate in approximately the same moisture condition, amount, and proportions occurring in the concrete sample under test.

6.2 *Aggregate Sample Size*—Calculate the weights of fine and coarse aggregate present in the sample of fresh concrete whose air content is to be determined, as follows:

$$F_s = (S/B) \times F_b \quad (1)$$

$$C_s = (S/B) \times C_b \quad (2)$$

where:

F_s = mass of fine aggregate in concrete sample under test, kg [lb],

S = volume of concrete sample (same as volume of measuring bowl), m^3 [ft^3],

B = volume of concrete produced per batch (Note 3), m^3 [ft^3],

F_b = total mass of fine aggregate in the moisture condition used in batch, kg [lb],

C_s = mass of coarse aggregate in concrete sample under test, kg [lb], and

C_b = total mass of coarse aggregate in the moisture condition used in batch, kg [lb].

NOTE 3—The volume of concrete produced per batch can be determined in accordance with applicable provisions of Test Method C138/C138M.

NOTE 4—The term "weight" is temporarily used in this test method because of established trade usage. The word is used to mean both "force" and "mass," and care must be taken to determine which is meant in each case (SI unit for force = newton and for mass = kilogram).

6.3 *Placement of Aggregate in Measuring Bowl*—Mix representative samples of fine aggregate F_s and coarse aggregate C_s, and place in the measuring bowl filled one-third full with water. Place the mixed aggregate, a small amount at a time, into the measuring bowl; if necessary, add additional water so as to inundate all of the aggregate. Add each scoopful in a manner that will entrap as little air as possible and remove accumulations of foam promptly. Tap the sides of the measuring bowl and lightly rod the upper 25 mm [1 in.] of the aggregate eight to twelve times. Stir after each addition of aggregate to eliminate entrapped air.

6.4 *Aggregate Correction Factor Determination*:

6.4.1 *Initial Procedure for Types A and B Meters*—When all of the aggregate has been placed in the measuring bowl, remove excess foam and keep the aggregate inundated for a period of time approximately equal to the time between introduction of the water into the mixer and the time of performing the test for air content before proceeding with the determination as directed in 6.4.2 or 6.4.3.

6.4.2 *Type A Meter*—Complete the test as described in 8.2.1-8.2.3. The aggregate correction factor, *G*, is equal to $h_1 - h_2$ (see Fig. 1) (Note 5).

6.4.3 *Type B Meter*—Perform the procedures as described in 8.3.1. Remove a volume of water from the assembled and filled apparatus approximately equivalent to the volume of air that would be contained in a typical concrete sample of a size equal to the volume of the measuring bowl. Remove the water in the manner described in A1.9 for the calibration tests. Complete the test as described in 8.3.2. The aggregate correction factor, *G*, is equal to the reading on the air-content scale minus the volume of water removed from the measuring bowl expressed as a percent of the volume of the measuring bowl (see Fig. 1).

NOTE 5—The aggregate correction factor will vary with different aggregates. It can be determined only by test, since apparently it is not directly related to absorption of the particles. The test can be made easily. Ordinarily the factor will remain reasonably constant for given aggregates, but an occasional check test is recommended.

7. Preparation of Concrete Test Sample

7.1 Obtain the sample of freshly mixed concrete in accordance with applicable procedures of Practice C172. If the concrete contains coarse aggregate particles that would be retained on a 50-mm (2-in.) sieve, wet-sieve a sufficient amount of the representative sample over a 37.5-mm (1½-in.) sieve, as described in Practice C172, to yield sufficient material to completely fill the measuring bowl of the size selected for use. Carry out the wet-sieving operation with the minimum

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practicable disturbance of the mortar. Make no attempt to wipe adhering mortar from coarse aggregate particles retained on the sieve.

8. Procedure for Determining Air Content of Concrete

8.1 *Placement and Consolidation of Sample*:

8.1.1 Prepare the concrete as described in 7.1. Dampen the interior of the measuring bowl and place it on a flat, level, firm surface. Using the scoop described in 4.17, place the concrete in the measuring bowl in the number of layers required by the consolidation method (8.1.2 or 8.1.3). While placing the concrete in the bowl, move the scoop around the perimeter of the bowl opening to ensure an even distribution of the concrete with minimal segregation. Consolidate each layer by the rodding procedure (8.1.2) or by vibration (8.1.3). Strike-off the finally consolidated layer (8.1.4). Rod concretes with a slump greater than 75 mm [3 in.]. Rod or vibrate concrete with a slump of 25 to 75 mm [1 to 3 in.]. Consolidate concretes with a slump less than 25 mm [1 in.] by vibration.

8.1.2 *Rodding*—Place the concrete in the measuring bowl in three layers of approximately equal volume. Rod each layer 25 times uniformly over the cross section with the rounded end of the rod. Rod the bottom layer throughout its depth. In rodding this layer, use care not to damage the bottom of the measuring bowl. For each upper layer, allow the rod to penetrate through the layer being rodded and into the layer below approximately 25 mm [1 in.]. After each layer is rodded, tap the sides of the measuring bowl smartly 10 to 15 times with the mallet to close any voids left by the tamping rod and to release any large bubbles of air that may have been trapped. Add the final layer of concrete in a manner to avoid excessive overfilling (8.1.4).

8.1.3 *Vibration*—Place the concrete in the measuring bowl in two layers of approximately equal volume. Place all of the concrete for each layer before starting vibration of that layer. Consolidate each layer by three insertions of the vibrator evenly distributed over the cross section. Add the final layer in a manner to avoid excessive overfilling (8.1.4). In consolidating each layer, do not allow the vibrator to rest on or touch the measuring bowl. Take care in withdrawing the vibrator to ensure that no air pockets are left in the specimen. Observe a standard duration of vibration for the particular kind of concrete, vibrator, and measuring bowl involved. The duration of vibration required will depend upon the workability of the concrete and the effectiveness of the vibrator. Continue vibration until the concrete is properly consolidated. Never continue vibration long enough to cause escape of froth from the sample.

NOTE 6—Overvibration may cause segregation and loss of intentionally entrained air. Usually, sufficient vibration has been applied as soon as the surface of the concrete becomes relatively smooth and has a glazed appearance.

8.1.4 *Strike Off*—After consolidation of the concrete, strike off the top surface by sliding the strike-off bar across the top flange or rim of the measuring bowl with a sawing motion until the bowl is just level full. On completion of consolidation, the measuring bowl must not contain an excess or deficiency of concrete. Removal of 3 mm [⅛ in.] during strike off is optimum. When a strike-off plate is used, strike off concrete as prescribed in Test Method C138/C138M.

NOTE 7—A small quantity of representative concrete may be added to correct a deficiency. If the measure contains a great excess, remove a representative portion of concrete with a trowel or scoop before the measure is struck off.

NOTE 8—The use of the strike-off plate on cast aluminum or other relatively soft metal air meter bases may cause rapid wear of the rim and require frequent maintenance, calibration, and ultimately, replacement.

8.1.5 *Application of Test Method*—Any portion of the test method not specifically designated as pertaining to Type A or Type B meter shall apply to both types.

8.2 *Procedure—Type A Meter*:

8.2.1 *Preparation for Test*—Thoroughly clean the flanges or rims of the measuring bowl and of the cover assembly so that when the cover is clamped in place a pressure-tight seal will be obtained. Assemble the apparatus and add water over the concrete by means of the tube until it rises to about the halfway mark in the standpipe. Incline the apparatus assembly about 0.5 rad [30°] from vertical and, using the bottom of the measuring bowl as a pivot, describe several complete circles with the upper end of the column, simultaneously tapping the cover lightly to remove any entrapped air bubbles above the concrete sample. Return the apparatus assembly to a vertical position and fill the water column slightly above the zero mark, while lightly tapping the sides of the measuring bowl. Bring the water level to the zero mark of the graduated tube before closing the vent at the top of the water column (see Fig. 1 A).

NOTE 9—Some Type A meters have a calibrated starting fill mark above the zero mark. Generally, this starting mark should not be used since, as noted in 8.2.3, the apparent air content is the difference between the water level reading H, at pressure P and the water level h_2 at zero pressure after release of pressure P.

8.2.2 The internal surface of the cover assembly shall be kept clean and free from oil or grease; the surface shall be wet to prevent adherence of air bubbles that might be difficult to dislodge after assembly of the apparatus.

8.2.3 *Test Procedure*—Apply more than the desired test pressure, P, (about 1.4 kPa [0.2 psi] more) to the concrete by means of the small hand pump. To relieve local restraints, tap the sides of the measuring bowl sharply and, when the pressure gauge indicates the exact test pressure, P, as determined in accordance with A1.7, read the water level, h_1, and record to the nearest division or half-division on the graduated precision-bore tube or gauge glass of the standpipe (see Fig. 1 B). For extremely harsh mixes tap the measuring bowl vigorously until further tapping produces no change in the indicated air content. Gradually release the air pressure through the vent at the top of the water column and tap the sides of the measuring bowl lightly for about 1 min. Record the water level, h_2, to the nearest division or half-division (see Fig. 1 C). Calculate the apparent air content as follows:

$$A_1 = h_1 - h_2 \tag{3}$$

where:

A_1 = apparent air content,
h_1 = water level reading at pressure, P (see Note 10), and
h_2 = water level reading at zero pressure after release of pressure, P.

8.2.4 *Check Test*—Repeat the steps described in 8.2.3 without adding water to reestablish the water level at the zero mark.

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The two consecutive determinations of apparent air content should check within 0.2 % of air and shall be averaged to give the value A_1 to be used in calculating the air content, A_s, in accordance with Section 9.

8.2.5 In the event the air content exceeds the range of the meter when it is operated at the normal test pressure P, reduce the test pressure to the alternative test pressure P_1 and repeat the steps outlined in 8.2.2 and 8.2.3.

NOTE 10—See A1.7 for exact calibration procedures. An approximate value of the alternative pressure, P_1, such that the apparent air content will equal twice the meter reading can be computed from the following relationship:

$$P_1 = P_a P/(2P_a + P) \quad (4)$$

where:

P_1 = alternative test pressure, kPa or [psi],
P_a = atmospheric pressure, kPa or [psi], (approximately 100 kPa [14.7 psi] but will vary with altitude and weather conditions), and
P = normal test or operating gauge pressure, kPa or [psi].

8.3 *Procedure—Type B Meter*:

8.3.1 *Preparation for Test*—Thoroughly clean the flanges or rims of the measuring bowl and the cover assembly so that when the cover is clamped in place a pressure-tight seal will be obtained. Assemble the apparatus. Close the main air valve between the air chamber and the measuring bowl and open both petcocks on the holes through the cover. Using a rubber syringe, inject water through one petcock until water emerges from the opposite petcock. Jar the meter gently until all air is expelled from this same petcock.

8.3.2 *Test Procedure*—Close the air bleeder valve on the air chamber and pump air into the air chamber until the gauge hand is on the initial pressure line. Allow a few seconds for the compressed air to cool to normal temperature. Stabilize the gauge hand at the initial pressure line by pumping or bleeding-off air as necessary, tapping the gauge lightly by hand. Close both petcocks on the holes through the cover. Open the main air valve between the air chamber and the measuring bowl. Tap the sides of the measuring bowl smartly with the mallet to relieve local restraints. Lightly tap the pressure gauge by hand to stabilize the gauge hand. Read the percentage of air on the dial of the pressure gauge. Release the main air valve. Failure to close the main air valve before releasing the pressure from either the container or the air chamber will result in water being drawn into the air chamber, thus introducing error in subsequent measurements. In the event water enters the air chamber, it must be bled from the air chamber through the air bleeder valve followed by several strokes of the pump to blow out the last traces of water. Release the pressure by opening both petcocks (Fig. 2) before removing the cover.

9. Calculation

9.1 *Air Content of Sample Tested*—Calculate the air content of the concrete in the measuring bowl as follows:

$$A_s = A_1 - G \quad (5)$$

where:

A_s = air content of the sample tested, %,
A_1 = apparent air content of the sample tested, % (see 8.2.3 and 8.3.2), and
G = aggregate correction factor, % (Section 6).

9.2 *Air Content of Full Mixture*—When the sample tested represents that portion of the mixture that is obtained by wet sieving to remove aggregate particles larger than a 37.5-mm (1½-in.) sieve, the air content of the full mixture is calculated as follows:

$$A_t = 100\,A_s V_c/(100\,V_t - A_s V_a) \quad (6)$$

where: (Note 11):

A_t = air content of the full mixture, %,
V_c = absolute volume of the ingredients of the mixture passing a 37.5-mm (1½-in.) sieve, airfree, as determined from the original batch weights, m^3 [ft^3],
V_t = absolute volume of all ingredients of the mixture, airfree, m^3 [ft^3], and
V_a = absolute volume of the aggregate in the mixture coarser than a 37.5-mm (1½-in.) sieve, as determined from original batch weights, m^3 [ft^3].

9.3 *Air Content of the Mortar Fraction*—When it is desired to know the air content of the mortar fraction of the mixture, calculate it as follows:

$$A_m = 100\,A_s\,V_c/[100\,V_m + A_s(V_c - V_m)] \quad (7)$$

where: (Note 11):

A_m = air content of the mortar fraction, %, and
V_m = absolute volume of the ingredients of the mortar fraction of the mixture, airfree, m^3 [ft^3].

NOTE 11—The values for use in Eq 6 and Eq 7 are most conveniently obtained from data on the concrete mixture tabulated as follows for a batch of any size:

		Absolute Volume, m^3 [ft^3]	
Cement			
Water		V_m	V_c
Fine aggregate			
Coarse aggregate (4.75-mm (No. 4) to 37.5-mm (1½-in.))			
Coarse aggregate (37.5-mm (1½-in.))		V_a	
Total		V_t	

10. Report

10.1 Report the following information:

10.1.1 The air content of the concrete sample to the nearest 0.1 % after subtracting the aggregate correction factor, unless the gauge reading of the meter exceeds 8 %, in which case the corrected reading shall be reported to the nearest ½ scale division on the dial.

10.1.2 The date and time of the test.

10.1.3 When requested, and when the absolute volume of the ingredients of the mortar fraction of the mixture can be determined, the air content of the mortar fraction of the mixture to the nearest ¼ %.

11. Precision and Bias

11.1 *Precision*:

11.1.1 *Single-Operator Precision*—The single-operator standard deviation cannot be established because the sampling

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requirements for this test, as established in Practice C172, do not allow a single operator time to conduct more than one test on a sample.

11.1.2 *Multilaboratory Precision*—The multilaboratory standard deviation has not been established.

11.1.3 *Multioperator Precision*—The multioperator standard deviation of a single test result has been found to be 0.28 % air by volume of concrete for Type A air meters as long as the air content does not exceed 7 %. Therefore results of two tests properly conducted by different operators but on the same material should not differ by more than 0.8 % air by volume of concrete (see Practice E177, Note 12 and Note 13).

NOTE 12—These numbers represent, respectively, the (1s) and (d2s) limits as described in Practice C670. The precision statements are based on the variations in tests on three different concretes, each tested by eleven different operators.[4]

NOTE 13—The precision of this test method using Type B air meters has not been determined.

11.2 *Bias*—This test method has no bias because the air content of freshly mixed concrete can only be defined in terms of the test methods.

12. Keywords

12.1 air content; calibration; concrete; correction factor; measuring bowl; meter; pressure; pump; unit weight

[4] Reidenour, D. R., and Howe, R. H., "Air Content of Plastic and Hardened Concrete," presented at the 2nd International Conference on" Durability of Building Materials and Components" Sept. 14–16, 1981. Reprints compiled by: G. Frohnsdorff and B. Horner, National Institute for Standards and Technology, Gaithersburg, MD 20899, formerly National Bureau of Standards, Washington, DC 20234.

ANNEX

(Mandatory Information)

A1. CALIBRATION OF APPARATUS

A1.1 Calibration tests shall be performed in accordance with the following procedures as applicable to the meter type being employed.

A1.2 *Calibration of the Calibration Vessel*—Determine accurately the weight of water, w, required to fill the calibration vessel, using a scale accurate to 0.1 % of the weight of the vessel filled with water. This step shall be performed for Type A and B meters.

A1.3 *Calibration of the Measuring Bowl*—Determine the weight of water, W, required to fill the measuring bowl, using a scale accurate to 0.1 % of the weight of the measuring bowl filled with water. Slide a glass plate carefully over the flange of the measuring bowl in a manner to ensure that the measuring bowl is completely filled with water. A thin film of cup grease smeared on the flange of the measuring bowl will make a watertight joint between the glass plate and the top of the measuring bowl. This step shall be performed for Type A and B meters.

A1.4 *Effective Volume of the Calibration Vessel, R*—The constant R represents the effective volume of the calibration vessel expressed as a percentage of the volume of the measuring bowl.

A1.4.1 For meter Types A, calculate R as follows (Note A1.1):

$$R = 0.98\ w/W \tag{A1.1}$$

where:

w = weight of water required to fill the calibration vessel, and
W = weight of water required to fill the measuring bowl.

NOTE A1.1—The factor 0.98 is used to correct for the reduction in the volume of air in the calibration vessel when it is compressed by a depth of water equal to the depth of the measuring bowl. This factor is approximately 0.98 for a 200-mm [8-in.] deep measuring bowl at sea level. Its value decreases to approximately 0.975 at 1500 m [5000 ft] above sea level and 0.970 at 4000 m [13 000 ft] above sea level. The value of this constant will decrease by about 0.01 for each 100-mm [4-in.] increase in measuring bowl depth. The depth of the measuring bowl and atmospheric pressure do not affect the effective volume of the calibration vessel for meter Types B.

A1.4.2 For meter Types B calculate R as follows (Note A1.1):

$$R = w/W \tag{A1.2}$$

A1.5 *Determination of, or Check of, Allowance for Expansion Factor, D*:

A1.5.1 For meter assemblies of Type A determine the expansion factor, D (Note A1.2) by filling the apparatus with water only (making certain that all entrapped air has been removed and the water level is exactly on the zero mark (Note A1.3) and applying an air pressure approximately equal to the operating pressure, P, determined by the calibration test described in A1.7. The amount the water column lowers will be the equivalent expansion factor, D, for that particular apparatus and pressure (Note A1.5).

NOTE A1.2—Although the measuring bowl, cover, and clamping mechanism of the apparatus must of necessity be sturdily constructed so

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that it will be pressure-tight, the application of internal pressure will result in a small increase in volume. This expansion will not affect the test results because, with the procedure described in Sections 6 and 8, the amount of expansion is the same for the test for air in concrete as for the test for aggregate correction factor on combined fine and coarse aggregates, and is thereby automatically cancelled. However, it does enter into the calibration test to determine the air pressure to be used in testing fresh concrete.

NOTE A1.3—The water columns on some meters of Type-A design are marked with an initial water level and a zero mark, the difference between the two marks being the allowance for the expansion factor. This allowance should be checked in the same manner as for meters not so marked and in such a case, the expansion factor should be omitted in computing the calibration readings in A1.7.

NOTE A1.4—It will be sufficiently accurate for this purpose to use an approximate value for P determined by making a preliminary calibration test as described in A1.7 except that an approximate value for the calibration factor, K, should be used. For this test $K = 0.98R$ which is the same as Eq A1.2 except that the expansion reading, D, as yet unknown, is assumed to be zero.

A1.5.2 For meters of Type B design, the allowance for the expansion factor, D, is included in the difference between the initial pressure indicated on the pressure gauge and the zero percent mark on the air-content scale on the pressure gauge. This allowance shall be checked by filling the apparatus with water (making certain that all entrapped air has been removed), pumping air into the air chamber until the gauge hand is stabilized at the indicated initial pressure line, and then releasing the air to the measuring bowl (Note A1.5). If the initial pressure line is correctly positioned, the gauge should read zero percent. The initial pressure line shall be adjusted if two or more determinations show the same variation from zero percent and the test repeated to check the adjusted initial pressure line.

NOTE A1.5—This procedure may be accomplished in conjunction with the calibration test described in A1.9.

A1.6 *Calibration Reading, K*—The calibration reading, K, is the final meter reading to be obtained when the meter is operated at the correct calibration pressure.

A1.6.1 For meter Types A, the calibration reading, K, is as follows:

$$K = R + D \tag{A1.3}$$

where:

R = effective volume of the calibration vessel (A1.4.1), and

D = expansion factor (A1.5.1, Note A1.6).

A1.6.2 For meter Types B the calibration reading, K, equals the effective volume of the calibration vessel (A1.4.2) as follows:

$$K = R \tag{A1.4}$$

NOTE A1.6—If the water column indicator is graduated to include an initial water level and a zero mark, the difference between the two marks being equivalent to the expansion factor, the term D shall be omitted from Eq A1.3.

A1.7 *Calibration Test to Determine Operating Pressure, P, on Pressure Gauge, Type A Meter*—If the rim of the calibration cylinder contains no recesses or projections, fit it with three or more spacers equally spaced around the circumference. Invert the cylinder and place it at the center of the dry bottom of the measuring bowl. The spacers will provide an opening for flow of water into the calibration cylinder when pressure is applied. Secure the inverted cylinder against displacement and carefully lower the cover assembly. After the cover is clamped in place, carefully adjust the apparatus assembly to a vertical position and add water at air temperature, by means of the tube and funnel, until it rises above the zero mark on the standpipe. Close the vent and pump air into the apparatus to the approximate operating pressure. Incline the assembly about 0.5 rad [30°] from vertical and, using the bottom of the measuring bowl as a pivot, describe several complete circles with the upper end of the standpipe, simultaneously tapping the cover and sides of the measuring bowl lightly to remove any entrapped air adhering to the inner surfaces of the apparatus. Return the apparatus to a vertical position, gradually release the pressure (to avoid loss of air from the calibration vessel), and open the vent. Bring the water level exactly to the zero mark by bleeding water through the petcock in the top of the conical cover. After closing the vent, apply pressure until the water level has dropped an amount equivalent to about 0.1 to 0.2 % of air more than the value of the calibration reading, K, determined as described in A1.6. To relieve local restraints, lightly tap the sides of the measuring bowl, and when the water level is exactly at the value of the calibration reading, K, read the pressure, P, indicated by the gauge and record to the nearest 700 Pa [0.1 psi]. Gradually release the pressure and open the vent to determine whether the water level returns to the zero mark when the sides of the measuring bowl are tapped lightly (failure to do so indicates loss of air from the calibration vessel or loss of water due to a leak in the assembly). If the water levels fails to return to within 0.05 % air of the zero mark and no leakage beyond a few drops of water is found, some air probably was lost from the calibration cylinder. In this case, repeat the calibration procedure step by step from the beginning of this paragraph. If the leakage is more than a few drops of water, tighten the leaking joint before repeating the calibration procedure. Check the indicated pressure reading promptly by bringing the water level exactly to the zero mark, closing the vent, and applying the pressure, P, just determined. Tap the gauge lightly with a finger. When the gauge indicates the exact pressure, P, the water column should read the value of the calibration factor, K, used in the first pressure application within about 0.05 % of air.

A1.7.1 The apparatus assembly must not be moved from the vertical position until pressure has been applied, which will force water about one third of the way up into the calibration cylinder. Any loss of air from this cylinder will nullify the calibration.

A1.8 *Calibration Test to Determine Alternative Operating Pressure P_1—Meter Type A*—The range of air contents which can be measured with a given meter can be doubled by determining an alternative operating pressure P_1 such that the meter reads half of the calibration reading, K, (Eq A1.3). Exact calibration will require determination of the expansion factor at the reduced pressure in A1.5. For most purposes the change in expansion factor can be disregarded and the alternative operating pressure determined during the determination of the

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regular operating pressure in A1.7.

A1.9 *Calibration Test to Check the Air Content Graduations on the Pressure Gauge, Type B Meter*—Fill the measuring bowl with water as described in A1.3. Screw the short piece of tubing or pipe furnished with the apparatus into the threaded petcock hole on the underside of the cover assembly. Assemble the apparatus. Close the main air valve between the air chamber and the measuring bowl and open the two petcocks on holes through the cover assembly. Add water through the petcock on the cover assembly having the extension below until all air is expelled from the second petcock. Pump air into the air chamber until the pressure reaches the indicated initial pressure line. Allow a few seconds for the compressed air to cool to normal temperature. Stabilize the gauge hand at the initial pressure line by pumping or bleeding off air as necessary, tapping the gauge lightly. Close the petcock not provided with the tube or pipe extension on the under side of the cover. Remove water from the assembly to the calibrating vessel controlling the flow, depending on the particular meter design, by opening the petcock provided with the tube or pipe extension and cracking the main air valve between the air chamber and the measuring bowl, or by opening the main air valve and using the petcock to control flow. Perform the calibration at an air content which is within the normal range of use. If the calibration vessel (A1.2) has a capacity within the normal range of use, remove exactly that amount of water. With some meters the calibrating vessel is quite small and it will be necessary to remove several times that volume to obtain an air content within the normal range of use. In this instance, carefully collect the water in an auxiliary container and determine the amount removed by weighing to the nearest 0.1 %. Calculate the correct air content, *R*, by using Eq A1.2. Release the air from the apparatus at the petcock not used for filling the calibration vessel and if the apparatus employs an auxiliary tube for filling the calibration container, open the petcock to which the tube is connected to drain the tube back into the measuring bowl (see A1.7.1). At this point of procedure the measuring bowl contains the percentage of air determined by the calibration test of the calibrating vessel. Pump air into the air chamber until the pressure reaches the initial pressure line marked on the pressure gauge, close both petcocks in the cover assembly, and then open the main air valve between the air chamber and the measuring bowl. The indicated air content on the pressure gauge dial should correspond to the percentage of air determined to be in the measuring bowl. If two or more determinations show the same variation from the correct air content, the dial hand shall be reset to the correct air content and the test repeated until the gauge reading corresponds to the calibrated air content within 0.1 %. If the dial hand was reset to obtain the correct air content, recheck the initial pressure mark as in A1.5.2. If a new initial pressure reading is required, repeat the calibration to check the accuracy of the graduation on the pressure gauge described earlier in this section. If difficulty is encountered in obtaining consistent readings, check for leaks, for the presence of water inside the air chamber (see Fig. 2), or the presence of air bubbles clinging to the inside surfaces of the meter from the use of cool aerated water. In this latter instance use deaerated water which can be obtained by cooling hot water to room temperature.

NOTE A1.7—If the calibrating vessel is an integral part of the cover assembly, the petcock used in filling the vessel should be closed immediately after filling the calibration vessel and not opened until the test is complete.

SUMMARY OF CHANGES

Committee C09 has identified the location of selected changes to this test method since the last issue, C231 – 09a, that may impact the use of this test method. (Approved December 15, 2009)

(*1*) Revised the standard as a dual units test method with SI units first and inch-pound units in brackets.

Committee C09 has identified the location of selected changes to this test method since the last issue, C231 – 09, that may impact the use of this test method. (Approved July 1, 2009)

(*1*) Revised 4.4.

Committee C09 has identified the location of selected changes to this test method since the last issue, C231 – 08c, that may impact the use of this test method. (Approved June 1, 2009)

(*1*) Revised 4.9 to alter tamping rod requirements.
(*2*) Added Note 2 describing acceptable tamping rod length.
(*3*) Revised 8.1.2 to alter wording of tamping rod use.

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Committee C09 has identified the location of selected changes to this test method since the last issue, C231 – 08b, that may impact the use of this test method. (Approved October 1, 2008)

(*1*) Replaced Fig. 2 with an updated line drawing of two different style meters.

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Designation: C 232/C 232M – 09

Standard Test Methods for Bleeding of Concrete[1]

This standard is issued under the fixed designation C 232/C 232M; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

This standard has been approved for use by agencies of the Department of Defense.

1. Scope*

1.1 These test methods cover the determination of the relative quantity of mixing water that will bleed from a sample of freshly mixed concrete. Two test methods, that differ primarily in the degree of vibration to which the concrete sample is subjected, are included.

1.2 The two test methods are not expected to yield the same test results when samples of concrete from the same batch are tested by each method. When various concretes are to be compared, all the tests must be conducted using the same method, and if the batches are of similar unit weight, the sample masses shall not differ by more than 1 kg [2 lb].

1.3 The values stated in either SI units or inch-pound units are to be regarded separately as standard. The values stated in each system may not be exact equivalents; therefore, each system shall be used independently of the other. Combining values from the two systems may result in non-conformance with the standard.

1.4 The text of this standard references notes and footnotes which provide explanatory material. These notes and footnotes (excluding those in tables and figures) shall not be considered as requirements of the standard.

1.5 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.* (**Warning—**Fresh hydraulic cementitious mixtures are caustic and may cause chemical burns to skin and tissue upon prolonged exposure).[2]

2. Referenced Documents

2.1 *ASTM Standards:*[3]

C 138/C 138M Test Method for Density (Unit Weight), Yield, and Air Content (Gravimetric) of Concrete

C 172 Practice for Sampling Freshly Mixed Concrete

C 192/C 192M Practice for Making and Curing Concrete Test Specimens in the Laboratory

C 670 Practice for Preparing Precision and Bias Statements for Test Methods for Construction Materials

3. Significance and Use

3.1 This test method provides procedures to be used for determining the effect of variables of composition, treatment, environment, or other factors in the bleeding of concrete. It is also permitted to be used to determine the conformance of a product or treatment with a requirement relating to its effect on bleeding of concrete.

3.2 *Method A*—For a sample consolidated by rodding only and tested without further disturbance, thus simulating conditions in which the concrete, after placement, is not subjected to intermittent vibration.

3.3 *Method B*—For a sample consolidated by vibration and tested with further intermittent periods of vibration, thus simulating conditions in which concrete, after being placed, is subjected to intermittent vibration.

TEST METHOD A—SAMPLE CONSOLIDATED BY TAMPING

4. Apparatus

4.1 *Container*—A cylindrical container of approximately 14-L [½-ft^3] capacity, having an inside diameter of 255 ± 5 mm [10 ± ¼ in.] and an inside height of 280 ± 5 mm [11 ± ¼ in.]. The container shall be made of metal having a thickness of 2.67 to 3.40 mm [0.105 to 0.134 in.] and shall be externally reinforced around the top with a 2.67 to 3.40 mm [0.105 to 0.134 in.] metal band, 40 mm [1½ in.] wide. The inside shall be smooth and free of corrosion, coatings, or lubricants.

4.2 *Scale*, of sufficient capacity to determine the mass of the load required with an accuracy of 0.5 %. Balances or scales shall be calibrated at least annually or whenever there is reason to question the accuracy of the equipment. Equipment not in operating condition or out of tolerance shall be marked as such and taken out of service until corrected.

[1] These test methods are under the jurisdiction of ASTM Committee C09 on Concrete and Concrete Aggregates and are the direct responsibility of Subcommittee C09.60 on Testing Fresh Concrete.

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[2] Section on Safety Precautions, Manual of Aggregate and Concrete Testing, *Annual Book of ASTM Standards, Vol 04.02*.

[3] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

***A Summary of Changes section appears at the end of this standard.**

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4.3 *Pipet*, or similar instrument, for drawing off free water from the surface of the test specimen.

4.4 *Glass Graduate*, 100-mL capacity for collecting and measuring the quantity of water withdrawn.

4.5 *Tamping Rod*—A round, straight steel rod, 16 mm [⅝ in.] in diameter and approximately 610 mm [24 in.] in length, having the tamping end rounded to a hemispherical tip, the diameter of which is 16 mm [⅝ in.].

4.6 The apparatus listed in 4.7, 4.8, and 4.9 are required if the procedure of measuring the amount of bleeding water recovered is one involving weighing, evaporation, and re-weighing.

4.7 *Metal Beaker (Optional)*—A 1000-mL metal beaker for collecting the decanted supernatant water and sludge.

4.8 *Balance (Optional)*—A balance sensitive to 1 g for determining the mass of the decanted water and sludge.

4.9 *Hot Plate (Optional)*—A small electric hot plate or other source of heat for evaporating decanted water.

5. Test Specimen

5.1 For concrete made in the laboratory, prepare as described in Practice C 192/C 192M. For concrete made in the field, sample the concrete as described in Practice C 172. The apparatus described in this test method is permitted to be used with samples of concrete containing any size of aggregate graded up to and including a nominal maximum size of 50 mm [2 in.]. Concrete containing aggregate larger than 50 mm [2 in.] in nominal maximum size shall be wet sieved over a 3.75 mm [1½-in.] sieve and the test performed on a portion of the sample that passes through the sieve.

5.2 Fill the container with the concrete in accordance with Test Method C 138/C 138M except that the container shall be filled to a height of 254 ± 3 mm [10 ± ⅛ in.]. Level the top surface of the concrete to a reasonably smooth surface by a minimum amount of troweling.

6. Procedure

6.1 During the test, maintain the ambient temperature between 18 and 24 °C [65 and 75 °F]. Immediately after troweling the surface of the specimen, record the time and determine the mass of the container and its contents. Place the specimen and container on a level platform or floor free of noticeable vibration and cover the container to prevent evaporation of the bleed water. Keep the cover in place throughout the test, except when drawing off the water. Draw off (with pipet or similar instrument) the water that has accumulated on the surface at 10-min intervals during the first 40 min and at 30-min intervals thereafter until cessation of bleeding, recording the time of last observation. To facilitate the collection of bleeding water, tilt the specimen carefully by placing a block approximately 50 mm [2 in.] thick under one side of the container 2 min prior to each time the water is withdrawn. After the water is removed, return the container to a level position without jarring. After each withdrawal, transfer the water to a 100-mL graduated cylinder. Record the accumulated quantity of water after each transfer. When only the total volume of bleeding is desired to be determined, the periodic removal procedure shall be omitted and the entire amount removed in a single operation. If it is desired to determine the mass of the bleeding water and to exclude the material present other than the water, carefully decant the contents of the cylinder into a metal beaker. Determine the mass and record the mass of the beaker and its contents. Dry the beaker and its contents to constant mass and record the final mass. The difference between the two masses, D, is equal to the mass of the bleeding water. The mass of the sludge shall also be obtained, if desired, by initially determining the tare mass of the beaker.

7. Calculation

7.1 Calculate the volume of bleeding water per unit area of surface, V, as follows:

$$V = V_1/A \quad (1)$$

where:

V_1 = volume of bleeding water measured during the selected time interval, mL, and

A = area of exposed concrete, cm^2.

The comparative rate of bleeding shall be determined as the test progresses by comparing the volume of bleeding water for each equal time interval.

7.2 Calculate the accumulated bleeding water, expressed as a percentage of the net mixing water contained within the test specimen, as follows:

$$C = (w/W) \times S \quad (2)$$

$$\text{Bleeding, } \% = (D/C) \times 100$$

where:

C = mass of the water in the test specimen, g,

W = total mass of the batch, kg,

w = net mixing water (the total amount of water minus the water absorbed by the aggregates), kg,

S = mass of the sample, g, and

D = mass of the bleeding water, g, or total volume withdrawn from the test specimen in cubic centimeters multiplied by 1 g/cm^3.

TEST METHOD B—SAMPLE CONSOLIDATED BY VIBRATION

8. Apparatus

8.1 *Vibrating Platform*—A platform shall be provided upon which the filled container shall be mounted. The platform shall be equipped with a suitable device so that intermittent periods of vibration of reproducible duration, frequency, and amplitudes will be imparted to the specimen container as prescribed by Section 8 (see Fig. 1). Suitable vibration will be provided if there is bolted to the platform a 93W [⅛-hp] electric motor, to the shaft of which a small eccentric whose mass is approximately 110 g [0.24 lb] is attached by means of a setscrew. The eccentric shall be fabricated from cold-rolled stock in accordance with the details and dimensions shown in Fig. 2. The hole through the eccentric is 13.5 mm [34/64 in.] or an appropriate size to accommodate the motor shaft. The platform shall be supported on rubber supports resting on a concrete slab. The concrete slab shall be separated from the floor by a layer of cork as shown in Fig. 2.

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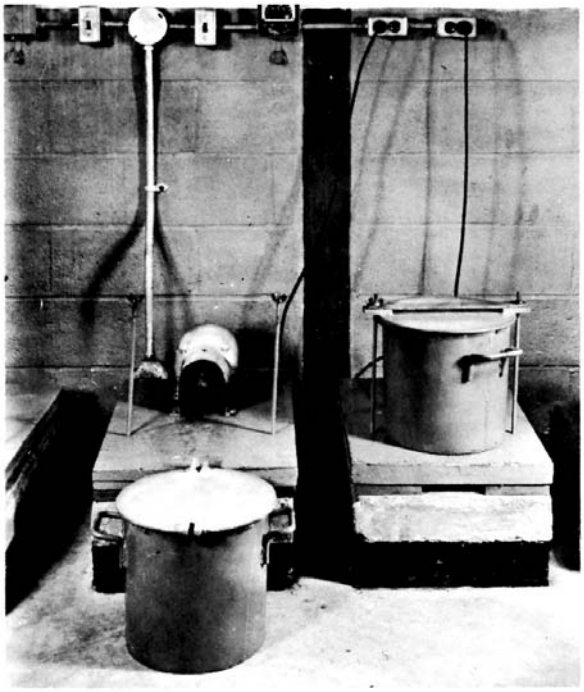

FIG. 1 Vibrating Platform and Timer

8.2 *Timer*—A timing device, by means of which the periods of vibration provided to the platform and specimen in accordance with the provisions of Section 8 is permitted to be regulated.

8.3 *Container*—A steel container 290 mm [11½ in.] in diameter at the top, 280 mm [11 in.] in diameter at the bottom, and 285 mm [11⅛ in.] high shall be provided. A steel container cover shall also be provided. The container and cover shall conform with the details given in Fig. 3.

8.3.1 The remainder of the apparatus is identical with that given for Method A.

9. Vibrating Cycle

9.1 The vibrating cycle shall be as follows: Power on for 3 s, power off 30 s. However, due to the coasting of the motor after the power is turned off, the period of perceptible vibration is approximately 7 s.

10. Test Specimen

10.1 The sample shall be prepared as described for Method A.

10.2 The sample shall be placed in the container to a depth equal to approximately one half the average diameter of the container. The size of the test sample can best be regulated by mass; a sample with a mass of 20 ± 0.5 kg [45 ± 1 lb] usually meets the requirements for the apparatus described herein.

11. Procedure

11.1 *Consolidation of Test Specimen*—Consolidate the sample in the container by means of vibration of only that duration required to effect the desired degree of compaction. Sufficient vibration has been applied as soon as the surface of the concrete has become relatively smooth. Stop the consolidating procedure immediately upon the first appearance of free water segregating from the concrete as indicated by the development of a water sheen on its surface. For some unusually wet or plastic mixtures, no consolidating effort will be needed beyond that supplied by placing the sample in the container and handling the container during the operations of determining the mass and placing it on the platform for test.

11.2 *Intermittent Vibration*—Place the cover on the container and the container on the vibrating platform. Clamp the container and cover down tightly. Note and record the time, and start the motor. Continue intermittent vibration for 1 h.

11.3 *Determination of Bleeding Water*—The intermittent periods of vibrations do not permit the determination of bleeding water at a number of different time intervals. Determine the total volume of bleeding water as described for Method A.

12. Calculation

12.1 Calculate the percentage bleeding water as described for Method A.

13. Report

13.1 Concrete mixture proportions,

13.2 Source and identification of each material used,

13.3 Method used for collection of the bleeding data (A or B),

13.4 The volume of bleeding water per unit area of surface, and the accumulated bleeding water, expressed as a percentage of the net mixing water contained within the test specimen, and

13.5 Elapsed time required for cessation of bleeding.

14. Precision and Bias

14.1 *Precision*:

14.1.1 *Method A*—Data are not available to evaluate the precision of Method A directly. However, there is reason to believe that the precision for Method A is at least as good as that for Method B. The values given for Method B shall be used as maximum precision limits for Method A.

14.1.2 *Method B*—The single operator-day-multibatch standard deviation (1s) has been found to be 0.71 % for a bleeding range from 0 to 10 %, 1.06 % for a bleeding range from 10 to 20 %, and 1.77 % for more than 20 %. Therefore, results of two properly conducted tests by the same operator on the same day on different batches of the same mixture are not expected to differ by more than 2.0 % (d2s) for a bleeding range from 0 to 10 %, 3.0 % for a range from 10 to 20 %, and 5.0 % for more than 20 %. (See Note 1.)

NOTE 1—These numbers represent, respectively, the (1s) and (d2s) limits as described in Practice C 670.

14.2 *Bias*—The test methods have no bias because the values determined can be defined only in terms of the test methods.

15. Keywords

15.1 bleeding; concrete, bleeding of

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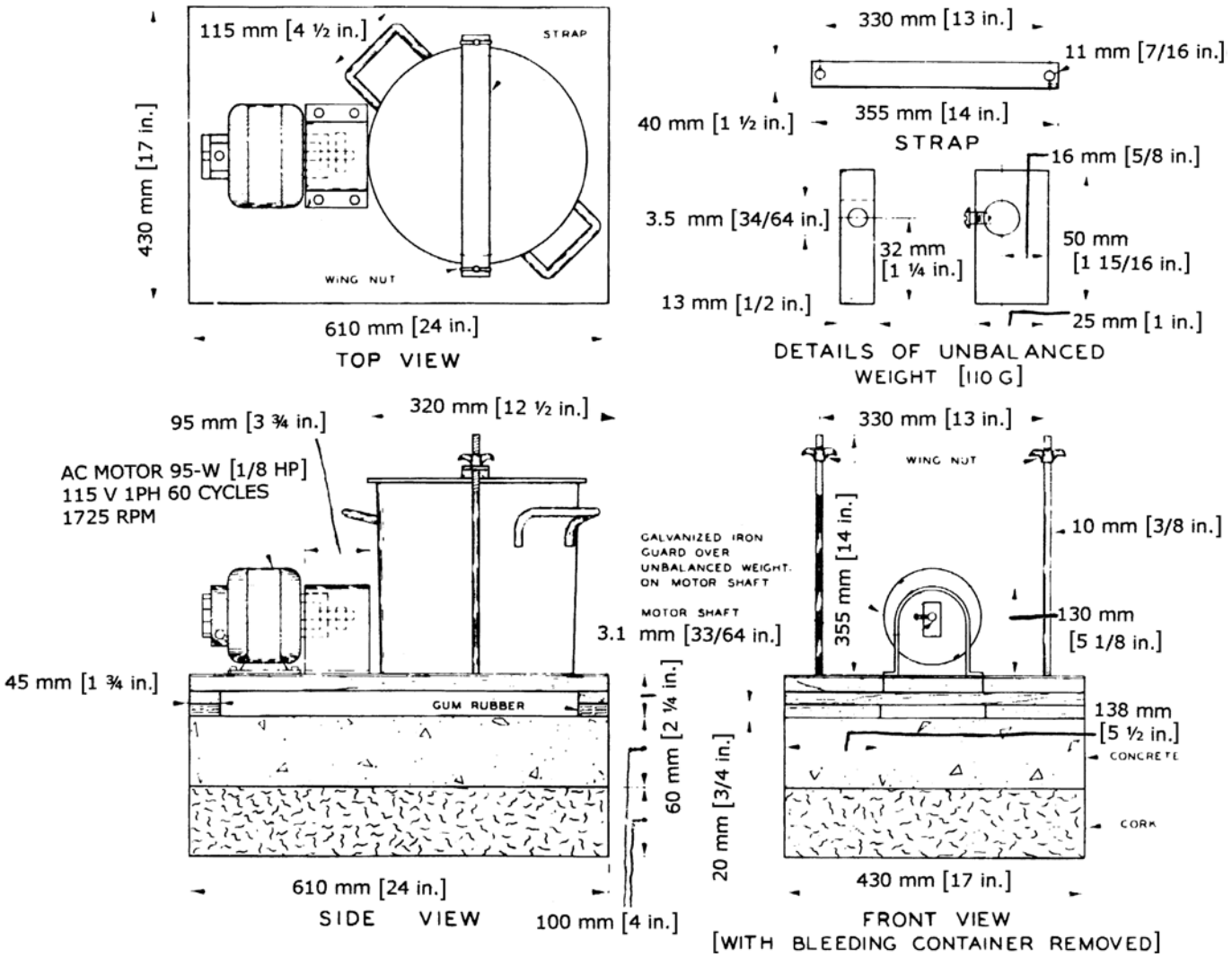

FIG. 2 Detail of Vibrating Platform Apparatus

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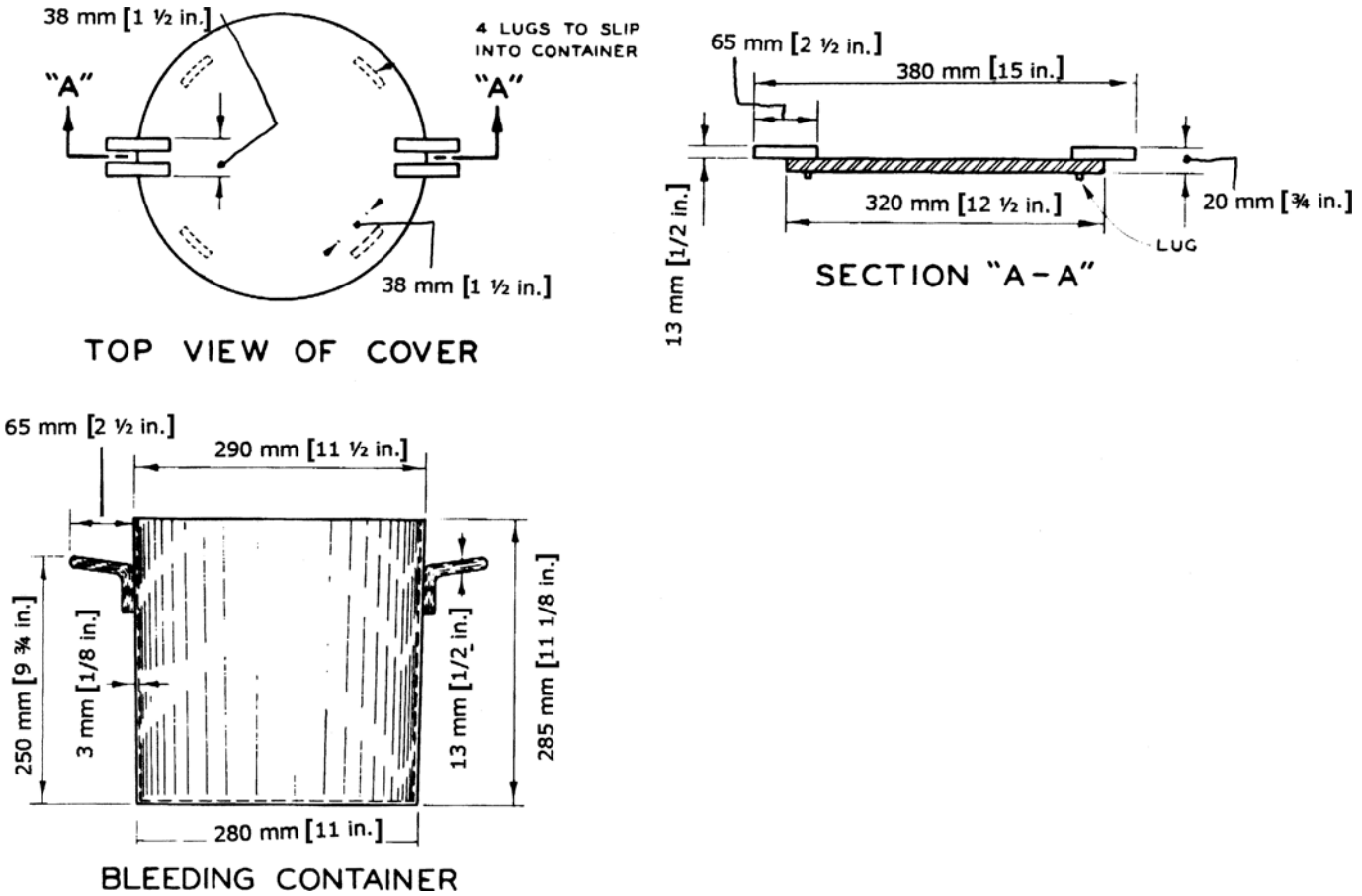

FIG. 3 Container and Cover

SUMMARY OF CHANGES

Committee C09 has identified the location of selected changes to these test methods since the last issue, C 232 – 07, that may impact the use of these test methods. (Approved June 1, 2009)

(*1*) Revised the standard as dual-units test methods.

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Designation: C 233 – 07

Standard Test Method for Air-Entraining Admixtures for Concrete[1]

This standard is issued under the fixed designation C 233; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

This standard has been approved for use by agencies of the Department of Defense.

1. Scope*

1.1 This test method covers the testing of materials proposed for use as air-entraining admixtures in the field.

1.2 The values stated in SI units are to be regarded as the standard. The values given in parentheses are for information purposes only.

1.3 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

1.4 The text of this test method references notes and footnotes which provide explanatory material. These notes and footnotes (excluding those in tables and figures) shall not be considered as requirements of the standard.

2. Referenced Documents

2.1 *ASTM Standards:* [2]

C 33 Specification for Concrete Aggregates

C 39/C 39M Test Method for Compressive Strength of Cylindrical Concrete Specimens

C 78 Test Method for Flexural Strength of Concrete (Using Simple Beam with Third-Point Loading)

C 136 Test Method for Sieve Analysis of Fine and Coarse Aggregates

C 143/C 143M Test Method for Slump of Hydraulic-Cement Concrete

C 150 Specification for Portland Cement

C 157/C 157M Test Method for Length Change of Hardened Hydraulic-Cement Mortar and Concrete

C 172 Practice for Sampling Freshly Mixed Concrete

C 173/C 173M Test Method for Air Content of Freshly Mixed Concrete by the Volumetric Method

C 185 Test Method for Air Content of Hydraulic Cement Mortar

C 192/C 192M Practice for Making and Curing Concrete Test Specimens in the Laboratory

C 231 Test Method for Air Content of Freshly Mixed Concrete by the Pressure Method

C 232 Test Methods for Bleeding of Concrete

C 260 Specification for Air-Entraining Admixtures for Concrete

C 403/C 403M Test Method for Time of Setting of Concrete Mixtures by Penetration Resistance

C 666/C 666M Test Method for Resistance of Concrete to Rapid Freezing and Thawing

C 670 Practice for Preparing Precision and Bias Statements for Test Methods for Construction Materials

D 75 Practice for Sampling Aggregates

D 1193 Specification for Reagent Water

E 70 Test Method for pH of Aqueous Solutions With the Glass Electrode

2.2 *ACI Standards:*

ACI 211.1 Recommended Practice for Selecting Proportions for Normal, Heavyweight, and Mass Concrete[3]

3. Significance and Use

3.1 This test method is used to develop data for comparison with the requirements of Specification C 260. These tests are based on arbitrary stipulations permitting highly standardized testing in the laboratory, and are not intended to simulate actual job conditions.

4. Materials

4.1 *Cement*—The cement used in any series of tests shall be either the cement proposed for specific work in accordance with 4.4, a Type I or Type II cement conforming to Specification C 150, or a blend of two or more cements, in equal parts. Each cement of the blend shall conform to the requirements of either Type I or Type II, Specification C 150. If a blend of cements is used, it shall be a combination which produces an

[1] This test method is under the jurisdiction of ASTM Committee C09 on Concrete and Concrete Aggregates and is the direct responsibility of Subcommittee C09.23 on Chemical Admixtures.

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[2] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

[3] American Concrete Institute Manual of Concrete Practice, Part 1, pp. 211-1 to 211-38 (1993).

***A Summary of Changes section appears at the end of this standard.**

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air content of less than 10 % when tested in accordance with Test Method C 185 (Note 4).

4.2 *Aggregates*—Except when tests are made in accordance with 4.4, using the aggregates proposed for specific work, the fine and coarse aggregates used in any series of tests shall come from single lots of well-graded, sound materials that conform to the requirements of Specification C 33, except that the grading of the aggregates shall conform to the following requirements:

4.2.1 *Fine Aggregate Grading*—The fine aggregate shall meet the requirements for the fine aggregate in Specification C 33.

4.2.2 *Coarse Aggregate Grading*—The coarse aggregate grading shall meet the Size 57 grading requirements of Specification C 33.

NOTE 1—Take care in loading and delivery to avoid segregation.

4.2.3 The coarse aggregate used for the reference concrete and test concretes shall be essentially the same. Provide sufficient coarse aggregate for the reference concrete, the test concrete, and for the grading analysis. Concrete consists of one reference concrete and as many test admixture-containing concretes as are intended to be compared.

4.2.3.1 Prepare required quantities of coarse aggregate as follows: Fill tared containers, one for sieve analysis, one for a batch of reference concrete, and one for a batch of test concrete, to the required mass from the aggregate stockpile (See Note 2). Accomplish this by placing equal quantities into each container, successively, and repeat the procedure until all the containers have their required mass (See Note 2).

NOTE 2—See the Appendix of Practice D 75, Sampling from Stockpiles, and the section on Sampling Aggregates in the Manual of Aggregate and Concrete Testing[4] for guidance on procedures for sampling from stockpiles.

4.2.4 Perform sieve analysis on the coarse aggregate sample prepared in 4.2.3.1 by Test Method C 136. Discard any set for which the sample does not comply with Size 57. Average test results for samples that comply with Size 57 for each sieve size. Discard any set for which the sample deviates from this average by more than the amount shown in column 3. Continue the process of preparation, testing and averaging until sufficient sets of aggregate within tolerance are obtained.

[4] Manual of Aggregate and Concrete Testing, *Annual Book of ASTM Standards* , Vol 04.02.

Sieve	Specification C 33, No. 57 Percent Passing	Maximum variation from average/passing
37.5-mm	100	00
25.0-mm	95 to 100	1.0
12.5-mm	25 to 60	4.0
4.75-mm	0 to 10	4.0
2.36-mm	0 to 5	1.0

NOTE 3—All of the results required for demonstrating compliance under this specification are dependent on the uniformity of the aggregate samples prepared and used. Careful, skilled and well-supervised work is essential.

4.3 *Reference Admixture*—For this test method, unless otherwise requested by the purchaser, the reference admixture used in the concrete mixture specified in Section 4 shall be "neutralized Vinsol resin."[5]

4.4 *Materials for Tests for Specific Uses*—When it is desired to test an air-entraining admixture for use in specific work, the cement and aggregates used shall be representative of those proposed for use in the work, and the concrete mixtures shall be designed to have the cement content specified for use in the work (Note 4). If the maximum size of coarse aggregate is greater than 25.0 mm (1 in.), the freshly mixed concrete shall be screened over a 25.0-mm (1-in.) sieve prior to fabricating the test specimens in accordance with the wet sieving procedure described in Practice C 172.

4.5 *Preparation and Weighing*—All materials shall be prepared and all weighings shall be made as prescribed in Practice C 192/C 192M.

NOTE 4—It is recommended that whenever practicable, tests be made in accordance with 4.4 using the cement and pozzolanic or chemical admixtures, if any, proposed for specific work.

5. Concrete Mixtures

5.1 *Proportions*—Using ACI 211.1, all concrete shall be proportioned to conform to the following requirements:

5.1.1 The cement content shall be 307 ± 3 kg/m^3 (517 ± 5 lb/yd^3) except when tests are being made for specific uses (see 4.4).

5.1.2 The first trial mixture shall contain the amount of coarse aggregate shown in Table 6.3.6 of ACI 211.1 for the maximum size of aggregate and for the fineness modulus of the sand being used.

[5] The sole source of supply of Vinsol resin known to the committee at this time is Hercules Inc., Wilmington, DE. If you are aware of alternative suppliers, please provide this information to ASTM International Headquarters. Your comments will receive careful consideration at a meeting of the responsible technical committee,[1] which you may attend. Neutralization may be accomplished by treating 100 parts of the Vinsol resin with 9 to 15 parts of NaOH by weight. In an aqueous solution, the ratio of reagent water (See Specification D 1193) to the resinate shall not exceed 12:1 by weight.

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NOTE 5—The volumes of coarse aggregate recommended in ACI 211.1 are intended to ensure workable mixtures with the least favorable combinations of aggregate likely to be used. It is suggested, therefore, that for a closer approximation of the proportions required for this test, the recommended values in ACI 211.1 be multiplied by 1.07 for the first trial mixture.

5.1.3 The air content used in the computation of proportions for all concrete shall be 5.5 % except where the admixture under test is for use in specific work (see 4.4). In this case the air content used in selecting proportions shall be the median of the range to be permitted in the work. If lightweight aggregates are to be used in specific work, the unit weight of concrete used in selecting proportions shall be the median of the range permitted in the work.

5.1.4 The water content and sand content shall be adjusted to obtain a slump of 90 ± 15 mm (3½ ± ½ in.). The workability of the concrete mixture shall be suitable for consolidation by hand rodding and the concrete mixture shall have the minimum water content possible. These conditions shall be achieved by final adjustments in the proportion of fine aggregate to total aggregate, in the amount of total aggregate, or both, while maintaining the yield and slump in the required ranges.

5.2 *Conditions*—Concrete mixtures shall be prepared both with the air-entraining admixture under test and with the reference admixture. The admixtures shall be added in the amounts necessary to produce the air content selected in accordance with 5.1.3 within a tolerance of ±0.5 % of the volume of concrete.

6. Mixing

6.1 Machine mix the concrete as prescribed in Practice C 192/C 192M.

7. Tests and Properties of Freshly Mixed Concrete

7.1 Test samples of freshly mixed concrete from at least three separate batches for each condition of concrete in accordance with the following methods and the minimum number of tests shall be as prescribed in Table 1.

7.1.1 *Slump*—Test Method C 143/C 143M.

7.1.2 *Air Content*—Test Method C 231. When lightweight aggregates, air-cooled blast furnace slag, or aggregates of high porosity, for which the aggregate correction factor defined in Test Method C 231 exceeds 0.5 %, are used under the provisions of 4.4, use Test Method C 173/C 173M.

7.1.3 *Bleeding*—Test Methods C 232.

7.1.4 *Time of Setting*—Test Method C 403/C 403M, except that the temperature of each of the ingredients of the concrete mixtures, just prior to mixing, and the temperature at which the time of setting specimens are stored during the test period shall be 23.0± 2 °C (73 ± 3 °F).

8. Preparation of Test Specimens

8.1 Specimens for test of hardened concrete, representing each test and age of test and each condition of concrete being compared, shall be made from at least three separate batches, and the minimum number of specimens shall be as prescribed in Table 1. On a given day at least one specimen shall be made for each test and age of test from each condition of concrete except that at least two specimens for the freezing and thawing test shall be made from each condition of concrete. The preparation of all specimens shall be completed in three days of mixing.

8.2 *Manifestly Faulty Specimens*—Each group of specimens representing a given test or a given age of test, including tests of freshly mixed concrete, shall be examined visually before or during the test, or both, whichever is appropriate. Discard any specimen found to be manifestly faulty by such examination without testing. Visually examine all specimens representing a given test at a given age after testing, and should any specimen be found to be manifestly faulty, the test results thereof shall be disregarded. Should more than one specimen representing a given test at a given age be found manifestly faulty, either before or after testing, the entire test shall be disregarded and repeated. The test result reported shall be the average of the individual test results of the specimens tested or, in the event that one specimen or one result has been discarded, it shall be the average of the test results of the remaining specimens.

9. Test Specimens of Hardened Concrete

9.1 *Number of Specimens*—Make six or more test specimens for the freezing and thawing test and three or more test specimens for each other type of test and age of test specified in Table 1 for each condition of concrete to be compared.

TABLE 1 Types and Minimum Number of Specimens and Tests

Test	Number of Types of Specimens[A]	Number of Test Ages	Number of Conditions of Concrete[B]	Minimum Number of Specimens
Slump	1	1	2	[C]
Air content	1	1	2	[C]
Bleeding	1	1	2	6
Time of setting	1	[D]	2	6
Compressive strength	1	3	2	18
Flexural strength[E]	1	3	2	18
Freezing and thawing	1	1	2	12[F]
Length change[E]	1	1	2	6

[A] See Section 7 and 9.2.
[B] See 4.2.
[C] Determined on each batch of concrete mixed.
[D] See 7.1.4.
[E] Optional tests, see 10.1.5.
[F] Specimens for duplicate tests from each batch.

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9.2 *Types of Specimens*—Prepare specimens made from concrete with and without the air-entraining admixture under test in accordance with the following:

9.2.1 *Compressive Strength*—Make and cure test specimens in accordance with Practice C 192/C 192M.

9.2.2 *Flexural Strength*—Make and cure test specimens in accordance with Practice C 192/C 192M.

9.2.3 *Resistance to Freezing and Thawing*—Test specimens shall consist of prisms made and cured in accordance with the applicable requirement of Practice C 192/C 192M. Test specimen dimensions shall be as required by Test Method C 666/C 666M. Make one set of specimens from the concrete mixture containing the air-entraining admixture under test and from the reference concrete mixture, the air content of each mixture being as specified in 5.2.

9.2.4 *Length Change*—Make and cure test specimens in accordance with Test Method C 157/C 157M. The moist-curing period, including the period in the molds, shall be 14 days.

10. Tests on Hardened Concrete

10.1 Test specimens of hardened concrete in accordance with the following test methods:

10.1.1 *Compressive Strength*—Test Method C 39/C 39M. Test specimens at ages of 3, 7, and 28 days. Calculate the compressive strength of the concrete containing the admixture under test as a percentage of the compressive strength of the reference concrete as follows:

10.1.1.1 Divide the average compressive strength of the specimens made from the concrete containing the admixture under test at a given age of test by the average compressive strength of the specimens made from the reference concrete at the same age of test and multiply the quotient by 100.

10.1.2 *Flexural Strength*—Test Method C 78. Test specimens at ages 3, 7, and 28 days. Calculate the flexural strength of the concrete containing the admixture under test as a percentage of the flexural strength of the reference concrete as follows:

10.1.2.1 Divide the average flexural strength of the specimens made from the concrete containing the admixture under test at a given age of test by the average flexural strength of the specimens made from the reference concrete at the same age of test, and multiply the quotient by 100.

10.1.3 *Resistance to Freezing and Thawing*—Procedure A of Test Method C 666/C 666M. Place specimens under test at the age of 14 days.

10.1.4 *Length Change*—Test Method C 157/C 157M. The drying period shall be 14 days.

10.1.5 The flexural strength and length change tests are applicable only when specifically required by the purchaser.

11. Check Tests for Uniformity

11.1 The check tests enumerated in Specification C 260 in the section on Optional Uniformity Requirements shall be determined as follows:

11.1.1 *pH*—The pH of liquid air-entraining admixtures shall be determined in accordance with Test Method E 70. Non-liquid admixtures shall be prepared in solution to determine pH. Unless there is reason to do otherwise, dissolve the material in reagent water in the proportions specified for job use as shown on the package or in other manufacturer's instructions. The temperature of the check test sample shall be within ± 1 °C (± 2 °F) of that for the acceptance sample and preferably in the range of 21 to 27 °C (70 to 80 °F).

11.1.2 *Air Content of Mortar*—Using the same amounts of successive lots of air-entraining admixtures with the same cement, determine the air contents of mortars in accordance with Test Method C 185. The air-entraining admixture shall be combined with the mixing water prior to the start of the mixing procedure. The determinations for both the check test sample and acceptance sample shall be made on the same day.

12. Procedure for Residue by Oven Drying

12.1 Determine the mass of an aluminum dish (about 57 mm diameter, 15 mm height, and about 1 g in weight) to the nearest 0.0001 g. Using a pipet, evenly distribute 1 ml of the liquid air entraining admixture in the dish, and weigh to the nearest 0.0001 g. Place the weighing dish in a drying oven (12.2). Dry for 25 ± 2 min at 125 ± 1 °C. At the end of the drying period transfer the weighing dish to a desiccator, cool to room temperature, and weigh to the nearest 0.0001 g.

12.2 The drying oven shall be either a forced circulation type or one with provision for free access of air. There shall be precise control of temperature and time of drying so that the degree of volatilization of the material other than water from sample to sample will not vary.

12.3 *Calculation*:

12.3.1 Record the following weights:

M_1 = mass of weighing dish and admixture prior to heating,
M_2 = mass of empty weighing dish,
M_3 = $M_1 - M_2$ = mass of sample,
M_4 = mass of weighing dish and dried residue, and
M_5 = $M_4 - M_2$ = mass of dried residue.

12.3.2 Calculate the residue by using the following equation:

$$\text{Residue by oven drying (\% by mass)} = (M_5 \times 100)/M_3 \quad (1)$$

13. Report

13.1 Report the following information:

13.1.1 Results of the tests specified in this method as compared with the requirements of Specification C 260,

13.1.2 Brand name, manufacturer's name and lot number, character of the material, and quantity represented by the sample of the admixture under test,

13.1.3 Brand name, manufacturer's name, and other data on the reference admixture,

13.1.4 Brand name, manufacturer's name, type, and test data on the portland cement or cements used,

13.1.5 Description of, and test data on the fine and coarse aggregates used,

13.1.6 Detailed data on the concrete mixtures used, including amounts and proportions of admixtures used, actual cement factors, water-cement ratios, ratios of fine to total aggregate, consistency, and air content.

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13.1.7 In reporting on check tests for uniformity, report both the initial and current air contents of mortar for the acceptance sample, and the air content of the check test sample, all as determined by Test Method C 185.

14. Precision and Bias [6]

14.1 *Precision*:

14.1.1 The single-laboratory coefficient of variation of residue by oven drying has been found to be 0.79 %. Therefore, the results of two properly conducted tests on the same material in the same laboratory are not expected to differ by more than 2.24 % of their average.[7]

NOTE 6—As an example, two tests conducted on the same material yield residues by oven drying of 6.14 % and 6.04 %, respectively. The average of these two measurements is 6.09 %. The acceptable range of results is then 2.24 % of 6.09 % or ±0.136 %. As the difference between 6.14 % and 6.04 % is 0.10 % the results are within the acceptable range.

14.1.2 The multilaboratory coefficient of variation of residue by oven drying has been found to be 2.35 %. Therefore, the results of two properly conducted tests on the same material in different laboratories are not expected to differ by more than 6.65 % of their average.[7]

14.1.3 Other procedures referenced in this test method use results obtained from other ASTM test methods listed in Section 2. These documents are to be referred to for their respective precision statements.

14.2 *Bias*—Since there is no accepted reference material suitable for determining the bias of this test method, no statement on bias is made.

15. Keywords

15.1 air content; air-entraining admixture; cement; concrete; pH; residue; specific gravity

[6] Supporting data have been filed at ASTM International Headquarters and may be obtained by requesting Research Report RR: C09-1005.

[7] These numbers represent, respectively, the (1s %) and (d2s %) limits as described in Practice C 670.

SUMMARY OF CHANGES

Committee C09 has identified the location of selected changes to this test method since the last issue, C 233 – 04, that may impact the use of this test method. (Approved July 15, 2007)

(*1*) Revised 4.2.2, 4.2.3, 4.2.3.1, and 4.2.4.

(*2*) Added new Note 2 and renumbered subsequent notes.

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Designation: C 260 – 06

Standard Specification for Air-Entraining Admixtures for Concrete[1]

This standard is issued under the fixed designation C 260; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

This standard has been approved for use by agencies of the Department of Defense.

1. Scope*

1.1 This specification covers materials proposed for use as air-entraining admixtures to be added to concrete mixtures in the field.

1.2 The values stated in SI units are to be regarded as the standard. The values given in parentheses are for information only.

1.3 The text of this specification references notes and footnotes which provide explanatory material. These notes and footnotes (excluding those in tables and figures) shall not be considered as requirements of the standard.

2. Referenced Documents

2.1 *ASTM Standards:* [2]

C 183 Practice for Sampling and the Amount of Testing of Hydraulic Cement

C 185 Test Method for Air Content of Hydraulic Cement Mortar

C 233 Test Method for Air-Entraining Admixtures for Concrete

3. Terminology

3.1 *Definitions of Terms Specific to This Standard:*

3.1.1 *air-entraining admixture*, *n—for the purpose of this specification*, a material that is used as an ingredient of concrete, added to the batch immediately before or during its mixing, for the purpose of entraining air.

4. General Requirements

4.1 At the request of the purchaser, the manufacturer shall state in writing that the air-entraining admixture supplied for use in the work is essentially identical in concentration, composition, and performance to the air-entraining admixture tested under this specification.

NOTE 1—It is recommended that, whenever practicable, tests with the air-entraining admixture be made using all of the ingredients of the concrete proposed for the specific work, because the effect produced by the air-entraining admixture may vary with the properties of the other ingredients of the concrete.

4.2 Requirements for establishing compositional or chemical equivalence of a subsequent lot relative to a previous lot that was subjected to quality tests and found to comply with the requirements of 5.1 shall be determined if agreed upon by the purchaser and the manufacturer. At the request of the purchaser, the manufacturer shall recommend appropriate test procedures, such as infrared spectrophotometry (I.R.), pH value and solids content, for establishing the equivalence of materials from different lots or different portions of the same lot.

NOTE 2—Ultraviolet light absorption (UV) of solutions and infrared spectroscopy of dried residues have been found to be valuable for these purposes. The specific procedures to be employed and the criteria to establish equivalence should be stipulated with due regard to the composition and properties of the sample.

4.3 At the request of the purchaser, the manufacturer shall state in writing the chloride content of the air-entraining admixture and whether or not chloride was added during its manufacture.

NOTE 3—Admixtures that contain chlorides may accelerate corrosion of embedded metals.

5. Optional Uniformity Requirements

5.1 A series of two or more samples from a manufacturing lot will be considered sufficiently uniform to be properly composited into a single sample for quality testing provided they do not differ more than the amounts indicated in 5.4.

5.2 A subsequent sample or composite sample shall be considered in compliance with these requirements, so long as they differ from the original sample, tested to the requirements of 6.1, by no more than the amounts listed in 5.4, and provided that any additional optional, appropriate tests, such as infrared spectroscopy and ultraviolet light absorption, referred to in 4.2, also meet pre-agreed requirements.

[1] This specification is under the jurisdiction of ASTM Committee C09 on Concrete and Concrete Aggregates and is the direct responsibility of Subcommittee C09.23 on Chemical Admixtures.

Current edition approved Aug. 1, 2006. Published August 2006. Originally approved in 1950. Last previous edition approved in 2001 as C 260 – 01.

[2] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

***A Summary of Changes section appears at the end of this standard.**

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5.3 Determinations of uniformity shall be made in accordance with the procedures given in the sections "Check Tests for Uniformity" and "Procedure for Residue by Oven Drying" of Test Method C 233.

5.4 Allowable differences in results of uniformity determinations shall not exceed the following amounts:

5.4.1 The manufacturer shall provide an acceptable range of pH not to exceed a range of 3.0. The pH of samples tested shall fall within this range.

5.4.2 The air content in percent of Test Method C 185 mortars prepared from successive lots shall not differ by more than 2.0 from that for the acceptance sample.

5.4.3 The manufacturer shall provide acceptable limits of residue content not to exceed ±12 % of the midpoint of the limits. The residue content of samples tested shall fall within these limits (Note 4).

NOTE 4—As an example, an admixture may commonly be produced with residue content ranging from 5.0 to 6.5 %. The manufacturer would provide acceptable limits of 5.06 to 6.44 %, representing ±12 % of the midpoint of the limits which is 5.75 %.

6. Performance Requirements

6.1 The air-entraining admixture shall conform to the requirements in Table 1.

6.1.1 *Resistance to Freezing and Thawing*—The relative durability factor of concrete containing the admixture under test shall be not less than 80. The relative durability factor shall be calculated as follows:

TABLE 1 Physical Requirements[A]

Air-Entraining Admixtures	
Time of setting, allowable deviation from control, h:min:	
Initial: not more than	1:15 earlier nor 1:15 later
Final: not more than	1:15 earlier nor 1:15 later
Compressive strength, min, % of control:	
3 days	90
7 days	90
28 days	90
Flexural strength, min, % of control:[B]	
3 days	90
7 days	90
28 days	90
Length change, max shrinkage (alternative requirements):[B,C]	
Percent of control	120
Increase over control, percentage points[D]	0.006
Relative durability factor, min	80
Bleeding of the net amount of mixing water, max percent over control[E]	2

[A] The values in the table include allowance for normal variation in test results. The object of the 90 % compressive strength requirement for air entraining admixtures is to require a level of performance comparable to that of the reference concrete.

[B] Applicable only when required by the purchaser.

[C] Alternative requirements, see 6.1.2, "percent of control" limit applies when the length change of the control is 0.030 % or greater, "increase over control" limit applies when the length change of the control is less than 0.030 %.

[D] Applicable when shrinkage of control concrete is less than 0.030 %.

[E] Bleeding is computed as a percentage of the net amount of mixing water in each concrete. The net mixing water is the water in excess of that present as absorbed water in the aggregates. For example, a test concrete mixture that contains 4.65 kg of net mix water and produces 0.29 kg of bleed water would have 6.24 % bleed water by mass of net mixing water. If a control mixture produces 7.05 % bleed water, the change in bleeding between the test and control concrete mixtures would be – 0.81 percentage points.

$$DF \text{ (or } DF_1) = PN/300 \quad (1)$$

$$RDF = (DF/DF_1) \times 100$$

where:

DF = durability factor of the concrete containing the admixture under test,

DF_1 = durability factor of the concrete containing the reference admixture,

P = relative dynamic modulus of elasticity in percentage of the dynamic modulus of elasticity at zero cycles (values of P will be 60 or greater),

N = number of cycles at which P reaches 60 %, or 300 if P does not reach 60 % prior to the end of the test (300 cycles), and

RDF = relative durability factor.

6.1.2 *Length Change*—After 14 days of drying, the length change of the concrete containing the test admixture shall not be more than 120 % of that of the concrete containing the reference admixture. When, after 14 days of drying, the length change of the reference concrete is less than 0.030 %, the length change of the concrete containing the test admixture shall not be more than 0.006 percentage points greater than that of the reference concrete.

7. Sampling

7.1 Opportunity shall be provided the purchaser for careful sampling and inspection, either at the point of manufacture or at the site of the work, as specified by the purchaser.

7.2 Samples shall be either "grab" or "composite" samples, as specified or required by this specification. A grab sample is one obtained in a single operation. A composite sample is one obtained by combining three or more grab samples.

7.3 For the purpose of this specification, it is recognized that samples will be taken for the two following reasons:

7.3.1 *Quality Tests*—A sample taken for the purpose of evaluating the quality of a source or lot of admixture will be required to meet all the applicable requirements of this specification. Samples used to determine conformance with the requirements of this specification shall be composites of grab samples taken from sufficient locations to ensure that the composite sample will be representative of the lot.

7.3.2 *Uniformity Tests*—A sample taken for the purpose of evaluating the uniformity of a single lot or of different lots from the same source will generally be subjected to a limited number of tests as the result of agreement between the purchaser and manufacturer (see Section 4). Such samples shall be composite samples from individual lots when different lots from the same source are being compared. When the uniformity of a single lot is being determined, grab samples shall be used.

7.4 *Liquid Air-Entraining Admixtures*—Liquid admixtures shall be agitated thoroughly immediately prior to sampling. Grab samples taken for quality or uniformity tests shall represent not more than 9500 L (2500 gal) of admixture and shall have a volume of at least 1 L (1 qt). A minimum of three grab samples shall be taken. Composite samples shall be prepared by thoroughly mixing the grab samples selected and the resultant mixture sampled to provide at least 4 L (1 gal) for

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quality tests. Grab samples shall be taken from different locations well distributed throughout the quantity to be represented.

7.4.1 Admixtures in bulk storage tanks shall be sampled equally from the upper, intermediate, and lower levels by means of drain cocks in the sides of the tanks or a weighted sampling bottle fitted with a stopper that can be removed after the bottle is lowered to the desired depth.

7.4.2 Samples shall be packaged in impermeable, airtight containers that are resistant to attack by the admixture.

7.5 *Nonliquid Air-Entraining Admixtures*—Grab samples taken for quality or uniformity tests shall represent not more than 2 metric tons (2 tons) of admixture and shall have a mass of at least 1 kg (2 lb). A minimum of four grab samples shall be taken. Composite samples shall be prepared by thoroughly mixing the grab samples selected and the resultant mixture sampled to provide at least 2.5 kg (5 lb) for the composite sample. Grab samples shall be taken from different locations well distributed throughout the quantity to be represented.

7.5.1 Samples of packaged admixtures shall be obtained by means of a tube sampler as described in Practice C 183.

7.5.2 Samples shall be packaged in moisture-proof, airtight containers.

7.6 Samples shall be thoroughly mixed before testing to assure uniformity. When recommended by the manufacturer, the entire sample of a nonliquid admixture shall be dissolved in water prior to testing.

8. Test Methods

8.1 Determine the properties enumerated in Section 6 in accordance with Test Method C 233. It is recommended that, whenever practicable, tests be made in accordance with the section on Materials for Tests for Specific Uses in Test Method C 233, using the cement proposed for the specific work.

9. Rejection

9.1 The air-entraining admixture shall be rejected if the purchaser desires when it fails to meet any of the applicable requirements of this specification.

9.2 After completion of tests, an admixture stored at the point of manufacture for more than 6 months prior to shipment, or an admixture in local storage in the hands of a seller for more than 6 months, shall be retested before use when requested by the purchaser. It shall be rejected, if the purchaser desires, when it fails to conform to any of the applicable requirements of this specification.

9.3 Packages or containers varying more than 5 % from the specified weight or volume shall be rejected if the purchaser desires. If the average weight or volume of 50 packages or containers taken at random is less than that specified, the entire shipment shall be rejected if the purchaser desires.

10. Packaging and Marking

10.1 The proprietary name of the air-entraining admixture and the net quantity in pounds or gallons (kilograms or litres) shall be plainly indicated on the packages or containers in which the admixture is delivered. Similar information shall be provided in the shipping advices accompanying packaged or bulk shipments of admixtures.

11. Keywords

11.1 air content; air entraining admixtures; cement; concrete; pH, residue; specific gravity

SUMMARY OF CHANGES

Committee C09 has identified the location of selected changes to this specification since the last issue, C 260 – 01, that may impact the use of this specification. (Approved August 1, 2006)

(*1*) Revised 5.4.1.

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Designation: C 265 – 08

Standard Test Method for Water-Extractable Sulfate in Hydrated Hydraulic Cement Mortar[1]

This standard is issued under the fixed designation C 265; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope*

1.1 This test method covers the measurement of water-extractable SO_3 in hardened hydraulic cement mortar. This measurement is assumed to represent unreacted, available sulfate remaining in the mortar.

1.1.1 **Warning—**Fresh hydraulic cementious mixtures are caustic and may cause chemical burns to skin and tissue upon prolonged exposure.

1.2 The values stated in SI units are to be regarded as the standard. The values given in parentheses are for information only.

1.3 Values in SI units were obtained by measurement in SI units or by appropriate conversion using the Rules for Conversion and Rounding given in IEEE/ASTM SI-10 Standard of measurements made in other units.

1.4 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

2. Referenced Documents

2.1 *ASTM Standards:* [2]

C 109/C 109M Test Method for Compressive Strength of Hydraulic Cement Mortars (Using 2-in. or [50-mm] Cube Specimens)

C 114 Test Methods for Chemical Analysis of Hydraulic Cement

C 150 Specification for Portland Cement

C 219 Terminology Relating to Hydraulic Cement

C 305 Practice for Mechanical Mixing of Hydraulic Cement Pastes and Mortars of Plastic Consistency

C 563 Test Method for Approximation of Optimum SO_3 in Hydraulic Cement Using Compressive Strength

C 595 Specification for Blended Hydraulic Cements

C 778 Specification for Standard Sand

C 1157 Performance Specification for Hydraulic Cement

D 1193 Specification for Reagent Water

E 11 Specification for Wire Cloth and Sieves for Testing Purposes

IEEE/ASTM SI-10 Standard for Use of the International System of Units (SI): The Modern Metric System

3. Terminology

3.1 *Definitions*—The terms used in this test method are defined in accordance with Terminology C 219.

4. Significance and Use

4.1 Excess soluble sulfate ions in hardened cement can result in reduced durability. This test method is intended to show whether calcium sulfate has been used in cement in such amount to leave excess soluble sulfate in hardened mortar. The test method is used to establish compliance in Specification C 595 for those cements in which optimized SO_3 exceeds the table limit. This test method also can provide useful information on other hydraulic cements, such as those specified in Specifications C 150 and C 1157.

4.2 When this test method is used in conjunction with Test Method C 563, use the appropriate age of test specimens (24 h, 3 days, or 7 days) to coincide with the age of specimens used in Test Method C 563.

5. Apparatus

5.1 *Sieve*—A 2.36-mm (No.8) sieve conforming to Specification E 11.

5.2 *Mixer, Bowl, and Paddle*—An electrically driven mechanical mixer equipped with a paddle and bowl, as specified in the Apparatus section of Practice C 305.

5.3 *Polyethylene Containers*—Watertight polyethylene bags of 1-L (1-qt) capacity or approximately 360-mm (14-in.) sheet material, made using polyethylene at least 0.10-mm (0.004-in.) in thickness.

[1] This test method is under the jurisdiction of ASTM Committee C01 on Cement and is the direct responsibility of Subcommittee C01.28 on Sulfate Content

Current edition approved May 1, 2008. Published June 2008. Originally approved in 1951. Last previous edition approved in 2006 as C 265 – 06.

[2] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

***A Summary of Changes section appears at the end of this standard.**

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5.4 *Mortar and Pestle*—A mortar of 1.5-L (1½-qt) size, and a pestle, both of which shall be iron or porcelain.

5.5 *Water Bath*—A water bath thermostatically controlled at 23.0 ± 0.15 °C .

6. Reagents and Materials

6.1 *Mixing Water*—Reagent water conforming to the numerical limits of Type II of Specification D 1193.

6.2 *Graded Sand*—Sand conforming to the requirements for graded sand in Specification C 778.

7. Temperature and Relative Humidity

7.1 Maintain the temperature of the molding room at 23.0 ± 2.0 °C . Adjust the temperature of the dry materials and the mixing water, prior to mixing, so that the temperature of the mortar, immediately upon completion of mixing is 23 ± 1 °C .

7.2 Maintain the relative humidity of the laboratory so that it is not less than 50 %.

8. Preparation of Test Mortar

8.1 Proportion the mortar in accordance with the instructions for a six-cube batch given in the section on Composition of Mortars of Test Method C 109/C 109M, except use a water-cementious material ratio of 0.5, by mass. Mix mechanically in accordance with Procedure for Mixing Mortars of Practice C 305.

8.2 Split the batch immediately after mixing then place approximately 450 g of mortar in each of the two polyethylene containers. Obtain the temperature of each portion to ensure that it is within the range 23 ± 1 °C . If bags are used, twist the neck of each and seal with a rubber band; double the neck over and seal with a second band. If sheets are used to contain the samples, gather the corners and edges to make a bag and seal in similar manner.

9. Storage of Test Mortar

9.1 Immediately immerse both containers in the water bath maintained at (23.0 ± 0.15 °C) .

10. Preparation of Cement Extract

10.1 At 24 ± ¼ h, 3 days ± 1 h, or 7 days ± 3 h, after the instant the cement and water were mixed together, remove the containers successively from the water bath, pulverizing each sample in turn with the pestle in the mortar as rapidly as possible. Immediately upon removal from the water bath treat each sample individually as follows: First pulverize approximately one third of the specimen until most of it passes the 2.36-mm (No. 8) sieve. Return the coarse residue to the mortar and grind another one third of the specimen as before. Repeat the process until the entire specimen is pulverized to pass the 2.36-mm (No. 8) sieve. Place 400 g of the pulverized material in a 600-mL beaker and add 100 mL of water at a temperature of 23.0 ± 0.6 °C . Quickly mix to uniform consistency with a spatula; then stir mechanically for 2 min. Use a stirrer of such a type and speed that all particles of the slurry are suspended, with no settling and no appreciable increase of the temperature of the slurry occurs.

10.2 Filter the slurry on a dry No. 2A Büchner funnel with the aid of suction using a dry 90-mm, medium, ashless paper. Complete filtration within a period of 2 min. Filter again, whether the filtrate is turbid or not, using a new dry filter paper without suction.

11. Analysis of the Extract

11.1 Transfer 50.0 mL of the clear extract by means of a 50-mL pipet to a 400-mL beaker, dilute with distilled water to about 250 mL, and add 5 mL of concentrated hydrochloric acid (HCl, sp gr 1.19). Heat to boiling, and proceed in accordance with the sulfur trioxide determination section of Test Methods C 114. Perform a blank on the reagents in use in the analysis.

11.1.1 After the $BaCl_2$ solution is added in accordance with the sulfur trioxide determination section of Test Methods C 114, boil the solution vigorously for 15 min.

11.2 When the amount of filtrate is insufficient to provide a 50-mL aliquot, use 25 mL of the extract and a factor twice that given in Section 12.

12. Calculation and Report

12.1 Calculate the SO_3 content to the nearest 0.01 g/L of solution, as follows:

$$SO_3, g/L = W \times 6.86 \quad (1)$$

where:

W = grams of barium sulfate ($BaSO_4$) precipitated.

12.2 Report the average of the two determinations.

12.3 Report the age of the test specimens.

13. Precision and Bias

13.1 *Precision*—The single-operator (within-laboratory) standard deviation for testing at 24 h has been found to be 0.077 g/L SO_3 throughout the range of 0.20 to 0.85 g/L SO_3. Therefore, results of two properly conducted tests at 24 h by the same operator on water-extractable SO_3 in hardened hydraulic cement mortars of the same material should not differ from each other by more than 0.22 g/L SO_3. The multi-laboratory (between-laboratory) standard deviation for testing at 24 h has been found to be 0.137g/L SO_3 throughout the range of 0.20 to 0.85 g/L SO_3. Therefore, results of two properly conducted tests at 24 h on the same material, from two different laboratories on water-extractable SO_3 in hardened hydraulic cement mortars should not differ from each other by more than 0.39 g/L SO_3.

13.2 *Bias*—No justifiable statement can be made on the bias of the procedure in this test method for measuring the water-extractable SO_3 in hardened hydraulic cement mortars, because no reference samples are available.

14. Keywords

14.1 hydraulic cement; optimum sulfate content; sulfate; sulfate content

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For additional useful information on details of cement test methods, reference may be made to the "Manual of Cement Testing," *Annual Book of ASTM Standards,* **Vol 04.01.**

SUMMARY OF CHANGES

Committee C01 has identified the location of selected changes to this test method since the last issue, C 265 – 06, that may impact the use of this test method. (Approved May 1, 2008)

(*1*) Revised paragraph 13.1.

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Designation: C 266 – 08

Standard Test Method for Time of Setting of Hydraulic-Cement Paste by Gillmore Needles[1]

This standard is issued under the fixed designation C 266; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope*

1.1 This test method covers the determination of the time of setting of hydraulic-cement paste by means of the Gillmore needles.

1.2 The values stated in inch-pound units are to be regarded as standard. The values given in parentheses are mathematical conversions to SI units that are provided for information only and are not considered standard.

1.3 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

Warning: Fresh hydraulic cementitious mixtures are caustic and may cause chemical burns to skin and tissue upon prolonged exposure. The use of gloves, protective clothing, and eye protection is recommended. Wash contact area with copious amounts of water after contact. Wash eyes for a minimum of 15 min. Avoid exposure of the body to clothing saturated with the liquid phase of the unhardened material. Remove contaminated clothing immediately after exposure.

1.4 The text of this standard references notes and footnotes which provide explanatory material. These notes and footnotes (excluding those in tables and figures) shall not be considered as requirements of the standard.

2. Referenced Documents

2.1 *ASTM Standards:* [2]

C 151 Test Method for Autoclave Expansion of Hydraulic Cement

C 183 Practice for Sampling and the Amount of Testing of Hydraulic Cement

C 187 Test Method for Normal Consistency of Hydraulic Cement

C 219 Terminology Relating to Hydraulic Cement

C 305 Practice for Mechanical Mixing of Hydraulic Cement Pastes and Mortars of Plastic Consistency

C 511 Specification for Mixing Rooms, Moist Cabinets, Moist Rooms, and Water Storage Tanks Used in the Testing of Hydraulic Cements and Concretes

C 670 Practice for Preparing Precision and Bias Statements for Test Methods for Construction Materials

C 1005 Specification for Reference Masses and Devices for Determining Mass and Volume for Use in the Physical Testing of Hydraulic Cements

D 1193 Specification for Reagent Water

3. Terminology

3.1 Refer to Terminology C 219 for definitions of terms.

4. Summary of Test Method

4.1 Sufficient water is added to the cement that is being tested to produce a paste of normal consistency. A specimen is molded from this paste and is tested for time of setting by means of the Gillmore initial and final needles. The initial time of setting is the time elapsed between initial contact of cement and water and the time when the Gillmore Initial needle does not leave a complete circular impression in the paste surface. The final time of setting is the time elapsed between initial contact of cement and water and the time when the Gillmore Final needle does not leave a complete circular impression in the paste surface.

5. Significance and Use

5.1 The purpose of this test method is to establish whether a cement complies with a specification limit on Gillmore time of setting.

6. Apparatus

6.1 *Flat Trowel*, having a sharpened straight-edged steel blade 100 to 150 mm in length. The edges when placed on a plane surface shall not depart from straightness by more than 1 mm.

[1] This test method is under the jurisdiction of ASTM Committee C01 on Cement and is the direct responsibility of Subcommittee C01.30 on Time of Set

Current edition approved June 1, 2008. Published July 2008. Originally approved in 1951. Last previous edition approved in 2007 as C 266 – 07.

[2] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

***A Summary of Changes section appears at the end of this standard.**

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6.2 *Mixer, Bowl, Paddle, and Scraper*, conforming to the requirements of Practice C 305.

6.3 *Glass Graduates*, 200 or 250 mL capacity, conforming to the requirements of Specification C 1005.

6.4 *Mass Determining Devices*, conforming to the requirements of Specification C 1005. The devices for determining mass shall be evaluated for precision and accuracy at a total load of 1000 g.

6.5 *Plane Non-absorptive Plates*, 100 mm ± 5 mm square, of similar planeness, corrosivity, and absorptivity to that of glass (see Test Method C 187 Fig. 1, item H).

6.6 *Gillmore Needles*, conforming to the following requirements:

6.6.1 The initial time of setting needle shall have a mass of 0.250 ± 0.001 lb (113.4 ± 0.5 g) and a tip diameter of 0.084 ± 0.002 in. (2.12 ± 0.05 mm).

6.6.2 The final time of setting needle shall have a mass of 1.000 ± 0.001 lb (453.6 ± 0.5 g) and a tip diameter of 0.042 ± 0.002 in. (1.06 ± 0.05 mm).

6.6.3 The needle tips shall be cylindrical for a distance of 0.189 ± 0.020 in. (4.8 ± 0.5 mm). The needle ends shall be plane and at right angles to the axis of the rod and shall be maintained in a clean condition (See Note 1).

6.7 Inspect and document Section 6 apparatus for conformance to the requirements of this test method at least every 2 ½ years.

NOTE 1—The Gillmore needles should preferably be mounted as shown in Fig. 1 (b).

7. Reagents

7.1 *Mixing Water*—Potable water is satisfactory for routine tests. For all referee and cooperative tests, reagent water conforming to the requirements of Specification D 1193 for Type III or Type IV grade of reagent water shall be used.

8. Sampling

8.1 When the test is part of acceptance testing, sample the cement in accordance with Practice C 183.

9. Conditioning

9.1 Maintain the temperature of the room, dry materials, paddle, bowl, and plane non-absorptive plates at 23.0 ± 3.0 °C. Maintain the temperature of the mixing water at 23.0 ± 2.0 °C.

9.2 Maintain the relative humidity of the mixing room at not less than 50%.

9.3 The moist cabinet or moist room shall conform to the requirements of Specification C 511.

10. Procedure

10.1 *Preparation of Cement Paste*:

Obtain the cement paste used for determination of the time of setting from one of the following methods:

10.1.1 Prepare a new batch of paste by mixing 650 g of cement with the percentage of mixing water required for normal consistency (Test Method C 187), following the procedure described in Practice C 305.

10.1.2 At the option of the tester, use the paste remaining from the batch used for the autoclave expansion specimen (Test Method C 151) or from the normal consistency determination (Test Method C 187).

10.2 *Molding Test Specimen*—From the cement paste prepared as described in 10.1, make a pat with a flat top and the sides tapering to a thin edge on a plane non-absorptive plate, conforming to the dimensions and tolerances in Fig. 1 (a). In molding the pat, flatten the cement paste first on the plate and then form the pat by drawing the trowel from the outer edge toward the center, then flattening the top. After making, place the pat in the moist cabinet or moist room and allow it to remain there except when the determinations of time of setting are being made.

10.3 *Time of Setting Determination*—Determine the time of setting by holding the needle in a vertical position and lightly applying it to the surface of the pat.

10.3.1 Using the Initial Gillmore needle, determine the Gillmore Initial time of setting end point to be the first penetration measurement that does not mark the specimen surface with a complete circular impression. Verify Initial set by obtaining two additional penetration measurements on different areas of the specimen surface. Verification measurements must be obtained within 90 s of the first "initial set" measurement. The elapsed time, in minutes, between the time of contact of cement and mixing water and the end point determined above is the Gillmore initial time of setting.

10.3.2 Using the Final Gillmore needle, determine the Gillmore Final time of setting end point to be the first penetration measurement that does not mark the specimen surface with a complete circular impression. Verify Final set by obtaining two additional penetration measurements on different areas of the specimen surface. Verification measurements must be obtained within 90 s of the first "final set" measurement. The elapsed time, in minutes, between the time of contact of cement and mixing water and the end point determined above is the Gillmore final time of setting.

11. Report

11.1 Report the time of setting, to the nearest 5 min, as follows:

Initial Time of Setting, Gillmore	__ min
Final Time of Setting, Gillmore	__min

12. Precision and Bias

12.1 Precision, Gillmore Initial Time of Setting on samples testing between 100 and 341 min. (See Note 2)

12.1.1 The single-operator (within laboratory) standard deviation has been found to be 16 min (1s), therefore, results of two properly conducted tests by the same operator on samples of the same cement should not differ from each other by more than 44 min (d2s) (1s and d2s are defined in Practice C 670).

12.1.2 The multi-laboratory standard deviation has been found to be 28 min (1s), therefore, results of two properly conducted tests from two different laboratories should not differ from each other by more than 78 min (d2s).

12.2 Precision, Gillmore Final Time of Setting on samples testing between 239 and 561 min (See Note 2).

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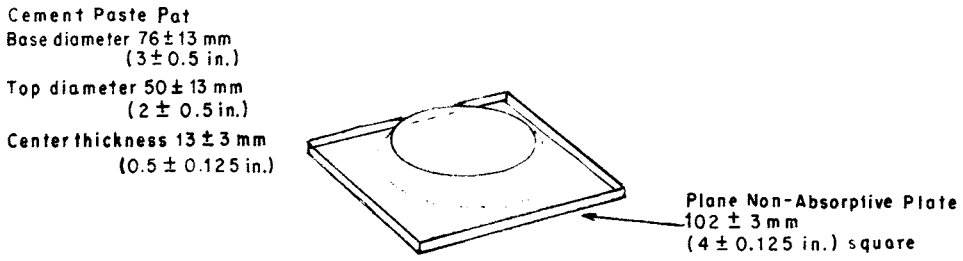
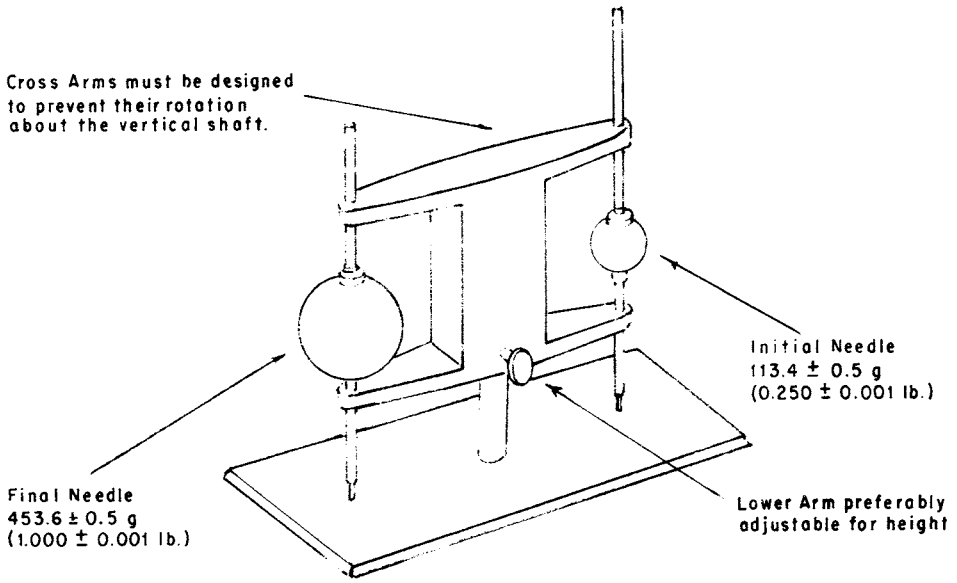
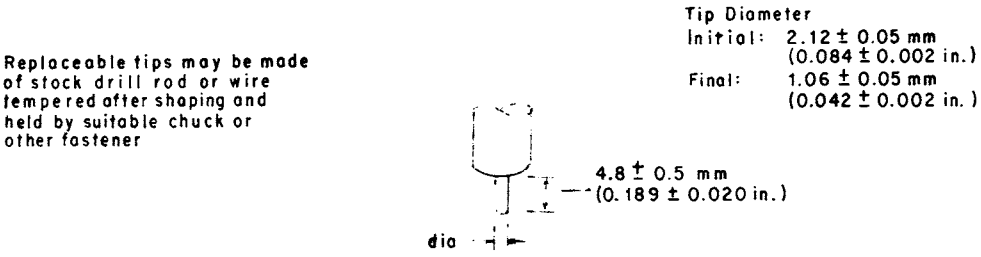


(a) Pat with Top Surface Flattened for Determining Time of Setting by Gillmore Method



(b) Gillmore Apparatus



(c) Detail of Gillmore Apparatus Needle Tips

FIG. 1 Gillmore Apparatus and Test Specimen

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12.2.1 The single-operator (within laboratory) standard deviation has been found to be 22 min (1s), therefore, results of two properly conducted tests by the same operator on samples of the same cement should not differ from each other by more than 62 min (d2s).

12.2.2 The multi-laboratory standard deviation has been found to be 46 min (1s), therefore, results of two properly conducted tests from two different laboratories on samples of the same cement should not differ by more than 129 min (d2s).

12.3 Bias

12.3.1 Since an acceptable reference material suitable for determining any bias of this method does not exist, no statement on bias is being made.

NOTE 2—This data is based upon CCRL Portland cement round robin test samples 47 to 138 and CCRL Masonry cement round robin test samples 1 to 46.

13. Keywords

13.1 gillmore needles; hydraulic cement paste; time of setting

SUMMARY OF CHANGES

Committee C01 has identified the location of selected changes to this test method since the last issue, C 266 – 07, that may impact the use of this test method. (Approved June 1, 2008)

(*1*) Revised 4.1, 6.1, 6.4, and 9.2.

(*2*) Revised the units statement in 1.2 and reversed the order of units throughout the standard editorially to comply with ASTM Form and Style.

Committee C01 has identified the location of selected changes to this test method since the last issue, C 266 – 04, that may impact the use of this test method. (Approved July 15, 2007)

(*1*) Added new 6.7.

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Designation: C 289 – 07

Standard Test Method for Potential Alkali-Silica Reactivity of Aggregates (Chemical Method)[1]

This standard is issued under the fixed designation C 289; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

This standard has been approved for use by agencies of the Department of Defense.

1. Scope*

1.1 This test method covers chemical determination of the potential reactivity of an aggregate with alkalies in portland-cement concrete as indicated by the amount of reaction during 24 h at 80 °C between 1 *N* sodium hydroxide solution and aggregate that has been crushed and sieved to pass a 300-µm sieve and be retained on a 150-µm sieve.

1.2 The values stated in SI units are to be regarded as standard.

1.3 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.* A specific precautionary statement is given in 5.7.1.

2. Referenced Documents

2.1 *ASTM Standards:* [2]

C 114 Test Methods for Chemical Analysis of Hydraulic Cement

C 227 Test Method for Potential Alkali Reactivity of Cement-Aggregate Combinations (Mortar-Bar Method)

C 295 Guide for Petrographic Examination of Aggregates for Concrete

C 702 Practice for Reducing Samples of Aggregate to Testing Size

C 1005 Specification for Reference Masses and Devices for Determining Mass and Volume for Use in the Physical Testing of Hydraulic Cements

C 1260 Test Method for Potential Alkali Reactivity of Aggregates (Mortar-Bar Method)

C 1293 Test Method for Determination of Length Change of Concrete Due to Alkali-Silica Reaction

D 75 Practice for Sampling Aggregates

D 1193 Specification for Reagent Water

D 1248 Specification for Polyethylene Plastics Extrusion Materials for Wire and Cable

E 11 Specification for Wire Cloth and Sieves for Testing Purposes

E 60 Practice for Analysis of Metals, Ores, and Related Materials by Molecular Absorption Spectrometry

2.2 *American Chemical Society Documents:*

Reagent Chemicals, American Chemical Society Specifications

NOTE 1—For suggestions on the testing of reagents not listed by the American Chemical Society, see "Reagent Chemicals and Standards," by Joseph Rosin, D. Van Nostrand Co., Inc., New York, NY, and the "United States Pharmacopeia."

3. Significance and Use

3.1 When this test method is used to evaluate the potential reactivity of siliceous components in the aggregate with alkalies in hydraulic-cement concrete, it must be used in combination with other methods. Do not use the results of tests by this test method as the sole basis for acceptance or rejection for sources with regard to ASR.

3.2 Reactions between a sodium hydroxide solution and siliceous components in the aggregate have been shown to correlate with the performance of some aggregates in concrete structures. The results from this test method can be obtained quickly, and, while not completely reliable in all cases, they can provide useful data.

3.3 This test method can be employed as a quality control tool to periodically check samples from an existing source with an acceptable service history.

4. Apparatus

4.1 *Scales*—The scales and weights used for weighing materials shall conform to the requirements prescribed in Specification C 1005.

[1] This test method is under the jurisdiction of ASTM Committee C09 on Concrete and Concrete Aggregates and is the direct responsibility of Subcommittee C09.26 on Chemical Reactions.

Current edition approved Nov. 1, 2007. Published December 2007. Originally approved in 1952. Last previous edition approved in 2003 as C 289 – 03.

[2] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

***A Summary of Changes section appears at the end of this standard.**

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4.2 *Balances*—The analytical balance and weights used for determining dissolved silica by the gravimetric method shall conform to the requirements prescribed in Test Methods C 114.

4.3 *Crushing and Grinding Equipment*—A small jaw crusher and disk pulverizer or other suitable equipment capable of crushing and grinding aggregate to pass a 300-µm sieve.

4.4 *Sieves*:

4.4.1 300-µm and 150-µm square-hole, woven wire-cloth sieves conforming to Specification E 11.

4.4.2 A 4.75-mm (No. 4) sieve.

4.5 *Containers*—Reaction containers of 50 to 75-mL capacity, made of corrosion-resistant steel or other corrosion-resistant material, and fitted with airtight covers. A container that has been found suitable is shown in Fig. 1. Other containers, made of corrosion-resistant material such as polyethylene, may be suitable. Such suitability can be demonstrated by a change in the alkalinity of the sodium hydroxide solution (R_c, Section on Reduction in Alkalinity) when used alone as a blank in the container in question, of less than 10 mmol/L.

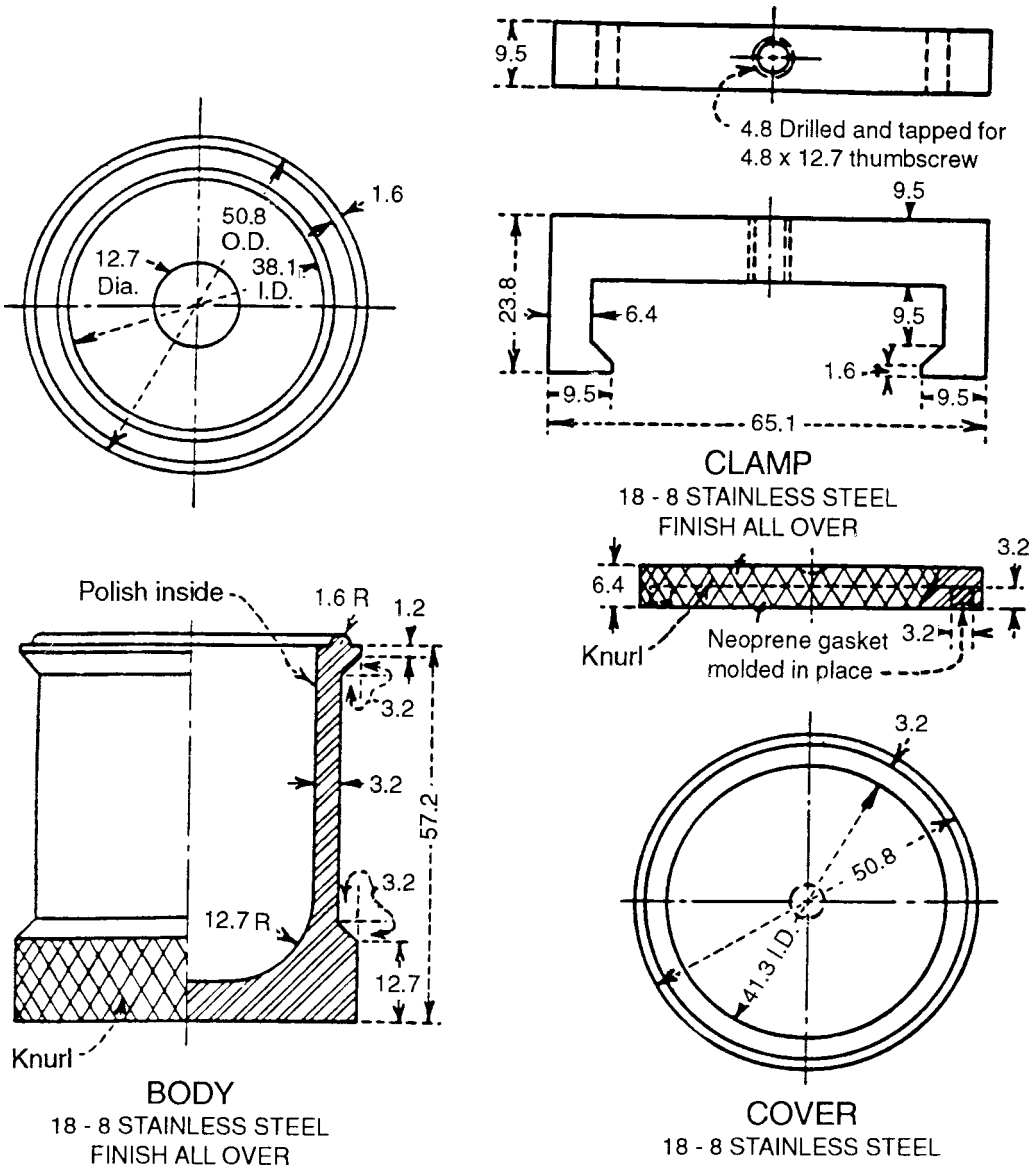
4.6 *Constant-Temperature Bath*—A liquid bath capable of maintaining a temperature of 80 ± 1 °C for 24 h.

4.7 *Spectrophotometer or Photometer*—A spectrophotometer or photoelectric photometer capable of measuring the transmission of light at a constant wavelength of approximately 410 nm (see Practice E 60).

4.8 *Glassware*—All glass apparatus and vessels should be carefully selected to meet the particular requirements for each operation. Standard volumetric flasks, burets, and pipets should be of precision grade.

5. Reagents

5.1 *Purity of Reagents*—Reagent grade chemicals shall be used in all tests. Unless otherwise indicated, all reagents shall conform to Reagent Chemicals, American Chemical Society



NOTE 1—All dimensions are in mm.

FIG. 1 Reaction Container

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Specifications. Other grades may be used, provided it is first ascertained that the reagent is of sufficiently high purity to permit its use without lessening the accuracy of the determination.

5.2 *Purity of Water*—Unless otherwise indicated, references to water shall be understood to mean reagent water conforming to Type IV of Specification D 1193.

5.3 *Ammonium Molybdate Solution*—Dissolve 10 g of ammonium molybdate ($(NH_4)_6\ Mo_7O_{24}\cdot 4H_2O$) in 100 mL of water. If the solution is not clear, filter through a fine-texture paper. Store the solution in a polyethylene container (see Note 2).

5.4 *Hydrochloric Acid (1.19 kg/L)*—Concentrated hydrochloric acid (HCl). Store the solution in a chemically resistant glass or suitable plastic container (see Note 2).

5.5 *Hydrochloric Acid, Standard* (0.05 *N*)—Prepare approximately 0.05 *N* HCl and standardize to ±0.0001 *N*. Store the solution in a chemically resistant glass or suitable plastic container (see Note 2).

5.6 *Hydrochloric Acid (1 + 1)*—Mix equal volumes of concentrated HCl (1.19 kg/L) and water. Store the solution in a chemically resistant glass or suitable plastic container (see Note 2).

5.7 *Hydrofluoric Acid (approximately 50 % HF)*—Concentrated hydrofluoric acid. Store in a polyethylene bottle (see Note 2).

5.7.1 **Warning—**Before using HF, review (*1*) the safety precautions for using HF, (*2*) first aid for burns, and (*3*) the emergency response to spills, as described in the manufacturer's Material Safety Data Sheet or other reliable safety literature. HF can cause very severe burns and injury to unprotected skin and eyes. Suitable personal protective equipment should always be used. These should include full-face shields, rubber aprons, and gloves impervious to HF. Gloves should be checked periodically for pin holes.

5.8 *Oxalic Acid Solution*—Dissolve 10 g of oxalic acid dihydrate in 100 mL of water. Store the solution in a chemically resistant glass or suitable plastic container (see Note 2).

5.9 *Phenolphthalein Indicator Solution*—Dissolve 1 g of phenolphthalein in 100 mL of ethanol (1 + 1). Store the solution in a chemically resistant glass or suitable plastic container (see Note 2).

5.10 *Silica Standard Solution*—Prepare a standard silica solution containing approximately 10 mmol of silica (SiO_2)/L by dissolving sodium metasilicate in water. Store the solution in a polyethylene bottle. Use a 100-mL aliquot of the solution to determine its SiO_2 content by the procedure described in 8.2. Do not use a standard silica solution older than 1 year, since dissolved ionic silica in such a solution slowly polymerizes, causing spuriously low photometric readings (see Note 2).

5.11 *Sodium Hydroxide, Standard Solution* (1.000 ± 0.010 *N*)—Prepare a 1.000 ± 0.010 *N* sodium hydroxide (NaOH) solution and standardize to ±0.001 *N*. Store the solution in a polyethylene bottle (Note 2). Protect the dry reagent and solution from contamination by carbon dioxide.

5.12 *Sulfuric Acid (sp gr 1.84)*—Concentrated sulfuric acid (H_2SO_4). Store the solution in a chemically resistant glass container (see Note 2).

NOTE 2—In selecting the container, take care to ensure that the reagent will not be modified by reaction with the material composing the container, including pigments or other additives, or by transpiration of phases through the walls of the container. Containers with wall thickness not less than 0.51 mm and composed of high-density polyethylene meeting the requirements of Specification D 1248, for materials of Type III, Class A, are suitable.

6. Selection and Preparation of Test Samples

6.1 The test can be used for either fine or coarse aggregate, and when the fine and coarse aggregate are of the same material it can be used for the total aggregate.

6.2 Obtain the aggregate sample in accordance with Practice D 75. Use the sample sizes given in Table number 1 of Practice D 75.

6.2.1 For samples of aggregate with a nominal maximum size less than 19.0 mm, split the sample in half in accordance with Practice C 702. Crush one half as described in 6.2.3. Retain the other half for further testing if desired.

6.2.2 For samples of aggregate with a nominal maximum size 19.0 mm or larger, mix and quarter the sample in accordance with Practice C 702. Crush one quarter as described in 6.2.3. Retain the other three quarters of the sample for further testing if desired.

6.2.3 Crush the sample in a jaw-crusher using small portions at a time, retaining all fractions, until the sample passes a 4.75-mm (No. 4) sieve. Reduce the crushed sample to 300 ± 5 g by splitting in accordance with Practice C 702.

6.3 Sieve the 300-g sample, discarding all material that passes the 150-µm (No. 100) sieve. Crush or grind the sample in small portions using a disk pulverizer, rotary mill (rotating-puck) device, or mortar and pestle. To minimize the production of material passing the 150-µm (No.100) sieve, use several passes of the portion through the equipment, removing material passing the 300-µm (No. 50) sieve before regrinding the remainder. If the amount of material retained on the 150-µm (No. 100) sieve is less than 100 g after pulverizing the entire 300-g sample, discard the sample and pulverize a new 300-g sample (Note 3).

NOTE 3—An over-pulverized sample may not produce the correct chemical test results. A properly pulverized sample will have about 110 to 150 g of material remaining on the 150-µm (No. 100) sieve after washing.

6.4 To ensure that all material finer than the 150-µm sieve has been removed, wash the sample over a 150-µm sieve. Do not wash more than 100 g over a 203-mm diameter sieve at one time. Dry the washed sample at 105 ± 5 °C for 20 ± 4 h. Cool the sample and again sieve on the 150-µm sieve. If inspection of the sample indicates the presence of silty or clayey coatings on particles, repeat the washing and drying procedure, and sieve as before over the 150-µm sieve. Reserve the portion retained on the 150-µm sieve for the test sample.

7. Reaction Procedure

7.1 Weigh out three representative 25.00 ± 0.05-g portions of the dry 150-µm to 300-µm test sample prepared in accordance with Section 6. Place one portion in each of the three of the reaction containers, and add by means of a pipet, 25 mL of the 1.000 *N* NaOH solution. To a fourth reaction container, by means of a pipet, add 25 mL of the same NaOH solution to

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serve as a blank. Seal the four containers and gently swirl them to liberate trapped air.

7.2 Immediately after the containers have been sealed, place them in a liquid bath maintained at 80 ± 1.0 °C. After 24 ± ¼ h, remove the containers from the bath and cool them, for 15 ± 2 min, under running tap water having a temperature below 30 °C.

7.3 Immediately after the containers have been cooled, open them and filter the solution from the aggregate residue. Use a porcelain Gooch crucible (see Note 4) with a disk of rapid, analytical-grade filter paper cut to fit the bottom of the crucible, setting the crucible in a rubber crucible holder in a funnel. Place a dry test tube, 35 to 50-mL capacity, in the filter flask to collect the filtrate, and seat the funnel in the neck of the filter flask. With the aspirator in operation or the vacuum line open, decant a small quantity of the solution onto the filter paper so it will seat properly in the crucible. Without stirring the contents of the container, decant the remaining free liquid into the crucible. When the decantation of the liquid has been completed, discontinue the vacuum and transfer the solids remaining in the container to the crucible and pack in place with the aid of a stainless-steel spatula. Then apply and adjust the vacuum to approximately 51 kPa. Continue the filtration until further filtration yields filtrate at the approximate rate of 1 drop every 10 s; reserve the filtrate for further tests. Record the total amount of time during which the vacuum is applied as the filtration time; make every effort to achieve an equal filtration time for all samples in a set, by uniformity of procedure in the assembly of the filtration apparatus and the packing of the solids in the crucible.

NOTE 4—Coors Size No. 4 Gooch crucibles, or equivalent, have been found satisfactory for this purpose.

7.4 Filter the blank according to the procedure described in 7.3. Apply the vacuum for a length of time equal to the average filtration time for the three specimens.

7.5 Immediately following the completion of filtration, stir the filtrate to assure homogeneity, then take by pipet an aliquot of 10 mL of the filtrate and dilute with water to 200 mL in a volumetric flask. Reserve this diluted solution for the determination of the dissolved SiO_2 and the reduction in alkalinity.

7.6 If the diluted filtrate is not to be analyzed within 4 h following completion of the filtration, transfer the solution to a clean, dry polyethylene container and close the container by means of a stopper or tight-fitting cap or lid.

8. Analysis of Filtrate

8.1 Measure dissolved silica using either the gravimetric method (See 8.2) or the photometric method (See 8.3) and measure reduction in alkalinity (See 8.4).

8.2 Dissolved Silica by the Gravimetric Method

8.2.1 *Procedure*:

8.2.1.1 Transfer by pipet 100 mL of the dilute solution (7.5) to an evaporating dish, preferably of platinum for speed in evaporation, add 5 to 10 mL of HCl (1.19 kg/L), and evaporate to dryness on a steam bath. Without heating the residue further, treat it with 5 to 10 mL of HCl (1.19 kg/L) and then an equal amount of water, or at once pour 10 to 20 mL of HCl (1 + 1) upon the residue. Cover the dish and digest for 10 min on the steam bath or a hot plate. Dilute the solution with an equal volume of hot water, filter immediately through quantitative-grade, low–ash filter paper, and wash the separated silica (SiO_2) thoroughly with hot water (see Note 5) and reserve the residue.

NOTE 5—The washing of the SiO_2 precipitates can be made more effective by using hot HCl (1 + 99) and then completing the washing with hot water.

8.2.1.2 Again evaporate the filtrate to dryness, baking the residue in an oven for 1 h at 105 to 110 °C. Take up the residue with 10 to 15 mL of HCl (1 + 1) and heat on the bath or hot plate. Dilute the solution with an equal volume of hot water and catch and wash the small amount of SiO_2 it contains on another filter paper. This second evaporation is necessary only when determining the concentration of the standard sodium metasilicate solution in 5.10. For the other test solutions, it can be eliminated.

8.2.1.3 Transfer the papers containing the residue (8.2.1.1 and 8.2.1.2) to a platinum crucible (see Note 6). Dry and ignite the papers, first at a low heat until the carbon of the filter paper is completely consumed without inflaming, and finally at 1100 to 1200 °C until the mass remains constant.

NOTE 6—The mass of the empty crucible may be determined if one wishes to know the magnitude of impurities in the residue of SiO_2.

8.2.1.4 Treat the SiO_2 thus obtained, which will contain small amounts of impurities, in the crucible with a few drops of water, about 10 mL of HF, and one drop of H_2SO_4, and evaporate cautiously to dryness on the steam bath. Finally, heat the small residue at 1050 to 1100 °C for 1 to 2 min, cool, and determine the mass. The difference between this determination and that previously obtained represents the amount of SiO_2.

8.2.2 *Calculation*:

Calculate the SiO_2 concentration of the NaOH solution filtered from the aggregate material, as follows:

$$S_c = 3330 \times W \quad (1)$$

where:

S_c = concentration of SiO_2 in mmol/L in the original filtrate, and

W = grams of SiO_2 found in 100 mL of the dilute solution.

8.3 Dissolved Silica by the Photometric Method

8.3.1 *Application*:

This method is applicable to the determination of crystalloidal (noncolloidal) silica (see Note 7) in all aqueous solutions except those with excessive color interferences (tannin and so forth), but it will not determine total silica. The method is particularly applicable to rapid control analysis of crystalloidal silica below 10 ppm.

NOTE 7—Crystalloidal (noncolloidal) silica reacts with molybdate ion in acid solution (optimum pH 1.2 to 1.5) to form a greenish yellow silico-molybdate color complex the intensity of which is approximately proportional to the silica concentration of the solution, but does not follow Beer's law perfectly.

8.3.2 *Preparation of Calibration Curve*:

8.3.2.1 Prepare a series of solutions of known silica concentration varying from 0.0 to 0.5 mmol/L by diluting portions of the stock solution of sodium silicate (5.10). Transfer the

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portions of sodium silicate solution to 100-mL volumetric flasks about half filled with water.

8.3.2.2 Add 2 mL of the ammonium molybdate solution and 1 mL of HCl (1 + 1), and agitate by swirling the flask. Allow the solution to stand for 15 min at room temperature. Add 1.5 ± 0.2 mL of the oxalic acid solution, fill the flask to the mark with water, and mix thoroughly. Allow the solution to stand for 5.0 ± 0.1 min. Read the transmittance of the various solutions on the photometer at 410 nm, in comparison with that of water.

8.3.2.3 Prepare a calibration curve by plotting the percent transmittance or absorbance readings against the known concentrations of silica in each solution.

8.3.3 *Determination of Dissolved Silica*:

8.3.3.1 Transfer by pipet a 10-mL aliquot of the dilute solution to a 100-mL volumetric flask half filled with water and proceed as directed in 8.3.2.2 and 8.3.2.3. Read the concentration of silica in the solution directly from the previously prepared calibration curve correlating transmission of light of this wave length with silica concentration. If the transmittance is below 30 % or above 50 %, a smaller or larger aliquot of the diluted solution shall be used.

8.3.4 *Calculation*:

8.3.4.1 Calculate the SiO_2 concentration of the NaOH solution filtered from the aggregate material, as follows:

$$S_c = 20 \times (100/V) \times C \quad (2)$$

where:

S_c = concentration of SiO_2, mmol/L in the original filtrate,
C = concentration of silica in the solution measured in the photometer, mmol/L, and
V = millilitres of dilute solution used from 7.5.

8.4 Reduction in Alkalinity

8.4.1 *Procedure*:

Transfer by pipet a 20-mL aliquot of the dilute solution (7.5) to a 125-mL Erlenmeyer flask, add 2 or 3 drops of phenolphthalein solution, and titrate with 0.05-*N* HCl to the phenolphthalein end point.

8.4.2 *Calculation*:

Calculate the reduction in alkalinity as follows:

$$R_c = (20N/V_1)(V_3 - V_2) \times 1000 \quad (3)$$

where:

R_c = the reduction in alkalinity, mmol/L,
N = normality of the HCl used for the titration,
V_1 = millilitres of dilute solution used from 7.5,
V_2 = millilitres of HCl used to attain the phenolphthalein end point in the test sample, and
V_3 = millilitres of HCl used to attain the phenolphthalein end point in the blank.

9. Precision and Bias

9.1 *Precision*—Information concerning the precision of this test method is being investigated and will be published when the proper data have been obtained and analyzed as prescribed in Practice C 670.

9.2 Preliminary data on precision indicate that the test results may be considered satisfactory if none of the three values of R_c (and of S_c) differs from the average of the three by more than the following amounts: (*1*) when the average is 100 mmol or less, 12 mmol/L, and (*2*) when the average is more than 100 mmol/L, 12 %.

9.3 *Bias*—Since there is no accepted reference material suitable for determining the bias of this test method, no statement on bias is made.

10. Keywords

10.1 aggregate reactivity; alkali; alkali-silica reactivity; concrete aggregates

APPENDIX

(Nonmandatory Information)

X1. INTERPRETATION OF RESULTS

X1.1 Correlations between data obtained by this method, expansion of mortar bars containing high-alkali cement, petrographic examinations of aggregates, and performance of aggregates in concrete structures have been published **(1-7).**[3] On the basis of these data, the solid curve shown in Fig. X1.1 has been established. A potentially deleterious degree of alkali reactivity is indicated if any of the three R_c, S_c points lie on the deleterious side of the curve in Fig. X1.1. However, potentially deleterious aggregates represented by points lying above the dashed line in Fig. X1.1 may give relatively low expansions in mortar or concrete even though they are extremely reactive with alkalies. These aggregates should be considered to indicate a potentially deleterious degree of reactivity until the innocuous character of the aggregate is demonstrated by service records or by supplementary tests in accordance with the provisions of Test Methods C 227, C 1260, or C 1293, as applicable. The additional test method(s) should be selected based on the mineralogical characteristics of the aggregate. It is recommended that these mineralogical properties be determined with a petrographic examination in accordance with the provisions of Guide C 295.

X1.2 Results of this test may not be correct for aggregates containing carbonates of calcium, magnesium, or ferrous iron, such as calcite, dolomite, magnesite, or siderite; or silicates of magnesium such as antigorite (serpentine) **(6,7)**. The error

[3] The boldface numbers in parentheses refer to the references appearing at the end of this test method.

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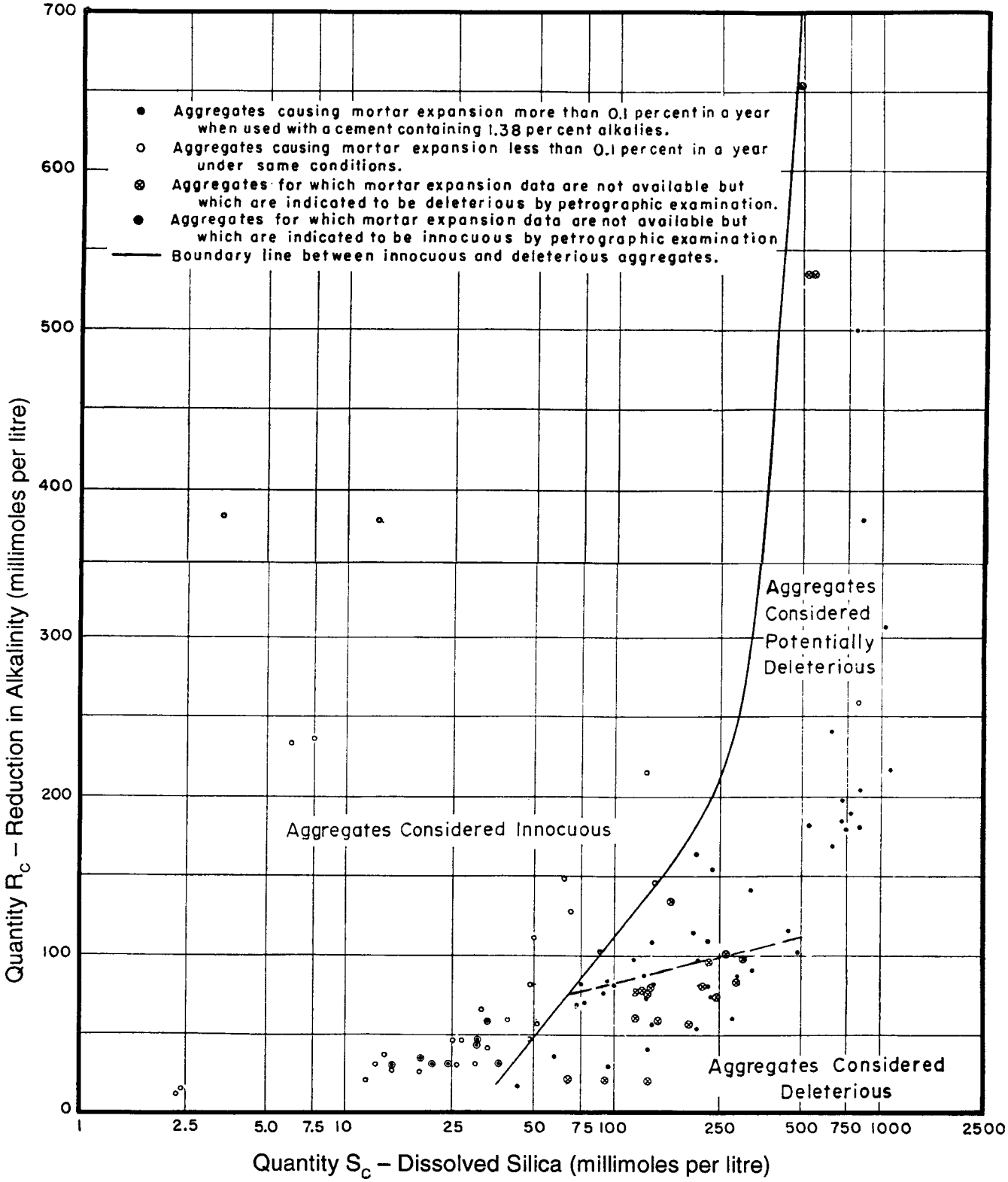

FIG. X1.1 Illustration of Division Between Innocuous and Deleterious Aggregates on Basis of Reduction in Alkalinity Test

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introduced by calcium carbonate is not significant unless S_c and R_c values indicate the potential reactivity is marginal. Examinations of the aggregate in accordance with Guide C 295, can be used to determine the presence of minerals of this type.

X1.3 It is recommended that interpretations based upon this method be correlated with Guide C 295 and service records of the aggregate. The results of this test do not predict the late-slow silica-silicate reactivity in concrete that may result with aggregates containing strained or micro-granulated quartz, or aggregates composed of metagraywacke, meta-siltstone, meta-quartz, and similar rocks.

REFERENCES

(1) Mielenz, R. C., and Witte, L. P., "Tests Used by the Bureau of Reclamation for Identifying Reactive Concrete Aggregates," *Proceedings*, ASTM, Vol 48, 1948, pp. 1071–1103 and discussion, p. 1104.

(2) Mielenz, R. C., Greene, K. T., and Benton, E. J., "Chemical Test for Reactivity of Aggregates with Cement Alkalies: Chemical Processes in Cement-Aggregate Reaction," *Proceedings*, Am. Concrete Inst., Vol 44, 1948, p. 193.

(3) Lerch, William, "Studies of Some Methods of Avoiding Expansion and Pattern Cracking Associated with the Alkali-Aggregate Reaction," *Symposium on Use of Pozzolanic Materials in Mortars and Concretes*, ASTM STP 99, ASTM, 1950, p. 153.

(4) Slate, F. O., "Chemical Reactions of Indiana Aggregates in Disintegration of Concrete," *Proceedings*, ASTM, Vol 49, 1949, p. 954.

(5) Lerch, William, "Chemical Reactions of Concrete Aggregates," *ASTM STP 169*, ASTM, 1956, p. 334.

(6) Mielenz, R. C., and Benton, E. J., "Evaluation of the Quick Chemical Test for Alkali Reactivity of Concrete Aggregate," *Bulletin 171*, Highway Research Board, 1958, p. 1.

(7) Chaiken, Bernard, and Halstead, W. J., "Correlation Between Chemical and Mortar Bar Tests for Potential Alkali Reactivity of Concrete Aggregates," *Public Roads*, Vol 30, 1959, p. 177.

SUMMARY OF CHANGES

Committee C09 has identified the location of selected changes to this test method since the last issue, C 289 – 03, that may impact the use of this test method. (Approved November 1, 2007)

(*1*) Reorganized the test method, moving old Sections 8–13 into new Section 8.

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Designation: C 293 – 07

Standard Test Method for Flexural Strength of Concrete (Using Simple Beam With Center-Point Loading)[1]

This standard is issued under the fixed designation C 293; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

This standard has been approved for use by agencies of the Department of Defense.

1. Scope*

1.1 This test method covers determination of the flexural strength of concrete specimens by the use of a simple beam with center-point loading. It is not an alternative to Test Method C 78.

1.2 The values stated in inch-pound units are to be regarded as standard. The SI equivalent of inch-pound units has been rounded where necessary for practical application.

1.3 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

2. Referenced Documents

2.1 *ASTM Standards:* [2]

C 31/C 31M Practice for Making and Curing Concrete Test Specimens in the Field

C 78 Test Method for Flexural Strength of Concrete (Using Simple Beam with Third-Point Loading)

C 192/C 192M Practice for Making and Curing Concrete Test Specimens in the Laboratory

C 617 Practice for Capping Cylindrical Concrete Specimens

C 1077 Practice for Laboratories Testing Concrete and Concrete Aggregates for Use in Construction and Criteria for Laboratory Evaluation

E 4 Practices for Force Verification of Testing Machines

3. Significance and Use

3.1 This test method is used to determine the modulus of rupture of specimens prepared and cured in accordance with Practices C 31 or C 192. The strength determined will vary where there are differences in specimen size, preparation, moisture condition, or curing.

3.2 The results of this test method may be used to determine compliance with specifications or as a basis for proportioning, mixing and placement operations. This test method produces values of flexural strength significantly higher than Test Method C 78 (Note 1).

NOTE 1—The testing laboratory performing this test method may be evaluated in accordance with Practice C 1077.

4. Apparatus

4.1 The testing machine shall conform to the requirements of the sections on Basis of Verification, Corrections, and Time Interval Between Verifications of Practices E 4. Hand operated testing machines having pumps that do not provide a continuous loading to failure in one stroke are not permitted. Motorized pumps or hand operated positive displacement pumps having sufficient volume in one continuous stroke to complete a test without requiring replenishment are permitted and shall be capable of applying loads at a uniform rate without shock or interruption.

4.2 *Loading Apparatus*—The mechanism by which forces are applied to the specimen shall employ a load-applying block and two specimen support blocks. It shall ensure that all forces are applied perpendicular to the face of the specimen without eccentricity. A diagram of an apparatus that accomplishes this purpose is shown in Fig. 1.

4.2.1 All apparatus for making center-point loading flexure tests shall be similar to Fig. 1 and maintain the span length and central position of the load-applying block with respect to the support blocks constant within ±0.05 in. (±1.3 mm).

4.2.2 Reactions shall be parallel to the direction of the applied load at all times during the test, and the ratio of the horizontal distance between the point of load application and nearest reaction to the depth of the beam shall be 1.5 ± 2 %.

4.2.3 The load-applying and support blocks shall not be more than 2½ in. (64 mm) high, measured from the center or the axis of pivot, and shall extend at least across the full width of the specimen. Each hardened bearing surface in contact with the specimen shall not depart from a plane by more than 0.002 in. (0.05 mm) and shall be a portion of a cylinder, the axis of

[1] This test method is under the jurisdiction of ASTM Committee C09 on Concrete and Concrete Aggregates and is the direct responsibility of Subcommittee C09.61 on Testing for Strength.

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[2] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

***A Summary of Changes section appears at the end of this standard.**

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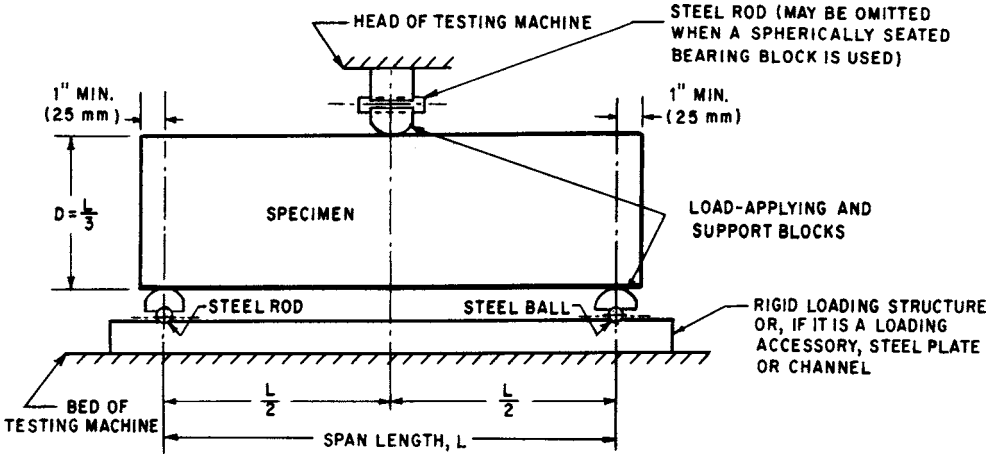

NOTE 1—Apparatus may be used inverted.

FIG. 1 Diagrammatic View of a Suitable Apparatus for Flexure Test of Concrete by Center-Point Loading Method.

which is coincidental with either the axis of the rod or center of the ball, whichever the block is pivoted upon. The angle subtended by the curved surface of each block shall be at least 45° (0.79 rad). The load-applying and support blocks shall be maintained in a vertical position and in contact with the rod or ball by means of spring-loaded screws that hold them in contact with the pivot rod or ball. The rod in the center load-applying block in Fig. 1 may be omitted when a spherically seated bearing block is used.

5. Test Specimen

5.1 The test specimen shall conform to all requirements of Practice C 31 or C 192 applicable to beam specimens and shall have a test span within 2 % of being three times its depth as tested. The sides of the specimen shall be at right angles with the top and bottom. All surfaces shall be smooth and free of scars, indentations, holes, or inscribed identification marks.

6. Procedure

6.1 Flexural tests of moist-cured specimens shall be made as soon as practical after removal from moist storage. Surface drying of the specimen results in a reduction in the measured modulus of rupture.

6.2 Turn the test specimen on its side with respect to its position as molded and center it on the support blocks. Center the loading system in relation to the applied force. Bring the load-applying block in contact with the surface of the specimen at the center and apply a load of between 3 and 6 % of the estimated ultimate load. Using 0.004 in. (0.10 mm) and 0.015 in. (0.38 mm) leaf-type feeler gages, determine whether any gap between the specimen and the load-applying or support blocks is greater or less than each of the gages over a length of 1 in. (25 mm) or more. Grind, cap, or use leather shims on the specimen contact surface to eliminate any gap in excess of 0.004 in. (0.10 mm). Leather shims shall be of uniform ¼ in. (6.4 mm) thickness, 1 to 2 in. (25 to 50 mm) in width, and shall extend across the full width of the specimen. Gaps in excess of 0.015 in. (0.38 mm) shall be eliminated only by capping or grinding. Grinding of lateral surfaces shall be minimized inasmuch as grinding may change the physical characteristics of the specimens. Capping shall be in accordance with Practice C 617.

6.3 Load the specimen continuously and without shock. The load shall be applied at a constant rate to the breaking point. Apply the load so that the maximum stress on the tension face increases at a rate between 125 and 175 psi/min (0.9 and 1.2 MPa/min). The loading rate is computed using:

$$r = 2Sbd^2/3L \quad (1)$$

where:

r = loading rate, lb/min (N/min),
S = rate of increase in the maximum stress on the tension face, psi/min (MPa/min),
b = average width of the specimen as oriented for testing, in. (mm),
d = average depth of the specimen as oriented for testing, in. (mm), and
L = span length, in. (mm).

7. Measurement of Specimens After Test

7.1 To determine the dimensions of the specimen section for use in calculating modulus of rupture, take measurements across one of the fractured faces after testing. The width and depth are measured with the specimen as oriented for testing. For each dimension, take one measurement at each edge and one at the center of the cross section. Use the three measurements for each direction to determine the average width and the average depth. Take all measurements to the nearest 0.05 in. (1 mm). If the fracture occurs at a capped section, include the cap thickness in the measurement.

8. Calculation

8.1 Calculate the modulus of rupture as follows:

$$R = 3\,PL/2bd^2 \quad (2)$$

where:

R = modulus of rupture, psi, or MPa,

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P = maximum applied load indicated by the testing machine, lbf, or N,
L = span length, in., or mm,
b = average width of specimen, at the fracture, in., or mm, and
d = average depth of specimen, at the fracture, in., or mm.

NOTE 2—The weight of the beam is not included in the above calculation.

9. Report

9.1 Report the following information:
9.1.1 Identification number,
9.1.2 Average width to the nearest 0.05 in. (1 mm), at the fracture,
9.1.3 Average depth to the nearest 0.05 in. (1 mm), at the fracture,
9.1.4 Span length in inches (or millimetres),
9.1.5 Maximum applied load in pounds-force (or newtons),
9.1.6 Modulus of rupture calculated to the nearest 5 psi (0.05 MPa),
9.1.7 Record of curing and apparent moisture condition of the specimens at the time of test,
9.1.8 If specimens were capped, ground, or if leather shims were used,
9.1.9 Defects in specimens, and
9.1.10 Age of specimens.

10. Precision and Bias

10.1 *Precision*—The coefficient of variation of test results has been observed to be dependent on the strength level of the beams.[3] The single operator coefficient of variation has been found to be 4.4 %. Therefore, results of two properly conducted tests by the same operator on beams made from the same batch sample should not differ from each other by more than 12 %. The multilaboratory coefficient of variation has been found to be 5.3 %. Therefore, results of two different laboratories on beams made from the same batch sample should not differ from each other by more than 15 %.

10.2 *Bias*—Since there is no accepted standard for determining bias in this test method, no statement on bias is made.

11. Keywords

11.1 beams; concrete; flexural strength testing; modulus of rupture

[3] See "Improved Concrete Quality Control Procedures Using Third Point Loading" by P. M. Carrasquillo and R. L. Carrasquillo, Research Report 119-1F, Project 3-9-87-1119, Center For Transportation Research, The University of Texas at Austin, November 1987, for information as to the relationship of strength and variability under center point loading.

SUMMARY OF CHANGES

Committee C09 has identified the location of selected changes to this test method since the last issue, C 293 – 02, that may impact the use of this test method.

(*1*) Revised 5.1.
(*2*) Revised 6.3.
(*3*) Revised 7.1.

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Designation: C 293 – 07

Standard Test Method for Flexural Strength of Concrete (Using Simple Beam With Center-Point Loading)[1]

This standard is issued under the fixed designation C 293; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

This standard has been approved for use by agencies of the Department of Defense.

1. Scope*

1.1 This test method covers determination of the flexural strength of concrete specimens by the use of a simple beam with center-point loading. It is not an alternative to Test Method C 78.

1.2 The values stated in inch-pound units are to be regarded as standard. The SI equivalent of inch-pound units has been rounded where necessary for practical application.

1.3 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

2. Referenced Documents

2.1 *ASTM Standards:* [2]

C 31/C 31M Practice for Making and Curing Concrete Test Specimens in the Field

C 78 Test Method for Flexural Strength of Concrete (Using Simple Beam with Third-Point Loading)

C 192/C 192M Practice for Making and Curing Concrete Test Specimens in the Laboratory

C 617 Practice for Capping Cylindrical Concrete Specimens

C 1077 Practice for Laboratories Testing Concrete and Concrete Aggregates for Use in Construction and Criteria for Laboratory Evaluation

E 4 Practices for Force Verification of Testing Machines

3. Significance and Use

3.1 This test method is used to determine the modulus of rupture of specimens prepared and cured in accordance with Practices C 31 or C 192. The strength determined will vary where there are differences in specimen size, preparation, moisture condition, or curing.

3.2 The results of this test method may be used to determine compliance with specifications or as a basis for proportioning, mixing and placement operations. This test method produces values of flexural strength significantly higher than Test Method C 78 (Note 1).

NOTE 1—The testing laboratory performing this test method may be evaluated in accordance with Practice C 1077.

4. Apparatus

4.1 The testing machine shall conform to the requirements of the sections on Basis of Verification, Corrections, and Time Interval Between Verifications of Practices E 4. Hand operated testing machines having pumps that do not provide a continuous loading to failure in one stroke are not permitted. Motorized pumps or hand operated positive displacement pumps having sufficient volume in one continuous stroke to complete a test without requiring replenishment are permitted and shall be capable of applying loads at a uniform rate without shock or interruption.

4.2 *Loading Apparatus*—The mechanism by which forces are applied to the specimen shall employ a load-applying block and two specimen support blocks. It shall ensure that all forces are applied perpendicular to the face of the specimen without eccentricity. A diagram of an apparatus that accomplishes this purpose is shown in Fig. 1.

4.2.1 All apparatus for making center-point loading flexure tests shall be similar to Fig. 1 and maintain the span length and central position of the load-applying block with respect to the support blocks constant within ±0.05 in. (±1.3 mm).

4.2.2 Reactions shall be parallel to the direction of the applied load at all times during the test, and the ratio of the horizontal distance between the point of load application and nearest reaction to the depth of the beam shall be 1.5 ± 2 %.

4.2.3 The load-applying and support blocks shall not be more than 2½ in. (64 mm) high, measured from the center or the axis of pivot, and shall extend at least across the full width of the specimen. Each hardened bearing surface in contact with the specimen shall not depart from a plane by more than 0.002 in. (0.05 mm) and shall be a portion of a cylinder, the axis of

[1] This test method is under the jurisdiction of ASTM Committee C09 on Concrete and Concrete Aggregates and is the direct responsibility of Subcommittee C09.61 on Testing for Strength.

Current edition approved July 15, 2007. Published August 2007. Originally approved in 1952. Last previous edition approved in 2002 as C 293 – 02.

[2] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

***A Summary of Changes section appears at the end of this standard.**

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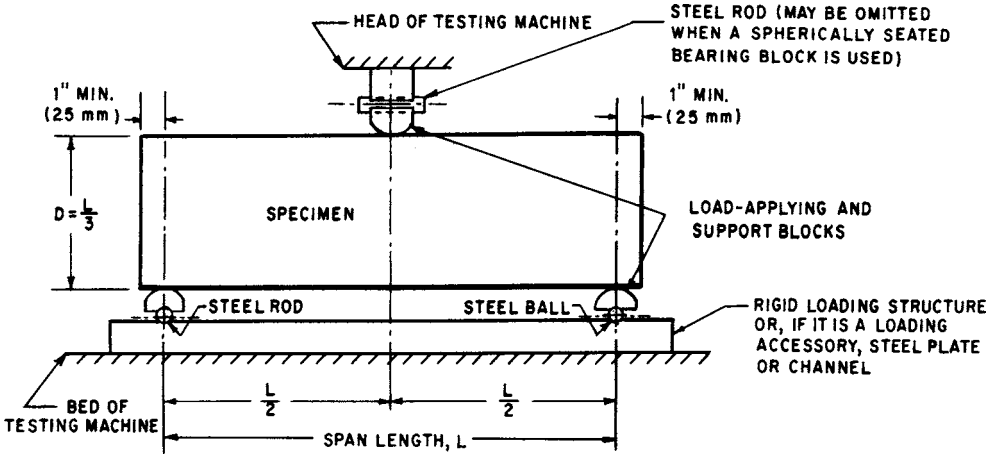

NOTE 1—Apparatus may be used inverted.

FIG. 1 Diagrammatic View of a Suitable Apparatus for Flexure Test of Concrete by Center-Point Loading Method.

which is coincidental with either the axis of the rod or center of the ball, whichever the block is pivoted upon. The angle subtended by the curved surface of each block shall be at least 45° (0.79 rad). The load-applying and support blocks shall be maintained in a vertical position and in contact with the rod or ball by means of spring-loaded screws that hold them in contact with the pivot rod or ball. The rod in the center load-applying block in Fig. 1 may be omitted when a spherically seated bearing block is used.

5. Test Specimen

5.1 The test specimen shall conform to all requirements of Practice C 31 or C 192 applicable to beam specimens and shall have a test span within 2 % of being three times its depth as tested. The sides of the specimen shall be at right angles with the top and bottom. All surfaces shall be smooth and free of scars, indentations, holes, or inscribed identification marks.

6. Procedure

6.1 Flexural tests of moist-cured specimens shall be made as soon as practical after removal from moist storage. Surface drying of the specimen results in a reduction in the measured modulus of rupture.

6.2 Turn the test specimen on its side with respect to its position as molded and center it on the support blocks. Center the loading system in relation to the applied force. Bring the load-applying block in contact with the surface of the specimen at the center and apply a load of between 3 and 6 % of the estimated ultimate load. Using 0.004 in. (0.10 mm) and 0.015 in. (0.38 mm) leaf-type feeler gages, determine whether any gap between the specimen and the load-applying or support blocks is greater or less than each of the gages over a length of 1 in. (25 mm) or more. Grind, cap, or use leather shims on the specimen contact surface to eliminate any gap in excess of 0.004 in. (0.10 mm). Leather shims shall be of uniform ¼ in. (6.4 mm) thickness, 1 to 2 in. (25 to 50 mm) in width, and shall extend across the full width of the specimen. Gaps in excess of 0.015 in. (0.38 mm) shall be eliminated only by capping or grinding. Grinding of lateral surfaces shall be minimized inasmuch as grinding may change the physical characteristics of the specimens. Capping shall be in accordance with Practice C 617.

6.3 Load the specimen continuously and without shock. The load shall be applied at a constant rate to the breaking point. Apply the load so that the maximum stress on the tension face increases at a rate between 125 and 175 psi/min (0.9 and 1.2 MPa/min). The loading rate is computed using:

$$r = 2Sbd^2/3L \quad (1)$$

where:

r = loading rate, lb/min (N/min),
S = rate of increase in the maximum stress on the tension face, psi/min (MPa/min),
b = average width of the specimen as oriented for testing, in. (mm),
d = average depth of the specimen as oriented for testing, in. (mm), and
L = span length, in. (mm).

7. Measurement of Specimens After Test

7.1 To determine the dimensions of the specimen section for use in calculating modulus of rupture, take measurements across one of the fractured faces after testing. The width and depth are measured with the specimen as oriented for testing. For each dimension, take one measurement at each edge and one at the center of the cross section. Use the three measurements for each direction to determine the average width and the average depth. Take all measurements to the nearest 0.05 in. (1 mm). If the fracture occurs at a capped section, include the cap thickness in the measurement.

8. Calculation

8.1 Calculate the modulus of rupture as follows:

$$R = 3\,PL/2bd^2 \quad (2)$$

where:

R = modulus of rupture, psi, or MPa,

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P = maximum applied load indicated by the testing machine, lbf, or N,
L = span length, in., or mm,
b = average width of specimen, at the fracture, in., or mm, and
d = average depth of specimen, at the fracture, in., or mm.

NOTE 2—The weight of the beam is not included in the above calculation.

9. Report

9.1 Report the following information:
9.1.1 Identification number,
9.1.2 Average width to the nearest 0.05 in. (1 mm), at the fracture,
9.1.3 Average depth to the nearest 0.05 in. (1 mm), at the fracture,
9.1.4 Span length in inches (or millimetres),
9.1.5 Maximum applied load in pounds-force (or newtons),
9.1.6 Modulus of rupture calculated to the nearest 5 psi (0.05 MPa),
9.1.7 Record of curing and apparent moisture condition of the specimens at the time of test,
9.1.8 If specimens were capped, ground, or if leather shims were used,
9.1.9 Defects in specimens, and
9.1.10 Age of specimens.

10. Precision and Bias

10.1 *Precision*—The coefficient of variation of test results has been observed to be dependent on the strength level of the beams.[3] The single operator coefficient of variation has been found to be 4.4 %. Therefore, results of two properly conducted tests by the same operator on beams made from the same batch sample should not differ from each other by more than 12 %. The multilaboratory coefficient of variation has been found to be 5.3 %. Therefore, results of two different laboratories on beams made from the same batch sample should not differ from each other by more than 15 %.

10.2 *Bias*—Since there is no accepted standard for determining bias in this test method, no statement on bias is made.

11. Keywords

11.1 beams; concrete; flexural strength testing; modulus of rupture

[3] See "Improved Concrete Quality Control Procedures Using Third Point Loading" by P. M. Carrasquillo and R. L. Carrasquillo, Research Report 119-1F, Project 3-9-87-1119, Center For Transportation Research, The University of Texas at Austin, November 1987, for information as to the relationship of strength and variability under center point loading.

SUMMARY OF CHANGES

Committee C09 has identified the location of selected changes to this test method since the last issue, C 293 – 02, that may impact the use of this test method.

(*1*) Revised 5.1.
(*2*) Revised 6.3.
(*3*) Revised 7.1.

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Designation: C 294 – 05

Standard Descriptive Nomenclature for Constituents of Concrete Aggregates[1]

This standard is issued under the fixed designation C 294; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

This standard has been approved for use by agencies of the Department of Defense.

1. Scope

1.1 This descriptive nomenclature provides brief descriptions of some of the more commonly occurring, or more important, natural and artificial materials of which mineral aggregates are composed. The descriptions provide a basis for understanding these terms as applied to concrete aggregates. When appropriate, brief observations regarding the potential effects of using the natural and artificial materials in concrete are discussed.

NOTE 1—These descriptions characterize minerals and rocks as they occur in nature and blast-furnace slag or lightweight aggregates that are prepared by the alteration of the structure and composition of natural material. Information about lightweight aggregates are given in Specifications C 330, C 331, and C 332.

1.2 This standard does not include descriptions of constituents of aggregates used in radiation shielding concrete. See Descriptive Nonmenclature C 638.

2. Referenced Documents

2.1 *ASTM Standards:* [2]

C 125 Terminology Relating to Concrete and Concrete Aggregates

C 227 Test Method for Potential Alkali Reactivity of Cement-Aggregate Combinations (Mortar Bar Method)

C 289 Test Method for Potential Alkali-Silica Reactivity of Aggregates (Chemical Method)

C 330 Specification for Lightweight Aggregates for Structural Concrete

C 331 Specification for Lightweight Aggregates for Concrete Masonry Units

C 332 Specification for Lightweight Aggregates for Insulating Concrete

C 638 Descriptive Nonmenclature of Constituents of Aggregates for Radiation-Shielding Concrete

3. Significance and Use

3.1 This descriptive nomenclature provides information on terms commonly applied to concrete aggregates. This standard is intended to assist in understanding the meaning and significance of the terms.

3.2 Many of the materials described frequently occur in particles that do not display all the characteristics given in the descriptions, and most of the described rocks grade from varieties meeting one description to varieties meeting another with all intermediate stages being found.

3.3 The accurate identification of rocks and minerals can, in many cases, be made only by a qualified geologist, mineralogist, or petrographer using the apparatus and procedures of these sciences. Reference to these descriptions may, however, serve to indicate or prevent gross errors in identification. Identification of the constituent materials in an aggregate may assist in characterizing its engineering properties, but identification alone cannot provide the sole basis for predicting behavior of aggregates in service. Aggregates of any type or combination of types may perform well or poorly in service depending upon the exposure to which the concrete is subjected, the physical and chemical properties of the matrix in which they are embedded, their physical condition at the time they are used, and other factors. Constituents that may occur only in minor amounts in the aggregate may or may not decisively influence its performance. Information about concrete aggregate performance in concrete has been published by ASTM.[3]

CONSTITUENTS OF NATURAL MINERAL AGGREGATES

4. Classes and Types

4.1 The materials found as constituents of natural mineral aggregates are minerals and rocks.

4.2 Minerals are naturally occurring inorganic substances of more or less definite chemical composition and usually of a specific crystalline structure. The physical nature of the rock-forming minerals and aspects of crystal chemistry determine the important physical and chemical properties of natural

[1] This descriptive nomenclature is under the jurisdiction of ASTM Committee C09 on Concrete and Concrete Aggregates and is the direct responsibility of Subcommittee C09.65 on Petrography.

Current edition approved Jan. 1, 2005. Published January 2005. Originally approved in 1952. Last previous edition approved in 2004 as C 294 – 04.

[2] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

[3] Klieger, P., and Lamond, J. F., editors, Significance of Tests and Properties of Concrete and Concrete-Making Materials, ASTM STP 169C, 1994.

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mineral aggregates. Certain assemblages of rock-forming minerals possess desirable qualities for use as aggregates in cementitious materials.

4.2.1 Minerals are characterized by their crystallographic, physical, and optical properties and their chemical composition. The crystallographic properties of minerals may be determined by x-ray diffraction and optical properties (**1-6**). The physical properties of minerals include but are not limited to crystal habit, cleavage, parting, fracture, hardness, specific gravity, luster, color, streak, magnetism, luminescence, and pyroelectricity (**7**). The optical properties of minerals include but are not limited to refractive index, birefringence, optic sign, pleochroism, and sign of elongation (**2-5**). Methods to determine the chemical composition of minerals include but are not limited to optical properties (**5**), flame photometry (**7,8**), chemical spot tests (**9,10**), various staining techniques (**11**), x-ray fluorescence, and electron microscopy (**12-14**).

4.2.2 Different minerals may have the same chemical composition but different crystallographic and physical properties. Such sets of minerals are known as polymorphs. Distinguishing between some polymorphs can be important for determining the suitability of aggregates for use in cementitious materials.

4.3 Rocks are classified according to origin into three major divisions: igneous, sedimentary, and metamorphic. These three major groups are subdivided into types according to mineral and chemical composition, texture, and internal structure. Most rocks are composed of several minerals but some are composed of only one mineral. Certain examples of the rock quartzite are composed exclusively of the mineral quartz, and certain limestones are composed exclusively of the mineral calcite. Individual sand grains frequently are composed of particles of rock, but they may be composed of a single mineral, particularly in the finer sizes.

4.3.1 Igneous rocks form from molten matter either at or below the earth's surface.

4.3.2 Sedimentary rocks form near the earth's surface by the accumulation and consolidation of the products of weathering and erosion of existing rocks, or by direct chemical precipitation. Sedimentary rocks may form from pre-existing igneous, metamorphic, or sedimentary rocks.

4.3.3 Metamorphic rocks form from pre-existing igneous, sedimentary, or metamorphic rocks by the action of heat or pressure or both.

5. Silica Minerals

5.1 *Quartz*—a very common hard mineral composed of silica (SiO_2). It will scratch glass and is not scratched by a knife. When pure it is colorless with a glassy (vitreous) luster and a shell-like (conchoidal) fracture. It lacks a visible cleavage (the ability to break in definite directions along even planes) and, when present in massive rocks such as granite, it usually has no characteristic shape. It is resistant to weathering and is therefore an important constituent of many sand and gravel deposits and many sandstones. It is also abundant in many light-colored igneous and metamorphic rocks. Some strained, or intensely fractured (granulated), and microcrystalline quartz may be potentially deleteriously reactive with the alkalies in the hydraulic cement paste.

5.2 *Opal*—a hydrous form of silica ($SiO_2 \cdot nH_2O$) which occurs without characteristic external form or internal crystalline arrangement as determined by ordinary visible light methods. When X-ray diffraction methods are used, opal may show some evidences of internal crystalline arrangement. Opal has a variable water content, generally ranging from 3 to 9 %. The specific gravity and hardness are always less than those of quartz. The color is variable and the luster is resinous to glassy. It is usually found in sedimentary rocks, especially some cherts, and is the principal constituent of diatomite. It is also found as a secondary material filling cavities and fissures in igneous rocks and may occur as a coating on gravel and sand. The recognition of opal in aggregates is important because it is potentially deleteriously reactive with the alkalies in hydraulic cement paste or with the alkalies from other sources, such as aggregates containing zeolites, and ground water.

5.3 *Chalcedony*—chalcedony has been considered both as a distinct mineral and a variety of quartz. It is frequently composed of a mixture of microscopic fibers of quartz with a large number of submicroscopic pores filled with water and air. The properties of chalcedony are intermediate between those of opal and quartz, from which it can sometimes be distinguished only by laboratory tests. It frequently occurs as a constituent of the rock chert and is potentially deleteriously reactive with the alkalies in hydraulic cement paste.

5.4 *Tridymite and cristobalite*—high temperature crystalline forms of silica (SiO_2) sometimes found in volcanic rocks. They are metastable at ordinary temperatures and pressures. They are rare minerals in aggregates except in areas where volcanic rocks are abundant. A type of cristobalite is a common constituent of opal. Tridymite and cristobalite are potentially deleteriously reactive with the alkalies in hydraulic cement paste.

6. Feldspars

6.1 The minerals of the feldspar group are the most abundant rock-forming minerals in the crust of the earth. They are important constituents of all three major rock groups, igneous, sedimentary, and metamorphic. Since all feldspars have good cleavages in two directions, particles of feldspar usually show several smooth surfaces. Frequently, the smooth cleavage surfaces show fine parallel lines. All feldspars are slightly less hard than, and can be scratched by, quartz and will, when fresh, easily scratch a penny. The various members of the group are differentiated by chemical composition and crystallographic properties. The feldspars *orthoclase, sanidine*, and *microcline* are potassium aluminum silicates, and are frequently referred to as *potassium feldspars*. The *plagioclase* feldspars include those that are sodium aluminum silicates and calcium aluminum silicates, or both sodium and calcium aluminum silicates. This group, frequently referred to as the "soda-lime" group, includes a continuous series, of varying chemical composition and optical properties, from *albite*, the sodium aluminum feldspar, to *anorthite*, the calcium aluminum feldspar, with intermediate members of the series designated *oligoclase, andesine, labradorite*, and *bytownite*. Potassium feldspars and sodium-rich plagioclase feldspars occur typically in igneous rocks such as granites and rhyolites, whereas, plagioclase

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feldspars of higher calcium content are found in igneous rocks of lower silica content such as diorite, gabbro, andesite, and basalt.

7. Ferromagnesian Minerals

7.1 Many igneous and metamorphic rocks contain dark green to black minerals that are generally silicates of iron or magnesium, or of both. They include the minerals of the amphibole, pyroxene, and olivine groups. The most common amphibole mineral is hornblende; the most common pyroxene mineral is augite; and the most common olivine mineral is forsterite. Dark mica, such as biotite and phlogopite, are also considered ferromagnesian minerals. The amphibole and pyroxene minerals are brown to green to black and generally occur as prismatic units. Olivine is usually olive green, glassy in appearance, and usually altered. Biotite has excellent cleavage and can be easily cleaved into thin flakes and plates. These minerals can be found as components of a variety of rocks, and in sands and gravels. Olivine is found only in dark igneous rocks where quartz is not present, and in sands and gravels close to the olivine source.

8. Micaceous Minerals

8.1 Micaceous minerals have perfect cleavage in one direction and can be easily split into thin flakes. The mica minerals of the muscovite group are colorless to light green; of the biotite group, dark brown to black or dark green; of the lepidolite group, white to pink and red or yellow; and of the chlorite group, shades of green. Another mica, phlogopite, is similar to biotite, commonly has a pearl-like luster and bronze color, and less commonly is brownish red, green, or yellow. The mica minerals are common and occur in igneous, sedimentary, and metamorphic rocks, and are common as minor to trace components in many sands and gravels. The muscovite, biotite, lepidolite, and phlogopite minerals cleave into flakes and plates that are elastic; the chlorite minerals, by comparison, form inelastic flakes and plates. Vermiculite (a mica-like mineral) forms by the alteration of other micas and is brown and has a bronze luster.

8.2 Because micaceous materials have a high surface area, they can influence the properties of freshly mixed and hardened concrete. Aggregates with a high mica content can reduce workability and increase the water demand of the concrete (**15**). The shape and perfect cleavage of micaceous minerals may result in a poor bond to the cementitious paste (**16**).

9. Clay Minerals

9.1 The term "clay" refers to natural material composed of particles in a specific size range less than 2 μm (0.002 mm). Mineralogically, clay refers to a group of layered silicate minerals including the clay-micas (illites), the kaolin group, very finely divided chlorites, and the swelling clays—smectite including montmorillonites. Members of several groups, particularly micas, chlorites, and vermiculites, occur both in the clay-size range and in larger sizes. Some clays are made up of alternating layers of two or more clay groups. Random, regular, or both types of interlayering are known. If smectite is a significant constituent in such mixtures, then fairly large volume changes may occur with wetting and drying.

9.2 Clay minerals are hydrous aluminum, magnesium, and iron silicates that may contain calcium, magnesium, potassium, sodium, and other exchangeable cations. They are formed by alteration and weathering of other silicates and volcanic glass. The clay minerals are major constituents of clays and shales. They are found disseminated in carbonate rocks as seams and pockets and in altered and weathered igneous and metamorphic rocks. Clays may also be found as matrix, void fillings, and cementing material in sandstones and other sedimentary rocks.

9.3 Most aggregate particles composed of, or containing, large proportions of clay minerals are soft and, because of the large internal surface area of the constituents, they are porous. Some of these aggregates will disintegrate when wetted. Rocks in which the cementing matrix is principally clay, such as clay-bonded sandstones, and rocks in which swelling clay minerals (smectite) are present as a continuous phase or matrix, such as in some altered volcanics, may slake in water or may disintegrate in the concrete mixer. Rocks of this type are unsuitable for use as aggregates. Rocks having these properties less well developed will abrade considerably during mixing, releasing clay, and raising the water requirement of the concrete containing them. When such rocks are present in hardened concrete, the concrete will manifest greater volume change on wetting and drying than similar concrete containing non-swelling aggregate.

10. Zeolites

10.1 The zeolite minerals are a large group of hydrated aluminum silicates of the alkali and alkaline earth elements which are soft and usually white or light colored. They are formed as a secondary filling in cavities or fissures in igneous rocks, or within the rock itself as a product of hydrothermal alteration of original minerals, especially feldspars. Some zeolites, particularly *heulandite, natrolite*, and *laumontite*, reportedly produce deleterious effects in concrete, the first two having been reported to raise the alkali content in concrete by releasing alkalies through cation exchange and thus increasing alkali reactivity when alkali-reactive aggregate constituents are present. Laumontite and its partially dehydrated variety *leonhardite* are notable for their substantial volume change with wetting and drying. Both are found in rocks such as quartz diorites and some sandstones.

11. Carbonate Minerals

11.1 The most common carbonate mineral is *calcite* (calcium carbonate, $CaCO_3$). The mineral *dolomite* consists of calcium carbonate and magnesium carbonate ($CaCO_3 \cdot MgCO_3$ or $CaMg(CO_3)_2$) in equivalent molecular amounts, which are 54.27 and 45.73 by mass %, respectively. Both calcite and dolomite are relatively soft, the hardness of calcite being 3 and that of dolomite 3½ to 4 on the Mohs scale, and are readily scratched by a knife blade. They have rhombohedral cleavage, which results in their breaking into fragments with smooth parallelogram shaped sides. Calcite is soluble with vigorous effervescence in cold dilute hydrochloric acid; dolomite is soluble with slow effervescence in cold dilute hydrochloric acid and with vigorous effervescence if the acid or the sample is heated or if the sample is pulverized.

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12. Sulfate Minerals

12.1 Carbonate rocks and shales may contain sulfates as impurities. The most abundant sulfate mineral is *gypsum* (hydrous calcium sulfate; $CaSO_4 \cdot 2H_2O$); *anhydrite* (anhydrous calcium sulfate, $CaSO_4$) is less common. Gypsum is usually white or colorless and characterized by a perfect cleavage along one plane and by its softness, representing hardness of 2 on the Mohs scale; it is readily scratched by the fingernail. Gypsum may form a whitish pulverulent or crystalline coating on sand and gravel. It is slightly soluble in water.

12.2 Anhydrite resembles dolomite in hand specimen but has three cleavages at right angles; it is less soluble in hydrochloric acid than dolomite, does not effervesce and is slightly soluble in water. Anhydrite is harder than gypsum. Gypsum and anhydrite occurring in aggregates can cause sulfate attack in concrete and mortar.

13. Iron Sulfide Minerals

13.1 The sulfides of iron, *pyrite, marcasite*, and *pyrrhotite* are frequently found in natural aggregates. Pyrite is found in igneous, sedimentary, and metamorphic rocks; marcasite is much less common and is found mainly in sedimentary rocks; pyrrhotite is less common but may be found in many types of igneous and metamorphic rocks. Pyrite is brass yellow, and pyrrhotite bronze brown, and both have a metallic luster. Marcasite is also metallic but lighter in color and finely divided iron sulfides are soot black. Pyrite is often found in cubic crystals. Marcasite readily oxidizes with the liberation of sulfuric acid and formation of iron oxides, hydroxides, and, to a much smaller extent, sulfates; pyrite and pyrrhotite do so less readily. Marcasite and certain forms of pyrite and pyrrhotite are reactive in mortar and concrete, producing a brown stain accompanied by a volume increase that has been reported as one source of popouts in concrete. Reactive forms of iron sulfides may be recognized by immersion in saturated lime water (calcium hydroxide solution); upon exposure to air the reactive varieties produce a brown coating within a few minutes.

14. Iron Oxide Minerals, Anhydrous and Hydrous

14.1 There are two common iron oxide minerals: (*1*) Black, magnetic: *magnetite* (Fe_3O_4), and (*2*) red or reddish when powdered: *hematite* (Fe_2O_3); and one common hydrous oxide mineral, brown or yellowish: *goethite* (FeO(OH)). Another common iron-bearing mineral is black, weakly magnetic, *ilmenite* ($FeTiO_3$). Magnetite and ilmenite are important accessory minerals in many dark igneous rocks and are common detrital minerals in sediments. Hematite is frequently found as an accessory mineral in reddish rocks. Limonite, the brown weathering product of iron-bearing minerals, is a field name for several varieties of hydrous iron oxide minerals including goethite; it frequently contains adsorbed water, and various impurities such as colloidal or crystalline silica, clay minerals, and organic matter. The presence of substantial amounts of soft iron-oxide minerals in concrete aggregate can color concrete various shades of yellow or brown. Very minor amounts of iron minerals color many rocks, such as ferruginous sandstones, shales, clay-ironstones, and granites. Magnetite, ilmenite, and hematite ores are used as heavy aggregates.

DESCRIPTIONS OF IGNEOUS ROCKS

15. General

15.1 Igneous rocks are those formed by cooling from a molten rock mass (magma). They may be divided into two classes: (*1*) plutonic, or intrusive, that have cooled slowly within the earth; and (*2*) volcanic, or extrusive, that formed from quickly cooled lavas. Plutonic rocks have grain sizes greater than approximately 1 mm, and are classified as coarse- or medium-grained. Volcanic rocks have grain sizes less than approximately 1 mm, and are classified as fine-grained. Volcanic rocks frequently contain glass. Both plutonic and volcanic rocks may consist of porphyries, that are characterized by the presence of large mineral grains in a fine-grained or glassy groundmass. This is the result of sharp changes in rate of cooling or other physico-chemical conditions during solidification of the melt.

15.2 Igneous rocks are usually classified and named on the basis of their texture, internal structure, and their mineral composition which in turn depends to a large extent on their chemical composition. Rocks in the plutonic class generally have chemical equivalents in the volcanic class.

16. Plutonic Rocks

16.1 *Granite*—granite is a medium- to coarse-grained, light-colored rock characterized by the presence of potassium feldspar with lesser amounts of plagioclase feldspars and quartz. The characteristic potassium feldspars are orthoclase or microcline, or both; the common plagioclase feldspars are albite and oligoclase. Feldspars are more abundant than quartz. Dark-colored mica (biotite) is usually present, and light-colored mica (muscovite) is frequently present. Other dark-colored ferromagnesian minerals, especially hornblende, may be present in amounts less than those of the light-colored constituents. *Quartz-monzonite* and *granodiorite* are rocks similar to granite, but they contain more plagioclase feldspar than potassium feldspar.

16.2 *Syenite*—syenite is a medium- to coarse-grained, light-colored rock composed essentially of alkali feldspars, namely microcline, orthoclase, or albite. Quartz is generally absent. Dark ferromagnesian minerals such as hornblende, biotite, or pyroxene are usually present.

16.3 *Diorite*—diorite is a medium- to coarse-grained rock composed essentially of plagioclase feldspar and one or more ferromagnesian minerals such as hornblende, biotite, or pyroxene. The plagioclase is intermediate in composition, usually of the variety andesine, and is more abundant than the ferromagnesian minerals. Diorite usually is darker in color than granite or syenite and lighter than gabbro. If quartz is present, the rock is called *quartz diorite.*

16.4 *Gabbro*—gabbro is a medium- to coarse-grained, dark-colored rock consisting essentially of ferromagnesian minerals and plagioclase feldspar. The ferromagnesian minerals may be pyroxenes, amphiboles, or both. The plagioclase is one of the calcium-rich varieties, namely labradorite, bytownite, or anorthite. Ferromagnesian minerals are usually more abundant than feldspar. *Diabase* (in European usage *dolerite*) is a rock of similar composition to gabbro and basalt but is intermediate in mode of origin, usually occurring in smaller intrusions than

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gabbro, and having a medium to fine-grained texture. The terms "trap" or "trap rock" are collective terms for dark-colored, medium- to fine-grained igneous rocks especially diabase and basalt.

16.5 *Peridotite*—peridotite is composed of olivine and pyroxene. Rocks composed almost entirely of pyroxene are known as *pyroxenites*, and those composed of olivine as *dunites.* Rocks of these types are relatively rare but their metamorphosed equivalent, serpentinite, is more common.

16.6 *Pegmatite*—extremely coarse-grained varieties of igneous rocks are known as pegmatites. These are *usually* light-colored and are most frequently equivalent to granite or syenite in mineral composition.

17. Fine-Grained and Glassy Extrusive Igneous Rocks

17.1 *Volcanic Rock*—volcanic or extrusive rocks are the fine-grained equivalents of the coarse-and-medium-grained plutonic rocks. Equivalent types have similar chemical compositions and may contain the same minerals. Volcanic rocks commonly are so fine-grained that the individual mineral grains usually are not visible to the naked eye. Porphyritic textures are common, and the rocks may be partially or wholly glassy or non-crystalline. The glassy portion of a partially glassy rock usually has a higher silica content than the crystalline portion. Some volcanic or extrusive rocks may not be distinguishable in texture and structure from plutonic or intrusive rocks that originated at shallow depth.

17.2 *Glassy Volcanic Rocks*—These rocks are of particular significance because they contain, or may contain, high silica glass that is alkali-reactive, and secondary minerals that are alkali-reactive or release alkalies into concrete. The high silica glasses, generally classed as those containing more than 55 % silica, are known to be alkali-reactive, whereas the low-silica glasses are not. Among igneous rocks that contain, or may contain, high silica glass are: obsidian, pumice, trachyte, rhyolite, scoria, dacite, basalt, andesite, and perlite. Aggregates containing these rocks include crushed parent rock where the aggregate is constituted totally of the rock, or as varying percentages in gravels and sands. Glassy rocks, particularly the more siliceous ones, are potentially deleteriously reactive with the alkalies in hydraulic cement paste.

17.3 *Volcanic Glass*—igneous rocks composed wholly of glass are named on the basis of their texture and internal structure. A dense dark natural glass of high silica content is called *obsidian*, while lighter colored finely vesicular glassy froth filled with elongated, tubular bubbles is called *pumice.* Dark-colored coarsely vesicular types containing more or less spherical bubbles are called *scoria.* Pumices are usually silica-rich (corresponding to rhyolites or dacites), whereas scorias usually are more basic (corresponding to basalts). A high-silica glassy lava with an onion-like structure and a pearly luster, containing 2 to 5 % water, is called *perlite.* When heated quickly to the softening temperature, perlite puffs to become an artificial pumice. Glass with up to 10 % water and with a dull resinous luster is called *pitchstone*.

17.4 *Felsite*—light-colored, very fine-grained igneous rocks are collectively known as felsites. The felsite group includes *rhyolite, dacite, andesite*, and *trachyte*, which are the equivalents of granite, quartz diorite, diorite, and syenite, respectively. These rocks are usually light colored but they may be gray, green, dark red, or black. When they are microcrystalline or contain natural glass, rhyolites, dacites, and andesites are potentially deleteriously reactive with the alkalies in hydraulic cement paste.

17.5 *Basalt*—fine-grained extrusive equivalent of gabbro and diabase. When basalt contains natural glass, the glass is generally lower in silica content than that of the lighter-colored extrusive rocks and hence is not deleteriously reactive with the alkalies in hydraulic cement paste; however, exceptions have been noted in the literature with respect to the alkali reactivity of basaltic glasses.

17.6 Vesicles and other voids in volcanic rocks may contain alkali-reactive forms of silica such as opal, cristobalite, tridymite, and various varieties of microcrystalline quartz. Additionally, zeolitic minerals can release alkalies and thus increase the alkalies in the paste.

DESCRIPTIONS OF SEDIMENTARY ROCKS

18. General

18.1 Sedimentary rocks are stratified rocks usually laid down under water, although they can also be formed by wind and glacial action. Sediments may be composed of particles of preexisting rocks derived by mechanical agencies or they may be of chemical or organic origin. The sediments are usually indurated by cementation or compaction during geologic time, although the degree of consolidation may vary widely.

18.2 *Gravel, sand, silt*, and *clay* form the group of unconsolidated sediments. Although the distinction between these four members is made on the basis of their particle size, a general trend in the composition occurs. Gravel and, to a lesser degree, coarse sands usually consist of rock fragments; fine sands and silt consist predominantly of mineral grains; and clay exclusively of mineral grains, largely of the group of clay minerals. All types of rocks and minerals may be represented in unconsolidated sediments.

19. Conglomerates, Sandstones, and Quartzites

19.1 These rocks consist of particles of *sand* or *gravel*, or both, with or without interstitial and cementing material. If the particles include a considerable proportion of gravel, the rock is a *conglomerate*. If the particles are in the sand sizes, that is, less than 2 mm but more than 0.06 mm in major diameter, the rock is a *sandstone* or a *quartzite*. If the rock breaks around the sand grains, it is a sandstone; if the grains are largely quartz and the rock breaks through the grains, it is quartzite. Conglomerates, and sandstones are sedimentary rocks but quartzites may be sedimentary (*orthoquartzites*) or metamorphic (*metaquartzites*). The cementing or interstitial materials of sandstones may be quartz, opal, calcite, dolomite, clay, iron oxides, or other materials. These may influence the quality of a sandstone as concrete aggregate. If the nature of the cementing material is known, the rock name may include a reference to it, such as *opal-bonded sandstone* or *ferruginous conglomerate.* Opal-containing rocks may be potentially deleteriously reactive with alkalies in the hydraulic cement paste.

19.2 *Graywackes and subgraywackes*—gray to greenish gray sandstones containing angular quartz and feldspar grains,

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and sand-sized rock fragments in an abundant matrix resembling claystone, shale, argillite, or slate. Graywackes grade into subgraywackes, the most common sandstones of the geologic column.

19.3 *Arkose*—coarse-grained sandstone derived from granite, containing conspicuous amounts of feldspar.

20. Claystones, Shales, Argillites, and Siltstones

20.1 These very fine-grained rocks are composed of, or derived by erosion of sedimentary *silts* and *clays*, or of any type of rock that contained clay. When relatively soft and massive, they are known as *claystones*, or *siltstones*, depending on the size of the majority of the particles of which they are composed. Siltstones consist predominantly of silt-sized particles (0.0625 to 0.002 mm in diameter) and are intermediate rocks between claystones and sandstones. When the claystones are harder and platy or fissile, they are known as *shales*. Claystones and shales may be gray, black, reddish, or green and may contain some carbonate minerals (calcareous shales). A massive, firmly indurated fine-grained argillaceous rock consisting of quartz, feldspar, and micaceous minerals is known as *argillite.* Argillites do not slake in water as some shales do. As an aid in distinguishing these fine-grained sediments from fine-grained, foliated metamorphic rocks such as slates and phyllites, it may be noted that the cleavage surfaces of shales are generally dull and earthy while those of slates are more lustrous. Phyllite has a glossier luster resembling a silky sheen. Clay ironstone concretions are generally nodular particles consisting of mixtures of clay minerals and iron oxides. They are commonly hard and range in color from red-brown to purplish brown to orange-brown to orange to yellow. They are commonly concentric and may contain soft cores of clay minerals.

20.2 Clay ironstones may cause popouts in concrete subject to freezing and thawing while saturated with water. Aggregates containing abundant shale may be detrimental to concrete because they can produce high shrinkage, but not all shales are harmful. Some shales and siltstones may cause popouts and scaling in concrete subject to freezing and thawing while saturated with water (**15**,**17**). Some argillites, siltstones, and shales are alkali-silica reactive and may cause popouts (**18**,**19**).

20.3 Although aggregates which are volumetrically unstable in wetting and drying are not confined to any class of rock, they do share some common characteristics. If there is a matrix or continuous phase, it is usually physically weak and consists of material of high specific surface, frequently including clay. However, no general relation has been demonstrated between clay content or type of clay and large volume change upon wetting and drying. Volumetrically unstable aggregates do not have mineral grains of high modulus interlocked in a continuous rigid structure capable of resisting volume change.

20.4 Aggregates having high elastic modulus and low volume change from the wet to the dry condition contribute to the volume stability of concrete by restraining the volume change of the cement paste. In a relatively few cases, aggregates have been demonstrated to contribute to unsatisfactory performance of concrete because they have relatively large volume change from the wet to the dry condition combined with relatively low modulus of elasticity. On drying, such aggregates shrink away from the surrounding cement paste and consequently fail to restrain its volume change with change in moisture content.

21. Carbonate Rocks

21.1 *Limestones*, the most widespread of carbonate rocks. They range from pure limestones consisting of the mineral calcite to pure *dolomites* (dolostones) consisting of the mineral dolomite. Usually they contain both minerals in various proportions. If 50 to 90 % is the mineral dolomite, the rock is called *calcitic dolomite*. The term "magnesium limestone" is sometimes applied to dolomitic limestones and calcitic dolomites but it is ambiguous and its use should be avoided. Most carbonate rocks contain some noncarbonate impurities such as quartz, chert, clay minerals, organic matter, gypsum, and sulfides. Carbonate rocks containing 10 to 50 % sand are *arenaceous* (or *sandy*) *limestones* (or *dolomites*); those containing 10 to 50 % clay are *argillaceous* (or *clayey* or *shaly*) *limestones* (or *dolomites*). *Marl* is a clayey limestone which is fine-grained and commonly soft. Chalk is fine-textured, very soft, porous, and somewhat friable limestone, composed chiefly of particles of microorganisms. Micrite is very fine-textured chemically precipitated carbonate or a mechanical ooze of carbonate particles, usually 0.001 to 0.003 mm in size. The term "limerock" is not recommended.

21.2 The reaction of the dolomite in certain carbonate rocks with alkalies in portland cement paste has been found to be associated with deleterious expansion of concrete containing such rocks as coarse aggregate. Carbonate rocks capable of such reaction possess a characteristic texture and composition. The characteristic microscopic texture is that in which relatively large crystals of dolomite (rhombs) are scattered in a finer-grained matrix of micritic calcite and clay. The characteristic composition is that in which the carbonate portion consists of substantial amounts of both dolomite and calcite, and the acid-insoluble residue contains a significant amount of clay. Except in certain areas, such rocks are of relatively infrequent occurrence and seldom make up a significant proportion of the material present in a deposit of rock being considered for use in making aggregate for concrete.

22. Chert

22.1 *Chert*—the general term for a group of variously colored, very fine-grained (aphanitic), siliceous rocks composed of microcrystalline or cryptocrystalline quartz, chalcedony, or opal, either singly or in combinations of varying proportions. Identification of the form or forms of silica requires careful determination of optical properties, absolute specific gravity, loss on ignition, or a combination of these characteristics. Dense cherts are very tough, with a waxy to greasy luster, and are usually gray, brown, white, or red, and less frequently, green, black or blue. Porous varieties are usually lighter in color, frequently off-white, or stained yellowish, brownish, or reddish, firm to very weak, and grade to tripoli. Ferruginous, dense, red, and in some cases, dense, yellow, brown, or green chert is sometimes called *jasper.* Dense black or gray chert is sometimes called *flint.* A very dense, even textured, light gray to white chert, composed mostly of microcrystalline to cryptocrystalline quartz, is called *novaculite.* Chert is hard (scratches glass, but is not scratched

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by a knife blade) and has a conchoidal (shell-like) fracture in the dense varieties, and a more splintery fracture in the porous varieties. Chert occurs most frequently as nodules, lenses, or interstitial material, in limestone and dolomite formations, as extensively bedded deposits, and as components of sand and gravel. Most cherts have been found to be alkali-silica reactive to some degree when tested with high-alkali cement, or in the quick chemical test (Test Method C 289). In the absence of information to the contrary, all chert should be regarded as potentially deleteriously reactive with the alkalies in hydraulic cement paste. The degree of alkali-silica reactivity, and whether a given chert will produce a deleterious degree of expansion in concrete, are complex functions of several factors. The degree of the alkali-silica reactivity and whether a given chert will produce a deleterious degree of expansion in concrete are complex functions of several factors. Among them are: the mineralogic composition and internal structure of the chert; the amount of the chert as a proportion of the aggregates; the particle-size distribution; the alkali content of the cement; and the cement content of the concrete. However, opaline cherts may produce deleterious expansion of mortar or concrete when present in very small proportions (less than 5 % by mass of the aggregate). Cherts that are porous may be susceptible to freezing and thawing deterioration in concrete and may cause popouts or cracking of the concrete surface above the chert particle.

DESCRIPTIONS OF METAMORPHIC ROCKS

23. General

23.1 Metamorphic rocks form from igneous, sedimentary, or pre-existing metamorphic rocks in response to changes in chemical and physical conditions occurring within the earth's crust after formation of the original rock. The changes may be textural, structural, or mineralogic and may be accompanied by changes in chemical composition. The rocks are dense and may be massive but are more frequently foliated (laminated or layered) and tend to break into platy particles. Rocks formed from argillaceous rocks by dynamic metamorphism usually split easily along one plane independent of original bedding; this feature is designated "platy cleavage." The mineral composition is very variable depending in part on the degree of metamorphism and in part on the composition of the original rock.

23.2 Most of the metamorphic rocks may derive either from igneous or sedimentary rocks but a few, such as marbles and slates, originate only from sediments.

23.3 Phyllites, slates, metaquartzites, gneisses, schists, mylonite, and other rocks containing low temperature silica and silicate minerals and highly strained or microcrystalline quartz are potentially deleteriously reactive with alkalies in the hydraulic cement paste.

24. Metamorphic Rocks

24.1 *Marble*—a recrystallized medium- to coarse-grained carbonate rock composed of calcite or dolomite, or calcite and dolomite. The original impurities are present in the form of new minerals, such as micas, amphiboles, pyroxenes, and graphite.

24.2 *Metaquartzite*—a granular rock consisting essentially of recrystallized quartz. Its strength and resistance to weathering derive from the interlocking of the quartz grains.

24.3 *Slate*—a fine-grained metamorphic rock that is distinctly laminated and tends to split into thin parallel layers. The mineral composition usually cannot be determined with the unaided eye.

24.4 *Phyllite*—a fine-grained thinly layered rock. Minerals, such as micas and chlorite, are noticeable and impart a silky sheen to the surface of schistosity. Phyllites are intermediate between slates and schists in grain size and mineral composition. They derive from argillaceous sedimentary rocks or fine-grained extrusive igneous rocks, such as felsites.

24.5 *Schist*—a highly layered rock tending to split into nearly parallel planes (schistose) in which the grain is coarse enough to permit identification of the principal minerals. Schists are subdivided into varieties on the basis of the most prominent mineral present in addition to quartz or to quartz and feldspars; for instance, *mica schist. Greenschist* is a green schistose rock whose color is due to abundance of one or more of the green minerals, chlorite or amphibole, and is commonly derived from altered volcanic rock.

24.6 *Amphibolite*—a medium- to coarse-grained dark-colored rock composed mainly of hornblende and plagioclase feldspar. Its schistosity, which is due to parallel alignment of hornblende grains, is commonly less obvious than in typical schists.

24.7 *Hornfels*—equigranular, massive, and usually tough rock produced by complete recrystallization of sedimentary, igneous, or metamorphic rocks through thermal metamorphism sometimes with the addition of components of molten rock. Their mineral compositions vary widely.

24.8 *Gneiss*—one of the most common metamorphic rocks, usually formed from igneous or sedimentary rocks by a higher degree of metamorphism than the schists. It is characterized by a layered or foliated structure resulting from approximately parallel lenses and bands of platy minerals, usually micas, or prisms, usually amphiboles, and of granular minerals, usually quartz and feldspars. All intermediate varieties between gneiss and schist, and between gneiss and granite are often found in the same areas in which well-defined gneisses occur.

24.9 *Serpentinite*—a relatively soft, light to dark green to almost black rock formed usually from silica-poor igneous rocks, such as pyroxenites, peridotites, and dunites. It may contain some of the original pyroxene or olivine but is largely composed of softer hydrous ferromagnesian minerals of the serpentine group. Very soft talc-like material is often present in serpentinite.

CONSTITUENTS OF ARTIFICIAL AGGREGATES

25. General

25.1 Artificial aggregates are aggregates resulting from reconstitution of natural materials, other than by physical processes, such as crushing and screening, or from physical or mechanical processing of pre-existing artificial materials to produce aggregates for new work. Examples of reconstitution processes are: (1) heat treatment, such as heating, sintering, calcination, or partial or complete fusion of volcanic rocks,

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clay, shale, or slate, with resulting mechanical disruption, vitrification, recrystallization, bloating, or combinations of these phenomena in production of lightweight aggregates, and (2) formation of new materials as a consequence of industrial processes, such as slag produced simultaneously with iron in a blast furnace. An example of mechanical processing of pre-existing artificial material is the recovery of hardened concrete from constructions to produce aggregate.

26. Artificial Aggregate

26.1 *Cinders (industrial)*—the agglomerated residue from combustion of coal or coke in an industrial furnace. Specifications may place limitations on content of combustible residues, sulfides, and sulfate. Undesirable sulfur compounds can be reduced by leaching during storage in stockpiles.

26.1.1 Industrial cinders are highly porous and variable in firmness, friability, particle shape, and surface texture. The matrix is a mixture of siliceous glass and finely divided residues of original silt, fine sand, and calcined clay minerals. Particles of unburned coal and coke may be present. Original laminations of sandstone or siltstone occurring in the coal will be represented by compact particles within the product. Such particles and unburned coal and coke may produce unsoundness in concrete.

26.2 *Blast-furnace slag*—the nonmetallic product, consisting essentially of silicates and aluminosilicates of calcium and other bases, that is developed in a molten condition simultaneously with iron in a blast furnace (as described in Terminology C 125). The glass phase of normal blast-furnace slag is not deleteriously reactive with alkalies in concrete.

NOTE 2—Steel furnace slag, unlike blast furnace slag, should not be used as aggregate for hydraulic cement concrete.

26.2.1 *Air-Cooled Blast-Furnace Slag*—the material resulting from solidification of molten blast-furnace slag under atmospheric conditions. Subsequent cooling may be accelerated by application of water to the solidified surface. Such slags are more or less crystallized, the crystals ranging from submicroscopic to several millimetres in size. More than 20 compounds have been identified in air-cooled slag but even well crystallized slag rarely contains more than five compounds. The most typical crystalline constituent is melilite, a compound of variable composition between akermanite ($2CaO \cdot MgO \cdot 2SiO_2$) and gehlenite ($2CaO \cdot Al_2O_3 \cdot SiO_2$). Calcium sulfide (CaS) is almost always present in small proportion.

26.2.1.1 Potentially deleterious constituents include iron sulfides that may produce unsightly staining of concrete or may result in formation of gypsum (calcium sulfate dihydrate, $CaSO_4 \cdot 2H_2O$) by weathering. Use of very old slag with high alumina cement may cause ettringite formation and concrete expansion. Rare chemical anomalies may cause inversion of β-dicalcium silicate to γ-dicalcium silicate with accompanying 10 % increase in volume, resulting in "dusting" or "blowing" of slag. Such inversion while cooling the slag allows removal of the disintegrated material by screening during the production of aggregate. Slower inversion may produce weak and friable particles that are unsuitable as constituents of concrete aggregate; this is determinable by appropriate tests.

26.2.2 *Granulated Blast-Furnace Slag*—the glassy, granular material formed when molten blast-furnace slag is rapidly chilled as by immersion in water. In the jet process, the steam of molten slag is disrupted by a high-pressure water jet and the water/slag mixture is separated by screening. Dry-granulated slag is produced by a mechanical device that breaks the stream of molten slag by impact into small particles which then are quenched by water and air.

26.2.3 *Lightweight Blast-Furnace Slag*—the foamed product formed when molten slag is expanded by applying a limited amount of water, typically less than that required for granulation, so that a relatively dry, cellular, lumpy product results. Aggregate is produced by crushing and screening the clinker. (see 26.2.2).

26.3 *Expanded Shale, Clay, and Slate*—aggregates produced by heating prepared materials of these types to a range of temperature between incipient and complete fusion with accompanying expansion (bloating) that occurs with formation and expansion of entrapped gases. The aggregate may be prepared by prior crushing and screening of the raw materials and fired with or without admixtures, with iron oxides, or carbonaceous materials, crushing and screening of the fired product, or by processing of pellets produced by any of several methods. Other processes involve production of light-weight aggregate by burning of mixtures of coal and shale, clays, or other materials in moving grates exposed to heated gas flow.

26.3.1 Expansion and vesiculation of clays, shales, and slates occurs during firing in the range from about 1650°C (3000°F) to 1700°C (3100°F), but the results obtained for a particular material depend upon the rate of heating, the temperature attained in the feed, the composition of the kiln atmosphere, residency in the kiln, and other factors. Expansion and vesiculation requires *(1)* presence of one or more substances that release gas after fusion has developed sufficient molten material to prevent its escape, and *(2)* the molten material be of sufficient viscosity to retain the expanding gas. The viscosity of the melt is determined to a large extent by the bulk chemical composition of the raw material as defined by proportions of SiO_2 and Al_2O_3 and the total of calcium, magnesium, ferrous iron, ferric iron, and alkalies. Increasing alumina content tends to increase refractory quality of the feed and decreases vesiculation.

26.3.2 Gas is released by several processes. The most significant reaction apparently is partial reduction of ferric oxide with release of oxygen. The ferric oxide is furnished by limonite or hematite in the raw feed or by decomposition of original iron-bearing minerals, most notably clays, micas, and clay-like minerals.

26.3.3 The internal structure or fabric of the clay, shale, or slate is significant in the expansion process. Most beneficial is a dense, relatively impervious fabric that resists shrinkage during heating and retards release of vapors and gases before fusion effects a seal in the particles. The fabric is especially important in firing of carbonaceous clays and shales inasmuch as a porous, open fabric permits ready burning out of the carbon, whereas a dense fabric retards oxidation by the kiln atmosphere and retains CO and CO_2 produced by reaction with

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interstitial water or with water or oxygen released by hydrated compounds or hydroxylated silicates.

26.3.4 The most promising sources of lightweight aggregate are shales and clays containing illite, beidellite, members of the montmorillonite (smectite) clays, and vermiculitechlorite. These minerals approximate the composition that has been found to yield a melt of optimum viscosity. Compared to members of the kaolin group, they contain lesser proportions of alumina and moderate proportions of alkalies and alkaline earths, which serve as fluxes in the firing process.

26.3.5 The matrix of expanded clays, shales, and slates is composed of an intimate intermingling of siliceous glass and residues of granular minerals. Decomposition of calcium and magnesium carbonates produces free lime, free magnesia, or both compounds, which may cause expansion or popouts in concrete constructions or products unless the aggregate is water- or steam-cured prior to use. Laminations or seams of sandstone or siltstone that were constituents of the geologic formation at the source will occur as individual particles or as portions of vesiculated particles in the aggregate. They may display efflorescence and may include free lime or magnesia when originally carbonaceous. The glass phase of expanded clays, shales, and slates may be alkali reactive but expansion of concrete from this cause has not been observed because any siliceous gels that are generated are accommodated within the abundant air-filled cavities that characterize the expanded particles.

26.4 *Diatomite (sintered)*—lightweight aggregate produced by crushing and screening of diatomaceous earth or shales, spraying with oil, and firing in a rotary kiln. The main constituents are opaline skeletons of diatoms together with variable proportions of siliceous glass produced by the firing process. Other constituents are fine sand, silt, clay, and finely divided volcanic glass.

26.4.1 Some sintered diatomites used as aggregate for concrete produce significant expansion with both low- and high-alkali cements.

26.5 *Vermiculite (exfoliated)*—a micaceous mineral caused to expand and exfoliate by rapid heating as a result of release of combined water. The final volume of the particles can be as much as 30 times the original size. However, the degree of expansion, elasticity, brittleness, and fragility of the particles varies widely, depending upon mineralogic composition of the vermiculite, crystal size, purity, and conditions of firing.

26.5.1 Bodies of vermiculite ore may grade at the margins to hydrobiotite and biotite mica and become intermingled with varying proportions of granular or other non-micaceous minerals.

26.6 *Perlite (expanded)*—rhyolitic volcanic glass having a relatively high water content and a perlitic structure that has been heated sufficiently to cause it to break into small, expanded particles. The product usually is produced only in fine aggregate sizes and used in products for insulating purposes.

26.6.1 Expanded perlite varies in particle shape, surface texture, friability, and content of dense volcanic rock particles and individual crystals. Typical expanded perlite is potentially alkali reactive although significant expansion may not occur because of porosity of the particles. Laboratory tests show that certain perlites produce significant expansion of mortar stored and tested in accordance with Test Method C 227 with either low- or high-alkali cements. Such volume change will not necessarily cause structural distress if appropriately accommodated in the design of structures or products.

26.7 Recycled concrete-hardened hydraulic-cement concrete that has been processed for use as concrete aggregate. Extensive evaluations in several countries have shown that use of recycled concrete as aggregate in new concrete is feasible and may become routine. Approval of an available source of concrete for recycling as aggregate should include two stages, namely, *(1)* planning the examination of the constructions to be demolished and *(2)* selection of procedures that should be included in evaluation of the aggregate that can be obtained economically for the intended new work. The following relationships are of especial significance:

26.7.1 The potential compressive strength of concrete containing recycled concrete as aggregate is controlled largely by the compressive strength of the concrete to be recycled, provided the fine aggregate is crushed rock or natural sand of suitable quality.

26.7.2 A substantial reduction in potential compressive strength may result when the conventional fine aggregate is replaced in whole or in part by fine aggregate derived from the recycled concrete. Hansen[4] concludes that all material smaller than 2 mm in recycled concrete should be screened and wasted.

26.7.3 Use of recycled concrete decreases workability of fresh concrete at given water content, increases water requirements for given consistency, increases drying shrinkage at given water content, and reduces modulus of elasticity at given water-cement ratio. The effects are greatest when the recycled concrete is used as both coarse and fine aggregate.

26.7.4 Freezing and thawing resistance of the new concrete relates to many factors, including the properties of the recycled concrete in terms of compressive strength, parameters of the air-void system, and frost resistance of the aggregate included in the recycled concrete as well as the parameters of the air-void system and other qualities of the cementitious matrix of the new concrete.

26.7.5 Chemical admixtures, air-entraining admixtures, and mineral admixtures included in the recycled concrete will not modify significantly the properties of the fresh or hardened, new concrete, except insofar as they modify the conditions enumerated in 26.7.1-26.7.4. High concentrations of water-soluble chloride ion in the recycled concrete may contribute to accelerated corrosion of steel embedments in the new concrete.

26.7.6 Prospective sources of recycled concrete may be unsound or have been rendered unsound in service, such as presence of physically unsound or chemically reactive aggregate, deterioration by aggressive chemical attack or leaching, damage by fire or service at high temperature, and so on.

26.7.7 Significance of contaminants in the recycled concrete should be analyzed in relation to the anticipated service, such

[4] Hansen, T. C., "Recycled Concrete and Recycled Aggregate," Materials and Structures, International Union of Testing and Research Laboratories for Materials and Structures (RILEM), vol. 19, 1986, pp. 201–246.

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as presence of noxious, toxic, or radioactive substances; presence of bituminous materials that may impair air entrainment; appreciable concentrations of organic materials that my produce excessive air entrainment; inclusion of metallic embedments that may cause rust staining or blistering of surfaces; and excessive fragments of glass, including bottle glass, that are expected to produce harmful effects of alkali-silica reaction.

27. Keywords

27.1 aggregates; artificial aggregates; carbonates; clays; concrete; feldspars; ferromagnesian minerals; igneous rocks; iron oxides; iron sulfides; metamorphic rocks; micas; minerals; nomenclature; recycled concrete; rocks; sedimentary rocks; silica; sulfates; zeolites

REFERENCES

(1) Cullity, Bernard D., and Stock, S.R. and Stock, Stuart, 2001, Elements of X-Ray Diffraction: Pearson Education, 3rd Edition, 664 p.

(2) Warren, B. E., 1990, X-Ray Diffraction, Dover, 381 p.

(3) Winchell, A. N., 1937, Elements of Optical Mineralogy Part I. Principles and Methods: New York, John Wiley and Sons, Fourth Edition, 203 p.

(4) Winchell, A. N., 1933, Elements of Optical Mineralogy Part II. Descriptions of Minerals: New York, John Wiley and Sons, Third Edition, 459 p.

(5) Deer, W. A., Howie, R. A., and Zussman, J., 1992, An Introduction to the Rock Forming Minerals: London, Longman, 2nd Edition, 696 p.

(6) Gaines, R. V., Skinner, H. C., Foord, E. E., Mason, B., and Rosenzweig, A., 1997, Dana's New Mineralogy: The System of Mineralogy of James Dwight Dana and Edward Salisbury Dana: New York, John Wiley & Sons, 1819 p.

(7) Klein, C., (revised by Hurlbut, Jr., C.S.), 1993, Manual of Mineralogy (after James D. Dana): New York, John Wiley & Sons, 704 p.

(8) Smith, O., 1953, Identification and Qualitative Chemical Analysis of Minerals: Princeton, D. Van Nostrand Company, 385 p.

(9) Feigl, F., and Anger, V., 1972, Spot Tests in Inorganic Analysis: Amsterdam, Elsevier, 669 p.

(10) Chamot, E. M., and Mason, C. W., 1989 (republication of 1940 2nd edition), Handbook of Chemical Microscopy, v. II: Chicago, McCrone Research Institute, 438 p.

(11) Hutchison, C. S., 1974, Laboratory Handbook of Petrographic Techniques: New York, John Wiley & Sons, 527 p.

(12) Goldstein, J. I., Newbury, D. E., Echlin, P., Joy, D. C., Romig, A. D., Jr., Lyman, C. E., Fiori, C., and Lifshin, E., 1992, Scanning Electron Microscopy and Microanalysis: A Text for Biologists, Materials Scientists, and Geologists: New York, Plenum Press, 820 p.

(13) Potts, P. J., Bowles, J. F. W., Reed, S. J. B., and Cave, M. R., 1995, Microprobe Techniques in the Earth Sciences, v. 6: London, Chapman & Hall, 419 p.

(14) Reed, S. J. B., 1996, Electron Microprobe Analysis and Scanning Electron Microscopy in Geology: Cambridge, Cambridge University Press, 201 p.

(15) Guide for Use of Normal and Heavyweight Aggregates in Concrete, American Concrete Institute, ACI 221 R-96.

(16) Dolar-Mantuani, L., 1983, Handbook of Concrete Aggregates, Park Ridge, NJ, Noyes Publications.

(17) Walker, S., 1943, Soundness of Aggregates, Report on Significance of Tests of Concrete and Concrete Aggregates: Philadelphia, American Society of Testing and Materials, p. 112-122.

(18) Landgren, Robert and Hadley, David W., Surface Popouts Caused by Alkali-Aggregate Reaction, RD 121, Portland Cement Association, Skokie, Illinois, USA 2002, 20 pages.

(19) Whiting, N. M., 1999, Comparison of Field Observations with Laboratory Test Results on Concretes Undergoing Alkali-Silica-Reaction: Cement, Concrete and Aggregates, v. 21, no. 2, p. 142-148.

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Designation: C 295 – 08

Standard Guide for Petrographic Examination of Aggregates for Concrete[1]

This standard is issued under the fixed designation C 295; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

This standard has been approved for use by agencies of the Department of Defense.

1. Scope*

1.1 This guide outlines procedures for the petrographic examination of samples representative of materials proposed for use as aggregates in cementitious mixtures or as raw materials for use in production of such aggregates. This guide is based on Ref (**1**).[2]

1.2 This guide outlines the extent to which petrographic techniques should be used, the selection of properties that should be looked for, and the manner in which such techniques may be employed in the examination of samples of aggregates for concrete.

1.3 The rock and mineral names given in Descriptive Nomenclature C 294 should be used, insofar as they are appropriate, in reports prepared in accordance with this guide.

1.4 The values stated in SI units are to be regarded as the standard. The values given in parentheses are mathematical conversions to inch-pound units that are provided for information purposes only and are not considered standard.

1.5 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

2. Referenced Documents

2.1 *ASTM Standards:*[3]

C 33 Specification for Concrete Aggregates

C 117 Test Method for Materials Finer than 75-μm (No. 200) Sieve in Mineral Aggregates by Washing

C 136 Test Method for Sieve Analysis of Fine and Coarse Aggregates

C 294 Descriptive Nomenclature for Constituents of Concrete Aggregates

C 702 Practice for Reducing Samples of Aggregate to Testing Size

D 75 Practice for Sampling Aggregates

E 11 Specification for Wire Cloth and Sieves for Testing Purposes

E 883 Guide for Reflected–Light Photomicrography

3. Qualifications of Petrographers

3.1 All petrographic examinations of aggregate for use in concrete as described in this guide should be performed by a petrographer with at least 5 years experience in petrographic examination of concrete or concrete-making materials. The petrographer should have completed college-level course work pertaining to basic geology, mineralogy, petrography, and optical mineralogy or have obtained equivalent knowledge through experience and on-the-job training. Completion of course work in concrete materials is also advantageous. The petrographer should have experience evaluating the effects of aggregates on the physical and chemical properties of hardened concrete. Identification of individual minerals in aggregate particles, classification of rock types, and categorizing the physical and chemical properties of rocks and minerals should also be included in the petrographer's experience. The petrographer should have expertise to properly use the equipment and apparatus described in Section 6 and provide detailed interpretations of the petrographic examination. If the petrographer does not meet these qualifications, the individual may perform such examinations under the technical direction of a full-time supervising petrographer who meets these qualifications. A resume of the professional experience and education of the petrographer shall be available.

3.1.1 Licensing, certification, or other accreditation by a governmental agency or other organization stating the individual is a professional geologist should not, by itself, constitute sufficient qualification for examination of aggregates for concrete.

[1] This guide is under the jurisdiction of ASTM Committee C09 on Concrete and Concrete Aggregates and is the direct responsibility of Subcommittee C09.65 on Petrography.

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[2] The boldface numbers in parentheses refer to the list of references at the end of this standard.

[3] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

***A Summary of Changes section appears at the end of this standard.**

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4. Summary of Method

4.1 The specific procedures employed in the petrographic examination of any sample will depend to a large extent on the purpose of the examination and the nature of the sample. In most cases the examination will require the use of optical microscopy. Complete petrographic examinations for particular purposes and to investigate particular problems may require examination of aggregates or of selected constituents by means of additional procedures, such as X-ray diffraction (XRD) analysis, differential thermal analysis (DTA), infrared spectroscopy, or other scanning electron microscopy (SEM) energy-dispersive x-ray analysis (EDX). In some instances, such procedures are more rapid and more definitive than are microscopical methods.

4.2 Identification of the constituents of a sample is usually a necessary step towards recognition of the properties that may be expected to influence the behavior of the material in its intended use, but identification is not an end in itself. The value of any petrographic examination will depend to a large extent on the representativeness of the samples examined, the completeness and accuracy of the information provided to the petrographer concerning the source and proposed use of the material, and the petrographer's ability to correlate these data with the findings of the examination.

4.3 This guide does not attempt to describe the techniques of petrographic work since it is assumed that the guide will be used by persons who are qualified by education and experience to employ such techniques for the recognition of the characteristic properties of rocks and minerals and to describe and classify the constituents of an aggregate sample. In some cases, the petrographer will have had experience adequate to provide detailed interpretation of the results. In others, the interpretation will be made in part by engineers or others qualified to relate the observations to the questions to be answered.

5. Significance and Use

5.1 Petrographic examinations are made for the following purposes:

5.1.1 To determine the physical and chemical characteristics of the material that may be observed by petrographic methods and that have a bearing on the performance of the material in its intended use.

5.1.2 To describe and classify the constituents of the sample,

5.1.3 To determine the relative amounts of the constituents of the sample that are essential for proper evaluation of the sample when the constituents differ significantly in properties that have a bearing on the performance of the material in its intended use, and

5.1.4 To compare samples of aggregate from new sources with samples of aggregate from one or more sources, for which test data or performance records are available.

5.2 This guide may be used by a petrographer employed directly by those for whom the examination is made. The employer should tell the petrographer, in as much detail as necessary, the purposes and objectives of the examination, the kind of information needed, and the extent of examination desired. Pertinent background information, including results of prior testing, should be made available. The petrographer's advice and judgment should be sought regarding the extent of the examination.

5.3 This guide may form the basis for establishing arrangements between a purchaser of consulting petrographic service and the petrographer. In such a case, the purchaser and the consultant should together determine the kind, extent, and objectives of the examination and analyses to be made, and should record their agreement in writing. The agreement may stipulate specific determinations to be made, observations to be reported, funds to be obligated, or a combination of these or other conditions.

5.4 Petrographic examination of aggregate considered for use in hydraulic-cement concrete is one aspect of the evaluation of aggregate, but petrographic examination is also used for many other purposes. Petrographic examinations provide identification of types and varieties of rocks present in potential aggregates. However, as noted above, identification of every rock and mineral present in an aggregate source is not required.

5.5 The petrographic examination should establish whether the aggregate contains chemically unstable minerals such as soluble sulfates, unstable sulfides that may form sulfuric acid or create distress in concrete exposed to high temperatures during service, or volumetrically unstable materials such as smectites (formerly known as the montmorillonite-saponite group of minerals or swelling clays). Specifications may limit the quartz content of aggregates for use in concrete that may be subject to high temperature (purposefully or accidentally) because of the conversion to beta-quartz at 573 °C (1063 °F), with accompanying volume increase.

5.6 Petrographic examination should identify the portion of each coarse aggregate that is composed of weathered or otherwise altered particles and the extent of that weathering or alteration, whether it is severe, moderate, or slight, and should determine the proportion of each rock type in each condition. If the concrete in which the aggregate may be used will be exposed to freezing and thawing in a critically saturated condition, finely porous and highly weathered or otherwise altered rocks should be identified because they will be especially susceptible to damage by freezing and thawing and will cause the aggregate portion of the concrete to fail in freezing and thawing. This will ultimately destroy the concrete because such aggregates cannot be protected by adequately air-entrained mortar. Finely porous aggregates near the concrete surface are also likely to form popouts, which are blemishes on pavements and walls.

5.7 Petrographic examinations may also be used to determine the proportions of cubic, spherical, ellipsoidal, pyramidal, tabular, flat, and elongated particles in an aggregate sample or samples. Flat, elongated, and thin chip-like particles in aggregate increase the mixing water requirement and hence decrease concrete strength.

5.8 Petrographic examination should identify and call attention to potentially alkali-silica reactive and alkali-carbonate reactive constituents, determine such constituents quantitatively, and recommend additional tests to confirm or refute the presence in significant amounts of aggregate constituents capable of alkali reaction in concrete. See Specification C 33.

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Alkali-silica reactive constituents found in aggregates include: opal, chalcedony, cristobalite, tridymite, highly strained quartz, microcrystalline quartz, volcanic glass, and synthetic siliceous glass. Aggregate materials containing these constituents include: glassy to cryptocrystalline intermediate to acidic volcanic rocks, some argillites, phyllites, graywacke, gneiss, schist, gneissic granite, vein quartz, quartzite, sandstone, and chert. Criteria are available for identifying the minerals in the list above by their optical properties or by XRD (**2**),(**3**). Criteria are available for identifying rocks by their mineral composition and texture (**4**). Examination in both reflected and transmitted light may be necessary to provide data for these identifications. X-ray microanalysis using energy-dispersive x-ray spectrometers with scanning electron microscopy (SEM/EDX) or wavelength-dispersive x-ray spectrometers in electron microprobes (EMPA/WDX) may provide useful information on the chemical composition of minerals and rocks. Potentially deleterious alkali-carbonate reactive rocks are usually calcareous dolomites or dolomitic limestones with clayey insoluble residues. Some dolomites essentially free of clay and some very fine-grained limestones free of clay and with minor insoluble residue, mostly quartz, are also capable of some alkali-carbonate reactions, however, such reactions are not necessarily deleterious.

5.9 Petrographic examination may be directed specifically at the possible presence of contaminants in aggregates, such as synthetic glass, cinders, clinker, or coal ash, magnesium oxide, calcium oxide, or both, gypsum, soil, hydrocarbons, chemicals that may affect the setting behavior of concrete or the properties of the aggregate, animal excrement, plants or rotten vegetation, and any other contaminant that may prove undesirable in concrete.

5.10 These objectives, for which this guide was prepared, will have been attained if those involved with the evaluation of aggregate materials for use in concrete construction have reasonable assurance that the petrographic examination results wherever and whenever obtained may confidently be compared.

6. Apparatus and Supplies

6.1 The apparatus and supplies listed as follows comprise a selection that will permit the use of the procedures described in this guide. All specific items listed have been used, in connection with the performance of petrographic examinations, by the procedures described herein; it is not, however, intended to imply that other items cannot be substituted to serve similar functions. Whenever possible the selection of particular apparatus and supplies should be left to the judgment of the petrographer who is to perform the work so that the items obtained will be those with the use of which the petrographer has the greatest experience and familiarity. The minimum equipment regarded as essential to the making of petrographic examinations of aggregate samples are those items, or equivalent apparatus or supplies that will serve the same purpose, that are indicated by asterisks in the lists given as follows.

6.1.1 *Apparatus and Supplies for Preparation of Specimens*:

6.1.1.1 *Rock-Cutting Saw*, * preferably with 350-mm or larger diamond blade, and automatic feed.

6.1.1.2 *Horizontal Grinding Wheel*, * preferably 400 mm in diameter.

6.1.1.3 *Polishing Wheel*, preferably 200 to 300 mm in diameter.

6.1.1.4 *Abrasives** , Silicon carbide grit No. 100 (122 μm), 220 (63 μm), 320 (31 μm), 600 (16 μm), and 800 (12 μm); alumina M-305 (5 μm).[4]

6.1.1.5 *Geologist's Pick or Hammer*.

6.1.1.6 *Microscope Slides**, clear, noncorrosive, 25 by 45 mm in size.

6.1.1.7 *Mounting Medium for Powder Mounts** —Canada balsam, neutral, in xylene; suitable low-viscosity epoxy resins; or Lakeside 70.

6.1.1.8 *Xylene**.

6.1.1.9 *Mounting Medium**, suitable for mounting rock slices for thin sections.

6.1.1.10 *Laboratory Oven**.

6.1.1.11 *Plate-Glass Squares**, about 300 mm on an edge for thin-section grinding.

6.1.1.12 *Sample Splitter* with pans.*

6.1.1.13 *Micro Cover Glasses*, * noncorrosive, square, 12 to 18 mm, 25 mm, etc.

6.1.1.14 *Plattner Mortar*.

6.1.2 *Apparatus and Supplies for Examination of Specimens*:

6.1.2.1 *Petrographic Microscope**, with mechanical stage; oculars and objective lenses that will allow magnifications of up to 600 x, and objective-centering devices; full- and quarter-wave compensators; quartz wedge; micrometer eyepiece; Bertrand lens.

6.1.2.2 *Microscope Lamps**

6.1.2.3 *Stereoscopic Microscope**, with objectives and oculars to give final magnifications from about 6× to about 150×.

6.1.2.4 *Magnet**, preferably Alnico, or an electromagnet.

6.1.2.5 *Needleholder and Points**.

6.1.2.6 *Dropping Bottle*, 60-mL capacity.

6.1.2.7 *Petri Culture Dishes*.

6.1.2.8 *Forceps*, smooth, straightpointed.

6.1.2.9 *Lens Paper.**

6.1.2.10 *Immersion Media**, $n = 1.410$ to $n = 1.785$ in steps of no more than 0.005.

6.1.2.11 *Counter*.

6.1.2.12 *Photomicrographic Camera* and accessories.

6.2 The items under Apparatus and Supplies include those used to make thin sections. Semiautomatic thin section machines are available, and there are several thin-section makers who advertise in *Geotimes*, the *American Mineralogist*, and other mineralogical or geological journals. Laboratories may find it reasonable to buy a thin-section machine or use a commercial thin-section maker. Remotely located laboratories have more need to be able to make their own thin sections.

6.3 It is necessary that facilities be available to the petrographer to check the index of refraction of the immersion media. If accurate identification of materials is to be attempted, as for example the differentiation of quartz and chalcedony, or the

[4] The values given in micrometres are the approximate average grain size of commercial silicon carbide grit in the designated size classification.

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differentiation of basic from intermediate volcanic glass, the indices of refraction of the media need to be known with accuracy. Media will not be stable for very long periods of time and are subject to considerable variation due to temperature change. In laboratories not provided with close temperature control, it is often necessary to recalibrate immersion media several times during the course of a single day when accurate identifications are required. The equipment needed for checking immersion media consists of an Abbé refractometer. The refractometer should be equipped with compensating prisms to read indices for sodium light from white light, or it should be used with a sodium arc lamp.

6.4 A laboratory that undertakes any considerable amount of petrographic work should be provided with facilities to make photomicrographic records of such features as cannot adequately be described in words. For illustrations of typical apparatus, reference may be made to Ref **(1)** and manufacturers of microscopes equipped with cameras and photomacrographic equipment may be consulted. Much useful guidance regarding photomicrography, especially using reflected light, is found in Guide E 883.

7. Sampling

7.1 Samples for petrographic examination should be taken by or under the direct supervision of a geologist familiar with the requirements for random sampling of aggregates for concrete and in general following the requirements of Practice D 75. Information on the exact location from which the sample was taken, the geology of the site, and other pertinent data should be submitted with the sample. The amount of material actually studied in the petrographic examination will be determined by the nature of the examination to be made and the nature of the material to be examined, as discussed below.

7.1.1 *Undeveloped quarries* should be sampled by means of cores drilled through the entire depth expected to be exploited. Drilling of such cores should be in a direction that is essentially perpendicular to the dominant structural feature of the rock. Massive material may be sampled by "NX" (53-mm (2⅛-in.) diameter) cores. Thinly bedded or complex material should be represented by cores not less than 100 mm (4 in.) in diameter. There should be an adequate number of cores to cover the limits of the deposit proposed for the project. The entire footage of the recovered core should be included in the sample and accurate data given as to elevations, depths, and core losses.

7.1.2 *Operating quarries and operating sand and gravel deposits*, in which stock piles of the material produced are available, should be represented by not less than 45 kg (100 lb) or 300 pieces, whichever is larger, of each size of material to be examined. Samples from stock piles should be composed of representative portions of larger samples collected with due consideration given to segregation in the piles.

7.1.3 *Exposed faces of nonproducing quarries*, where stock piles of processed material are not available, should be represented by not less than 2 kg (4 lb) from each distinctive stratum or bed, with no piece having a mass less than 0.5 kg (1 lb), or by a drilled core as described above.

7.1.4 *Undeveloped sand and gravel deposits* should be sampled by means of test pits dug to the anticipated depth of future economic production. Samples should consist of not less than the quantities of material indicated in Table 1, selected so as to be representative of the deposits.

NATURAL GRAVEL AND SAND

8. Procedure

8.1 *Selection of Samples for Examination*—Samples of gravel and natural sand for petrographic examination should be dry sieved in accordance with Method C 136 to provide samples of each sieve size. In the case of sands an additional portion should then be tested in accordance with Test Method C 117, with the wash water being saved and removed by drying in order to provide a sample of the material passing the 75-µm (No. 200) sieve (See Specification E 11). The results of the sieve analysis of each sample made in accordance with Method C 136 should be provided to the petrographer making the examination and used in calculating results of the petrographic examination. Each sieve fraction should be examined separately, starting with the largest size available. Rocks are more easily recognized in larger pieces; the breakdown of a heterogeneous type present in the larger sizes may have provided particles of several apparently different types in the smaller sizes. Some important and easily confused types may be recognizable using the stereoscopic microscope if they are first recognized and separated in the larger sizes, but may require examination using the petrographic microscope if they are first encountered in the smaller sizes.

8.2 The number of particles of each sieve fraction to be examined will be fixed by the required precision of determination of the less abundant constituents. Assuming that the field sampling and laboratory sampling procedures are accurate and reliable, the number of particles examined, identified, and counted in each sieve fraction will depend on the required accuracy of the estimate of constituents present in small quantities. The numbers given in this method are minimal. They are based on experience and on statistical considerations **(5, 6)**. It is believed that at least 150 particles of each sieve fraction should be identified and counted in order to obtain reliable results. Precise determinations of small quantities of an important constituent will require counts of larger numbers of particles. If the sample of a sieve fraction contains many more particles than need to be identified, the sample shall be reduced in accordance with one of the procedures in Practice C 702, so as to contain a proper number of particles for examination.

TABLE 1 Minimum Sizes for Samples from Undeveloped Sand and Gravel Deposits

Sieve Size	Quantity		
	kg	(lb)	Pieces
Larger than 150-mm (6-in.)	...	...	[A]
75 to 150-mm (3 to 6-in.)	...	...	300[A]
37.5 to 75-mm (1½ to 3-in.)	180	(400)	...
19.0 to 37.5-mm (¾ to 1½-in.)	90	(200)	...
4.75 to 19.0-mm (No. 4 to ¾-in.)	45	(100)	...
Finer than 4.75-mm (No. 4)[B]	23	(50)	...

[A] Not less than one piece from each apparent type of rock.
[B] Fine aggregate.

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9. Procedure for Examination of Natural Gravel

9.1 *Coatings*—The particles should be examined to establish whether exterior coatings are present. If coatings are present, it should be determined whether the coatings consist of materials likely to be deleterious in concrete (opal, gypsum, easily soluble salts, organic matter). It should also be determined qualitatively how firmly the coatings are bonded to the particles.

9.2 *Rock Types*—The sieve fraction should be sorted into rock types by visual examination. If all or most of the groups present are types easily identifiable in hand specimen by examination of a natural or broken surface, and by scratch and acid tests, no further identification may be needed. Fine-grained rocks that cannot be identified macroscopically or that may consist of or contain constituents known to be deleterious in concrete should be checked by examination with the stereoscopic microscope. If they cannot be identified by that means, they should be examined by means of the petrographic microscope. The amount of work done in identifying fine-grained rocks should be adapted to the information needed about the particular sample. Careful examination of one size of a sample, or study of information from previous examination of samples from the same source, will usually reveal the amount of additional detailed microscopical work required to obtain information adequate for the purpose. In some instances, petrographic methods other than microscopy, such as X-ray diffraction, may be required or might most rapidly serve to identify fine-grained rock materials.

9.3 *Condition*—The separated groups belonging to each rock type should be examined to determine whether a further separation by physical condition is necessary. If all of the particles of a rock type are in a similar condition, that fact should be noted. More frequently, particles in several degrees of weathering will be found in a group. They should be sorted into categories based on condition and on the expectation of comparable behavior in concrete. The types of categories intended are: (*1*) fresh, dense; (*2*) moderately weathered; (*3*) very weathered; or (*1*) dense; (*2*) porous (or porous and friable). It usually is not practicable to recognize more than three conditions per rock type, and one or two may be sufficient. An important constituent present in larger quantities may sometimes require separation into four groups by condition. The conspicuous example is chert when it is the major constituent of a gravel sample. It may be present as dense, unfractured chert; as vuggy chert; as porous chert; and as dense but highly fractured chert. The determination of which of these four conditions characterizes a particle may be expected to have an important influence on prediction of the behavior of the particle in concrete.

9.4 *Record*:

9.4.1 Notes should be taken during the examination. Each rock type should be described; the relevant features may include the following:

9.4.1.1 Particle shape,

9.4.1.2 Particle surface texture,

9.4.1.3 Grain size,

9.4.1.4 Internal structure, including observations of pore space, packing of grains, cementation of grains,

9.4.1.5 Color,

9.4.1.6 Mineral composition,

9.4.1.7 Significant heterogeneities,

9.4.1.8 General physical condition of the rock type in the sample,

9.4.1.9 Coatings or incrustations, and

9.4.1.10 Presence of constituents known to cause deleterious chemical reaction in concrete.

9.4.2 Particle counts should be recorded so that tables can be made for inclusion in the report. When the examination has been completed, the notes should contain enough information to permit the preparation of tables and descriptions. Tables should be prepared showing the composition and condition of the samples by sieve fractions, and the weighted average composition, based on the grading of the sample as received and on the distribution of constituents by sieve fractions. Descriptions of constituent groups should be prepared containing the relevant features among those enumerated in the preceding list.

10. Procedure for Examination of Natural Sand

10.1 The procedure for the examination of natural sand is similar to that for the examination of gravel, with the modifications necessitated by the differences in particle size.

10.1.1 *Sizes Coarser than 600 μm (No. 30)*—Each sieve fraction present that is coarser than the 600-μm (No. 30) sieve should be reduced in accordance with one of the procedures in Practice C 702 until a split or splits containing at least 150 particles are obtained. The reduced sample of each sieve fraction should be examined, and its constituents identified and counted, using the stereoscopic microscope. It is convenient to spread out the sample in a flat-bottom glass dish such as a Petri dish and manipulate the grains with a forceps and dissecting needle. The identification of grains in the coarser sand sizes is often easier when the grains are just submerged in water. The submergence lessens reflection from the outer surfaces and may show diagnostic features that cannot be seen when the grains are dry. There are exceptions to this generalization. Where identification is difficult, the examination includes examination of the natural surface (dry and wet), examination of a broken surface (dry and wet), and scratch and acid tests. Only after all of these steps have been taken and the grain is still unidentified should the petrographer resort to the petrographic microscope. Grains that cannot be identified using the stereoscopic microscope, or that are suspected of consisting of or containing substances known to react deleteriously in concrete, should be set aside to be examined with the petrographic microscope. If the question of reaction with alkalies is important in the examination of the sample, certain additions to the procedure are indicated. If the coarser sand sizes contain fine-grained, possibly glassy igneous rocks, several typical particles of each variety of such rocks should be selected for a more thorough examination. The petrographer should determine the presence or absence of glass by crushing typical grains and examining them in immersion media, using the petrographic microscope. In difficult or especially important cases, it may be necessary to break suspected grains and to make immersion mounts of part of the grain and a thin section of another part. Where the sand contains chert and the potential

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reactivity of the chert is an important consideration, a number of chert particles from the fractions retained on the 600-µm (No. 30) sieve should be set aside for determinations of the index of refraction. Methylene blue staining techniques may be useful in identifying the presence of smectite (**7**).

10.1.2 *Sizes Finer than 600 µm (No. 30)*—The sieve fractions finer than the 600-µm (No. 30) sieve should each be reduced in a sample splitter or by quartering to about 4 or 5 g (Note 1). These splits should be further reduced on a miniature sample splitter or by coning and quartering with a spatula on a clean sheet of paper. The examination may be conducted as described previously for the coarser sizes. As required, the petrographic microscope should be used. For this purpose, a representative portion of each reduced split should be mounted in immersion oil on a clean glass slide and covered with a clean cover glass. No entirely satisfactory method of reducing a split to a predetermined number of grains is known. The reduced split can be sampled by spreading it in a thin layer on glass or clean paper, dragging the end of a dissecting needle moistened in immersion oil through the sample and transferring the grains that adhere to the needle to a drop of immersion oil on a clean slide. If this is done carefully, a fairly representative sample will be obtained. If the dissecting needle is made of magnetized steel, a concentration of magnetic minerals may result. It is usually necessary to make several mounts of the 300-µm (No. 50) and 150-µm (No. 100) sieve fractions to obtain at least 150 grains of each. The refractive index of the immersion oil should be selected to make the identification of the important constituents as easy and as definite as possible. The use of an immersion oil with an index of or just below the lower index of quartz (1.544) is recommended. The slide should be mounted on a petrographic microscope equipped with a mechanical stage. Several traverses should be made, and each grain that passes under the intersection of the cross hairs should be identified and counted. Care should be taken to move the slide on the north-south adjustment between traverses so that no grain will be counted twice. Each sieve fraction passing the 600-µm (No. 30) and retained on the 75-µm (No. 200) sieve should be examined. Ordinarily, the material passing the 75-µm (No. 200) sieve is mounted on a slide following the procedure described above, examined by means of the petrographic microscope, and its composition estimated. If an unusually large amount of this size is present, or if it contains constituents that may be expected to have an important effect on the suitability of the aggregate for the intended use, it should be counted. In this event, it is suggested that the fraction passing the 75-µm (No. 200) sieve be washed over the 45-µm (No. 325) sieve before being counted.

NOTE 1—The volume will usually be less than a level teaspoonful. In some gradings the fractions retained on the 150-µm (No. 100) and 75-µm (No. 200) sieves may be present in such small amounts that reduction is unnecessary.

10.1.3 Grain thin sections using an epoxy as mounting medium also may be useful in classifying particles passing the 300-µm (No. 50) sieve.

DRILLED CORE, LEDGE ROCK, CRUSHED STONE, AND MANUFACTURED SAND

11. Procedure for Examination of Drilled Core

11.1 Each core should be examined and a log prepared showing length of core recovered, core loss and location; location and spacing of fractures and parting planes; lithologic type or types; alternation of types; physical condition and variations in condition; toughness, hardness (**8**), coherence; obvious porosity; grain size, texture, variations in grain size and texture; type or types of breakage; and presence of constituents capable of deleterious reaction in concrete. If the size of the core permits, the probability that the rock will make aggregate of the required maximum size should be considered. If the surface of the core being examined is wetted, it is usually easier to recognize significant features and changes in lithology. Most of the information usually required can be obtained by careful visual examination, scratch and acid tests, and hitting the core with a hammer. In the case of fine-grained rocks, it may be necessary to examine parts of the core, using the stereoscopic microscope, or to prepare thin sections of selected portions. Some considerations and procedures are more applicable to particular rock types than to others. Ordinarily, the layered rocks considered for concrete aggregate will be limestone, and occasionally metamorphic rocks, such as phyllite, gneiss, or schist. One of the most important questions arising in the examination of limestone is that of the presence, type, and distribution of argillaceous impurities. Limestones that contain intercalated thin beds of soft shale may make suitable sources of aggregate if the shale is so distributed that it does not prevent manufacture of the required maximum size, and if the shale can be eliminated or reduced in processing. Where argillaceous impurities are present, it should be determined whether they actually consist of clay minerals or of other minerals in clay sizes. If they do consist of clay minerals, it should be established whether the clay minerals include smectites (**9**). X-ray diffraction analysis is especially valuable in identification and quantitative determination of clay minerals. Methylene blue staining techniques (**7**) are useful in identifying smectite. In the examination of fine-grained igneous rocks, particular attention should be directed to the nature of the groundmass. This examination should include determination of the presence or absence of opal, chalcedony, natural glass, and swelling clays; if any of these are found the amount should be estimated; if natural glass is found the type should be determined.

12. Procedure for Examination of Ledge Rock

12.1 The procedure used in examination should be the same as for core samples to the extent that the spacing of samples and size of the individual pieces allow. If the sample consists of a relatively large quantity of broken stone produced by blasting, it is desirable to inspect the whole sample, estimate the relative abundance of rock types or varieties present, and sample each type before further processing. Subsequent procedure should be the same as given below for crushed stone.

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13. Procedure for Examination of Crushed Stone

13.1 The procedure for examination of crushed stone should be similar to that for core, except that necessary quantitative data should be obtained by particle counts of the separated sieve fractions obtained as described in the section on Natural Gravel and Sand.

14. Procedure for Examination of Manufactured Sand

14.1 The examination procedure should be similar to that for natural sand, with particular emphasis on the amount and extent of fracturing and the amount and nature of rock dust developed by the milling operations. If a sample of the rock from which the sand was produced is available, examination of it will provide useful information.

CALCULATION AND REPORT

15. Calculation

15.1 Calculate the composition of each sieve fraction of a heterogeneous sample and the weighted average composition of the whole sample as follows:

15.1.1 Express the composition of each sieve fraction by summing the total number of particles of that fraction counted, and calculating each constituent in each condition as a percentage of the total amount (as number of particles in percent, in each sieve fraction). It is convenient to calculate and record the percentages to tenths at this stage. An example of these calculations is given in the upper half of Table 2.

15.1.2 Obtain the percentage by mass of the sieve fraction in the whole sample (individual percentages retained on consecutive sieves) from the grading of the sample as determined by Method C 136.

15.1.3 By multiplying the percentage of the constituent in the sieve fraction, determined as described above by the percentage of the sieve fraction in the whole sample, obtained as described above, calculate the percentage in the whole sample of that constituent in that size (weighted percentage of constituents in sieve fraction, Table 2). It is convenient to calculate and record these percentages to tenths.

15.1.4 By adding the weighted percentages of each constituent in each sieve fraction, obtain the weighted percentage of each constituent in the whole sample (see under weighted composition of sample in Table 2).

15.1.5 Construct a table to show the composition of each sieve fraction and the weighted composition of the whole sample. Report values to the nearest whole number. Report constituents amounting to 0.5 % or less of a sieve fraction or of the whole sample as traces. Table 3 is an example constructed

TABLE 2 Calculation of Results of Particle Counts[A]

Individual Percentage Retained on Sieve	Composition of Fractions Retained on Sieves Shown Below							
	19.0-mm (¾-in.)		12.5-mm (½-in.)		9.5-mm (⅜-in.)		4.75-mm (No. 4)	
	17.4		32.6		29.5		20.5	
Constituents[B]	Number of Particles	%	Number of Particles	%	Number of Particles	%	Number of Particles	%
A_1	250	50.0	200	40.0	150	30.0	50	10.0
A_2	50	10.0	100	20.0	125	25.0	100	20.0
A_3	10	2.0	50	10.0	75	15.0	100	20.0
B_1	107	21.4	70	14.0	62	12.4	32	6.4
B_2	76	15.2	53	10.6	19	3.8	87	17.4
B_3	...	...	20	4.0	43	8.6	96	19.2
C_1	5	1.0	5	1.0	20	4.0	20	4.0
C_2	2	0.4	2	0.4	6	1.2	10	2.0
C_3	...	...	...	...	...	...	5	1.0
Totals	500[C]	100	500[C]	100	500[C]	100	500[C]	100

	Weighted Percentages of Constituents in Each Sieve Fraction				Weighted Composition of Sample
	19.0-mm (¾-in.)	12.5-mm (½-in.)	9.5-mm (⅜-in.)	4.75-mm (No. 4)	
A_1	8.7	13.0	8.9	2.1	32.7 64.6 (Total A)
A_2	1.7	6.5	7.4	4.1	19.7
A_3	0.4	3.3	4.4	4.1	12.2
B_1	3.7	4.6	3.7	1.3	13.3 31.8 (Total B)
B_2	2.6	3.5	1.1	3.6	10.8
B_3	...	1.3	2.5	3.9	7.7
C_1	0.2	0.3	1.2	0.8	2.5 3.6 (Total C)
C_2	0.1	0.1	0.3	0.4	0.9
C_3	...	...	...	0.2	0.2
Total in sieve fraction	17.4	32.6	29.5	20.5	
Total in sample, condition 1					48.5
Total in sample, condition 2					31.4
Total in sample, condition 3					20.1

[A] This table indicates a convenient method of setting up a work sheet for recording results and calculations. The results developed here are entered in the form indicated by Table number 3. Table number 3 is included in the petrographic report. Table number 2 is not.

[B] Letters (A, B, C) refer to the various constituents found, subscript numbers (1, 2, 3) refer to the various conditions in which each constituent has been found, such as relative degree of weathering.

[C] The recommendation concerning the number of particles to be counted has been met; the selection of 500 particles per fraction for the example is to illustrate the calculation; it is not intended to suggest that a predetermined number of particles per fraction should be selected.

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TABLE 3 Composition and Condition of an Aggregate Sample (Table Constructed from Calculations Shown in Table Number 2)[A]

Constituents	Amount, as Number of Particles in Percent							
	In Fractions Retained on Sieves Shown Below[B]				In Whole Sample[C]			
	19.0-mm (¾-in.)	12.5-mm (½-in.)	9.5-mm (⅜-in.)	4.75-mm (No. 4)	Condition 1	Condition 2	Condition 3	Totals
A	62	70	70	50	33	20	12	65
B	37	29	25	43	13	11	8	32
C	1	1	5	7	2	1	tr	3
Total	100	100	100	100	...	...	...	100
Weighted average, condition 1					48	...	...	...
Weighted average, condition 2					...	32	...	...
Weighted average, condition 3					...	...	20	...

[A] For other forms of presentation of results of petrographic analysis, see Table numbers 1- 4 in **(10)**.

[B] Based on count of 500 particles in each sieve fraction. (The number of particles of each sieve fraction counted should be shown in the report and this may conveniently be done as a footnote to the table.)

[C] Based on grading of the sample as received, and on the distribution of constituents by sieve fractions shown at the left above. (If the petrographic report forms part of a complete investigation of the sample, including a report of the grading, the grading need not be shown. If the petrographic report is to be submitted alone, the grading of the sample should be included with it.)

from the data obtained in Table 2. As a convention, the total in each sieve fraction and the total in the whole sample shall each be 100 % without the traces. Difficulties in abiding by this convention can usually be avoided by grouping minor constituents of little engineering importance. It is preferable to tabulate constituents known to react deleteriously in concrete so that their distribution will be apparent from inspection of the table, even though the amount in the whole sample or in any fraction is very small.

16. Report

16.1 The report of the petrographic examination should summarize the essential data needed to identify the sample as to source and proposed use, and include a description giving the essential data on composition and properties of the material as revealed by the examination. The report should record the test procedures employed, and give a description of the nature and features of each important constituent of the sample, accompanied by such tables and photographs as may be required. The findings and conclusions should be expressed in terms likely to be intelligible to those who must make decisions as to the suitability of a material for use as concrete aggregate.

16.2 When the sample has been found to possess properties or constituents that are known to have specific unfavorable effects in concrete, those properties or constituents should be described qualitatively and, to the extent practicable, quantitatively. The unfavorable effects that may be expected to ensue in concrete should be mentioned. When appropriate, it should be stated that a given sample was not found to contain any undesirable features. When such is the case it may also be appropriate, especially if the report of the petrographic examination is not accompanied by reports of results of physical and chemical tests for which numerical limits may be applicable, to add that the material appears acceptable for use provided the applicable acceptance tests are made and the results are within the appropriate limits. The report should not, however, contain conclusions other than those based upon the finding of the examination unless the additional data to support such conclusions are included in or with the petrographic report and the petrographer has been authorized to analyze the other relevant nonpetrographic data.

16.3 The petrographic report should include recommendations regarding any additional petrographic, chemical, physical, or geological investigations that may be required to evaluate adverse properties that are indicated by the petrographic examination that has been performed. Supplementary petrographic investigations might include qualitative or quantitative analysis of the aggregate or of selected portions thereof by X-ray diffraction, differential thermal methods, or other procedures that are directed to identification and description of the constituents of the aggregate.

17. Precision and Bias

17.1 Those test methods that are used in connection with this guide that have been standardized in ASTM are subject to having precision and bias sections. Those that have not been standardized will each be provided with such a section, if and when standardized. None of the nonstandardized procedures mentioned for optional use in this practice are used in ways that lend themselves to the preparation of precision and bias statements.

18. Keywords

18.1 aggregate; analysis; composition; crushed rock; crushed stone; examination; ledge rock; manufacture sand; natural sand; petrography; quarry

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REFERENCES

(1) Mather, Katharine and Mather, Bryant, "Method of Petrographic Examination of Aggregates for Concrete," *Proceedings*, ASTM, ASTEA, Vol 50, pp. 1288-1312, 1950.

(2) Kerr, Paul F., "Optical Mineralology," McGraw-Hill Book Company, NY, NY, 1977.

(3) Jenkins, Snyder, "Introduction to X-ray Powder Diffractometery," John Wiley and Sons, Inc, NY, NY, 1996.

(4) Williams, Turner, Gilbert, "Petrography an Introduction to the Study of Rocks in Thin Section," W.H. Freeman and Co., NY, NY, 1982.

(5) Simpson, G.G., and Rowe, A., *Quantitative Zoology*, McGraw-Hill Col, Inc., New York, NY, pp. 182-185, 1950.

(6) Dryden, A.L., Jr., "Accuracy in Percentage Representation of Heavy Mineral Frequencies," *Proceedings*, U.S. Nat. Academy of Sciences, Vol 17, No. 5, pp. 233-238, 1931.

(7) Higgs, Nelson B., "Preliminary Studies of Methylene Blue Adsorption as a Method of Evaluating Degradable Smectite-Bearing Concrete Aggregate Sands," *Cement and Concrete Research*, Vol 16, pp. 528-534, 1986.

(8) Woolf, D.O., "Methods for the Determination of Soft Pieces in Aggregate," *Proceedings*, ASTM, Vol 47, p. 967, 1947.

(9) Carroll, Dorothy, "Clay Minerals: A Guide to Their X-Ray Identification," *Special Paper 126*, The Geological Society of America, 1970.

(10) Mielenz, Richard C., "Petrographic Evaluation of Concrete Aggregates," Chapter 31, Significance of Tests and Properties of Concrete and Concrete-Making Materials, Paul and Joseph F. Lamond, eds., *ASTM STP 169*, pp. 341-364, 1994.

SUMMARY OF CHANGES

Committee C09 has identified the location of selected changes to this guide since the last issue, C 295 – 03, that may impact the use of this guide. (Approved July 1, 2008)

(1) Added new Section 3 and renumbered subsequent sections.

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Designation: C 305 – 06

American Association State
Highway and Transportation Officials Standard
AASHTO No.: T162

Standard Practice for Mechanical Mixing of Hydraulic Cement Pastes and Mortars of Plastic Consistency[1]

This standard is issued under the fixed designation C 305; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope*

1.1 This practice covers the mechanical mixing of hydraulic cement pastes and mortars of plastic consistency.

1.2 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

2. Referenced Documents

2.1 *ASTM Standards:* [2]

C 778 Specification for Standard Sand

3. Significance and Use

3.1 This practice is intended for use in the mechanical mixing of pastes and mortars for the testing of hydraulic cements.

4. Apparatus

4.1 *Mixer*—The mixer shall be an electrically driven mechanical mixer of the epicyclic type, which imparts both a planetary and a revolving motion to the mixer paddle. The mixer shall have a minimum of two speeds, controlled by definite mechanical means. (Rheostat adjustment of speed will not be acceptable.) The first, or slow speed shall revolve the paddle at a rate of 140 ± 5 r/min, with a planetary motion of approximately 62 r/min. The second speed shall revolve the paddle at a rate of 285 ± 10 r/min, with a planetary motion of approximately 125 r/min. The electric motor shall be at least 124 W (⅙ hp). The mixer shall be equipped with either an adjustment screw which is an integral part of the mixer or a clearance adjustment bracket such as the one shown in Fig. 1 (Note 1) to provide clearance between the lower end of the paddle and the bottom of the bowl that is not greater than 2.5 mm but not less than 0.8 mm (Note 2) when the bowl is in the mixing position.

NOTE 1—When the bracket is in the proper position beneath the motor housing, the lugs are to the front and facing upward and the heads of the adjustment screws are to the rear and facing downward in the path of the sliding frame that holds the bowl. It is intended that the bracket be fastened at the front housing connection by inserting replacement screws on an appropriate size upward through the opening in each lug and into the existing threaded holes in the bottom of the motor housing. The original stops for the sliding frame are to be filed down if they prevent the frame from coming in contact with the adjustment screws.

NOTE 2—This is the approximate diameter of a grain of 20-30 sand as described in Specification C 778.

4.2 *Paddle*—The paddle shall be readily removable, made of stainless steel, and shall conform to the basic design shown in Fig. 2. The dimensions of the paddle shall be such that when in the mixing position the paddle outline conforms to the contour of the bowl used with the mixer, and the clearance between corresponding points on the edge of the paddle and the side of the bowl in the position of closest approach shall be approximately 4.0 mm but not less than 0.8 mm.

4.3 *Mixing Bowl*—The removable mixing bowl shall have a nominal capacity of 4.73 L, shall be of the general shape and comply with the limiting dimensions shown in Fig. 3, and shall be made of stainless steel. The bowl shall be so equipped that it will be positively held in the mixing apparatus in a fixed position during the mixing procedure. There shall be provided a lid, made of a nonabsorbing material not attacked by the cement.

4.4 *Scraper*—The scraper shall consist of a semirigid rubber blade attached to a handle about 150 mm long. The blade shall be about 75 mm long, 50 mm wide, and tapered to a thin edge about 2 mm thick.

NOTE 3—A kitchen tool known as a plate and bowl scraper conforms to these requirements.

4.5 *Supplementary Apparatus*—The balances, weights, glass graduates, and any other supplementary apparatus used in measuring and preparing the mortar materials prior to mixing

[1] This practice is under the jurisdiction of ASTM Committee C01 on Cement and is the direct responsibility of Subcommittee C01.22 on Workability.

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[2] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

***A Summary of Changes section appears at the end of this standard.**

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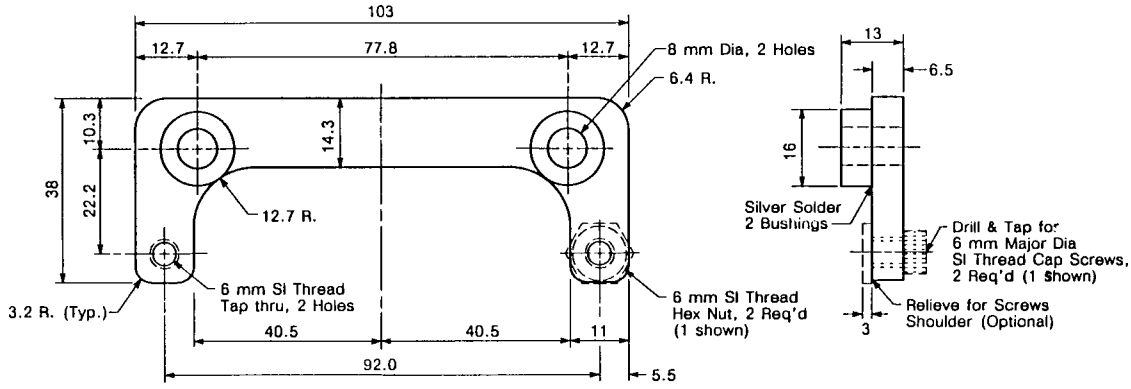

Plate and Bushings—Brass
Screws and Nuts—Steel
All Dimensions in mm

FIG. 1 Clearance Adjustment Bracket

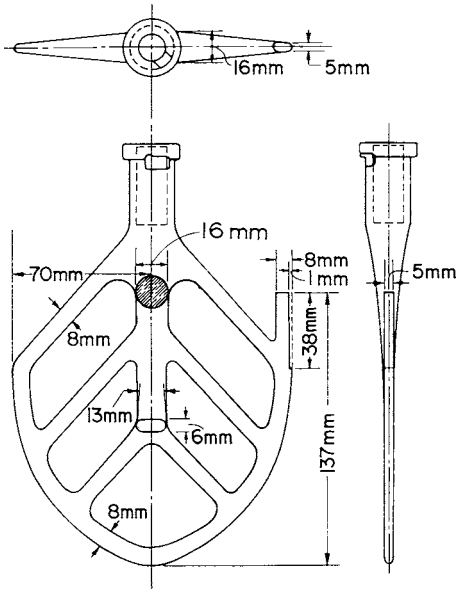

FIG. 2 Paddle

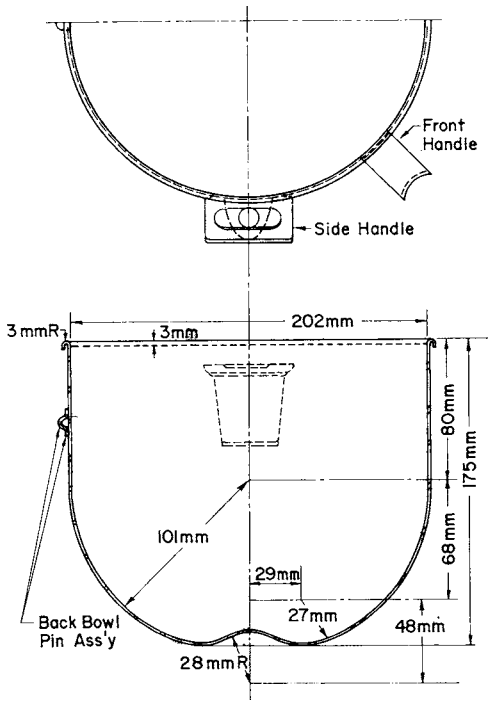

FIG. 3 Mixing Bowl

shall conform to the respective requirements for such apparatus as specified in the method for the particular test for which the mortar is being prepared.

5. Temperature and Humidity

5.1 The temperature of the room shall be maintained between 20 and 27.5 °C (68 and 81.5 °F), and the temperature of the dry materials, paddle, and bowl shall be within the above range at the time of test. The temperature of the mixing water shall not vary from 23 °C (73.4 °F) by more than ±1.7 °C (3 °F).

5.2 The relative humidity of the laboratory shall be not less than 50 %.

6. Materials, Proportioning, and Consistency

6.1 The materials and their proportions and quantities shall conform to the requirements contained in the particular method for which the paste or mortar is being prepared.

7. Procedure for Mixing Pastes

7.1 Place the dry paddle and the dry bowl in the mixing position in the mixer. Then introduce the materials for a batch into the bowl and mix in the following manner:

7.1.1 Place all the mixing water in the bowl.

7.1.2 Add the cement to the water and allow 30 s for the absorption of the water.

7.1.3 Start the mixer and mix at slow speed (140 ± 5 r/min) for 30 s.

7.1.4 Stop the mixer for 15 s and during this time scrape down into the batch any paste that may have collected on sides of the bowl.

7.1.5 Start the mixer at medium speed (285 ± 10 r/min) and mix for 60 s.

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8. Procedure for Mixing Mortars

8.1 Place the dry paddle and the dry bowl in the mixing position in the mixer. Then introduce the materials for a batch into the bowl and mix in the following manner:

8.1.1 Place all the mixing water in the bowl.

8.1.2 Add the cement to the water; then start the mixer and mix at the slow speed (140 ± 5 r/min) for 30 s.

8.1.3 Add the entire quantity of sand slowly over a 30-s period, while mixing at slow speed.

8.1.4 Stop the mixer, change to medium speed (285 ± 10 r/min), and mix for 30 s.

8.1.5 Stop the mixer and let the mortar stand for 90 s. During the first 15 s of this interval, quickly scrape down into the batch any mortar that may have collected on the side of the bowl; then for the remainder of this interval, close the mixer enclosure or cover the bowl with the lid.

8.1.6 Finish by mixing for 60 s at medium speed (285± 10 r/min).

8.1.7 In any case requiring a remixing interval, any mortar adhering to the side of the bowl shall be quickly scraped down into the batch with the scraper prior to remixing.

Warning—The clearances between the paddle and the bowl specified in this practice are suitable when using mortar made with standard sand as described in Specification C 778. To permit the mixer to operate freely and to avoid serious damage to the paddle and bowl when coarser aggregates are used, it may be necessary to set the clearance adjustment bracket to provide greater clearances than those specified in 4.1.

For additional useful information on details of cement test methods, reference may be made to the "Manual of Cement Testing," which appears in the *Annual Book of ASTM Standards*, Vol 04.01.

SUMMARY OF CHANGES

Committee C01 has identified the location of selected changes to this practice since the last issue, C 503 – 99$^{\epsilon 1}$, that may impact the use of this practice. (Approved August 1, 2006)

(*1*) Deleted current reference to Hobart N50A mixer because references to individual manufacturers are reserved for instances where a single manufacturer supplies the referred equipment.

(*2*) Revised 7.1.5.

(*3*) Revised 8.1.5.

(*4*) Revised 8.1.6.

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Designation: C 309 – 07

Standard Specification for Liquid Membrane-Forming Compounds for Curing Concrete[1]

This standard is issued under the fixed designation C 309; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

This standard has been approved for use by agencies of the Department of Defense.

1. Scope*

1.1 This specification covers liquid membrane-forming compounds suitable for application to concrete surfaces to reduce the loss of water during the early-hardening period. White-pigmented membrane-forming compounds serve the additional purpose of reducing the temperature rise in concrete exposed to radiation from the sun. The membrane-forming compounds covered by this specification are suitable for use as curing media for fresh concrete, and may also be used for further curing of concrete after removal of forms or after initial moist curing.

NOTE 1—This specification addresses only those properties listed in Sections 5 through 8. Membrane-forming compounds with special properties including better water retention, minimum solids content, resistance to ultraviolet radiation, acid and alkali resistance and non-interference with adhesives are described in Specification C 1315.

NOTE 2—Solutions of silicate salts are chemically reactive in concrete rather than membrane-forming; therefore, they do not meet the intent of this specification.

1.2 The values stated in SI units are to be regarded as the standard. The values given in parentheses are provided for informational purposes only.

1.3 The following precautionary caveat pertains only to the test methods portion, Section 10, of this specification: *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

1.4 The text of this standard references notes and footnotes which provide explanatory material. These notes and footnotes shall not be considered as requirements of the standard.

1.5 This is a performance specification. The allowable composition of products covered by this specification is limited by various local, regional, and national regulations. Issues related to air quality (solvent emission), worker exposure, and other hazards are not addressed here. It is the responsibility of the producers and users of these materials to comply with pertinent regulations.

Warning—Some VOC exempt solvents used to meet the regulations are extremely flammable with low auto ignition temperatures and rapid evaporation rates. Consult the manufacturer's product information sheet for important application and safety information.

2. Referenced Documents

2.1 *ASTM Standards:* [2]

C 156 Test Method for Water Retention by Liquid Membrane-Forming Curing Compounds for Concrete

C 1315 Specification for Liquid Membrane-Forming Compounds Having Special Properties for Curing and Sealing Concrete

D 869 Test Method for Evaluating Degree of Settling of Paint

D 883 Terminology Relating to Plastics

D 1309 Test Method for Settling Properties of Traffic Paints During Storage

D 2369 Test Method for Volatile Content of Coatings

E 1347 Test Method for Color and Color-Difference Measurement by Tristimulus Colorimetry

3. Classification

3.1 The following types of liquid membrane-forming compounds are included:

3.1.1 *Type 1*—Clear or translucent without dye,

3.1.2 *Type 1-D*—Clear or translucent with fugitive dye, and

3.1.3 *Type 2*—White pigmented.

3.2 The solids dissolved in the vehicle shall be one of the following classes:

3.2.1 *Class A*—No restrictions,

3.2.2 *Class B*—Must be a resin as defined in Terminology D 883.

NOTE 3—Permanent colors other than white, or other special attributes,

[1] This specification is under the jurisdiction of ASTM Committee C09 on Concrete and Concrete Aggregates and is the direct responsibility of Subcommittee C09.22 on Materials Applied to New Concrete Surfaces.

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[2] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

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are beyond the scope of this specification and are subject to negotiation between the purchaser and the supplier.

4. Ordering Information

4.1 The purchaser shall include the following information in the purchase order when applicable:

4.1.1 Type of liquid membrane-forming compound and class of solids to be furnished, and

4.1.2 Rate of application to be used to determine conformance to this specification. If not specified, the liquid membrane-forming material shall be applied at a rate of 5.0 m^2/L (200 ft^2/gal) for testing purposes.

NOTE 4—The application rate used for testing may, or may not, be the same as the rate to be used for field application. Many agencies use the same rate for field application on relatively smooth surfaces as the rate used for testing, while requiring a substantially greater field application rate on deeply textured surfaces.

4.1.3 The intended method of application (for example, spraying, brushing, or by roller). If not specified, the material shall be of a sprayable consistency.

4.1.4 Maximum permissible volatile organic compound (VOC) content if required by applicable regulations.

5. General Requirements

5.1 Liquid membrane-forming compound Types 1 and 1-D shall be clear or translucent. Membrane-forming compounds with a fugitive dye (Type 1-D) shall be readily distinguishable upon the concrete surface for at least 4 h after application but shall become inconspicuous within 7 days after application if exposed to direct sunlight.

NOTE 5—No laboratory test for the fugitive characteristic of the color in dyed (Type 1-D) compounds is provided in this specification. The disappearance of these colors is strongly dependent on the nature of the exposure and the rate of application of the compounds.

5.2 Type 2 liquid membrane-forming compounds shall consist of finely-divided white pigment and vehicle, ready-mixed for immediate use as is. The membrane-forming compound shall present a uniform white appearance when applied uniformly to a new concrete surface at the specified rate of application.

5.3 Liquid membrane-forming compounds shall be of such a consistency that they can be readily applied by spraying, or by brushing or rolling, when specified, to a uniform coating at temperatures above 4 °C (40 °F).

NOTE 6—For uniform application in the field on vertical concrete surfaces, the specified rate of application may be achieved by two coats applied at an interval of approximately 1 h.

5.4 Liquid membrane-forming compounds shall adhere to freshly placed concrete that has stiffened or set sufficiently to resist marring during application, and to damp, hardened concrete, and shall form a continuous film when applied at the specified rate of application.

5.5 Liquid membrane-forming compounds shall not react deleteriously with concrete. Deleterious reactions are detected by scratching the surface of a mortar specimen (used for the water-retention test) with a knife or screwdriver, not less than 72 h after application, and comparing with the surface hardness similarly determined of a similar specimen that has been moist-cured for approximately half as long. Any softening of the liquid membrane-forming compound-treated surface indicated by such a comparison shall be considered sufficient cause for rejection of the compound.

NOTE 7—Testing for deleterious reactions need only be done for curing compounds of a new or unknown composition.

5.6 Liquid membrane-forming compounds shall be storable for at least 6 months without deterioration, except compounds of the water-emulsion type will not be expected to resist freezing. Type 2 liquid membrane-forming compounds shall not settle out excessively or cake in the container, and shall be capable of being mixed to a uniform consistency by moderate stirring or agitation. When tested for long-term settling, as stated in 10.4, the compound shall have a rating of not less than four.

6. Water Retention Properties

6.1 Liquid membrane-forming compounds, when tested in accordance with 10.1, shall restrict the loss of water to not more than 0.55 kg/m^2 in 72 h.

7. Reflectance Properties

7.1 Type 2 liquid membrane-forming compounds, when tested in accordance with 10.2, shall exhibit a daylight reflectance of not less than 60 %.

8. Drying Time Requirement

8.1 Liquid membrane-forming compounds, when tested in accordance with 10.3, shall dry to touch in not more than 4 h.

9. Sampling

9.1 Samples shall be taken either at the plant or warehouse prior to delivery, or at the point of delivery, at the option of the purchaser. If sampling is done prior to shipment, the inspector representing the purchaser shall have free access to the materials being sampled and shall be afforded all reasonable facilities for inspection and sampling.

9.2 Shake or thoroughly stir liquid membrane-forming compounds before taking a sample. Take one sample for each lot, batch, or other unit of production in a shipment. If the liquid membrane-forming compound is in mixing tanks or vats, one third of the sample shall represent the material coming from the tank at the beginning of the filling operation, one third shall represent the material coming at the middle of the filling operation, and one third shall represent the material coming at the end of the filling operation. If the liquid membrane-forming compound to be sampled is in containers, obtain a sample by taking a portion out of a number of containers equal in number to the next integer larger than the cube root of the total number of containers in the lot.

9.3 Seal all of the filled containers represented by the sample to prevent leakage, substitution, or dilution. The sampling agency shall mark each container represented by the sample with a suitable identification mark for later identification and correlation.

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10. Test Methods

10.1 *Water Retention Test*—Using the application rate specified by the purchaser, or 5.0 m^2/L (200 ft^2/gal) if no rate is specified, test for water retention using Test Method C 156.

10.2 *Reflectance Test*—For Type 2 compounds, on completion of the water retention test, determine the daylight reflectance of the specimens in accordance with Test Method E 1347.

NOTE 8—Daylight reflectance is total luminous reflectance factor, CIE tristimulus value Y for CIE 1931 (2°) standard observer and CIE standard illuminant C or D56.

10.3 *Drying Time Test*:

10.3.1 *Scope*—This test method is used to determine the length of time for a liquid membrane-forming curing compound to dry to the touch and develop into a film that will not track off the concrete.

10.3.2 *Significance and Use*—The ability of a liquid membrane-forming curing compound to dry in a suitable length of time ensures the user of the ability to perform other tasks on the concrete, such as sawing joints, and so forth, without lifting the membrane from the concrete by tracking.

10.3.3 *Procedure*—Apply the membrane-forming compound to a fresh mortar specimen at the specified rate of application and expose it to air at 23 ± 2 °C (73.4 ± 3.6 °F), 50 ± 10 % relative humidity, and at an air velocity of approximately 183 m/min (600 ft/min) horizontally across the surface of the test specimen. Test the film with the finger using moderate pressure. Consider the film to be dry when the soft tacky condition no longer exists and the film feels firm.

10.3.4 *Precision and Bias*—The precision for this procedure is still being determined. The value of drying time can be defined only in terms of a test method; therefore, no statement of bias is being made.

10.4 *Long-Term Settling Test*—Use Test Method D 1309 for routine testing. In the case of dispute, use Test Method D 869.

10.5 *Nonvolatile Content Test*—Test in accordance with Test Method D 2369.

11. Packaging and Package Marking

11.1 The liquid membrane-forming compound shall be delivered in the manufacturer's original, clean, sealed containers. Each container shall be legibly marked with the name of the manufacturer, the trade name of the liquid membrane-forming compound, the type of liquid membrane-forming compound and class of solids, the nominal percentage of nonvolatile material, and the manufacturer's batch or lot number (Note 9). The manufacturer will assign batch or lot numbers to the quantity of membrane-forming compound mixed, sampled, and tested as a single lot. The manufacturer shall exercise care in filling the containers so that all are equally representative of the compound produced.

NOTE 9—The listing of the nominal percentage of nonvolatile material by the manufacturer, and the reporting of this information on the identification accompanying the sample, will assist the testing agency in determining whether the compound in the containers was adequately stirred and the sample is reasonably representative of the membrane-forming compound produced. Type 2 membrane-forming compounds are especially prone to separation due to settling of the pigment.

12. Keywords

12.1 concrete curing; liquid membrane-forming compounds for curing concrete

SUMMARY OF CHANGES

Committee C09 has identified the location of selected changes to this specification since the last issue, C 309 – 06, that may impact the use of this specification. (Approved June 1, 2007)

(*1*) Added new paragraph 1.5.

(*2*) Deleted old 5.7, 10.6, 10.7, and Footnote 3.

Committee C09 has identified the location of selected changes to this specification since the last issue, C 309 – 03, that may impact the use of this specification. (Approved June 1, 2006)

(*1*) Added new Note 1 and renumbered subsequent notes.

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Designation: C 309 – 07

Standard Specification for Liquid Membrane-Forming Compounds for Curing Concrete[1]

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This standard has been approved for use by agencies of the Department of Defense.

1. Scope*

1.1 This specification covers liquid membrane-forming compounds suitable for application to concrete surfaces to reduce the loss of water during the early-hardening period. White-pigmented membrane-forming compounds serve the additional purpose of reducing the temperature rise in concrete exposed to radiation from the sun. The membrane-forming compounds covered by this specification are suitable for use as curing media for fresh concrete, and may also be used for further curing of concrete after removal of forms or after initial moist curing.

NOTE 1—This specification addresses only those properties listed in Sections 5 through 8. Membrane-forming compounds with special properties including better water retention, minimum solids content, resistance to ultraviolet radiation, acid and alkali resistance and non-interference with adhesives are described in Specification C 1315.

NOTE 2—Solutions of silicate salts are chemically reactive in concrete rather than membrane-forming; therefore, they do not meet the intent of this specification.

1.2 The values stated in SI units are to be regarded as the standard. The values given in parentheses are provided for informational purposes only.

1.3 The following precautionary caveat pertains only to the test methods portion, Section 10, of this specification: *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

1.4 The text of this standard references notes and footnotes which provide explanatory material. These notes and footnotes shall not be considered as requirements of the standard.

1.5 This is a performance specification. The allowable composition of products covered by this specification is limited by various local, regional, and national regulations. Issues related to air quality (solvent emission), worker exposure, and other hazards are not addressed here. It is the responsibility of the producers and users of these materials to comply with pertinent regulations.

Warning—Some VOC exempt solvents used to meet the regulations are extremely flammable with low auto ignition temperatures and rapid evaporation rates. Consult the manufacturer's product information sheet for important application and safety information.

2. Referenced Documents

2.1 *ASTM Standards:* [2]

C 156 Test Method for Water Retention by Liquid Membrane-Forming Curing Compounds for Concrete

C 1315 Specification for Liquid Membrane-Forming Compounds Having Special Properties for Curing and Sealing Concrete

D 869 Test Method for Evaluating Degree of Settling of Paint

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D 1309 Test Method for Settling Properties of Traffic Paints During Storage

D 2369 Test Method for Volatile Content of Coatings

E 1347 Test Method for Color and Color-Difference Measurement by Tristimulus Colorimetry

3. Classification

3.1 The following types of liquid membrane-forming compounds are included:

3.1.1 *Type 1*—Clear or translucent without dye,

3.1.2 *Type 1-D*—Clear or translucent with fugitive dye, and

3.1.3 *Type 2*—White pigmented.

3.2 The solids dissolved in the vehicle shall be one of the following classes:

3.2.1 *Class A*—No restrictions,

3.2.2 *Class B*—Must be a resin as defined in Terminology D 883.

NOTE 3—Permanent colors other than white, or other special attributes,

[1] This specification is under the jurisdiction of ASTM Committee C09 on Concrete and Concrete Aggregates and is the direct responsibility of Subcommittee C09.22 on Materials Applied to New Concrete Surfaces.

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are beyond the scope of this specification and are subject to negotiation between the purchaser and the supplier.

4. Ordering Information

4.1 The purchaser shall include the following information in the purchase order when applicable:

4.1.1 Type of liquid membrane-forming compound and class of solids to be furnished, and

4.1.2 Rate of application to be used to determine conformance to this specification. If not specified, the liquid membrane-forming material shall be applied at a rate of 5.0 m^2/L (200 ft^2/gal) for testing purposes.

NOTE 4—The application rate used for testing may, or may not, be the same as the rate to be used for field application. Many agencies use the same rate for field application on relatively smooth surfaces as the rate used for testing, while requiring a substantially greater field application rate on deeply textured surfaces.

4.1.3 The intended method of application (for example, spraying, brushing, or by roller). If not specified, the material shall be of a sprayable consistency.

4.1.4 Maximum permissible volatile organic compound (VOC) content if required by applicable regulations.

5. General Requirements

5.1 Liquid membrane-forming compound Types 1 and 1-D shall be clear or translucent. Membrane-forming compounds with a fugitive dye (Type 1-D) shall be readily distinguishable upon the concrete surface for at least 4 h after application but shall become inconspicuous within 7 days after application if exposed to direct sunlight.

NOTE 5—No laboratory test for the fugitive characteristic of the color in dyed (Type 1-D) compounds is provided in this specification. The disappearance of these colors is strongly dependent on the nature of the exposure and the rate of application of the compounds.

5.2 Type 2 liquid membrane-forming compounds shall consist of finely-divided white pigment and vehicle, ready-mixed for immediate use as is. The membrane-forming compound shall present a uniform white appearance when applied uniformly to a new concrete surface at the specified rate of application.

5.3 Liquid membrane-forming compounds shall be of such a consistency that they can be readily applied by spraying, or by brushing or rolling, when specified, to a uniform coating at temperatures above 4 °C (40 °F).

NOTE 6—For uniform application in the field on vertical concrete surfaces, the specified rate of application may be achieved by two coats applied at an interval of approximately 1 h.

5.4 Liquid membrane-forming compounds shall adhere to freshly placed concrete that has stiffened or set sufficiently to resist marring during application, and to damp, hardened concrete, and shall form a continuous film when applied at the specified rate of application.

5.5 Liquid membrane-forming compounds shall not react deleteriously with concrete. Deleterious reactions are detected by scratching the surface of a mortar specimen (used for the water-retention test) with a knife or screwdriver, not less than 72 h after application, and comparing with the surface hardness similarly determined of a similar specimen that has been moist-cured for approximately half as long. Any softening of the liquid membrane-forming compound-treated surface indicated by such a comparison shall be considered sufficient cause for rejection of the compound.

NOTE 7—Testing for deleterious reactions need only be done for curing compounds of a new or unknown composition.

5.6 Liquid membrane-forming compounds shall be storable for at least 6 months without deterioration, except compounds of the water-emulsion type will not be expected to resist freezing. Type 2 liquid membrane-forming compounds shall not settle out excessively or cake in the container, and shall be capable of being mixed to a uniform consistency by moderate stirring or agitation. When tested for long-term settling, as stated in 10.4, the compound shall have a rating of not less than four.

6. Water Retention Properties

6.1 Liquid membrane-forming compounds, when tested in accordance with 10.1, shall restrict the loss of water to not more than 0.55 kg/m^2 in 72 h.

7. Reflectance Properties

7.1 Type 2 liquid membrane-forming compounds, when tested in accordance with 10.2, shall exhibit a daylight reflectance of not less than 60 %.

8. Drying Time Requirement

8.1 Liquid membrane-forming compounds, when tested in accordance with 10.3, shall dry to touch in not more than 4 h.

9. Sampling

9.1 Samples shall be taken either at the plant or warehouse prior to delivery, or at the point of delivery, at the option of the purchaser. If sampling is done prior to shipment, the inspector representing the purchaser shall have free access to the materials being sampled and shall be afforded all reasonable facilities for inspection and sampling.

9.2 Shake or thoroughly stir liquid membrane-forming compounds before taking a sample. Take one sample for each lot, batch, or other unit of production in a shipment. If the liquid membrane-forming compound is in mixing tanks or vats, one third of the sample shall represent the material coming from the tank at the beginning of the filling operation, one third shall represent the material coming at the middle of the filling operation, and one third shall represent the material coming at the end of the filling operation. If the liquid membrane-forming compound to be sampled is in containers, obtain a sample by taking a portion out of a number of containers equal in number to the next integer larger than the cube root of the total number of containers in the lot.

9.3 Seal all of the filled containers represented by the sample to prevent leakage, substitution, or dilution. The sampling agency shall mark each container represented by the sample with a suitable identification mark for later identification and correlation.

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10. Test Methods

10.1 *Water Retention Test*—Using the application rate specified by the purchaser, or 5.0 m^2/L (200 ft^2/gal) if no rate is specified, test for water retention using Test Method C 156.

10.2 *Reflectance Test*—For Type 2 compounds, on completion of the water retention test, determine the daylight reflectance of the specimens in accordance with Test Method E 1347.

NOTE 8—Daylight reflectance is total luminous reflectance factor, CIE tristimulus value Y for CIE 1931 (2°) standard observer and CIE standard illuminant C or D56.

10.3 *Drying Time Test*:

10.3.1 *Scope*—This test method is used to determine the length of time for a liquid membrane-forming curing compound to dry to the touch and develop into a film that will not track off the concrete.

10.3.2 *Significance and Use*—The ability of a liquid membrane-forming curing compound to dry in a suitable length of time ensures the user of the ability to perform other tasks on the concrete, such as sawing joints, and so forth, without lifting the membrane from the concrete by tracking.

10.3.3 *Procedure*—Apply the membrane-forming compound to a fresh mortar specimen at the specified rate of application and expose it to air at 23 ± 2 °C (73.4 ± 3.6 °F), 50 ± 10 % relative humidity, and at an air velocity of approximately 183 m/min (600 ft/min) horizontally across the surface of the test specimen. Test the film with the finger using moderate pressure. Consider the film to be dry when the soft tacky condition no longer exists and the film feels firm.

10.3.4 *Precision and Bias*—The precision for this procedure is still being determined. The value of drying time can be defined only in terms of a test method; therefore, no statement of bias is being made.

10.4 *Long-Term Settling Test*—Use Test Method D 1309 for routine testing. In the case of dispute, use Test Method D 869.

10.5 *Nonvolatile Content Test*—Test in accordance with Test Method D 2369.

11. Packaging and Package Marking

11.1 The liquid membrane-forming compound shall be delivered in the manufacturer's original, clean, sealed containers. Each container shall be legibly marked with the name of the manufacturer, the trade name of the liquid membrane-forming compound, the type of liquid membrane-forming compound and class of solids, the nominal percentage of nonvolatile material, and the manufacturer's batch or lot number (Note 9). The manufacturer will assign batch or lot numbers to the quantity of membrane-forming compound mixed, sampled, and tested as a single lot. The manufacturer shall exercise care in filling the containers so that all are equally representative of the compound produced.

NOTE 9—The listing of the nominal percentage of nonvolatile material by the manufacturer, and the reporting of this information on the identification accompanying the sample, will assist the testing agency in determining whether the compound in the containers was adequately stirred and the sample is reasonably representative of the membrane-forming compound produced. Type 2 membrane-forming compounds are especially prone to separation due to settling of the pigment.

12. Keywords

12.1 concrete curing; liquid membrane-forming compounds for curing concrete

SUMMARY OF CHANGES

Committee C09 has identified the location of selected changes to this specification since the last issue, C 309 – 06, that may impact the use of this specification. (Approved June 1, 2007)

(*1*) Added new paragraph 1.5.

(*2*) Deleted old 5.7, 10.6, 10.7, and Footnote 3.

Committee C09 has identified the location of selected changes to this specification since the last issue, C 309 – 03, that may impact the use of this specification. (Approved June 1, 2006)

(*1*) Added new Note 1 and renumbered subsequent notes.

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Designation: C 311 – 07

Standard Test Methods for Sampling and Testing Fly Ash or Natural Pozzolans for Use in Portland-Cement Concrete[1]

This standard is issued under the fixed designation C 311; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

This standard has been approved for use by agencies of the Department of Defense.

1. Scope*

1.1 These test methods cover procedures for sampling and testing fly ash and raw or calcined pozzolans for use in portland-cement concrete.

1.2 The procedures appear in the following order:

	Sections
Sampling	7
CHEMICAL ANALYSIS	
Reagents and apparatus	10
Moisture content	11 and 12
Loss on ignition	13 and 14
Silicon dioxide, aluminum oxide, iron oxide, calcium oxide, magnesium oxide, sulfur trioxide, sodium oxide and potassium oxide	15
Available alkali	16 and 17
Ammonia	18
PHYSICAL TESTS	
Density	19
Fineness	20
Increase of drying shrinkage of mortar bars	21-23
Soundness	24
Air-entrainment of mortar	25 and 26
Strength activity index with portland cement	27-30
Water requirement	31
Effectiveness of Fly Ash or Natural Pozzolan in Controlling Alkali-Silica Reactions	32
Effectiveness of Fly Ash or Natural Pozzolan in Contributing to Sulfate Resistance	34

1.3 The values stated in SI units are to be regarded as the standard. The values given in parentheses are provided for information purposes only.

1.4 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

1.5 The text of this standard references notes and footnotes that provide explanatory information. These notes and footnotes (excluding those in tables) shall not be considered as requirements of this standard.

2. Referenced Documents

2.1 *ASTM Standards:* [2]

C 33 Specification for Concrete Aggregates

C 109/C 109M Test Method for Compressive Strength of Hydraulic Cement Mortars (Using 2-in. or [50-mm] Cube Specimens)

C 114 Test Methods for Chemical Analysis of Hydraulic Cement

C 150 Specification for Portland Cement

C 151 Test Method for Autoclave Expansion of Hydraulic Cement

C 157/C 157M Test Method for Length Change of Hardened Hydraulic-Cement Mortar and Concrete

C 185 Test Method for Air Content of Hydraulic Cement Mortar

C 188 Test Method for Density of Hydraulic Cement

C 204 Test Methods for Fineness of Hydraulic Cement by Air-Permeability Apparatus

C 226 Specification for Air-Entraining Additions for Use in the Manufacture of Air-Entraining Hydraulic Cement

C 227 Test Method for Potential Alkali Reactivity of Cement-Aggregate Combinations (Mortar-Bar Method)

C 430 Test Method for Fineness of Hydraulic Cement by the 45-μm (No. 325) Sieve

C 441 Test Method for Effectiveness of Pozzolans or Ground Blast-Furnace Slag in Preventing Excessive Expansion of Concrete Due to the Alkali-Silica Reaction

C 618 Specification for Coal Fly Ash and Raw or Calcined Natural Pozzolan for Use in Concrete

C 670 Practice for Preparing Precision and Bias Statements for Test Methods for Construction Materials

C 778 Specification for Standard Sand

C 1012 Test Method for Length Change of Hydraulic-Cement Mortars Exposed to a Sulfate Solution

C 1157 Performance Specification for Hydraulic Cement

C 1437 Test Method for Flow of Hydraulic Cement Mortar

D 1426 Test Methods for Ammonia Nitrogen In Water

[1] These test methods are under the jurisdiction of ASTM Committee C09 on Concrete and Concrete Aggregates and are the direct responsibility of Subcommittee C09.24 on Supplementary Cementitious Materials.

Current edition approved Dec. 15, 2007. Published January 2008. Originally approved in 1953. Last previous edition approved in 2005 as C 311 – 05.

[2] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

***A Summary of Changes section appears at the end of this standard.**

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D 4326 Test Method for Major and Minor Elements in Coal and Coke Ash By X-Ray Fluorescence

2.2 *ACI Document:*[3]

ACI 201.2R Guide to Durable Concrete

3. Terminology

3.1 *Definitions of Terms Specific to This Standard:*

3.1.1 *composite sample*—a sample that is constructed by combining equal portions of grab or regular samples.

3.1.2 *established source*—a source for which at least six months of continuous production quality assurance records from a test frequency required for a new source are available, sampled at the source.

3.1.3 *grab sample*—a sample that is taken in a single operation from a conveyor delivering to bulk storage, from bags, or from a bulk shipment. Such a sample may, or may not, reflect the composition or physical properties of a single lot of fly ash or natural pozzolan. This type of sample can be used to characterize small amounts of material.

3.1.4 *jobsite or new source*—a source for which less than six months of production records are available, sampled at the source.

3.1.5 *lot*—specific quantity of fly ash or natural pozzolan offered for inspection at any one time. A lot may be one storage bin or the contents of one or more transport units representing material drawn from the same storage bin.

3.1.6 *regular sample*—a sample that is constructed by combining equal portions of grab samples that were taken at predetermined times or locations from any single lot of material.

4. Significance and Use

4.1 These test methods are used to develop data for comparison with the requirements of Specification C 618. These test methods are based on standardized testing in the laboratory and are not intended to simulate job conditions.

4.1.1 *Strength Activity Index*—The test for strength activity index is used to determine whether fly ash or natural pozzolan results in an acceptable level of strength development when used with hydraulic cement in concrete. Since the test is performed with mortar, the results may not provide a direct correlation of how the fly ash or natural pozzolan will contribute to strength in concrete.

4.1.2 *Chemical Tests*— The chemical component determinations and the limits placed on each do not predict the performance of a fly ash or natural pozzolan with hydraulic cement in concrete, but collectively help describe composition and uniformity of the material.

5. Materials

5.1 *Graded Standard Sand*—The sand used for making test specimens for the activity index with lime or portland cement shall be natural silica sand conforming to the requirements for graded standard sand in Specification C 778.

NOTE 1—*Segregation of Graded Sand*—The graded standard sand should be handled in such a manner as to prevent segregation, since variations in the grading of the sand cause variations in the consistency of the mortar. In emptying bins or sacks, care should be exercised to prevent the formation of mounds of sand or craters in the sand, down the slopes of which the coarser particles will roll. Bins should be of sufficient size to permit these precautions. Devices for drawing the sand from bins by gravity should not be used.

5.2 *Hydrated Lime*— The hydrated lime used in the tests shall be reagent-grade calcium hydroxide, 95 % minimum calculated as $Ca(OH)_2$(Note 2), and have a minimum fineness of 2500 m^2/kg as determined in accordance with Test Method C 204.

NOTE 2—The calcium hydroxide should be protected from exposure to carbon dioxide. Material remaining in an opened container after a test should not be used for subsequent tests.

5.3 *Portland Cement*— The portland cement used in the Strength Activity Index with Portland Cement test shall comply with the requirements of Specification C 150 and have a minimum compressive strength of 35 MPa (5000 psi) at 28 days and total alkalies ($Na_2O + 0.658\ K_2O$) not less than 0.50 % nor more than 0.80 %.

5.3.1 The use of a locally available portland cement in the Strength Activity Index or a project cement that does not meet the requirements of the section on Materials is permitted when the variations from the requirements of the section on Materials are reported and when the use of such portland cement is requested.

6. Sample Type and Size

6.1 Grab samples and regular samples shall have a mass of at least 2 kg (4 lb).

6.2 Grab samples or regular samples taken at prescribed intervals over a period of time (see Table 1), may be combined to form a composite sample representative of the fly ash or natural pozzolan produced during that period of time.

6.3 Composite samples shall have a mass of at least 4 kg (8 lb).

6.4 The sampling shall be done by, or under the direction of, a responsible representative of the purchaser.

7. Sampling Procedure

7.1 The fly ash or natural pozzolan may be sampled by any one of the following methods:

7.1.1 *From Bulk Storage at Point of Discharge or from Rail Cars and Road Tankers*—A sample may be taken by siphon

TABLE 1 Minimum Sampling and Testing Frequency[A]

Test	Sample Type	Jobsite or New Source[B]	Established Source[B]
Moisture content Loss on ignition Fineness	Regular	Daily or each 90 Mg[C] (100 Tons)	Daily or each 360 Mg[C] (400 Tons)
Density and the other tests in Specification C 618, Tables 1 and 2	Composite	Monthly or each 1 800 Mg[C] (2 000 Tons)	Monthly or each 2 900 Mg[C] (3 200 Tons)

[A] It should be noted that the minimum test frequency given in Table 1 is not necessarily the frequency needed for quality control programs on some fly ash or natural pozzolans.

[B] For definitions, refer to the Terminology section.

[C] Whichever comes first.

[3] Available from American Concrete Institute (ACI), P.O. Box 9094, Farmington Hills, MI 48333-9094, http://www.aci-int.org.

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tube during loading or by sampling tube from each loaded car or tanker. If the load is sampled at the point of discharge into the rail car or tanker, the top surface shall be removed to a depth of at least 200 mm (8 in.) before sampling. The sample shall be identified with at least the date and shipment number.

7.1.2 *From Bags in Storage*—The regular sample shall comprise increments of equal size taken by sampling tube from three bags selected at random from one lot of bagged material. The sample shall be identified with date and lot number.

7.1.3 *From Conveyor Delivering to Bulk Storage*—Take one sample of 2 kg (4 lb) or more of the material passing over the conveyor. This may be secured by taking the entire test sample in a single operation, known as the grab sample method, or by combining several equal portions taken at regular intervals, known as the regular sample method. Automatic samplers may be used to obtain samples.

7.2 Samples shall be treated as described in Section 8.

NOTE 3—Some methods of loading or delivery of fly ash or natural pozzolan, particularly from an airstream or conveyor belt, may create stratification or segregation in the material stream. Sampling techniques must be designed to ensure that the sample is representative of the material shipped.

8. Preparation and Storage of Samples

8.1 Prepare composite samples for the tests required in Section 9, by arranging all grab or regular samples into groups covering the period or quantity to be represented by the sample. Take equal portions from each, sufficient to produce a composite sample large enough for the tests required. Mix the composite sample thoroughly.

8.2 Samples shall be stored in clean, airtight containers identified with the source and lot or period of time represented. Untested portions of the sample shall be retained for at least one month after all test results have been reported.

9. Testing Frequency

9.1 *General*—When required, the purchaser shall specify the amount of testing for available alkalies, reactivity with cement alkalies, drying shrinkage, and air-entrainment. Make all other tests on regular or composite samples chosen as specified in Table 1.

CHEMICAL ANALYSIS

10. General

10.1 All apparatus, reagents and techniques shall comply with the requirements of Test Methods C 114.

10.2 *Purity of Water*— Unless otherwise indicated, references to water shall be understood to mean distilled water or water of equal purity.

MOISTURE CONTENT

11. Procedure

11.1 Dry a weighed sample, as received, to constant weight in an oven at 105 to 110 °C (221 to 230 °F).

12. Calculation

12.1 Calculate the percentage of moisture to the nearest 0.1 %, as follows:

$$\text{Moisture content, \%} = (A/B) \times 100 \quad (1)$$

where:

A = mass loss during drying, and
B = mass as received.

LOSS ON IGNITION

13. Procedure

13.1 Determine loss on ignition in accordance with the procedures outlined in Test Methods C 114, except that the material remaining from the determination of moisture content shall be ignited to constant mass in an uncovered porcelain, not platinum, crucible at 750 ± 50 °C (1382 ± 190 °F).

14. Calculation

14.1 Calculate the percentage of loss on ignition to the nearest 0.1, as follows:

$$\text{Loss on ignition, \%} = (A/B) \times 100 \quad (2)$$

where:

A = loss in mass between 105 and 750 °C (221 and 1382 °F),
B = mass of moisture-free sample used.

SILICON DIOXIDE, ALUMINUM OXIDE, IRON OXIDE, CALCIUM OXIDE, MAGNESIUM OXIDE, SULFUR TRIOXIDE, SODIUM OXIDE AND POTASSIUM OXIDE

15. Procedure

15.1 Determine the percentages of these oxides as required in accordance with the applicable sections of Test Methods C 114 for materials having an insoluble residue greater than 1 % (Note 4). Analysts performing sodium oxide and potassium oxide determinations shall observe the precautions outlined in the applicable section of Performance Specification C 1157 (refer to the section on Test Methods). Most pozzolans dissolve completely in lithium borate fluxes.

NOTE 4—Rapid and instrumental methods may be employed similar to those in Test Methods C 114 and D 4326.

AVAILABLE ALKALI

16. Procedure

16.1 Weigh 5.0 g of the sample and 2.0 g of hydrated lime on a piece of weighing paper, carefully mix using a metal spatula, and transfer to a small plastic vial of approximately 25-mL capacity. Add 10.0 mL of water to this mixture, seal the vial by securing the cap or lid to the vial with tape (Note 5), blend by shaking until the mixture is uniform, and store at 38 ± 2 °C.

NOTE 5—To ensure that moisture loss from the paste does not occur, place the sealed vial in a sealable container (such as a small sample or mason jar), add sufficient water to cover the bottom of the container, and seal.

16.2 Open the vial at the age of 28 days and transfer the contents to a 250-mL casserole. Break up and grind the cake with a pestle, adding a small amount of water, if necessary, so that a uniform slurry containing no lumps is obtained (Note 6). Add sufficient water to make the total volume 200 mL. Let

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stand 1 h at room temperature with frequent stirring. Filter through a medium-textured filter paper onto a 500-mL volumetric flask. Wash thoroughly with hot water (eight to ten times).

NOTE 6—At times it may be necessary to break the vial and peel off the plastic from the solid cake. In such cases, care should be exercised to avoid the loss of material and to remove all solid material from the fragments of the vial. If the cake is too hard to break up and grind in the casserole, a mortar should be used.

16.3 Neutralize the filtrate with dilute HCl (1 + 3), using 1 to 2 drops of phenolphthalein solution as the indicator. Add exactly 5 mL of dilute HCl (1 + 3) in excess. Cool the solution to room temperature and fill the flask to the mark with distilled water. Determine the amount of sodium and potassium oxides in the solution using the flame photometric procedure, described in Test Methods C 114, except that the standard solutions shall be made up to contain 8 mL of calcium chloride ($CaCl_2$) stock solution per litre of standard solution, and the solution as prepared shall be used in place of the solution of cement.

NOTE 7—The standard solutions made up with 8 mL of calcium chloride ($CaCl_2$) stock solution contain the equivalent of 504 ppm of CaO. Tests have shown that this amount closely approximates the amount of calcium dissolved in the test solution.

17. Calculation and Report

17.1 Calculate the results as weight percent of the original sample material. Report as equivalent percentage of sodium oxide (Na_2O), calculated as follows:

$$\text{Equivalent } Na_2O, \% = Na_2O, \% + 0.658 \times K_2O, \% \quad (3)$$

AMMONIA

18. Procedure

18.1 Weigh 1.00 g of the fly ash sample into a 125 mL Erlenmeyer flask. Add 100 mL of ammonia-free water. Place a neoprene rubber stopper on the flask and swirl the contents to thoroughly mix the sample and the water.

18.2 Filter the mixture using a medium-textured filter paper and save the filtrate for the ammonia determination.

18.3 Determine the concentration of ammonia in the filtrate in accordance with the procedures outlined in Test Methods D 1426, Method A–Direct Nesslerization or Method B–Selective Ion Electrode.

18.4 Calculate the ammonia concentration of the fly ash as follows:

$$Ammonia, mg/kg = N_W \times V_W / W_{fa} \quad (4)$$

where:

N_W = ammonia concentration of the water extract determined by Test Methods D 1426, mg/L,
V_W = volume of water used for extracting ammonia from the fly ash sample, mL, and
W_{fa} = Mass of fly ash sample used in the test, g.

PHYSICAL TESTS

DENSITY

19. Procedure

19.1 Determine the density of the sample in accordance with the procedure described in Test Method C 188, except use about 50 g of fly ash or natural pozzolan instead of approximately 64 g of cement as recommended in Test Method C 188.

FINENESS, AMOUNT RETAINED WHEN WET-SIEVED ON A 45-μm (NO. 325) SIEVE

20. Procedure

20.1 Determine the amount of the sample retained when wet-sieved on a 45-μm (No. 325) sieve, in accordance with Test Method C 430, with the following exceptions.

20.1.1 Calibrate the 45-μm (No. 325) sieve using a cement standard (SRM 114). Calculate the sieve correction factors as follows:

$$CF = std - obs \quad (5)$$

where:

CF = the sieve correction factor, %, (include a negative sign when appropriate),
std = the certified residue value for the SRM, %, and
obs = the observed residue value for the SRM, %.

20.1.2 Calculate the fineness of the fly ash or natural pozzolan to the nearest 0.1 % as follows:

$$R_C = R_S + CF \quad (6)$$

where:

R_C = corrected sieve residue, %,
R_S = observed residue for the test sample, %, and
CF = the sieve correction factor, %.

If the residue retained for the test sample is equal to zero ($R_S = 0$), then the sieve correction factor shall not be added to the test result to calculate the corrected sieve residue. In such cases, the corrected fineness shall be reported as zero.

NOTE 8—Test Method C 430 has been adopted for testing fly ash fineness. However, certain requirements, such as cleaning of sieves and interpretation of the test results, are sometimes not appropriate for fly ashes.

20.2 Numerical examples for calibrating a fineness sieve and calculating the corrected fineness.

20.2.1 Calibrating a fineness sieve (NIST standard reference material SRM 114p was used in this example):

Certified residue retained on a 45−*μm sieve*
= 8.24 % (*obtained from standard certificate*)

Measured residue retained on a 45−*μm sieve*
= 7.12 % (*measured in the laboratory*)

Correction factor (*CF*) = *standard value* (*std*) – *observed value* (*obs*)
= 8.24 – 7.12
= 1.12 %

20.2.2 Calculating a corrected fineness value for a calibrated sieve (fly ash A was used in this example):

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Amount of fly ash A retained on the sieve: R_s
= 15.2 % (*expressed as a % of sample mass*)

Corrected sieve residue for fly ash A: $R_c = R_s + CF$
= 15.2 + 1.12
= 16.3 %

INCREASE OF DRYING SHRINKAGE OF MORTAR BARS

21. Test Specimen

21.1 Prepare test specimens in accordance with the procedures described in Test Method C 157/C 157M, except mold three mortar bars from both the control mix and the test mix using the following proportions:

	Control Mix	Test Mix
Portland cement, g	500	500
Fly ash or natural pozzolan, g	None	125
Graded standard sand, g	1375	1250
Water	sufficient to produce a flow of 100 to 115 %	

22. Procedure

22.1 Cure and measure the test specimens in accordance with Test Method C 157/C 157M, except that the moist-curing period (including the period in the molds) shall be 7 days, and the comparator reading at the age of 24 ± ½ h shall be omitted. Immediately after taking the comparator reading at the end of the 7-day moist-curing period, store the specimens in accordance with Test Method C 157/C 157M, and after 28 days of air storage, take a comparator reading for the specimens in accordance with Test Method C 157/C 157M.

23. Calculation and Report

23.1 Calculate the increase in drying shrinkage of the mortar bars, S_i, as follows:

$$S_i = S_t - S_c \quad (7)$$

where:

S_t = average drying shrinkage of the test specimens calculated as follows, and
S_c = average drying shrinkage of the control specimens calculated as follows:

$$S = \frac{[\text{initial CRD} - \text{CRD}] \times 100}{G} \quad (8)$$

where:

S = drying shrinkage of test or control specimens, %,
initial CRD = difference between the comparator reading of the specimen and the reference bar at 7 days of moist curing,
CRD = difference between the comparator reading of the specimen and the reference bar at 28 days of drying, and
G = the gage length of the specimens 250 mm (10 in.).

23.2 Report the results to the nearest 0.01. If the average drying shrinkage of the control specimens is larger than the average drying shrinkage of the test specimens, prefix a minus sign to the increase of drying shrinkage of mortar bars reported.

SOUNDNESS

24. Procedure

24.1 Conduct the soundness test in accordance with Test Method C 151, except that the specimens shall be molded from a paste composed of 25 parts by weight of fly ash or natural pozzolan and 100 parts by weight of a portland cement conforming to Specification C 150.

AIR-ENTRAINMENT OF MORTAR

25. Procedure

25.1 Using portland cement conforming to the requirements for Type I or Type II of Specification C 150, prepare a test mixture in accordance with Test Method C 185, using the following proportions:

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	Test Mix
Portland cement, g	300
Fly ash or natural pozzolan	75
20–30 standard sand, g	1125
Water, mL, sufficient to give a flow of 80 to 95	Y
Neutralized Vinsol resin solution, mL,[A] sufficient to produce an air content of 18 ± 3 %	Z

[A] The amount of Vinsol resin solution used shall be considered as part of the mixing water.

25.2 The neutralized Vinsol resin solution used in this section on Air-Entrainment of Mortar shall be either a commercial neutralized Vinsol resin solution or a neutralized Vinsol resin solution prepared in accordance with Specification C 226. If it is necessary to dilute either of these solutions, use distilled or demineralized water. (Note 9.)

NOTE 9—Dissolved minerals in drinking water may precipitate Vinsol resin solutions and greatly diminish its air-entraining characteristics.

25.3 Prepare two test mixtures with sufficient neutralized Vinsol resin to produce an air content of 15 to 18 % in the first mix and 18 to 21 % in the second mix. Then, determine by interpolation the amount of Vinsol resin, expressed as weight percent of the cement, required to produce an air content of 18 %.

26. Calculation

26.1 Calculate the air content of the test mixtures as follows:

$$\text{Air content, volume } \% = 100[1-(W_a/W_c)] \quad (9)$$

$$W_a = W/400 \quad (10)$$

$$W_c = \frac{300+1125+75+(300 \times P \times 0.01)}{\left[\left(\frac{300}{3.15}\right)+\left(\frac{1125}{2.65}\right)+\left(\frac{75}{D}\right)+\left(\frac{300 \times P \times 0.01}{1}\right)\right]} \quad (11)$$

where:

W_a = actual weight per unit of volume of mortar as determined by Test Method C 185, g/mL,
W = weight of the specified 400 mL of mortar (see Test Method C 185), g,
W_c = theoretical weight per unit of volume, calculated on an air-free basis and using the values for density and quantities of the materials in the mix, g/mL,
P = percentage of mixing water plus Vinsol resin solution based on weight of cement, and
D = density of fly ash or natural pozzolan in the mixture, Mg/m^3.

STRENGTH ACTIVITY INDEX WITH PORTLAND CEMENT

27. Specimens

27.1 Mold the specimens from a control mixture and from a test mixture in accordance with Test Method C 109/C 109M. The portland cement used in the Strength Activity Index test shall comply with the requirements of Specification C 150 and with the alkali and strength limits given in the section on Materials. In the test mixture, replace 20 % of the mass of the amount of cement used in the control mixture by the same mass of the test sample. Make six-cube batches as follows:

27.1.1 Control Mixture:

500 g of portland cement
1375 g of graded standard sand
242 mL of water

27.1.2 Test Mixture:

400 g of portland cement
100 g of test sample
1375 g of graded standard sand
mL of water required for flow ± 5 of control mixture

27.2 *Number of Specimens*:

27.2.1 Since Specification C 618 specifies that "meeting the 7 day or 28 day Strength Activity Index will indicate specification compliance" only one age might be required. At the option of the producer or the user after preparing six-cube batches, only three cubes of control and test mixtures need to be molded for either 7 or 28 day testing.

28. Storage of Specimens

28.1 After molding, place the specimens and molds (on the base plates) in the moist room or closet at 23.0 ± 2.0 °C (73.4 ± 3 °F) for 20 to 24 h. While in the moist room or closet, protect the surface from dripping water. Remove the molds from the moist room or closet and remove the cubes from the molds. Place and store the cubes in saturated lime water as specified in Test Method C 109/C 109M.

NOTE 10—Take care to ensure against zones of stratification or pockets of variation in temperature in the curing chamber.

29. Compressive Strength Test

29.1 Determine the compressive strength, as specified in Test Method C 109/C 109M, of three specimens of the control mixture and three specimens of the test mixture at ages of 7 days, or 28 days, or both, depending upon how many specimens were molded as prescribed in the section on Number of Specimens.

30. Calculation

30.1 Calculate the strength activity index with portland cement as follows:

Strength activity index with portland cement =

$$(A/B) \times 100 \quad (11)$$

where:

A = average compressive strength of test mixture cubes, MPa (psi), and
B = average compressive strength of control mix cubes, MPa (psi).

WATER REQUIREMENT

31. Calculation

31.1 Calculate the water requirement for the Strength Activity Index with Portland Cement as follows:

Water requirement, percentage of control =

$$(Y/242 \times 100) \quad (12)$$

where:

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Y = water required for the test mixture to be ±5 of control flow.

EFFECTIVENESS OF FLY ASH OR NATURAL POZZOLAN IN CONTROLLING ALKALI SILICA-REACTIONS (SEE Appendix X1)

32. Procedure

32.1 Determine expansion of mortar made with a fly ash or natural pozzolan and a test cement as a percent of expansion of mortar made with low alkali cement in accordance with Test Method C 441 as modified in the following paragraphs:

32.1.1 *Control Mixture*— The control mixture will be made as required in Test Method C 441 except that the control cement shall have an alkali content (as equivalent Na_2O) less than 0.60 % (Note 11).

NOTE 11—Generally, the control cement should have an alkali content as equivalent Na_2O between 0.50 and 0.60 %. However, lower alkali control cement may be used, if desired, to demonstrate equivalence.

32.1.2 *Test Mixture Using Fly Ash or Natural Pozzolan*— The combined quantity of cement plus fly ash or natural pozzolan shall total 400 g (see Appendix X1). Use 900 g of borosilicate glass aggregate and sufficient mixing water to produce a flow between 100 and 115 % as determined in accordance with Test Method C 1437. The cement used in the test mixture shall have an alkali content greater than that of the cement in the control mixture (Note 12).

NOTE 12—Generally, this test cement will have an alkali content equal to or higher than that used in the job.

32.1.3 Store and measure specimens as required in Test Method C 227. Measure length of specimens at ages of 1 and 14 days.

33. Report

33.1 Include in the report for each test mixture comparison made:

33.1.1 The 14 day expansion of the test mixture as a percent of the control mixture at that age,

33.1.2 The identification and chemical analysis of the fly ash or natural pozzolan,

33.1.3 The mass percentage of fly ash or natural pozzolan based on the total mass of cement plus fly ash or natural pozzolan in the test mixture, and

33.1.4 The alkali content of control and test mixture cements as equivalent alkali ($Na_2O + 0.658\ K_2O$).

EFFECTIVENESS OF FLY ASH OR NATURAL POZZOLAN IN CONTRIBUTING TO SULFATE RESISTANCE

34. Procedure

34.1 Compare the length change of mortar bars with absolute expansion limits or compare the length change of mortar bars made with a control cement with the length change of mortar bars made with fly ash or natural pozzolan and a test cement, in accordance with Test Method C 1012, as modified in the following paragraphs. Results shall be evaluated using absolute limits (Procedure A) or the relative expansion limits (Procedure B) in Specification C 618, Table 2A.

34.2 *Control Mixture for Procedure A*—A control mixture is not mandatory since performance measured using Procedure A is based on maximum expansion of the test mixture. If a control mixture is made for Procedure A then proportion it as required in Test Method C 1012 using a cement meeting the requirements of Specification C 150, Type II or Type V.

34.3 *Test Mixture Using Fly Ash or Natural Pozzolan for Procedure A*—Make the combined quantity of cement plus fly ash or natural pozzolan, by mass, the same as the total cement content of the control mixture described in the Making Mortars section of Test Method C 1012. The proportion of fly ash or natural pozzolan may be varied using from 15 % to 50 %, by mass, of the total cement plus fly ash or natural pozzolan. Any type of portland cement may be used to prepare test mixtures.

34.4 *Control Mixture for Procedure B*—Make the control mixture for Procedure B as required in Test Method C 1012 with the cement that is proposed for use in the project or a cement that through performance or definition (Specification C 150, Section 1) is expected to give satisfactory results (or a cement for which the contribution to sulfate resistance is known and is satisfactory).

NOTE 13—The control cement should be chosen to give sulfate resistance for the expected level of sulfate exposure. Experience has shown that Type II cements are often used for moderate levels of exposure. Type V cement is commonly used for severe exposures (see X2.2 of Appendix X2).

34.5 *Test Mixture for Using Fly Ash or Natural Pozzolan for Procedure B*—Make the combined quantity of cement plus fly ash or natural pozzolan, by mass, the same as the total cement used in the control mixture. The proportion of fly ash or natural pozzolan may be varied from 15 % to 50 % of the total cement plus fly ash or natural pozzolan by mass. Any type of portland cement may be used to prepare test mixtures.

34.6 For either Procedure A or B, store and measure specimens as required in Test Method C 1012 for at least 6 months.

NOTE 14—Evaluation of the sulfate resistance of cementitious materials for use in certain situations or critical structures may require longer periods of storage and additional length measurements. Refer to Test Method C 1012 for guidance on this matter.

35. Report

35.1 In addition to the information required in Test Method C 1012, report the following information for each mixture comparison made:

35.2 For Procedure A, the age and expansion as a specific amount,

35.3 For Procedure B, the age and expansion as a percent of the control mixture at that age,

35.4 The identification and chemical analysis including C_3A content of the cements used in both the control and test mixtures,

35.5 The identification and chemical analysis of the fly ash or natural pozzolan used in the test mixtures,

35.6 The mass percentages of the fly ash or natural pozzolan based on the total mass of cement plus fly ash or natural pozzolan in the test mixture.

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TABLE 2 Within and Between Lab Precision Estimates for C 114 Methods Applied to the Analysis of Fly Ash[A]

Oxide	1s		d2s	
	W/L	B/L	W/L	B/L
SiO_2	0.62	0.86	1.75	2.45
Al_2O_3	1.46	2.29	4.12	6.48
Fe_2O_3				
<2 %	0.12	0.11	0.34	0.31
≥2 %	0.12	0.25	0.34	0.71
CaO	0.63	0.74	1.79	2.09
MgO	0.20	0.21	0.55	0.61
SO_3	0.10	0.16	0.28	0.45
Moisture	0.05	0.06	0.15	0.17
LOI	0.09	0.12	0.25	0.35

[A]The four values for SO_3 were editorially corrected to reflect updated research reports associated with this standard.

PRECISION AND BIAS

36. Precision and Bias

36.1 *Strength Activity Index Test*:

36.1.1 Precision was determined from two interlaboratory studies involving two Class C fly ashes, two Class F fly ashes, and one Class N pozzolan. Participating laboratories numbered 12 and 7 in the two studies.[4]

36.1.2 The single-operator standard deviation for the Strength Activity Index test has been found to be 3.7 % (1s). This does not appear to vary either with material or with test age, over the range of 7 to 28 days. Therefore, results of two properly conducted tests by the same operator on the same material should not differ by more than 10.5 % (d2s) of the average of the two results.

36.1.3 The multilaboratory standard deviation for the Strength Activity Index test has been found to be 4.5 % (1s). This does not appear to vary either with material or with test age, over the range of 7 to 28 days. Therefore, results of two properly conducted tests in different laboratories on the same material should not differ by more than 12.7 % (d2s) of the average of the two results.

36.1.4 Since there is no accepted reference material suitable for determining the bias for this procedure, no statement on bias is being made.

36.2 *Chemical Analysis*:

36.2.1 Precision and bias estimates for the test methods in C 114 when applied to the analysis of pozzolans were calculated from an interlaboratory study involving 7 laboratories each analyzing 4 NIST SRM fly ashes. A research report describing the results of this study is available from ASTM.[5]

36.2.2 *Precision*—Within-laboratory (W/L) and between-laboratory (B/L) estimates of standard deviation and estimates of maximum differences expected between duplicate determinations in 95 % of comparisons[6] are summarized in Table 2.

36.2.3 *Bias*—Statistically significant bias was found in the determination of CaO and MgO. CaO determinations averaged 0.46 % higher than the value certified for the SRM. MgO determinations averaged 0.19 % higher than the value certified for the SRM.

36.3 *Ammonia*:

36.3.1 Precision of Method A (Direct Nesslerization) – The single-laboratory coefficient of variation (repeatability) has been found to be 9.2 % (1s %). The reproducibility of this test method is being determined and will be available on or before July 2010.

36.3.2 Precision of Method B (Selective Ion Electrode) – The single-laboratory coefficient of variation (repeatability) has been found to be 7.4 % (1s %). The reproducibility of this test method is being determined and will be available on or before July 2010.

36.3.3 *Bias*—Since there is no accepted reference material suitable for determining the bias for these procedures, no statement on bias is being made.

37. Keywords

37.1 fly ash; natural pozzolan

[4] Supporting data have been filed at ASTM International Headquarters and may be obtained by requesting Research Report RR: C09-1001.

[5] Supporting data have been filed at ASTM International Headquarters and may be obtained by requesting Research Report RR: C09-1008.

[6] These values represent, respectively, the (1s) and (d2s) limits as described in Practice C 670.

APPENDIXES

(Nonmandatory Information)

X1. COMMENTARY ON SECTION 32

X1.1 Test procedures in Section 32 are designed to determine the effectiveness of fly ash, or natural pozzolan, in preventing excessive expansion resulting from a reaction between certain aggregates and alkalies in portland-cement mixtures. Tests are made in accordance with Test Method C 441 using:

X1.1.1 400 g of portland cement or a combined total of cement plus fly ash or natural pozzolan of 400 g,

X1.1.2 900 g of borosilicate glass, and

X1.1.3 Sufficient water to obtain a flow of 100 to 115 %.

X1.2 The control mixture is made with a low-alkali portland cement. The test mixture, made of a test percentage of the fly ash or natural pozzolan, can be made with the same cement or any other cement having an equivalent alkali content greater than 0.60 %.

X1.3 *Interpretation of Results*—The fly ash or natural pozzolan should be considered "effective" when used at

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percentages equal to or greater than the percentages used in the test mixture with cements having alkali contents that do not exceed by more than 0.05 percentage points the alkali content of the cement used in the test mixture.

X1.4 *Selection of the Percentage of Fly Ash or Natural Pozzolan*—It may be necessary to make test mixtures with several percentages of fly ash or natural pozzolan to determine the minimum amount necessary to be considered "effective" in reducing expansion to the level produced by the "control" low-alkali cement. The minimum amount of fly ash or natural pozzolan should be 15 % by weight of cementitious material.

X1.5 *Selection of the Alkali Content of the Cement Used in the Test Mixture*—In some instances it may not be necessary to demonstrate that the fly ash or natural pozzolan will reduce expansion, but rather that it will not increase expansion. In this instance the test and control mixtures should be made with the same low alkali cement used in the control mixture to better delineate any increase in expansion. The fly ash or natural pozzolan percentage used may need to be sufficiently high to demonstrate that the percentage exceeds the pessimum if such pessimum exists for the combination.

X1.6 *Selection of the Low Alkali Control Cement*—The test procedure in this test method and requirements in Specification C 618 are designed to measure the relative effectiveness of the fly ash or natural pozzolan in reducing expansion due to alkali-silica reactions. The effectiveness is a function of both the alkali content of the cement used in the test mixture and the percentage of fly ash or natural pozzolan. The higher the alkali content of the test mixture cement and the lower the percentage of fly ash or natural pozzolan used, the more effective the fly ash or natural pozzolan. This test procedure and the 100 % criterion of Specification C 618 can be used as a guide to enhance field performance of job mixtures if it is assumed that use of the low alkali control cement will prevent excessive expansion in service with materials proposed for use in the job. This is the situation when the aggregates proposed for use contain rapidly reactive constituents but do not exceed 0.05 % expansion in three months or 0.10 % expansion in six months when tested with the control cement in Test Method C 227. In such instances the control cement used in this test method should have an alkali content as required to control the expansive reactions of the aggregates being used, for example in the 0.50 to 0.60 % range. See the appendix to Specification C 33.

X1.6.1 Certain reactive aggregates have been identified which produce deleterious expansion after many years of service when used with cements with equivalent alkali contents well below 0.60 %. Often these reactive aggregates do not produce expansions in Test Method C 227 exceeding those discussed in the appendix of Specification C 33 until a much later age, perhaps one or two years. In such instances the use of a control cement with an alkali content significantly less than 0.60 % is appropriate.

X2. COMMENTARY ON SECTION 34

X2.1 The test procedures in Section 34 are designed to evaluate the performance of particular fly ashes or natural pozzolans in contributing to the resistance or durability of concrete in a sulfate environment. Tests are made on mortars in accordance with Test Method C 1012.

X2.2 The control mixture should be made with a cement that by performance or definition (Specification C 150, Section 1.1) is expected to give satisfactory results for the anticipated level of sulfate exposure. ACI 201.2R recommends Type II cement when the sulfate content, expressed as SO_4, is 0.10 to 0.20 percent in soils or 150 to 1500 ppm in waters. ACI 201.2R recommends Type V cements when the sulfate content, expressed as SO_4, is 0.20 to 2.0 % in soils, or 1500 to 10 000 ppm in waters. The test mixtures for both procedures may be made with varying percentages of fly ash or natural pozzolan. Test mixtures can use cements with equal or higher or lower C_3A contents that might not have given satisfactory results when used alone.

X2.3 *Interpretation of Results*—The absolute expansion limits used in Procedure A make it difficult to ascertain how the addition of fly ash or natural pozzolan influences sulfate resistance. However, as referenced in Test Method C 1012, research has indicated that mortars meeting the expansion criteria will perform adequately. Under Procedure B, the fly ash or natural pozzolan will be considered to be able to contribute to sulfate resistance if the expansion of the test mixture does not exceed that of the control mixture at an exposure time of at least 6 months. It is recommended that the proportion of fly ash or natural pozzolan used in the test mixture be the same one proposed for use in the project ± 2 %, and that the C_3A content of the project cement be equal to, or less than, that which was used in the test mixtures. See Appendix X1, Technical Background, Test Method C 1012.

X2.4 *Selection of the Percentage of Fly Ash or Natural Pozzolan*—It may be necessary to make test mixtures with several percentages of fly ash or natural pozzolan to determine the amount necessary to obtain adequate resistance to different concentrations of sulfates. Percentages used in a project should be within 2 % of those that are successful in the test mixtures or should be between two percentages that are successful.

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SUMMARY OF CHANGES

Committee C09 has identified the location of selected changes to these test methods since the last issue, C 311 – 05, that may impact the use of these test methods. (Approved December 15, 2007)

(*1*) Added paragraphs 20.2, 20.2.1, and 20.2.2.

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Designation: C 317/C 317M – 00 (Reapproved 2005)

Standard Specification for Gypsum Concrete[1]

This standard is issued under the fixed designation C 317/C 317M; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

This standard has been approved for use by agencies of the Department of Defense.

1. Scope*

1.1 This specification covers mill-mixed gypsum concrete, consisting essentially of calcined gypsum and suitable aggregate, requiring the addition of water only at the job site. Gypsum concrete is intended for use in the construction of poured-in-place roof decks or slabs. Two classes, based on the compressive strength and density, are covered.

1.2 The values stated in either inch-pound units or SI units are to be regarded separately as standard. The values stated in each system may not be exact equivalents; therefore, each system shall be used independently of the other. Combining values from the two systems may result in nonconformance with the standard.

2. Referenced Documents

2.1 *ASTM Standards:* [2]

C 11 Terminology Relating to Gypsum and Related Building Materials and Systems

C 28 Specification for Gypsum Plasters

C 35 Specification for Inorganic Aggregates for Use in Gypsum Plaster

C 472 Test Methods for Physical Testing of Gypsum, Gypsum Plasters and Gypsum Concrete

3. Terminology

3.1 Definitions of terms shall be in accordance with Terminology C 11.

4. Materials and Manufacture

4.1 Gypsum concrete shall consist of calcined gypsum to which is added aggregates, wood chips, or wood shavings in proportion to meet the applicable requirements of this specification.

4.2 *Calcined Gypsum*—Specification C 28.

4.3 *Aggregates*—Specification C 35.

4.4 *Wood Chips or Wood Shavings*, shall be dry wood, uniform and clean in appearance, passing a 1-in. [25-mm] sieve, and not more than 1/16 in. [1.5 mm] thick.

5. Physical Properties

5.1 *Setting Time*—Gypsum concrete shall set in not less than 20 min and not more than 90 min.

5.2 *Compressive Strength*—Gypsum concrete shall have the following compressive strength for the respective classes:

Class	Compressive Strength, min, psi [MPa]
A	500 [3.5]
B	1000 [7.0]

5.3 *Density*—Gypsum concrete, Class A, shall have a density of not more than 60 lb/ft^3[960 kg/m^3].

6. Sampling

6.1 Randomly select at least 1 % of the packages, but not less than five packages. Take samples from both the outer portion and the center of each package. Mix the samples so obtained to provide a composite sample of not less than 15 lb [6.5 kg]. Immediately place the sample in a clean, dry, airtight container for delivery to the laboratory.

7. Test Methods

7.1 Determine the physical properties of gypsum concrete in accordance with Test Methods C 472.

7.1.1 Determine the setting time by the Vicat method.

8. Inspection

8.1 Inspection of the gypsum concrete shall be agreed upon between the purchaser and the supplier as part of the purchase agreement.

9. Rejection

9.1 Rejection of gypsum concrete that fails to conform to the requirements of this specification shall be reported to the producer or supplier promptly and in writing. The notice of

[1] This specification is under the jurisdiction of ASTM Committee C11 on Gypsum and Related Building Materials and is the direct responsibility of Subcommittee C11.01 on Specifications and Test Methods for Gypsum Products.

Current edition approved May 1, 2005. Published June 2005. Originally approved in 1953. Last previous edition approved in 2000 as C 317 – 00.

[2] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

***A Summary of Changes section appears at the end of this standard.**

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rejection shall contain a statement documenting how the gypsum concrete has failed to conform to the requirements of this specification.

10. Certification

10.1 When specified in the purchase agreement, a producer's or supplier's report shall be furnished at the time of shipment certifying that the product is in compliance with this specification.

11. Packaging and Marking

11.1 Gypsum concrete shall be shipped dry and free of lumps.

11.2 When shipped for resale, the following information shall be legibly marked on each package or on a tag of suitable size attached thereto:

11.2.1 Name of the manufacturer or the seller,

11.2.2 Brand,

11.2.3 Description, and

11.2.4 Net and gross weight of the package.

12. Keywords

12.1 aggregates; calcined gypsum; gypsum; gypsum concrete

SUMMARY OF CHANGES

Committee C11 has identified the location of selected changes to this specification since the last issue, C 317/C 317M – 98, that may impact the use of this specification. (Approved August 10, 2000)

(*1*) The designation was changed to a dual inch-pound/SI standard.

(*2*) Paragraph 1.2 was revised to designate a dual inch-pound/SI standard.

(*3*) Paragraphs 4.4, 5.2, 5.3, and 6.1 were revised to reflect a metric conversion.

(*4*) All SI units were placed in brackets.

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4. Materials and Manufacture

4.1 Gypsum concrete shall consist of calcined gypsum to which is added aggregates, wood chips, or wood shavings in proportion to meet the applicable requirements of this specification.

4.2 *Calcined Gypsum*—Specification C 28.

4.3 *Aggregates*—Specification C 35.

4.4 *Wood Chips or Wood Shavings*, shall be dry wood, uniform and clean in appearance, passing a 1-in. [25-mm] sieve, and not more than 1/16 in. [1.5 mm] thick.

5. Physical Properties

5.1 *Setting Time*—Gypsum concrete shall set in not less than 20 min and not more than 90 min.

5.2 *Compressive Strength*—Gypsum concrete shall have the following compressive strength for the respective classes:

Class	Compressive Strength, min, psi [MPa]
A	500 [3.5]
B	1000 [7.0]

5.3 *Density*—Gypsum concrete, Class A, shall have a density of not more than 60 lb/ft^3[960 kg/m^3].

6. Sampling

6.1 Randomly select at least 1 % of the packages, but not less than five packages. Take samples from both the outer portion and the center of each package. Mix the samples so obtained to provide a composite sample of not less than 15 lb [6.5 kg]. Immediately place the sample in a clean, dry, airtight container for delivery to the laboratory.

7. Test Methods

7.1 Determine the physical properties of gypsum concrete in accordance with Test Methods C 472.

7.1.1 Determine the setting time by the Vicat method.

8. Inspection

8.1 Inspection of the gypsum concrete shall be agreed upon between the purchaser and the supplier as part of the purchase agreement.

9. Rejection

9.1 Rejection of gypsum concrete that fails to conform to the requirements of this specification shall be reported to the producer or supplier promptly and in writing. The notice of

[1] This specification is under the jurisdiction of ASTM Committee C11 on Gypsum and Related Building Materials and is the direct responsibility of Subcommittee C11.01 on Specifications and Test Methods for Gypsum Products.

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[2] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

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rejection shall contain a statement documenting how the gypsum concrete has failed to conform to the requirements of this specification.

10. Certification

10.1 When specified in the purchase agreement, a producer's or supplier's report shall be furnished at the time of shipment certifying that the product is in compliance with this specification.

11. Packaging and Marking

11.1 Gypsum concrete shall be shipped dry and free of lumps.

11.2 When shipped for resale, the following information shall be legibly marked on each package or on a tag of suitable size attached thereto:

11.2.1 Name of the manufacturer or the seller,

11.2.2 Brand,

11.2.3 Description, and

11.2.4 Net and gross weight of the package.

12. Keywords

12.1 aggregates; calcined gypsum; gypsum; gypsum concrete

SUMMARY OF CHANGES

Committee C11 has identified the location of selected changes to this specification since the last issue, C 317/C 317M – 98, that may impact the use of this specification. (Approved August 10, 2000)

(*1*) The designation was changed to a dual inch-pound/SI standard.

(*2*) Paragraph 1.2 was revised to designate a dual inch-pound/SI standard.

(*3*) Paragraphs 4.4, 5.2, 5.3, and 6.1 were revised to reflect a metric conversion.

(*4*) All SI units were placed in brackets.

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Designation: C 318/C 318M – 00 (Reapproved 2005)

Standard Specification for Gypsum Formboard[1]

This standard is issued under the fixed designation C 318/C 318M; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

This standard has been approved for use by agencies of the Department of Defense.

1. Scope*

1.1 This specification covers the minimum requirements for gypsum formboard designed for use as a permanent form for poured-in-place reinforced gypsum concrete roof decks.

1.2 The values stated in either inch-pound units or SI (metric) are to be regarded separately as standard. Within the text, the SI units are shown in brackets. The values stated in each system shall be used independent of the other. Values from the two systems shall not be combined.

1.3 The text of this standard references notes which provide explanatory material. These notes shall not be considered requirements of the standard.

2. Referenced Documents

2.1 *ASTM Standards:* [2]

C 11 Terminology Relating to Gypsum and Related Building Materials and Systems

C 473 Test Methods for Physical Testing of Gypsum Panel Products

C 1264 Specification for Sampling, Inspection, Rejection, Certification, Packaging, Marking, Shipping, Handling and Storage of Gypsum Board

G 21 Practice for Determining Resistance of Synthetic Polymeric Materials to Fungi

3. Terminology

3.1 *Definitions*—Definitions of terms used in this standard shall be in accordance with Terminology C 11.

4. Materials and Manufacture

4.1 Gypsum formboard shall consist of a noncombustible core, essentially gypsum, containing not more than 15 % by weight of fiber, either mineral or organic, synthetic or natural.

4.2 The face surface shall be specifically treated to resist fungus growth.

5. Physical Properties

5.1 Specimens shall be tested in accordance with Test Methods C 473.

NOTE 1—Since this product is laid between subpurlins without mechanical attachment, a nail pull requirement is not specified for this gypsum panel product.

5.1.1 Specimens shall be taken from the samples obtained in accordance with Specification C 1264.

5.1.2 *Flexural Strength*—The specimens shall be tested face up and face down. The average breaking load shall be not less than the following:

	Bearing Edges Across Fiber of Surfacing, lbf [N]	Bearing Edges Parallel Fiber of Surfacing, Face, lbf [N]	Bearing Edges Parallel Fiber of Surfacing, Back, lbf [N]
Method A	160 [715]	60 [270]	40 [180]
Method B	157 [700]	56 [250]	36 [160]

5.1.3 *Humidified Deflection*—The specimens shall have an average deflection of not more than the following:

Thickness, in. (mm)	Humidified Deflection, Eighths of an in. (mm)
½ [12.7]	10 [32]

5.1.4 *Core, End, and Edge Hardness*—The specimens shall have an average hardness of 15 lbf [65 N] when tested by Method A and 11 lbf [50 N] when tested by Method B.

5.1.5 *Resistance to Fungi*—The specimens shall obtain a rating not more than 1 (one) when judged in accordance with Practice G 21, paragraph 9.3, (Observation for Visible Effects).

6. Dimensions and Tolerances

6.1 Specimens shall be taken from the samples obtained in accordance with Section 8.

6.2 Thickness, width, length, and end squareness shall be determined in accordance with Test Methods C 473.

6.2.1 *Thickness*—The nominal thickness shall be ½ in. [12.7 mm] with tolerances in the nominal thickness of ±1/64 in. [0.4 mm] with local variations of ±1/32 in. [0.8 mm] from the nominal thickness.

[1] This specification is under the jurisdiction of ASTM Committee C11 on Gypsum and Related Building Materials and Systems and is the direct responsibility of Subcommittee C11.01 Specifications and Test Methods for Gypsum Products.

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6.2.2 *Width*—The nominal width shall be 32 in. [813 mm] with a tolerance of ⅛ in. [3 mm] over the specified width, and ¼ in. [6 mm] under the specified width.

6.2.3 *Length*—The nominal length of gypsum formboard shall conform to the purlin spacing of multiples thereof, with tolerances of ±¼ in. [6 mm] from the nominal length.

6.2.4 *End Squareness*—Corners shall be square with a tolerance of ±⅛ in. [±3 mm] in the full width of the board.

6.3 *Edges and Ends*—The edges and ends shall be square (90 ± 10°), straight, and solid.

7. Finish and Appearance

7.1 The surfaces of gypsum formboard shall be true and free from imperfections that would render it unfit for use with or without decoration.

8. Sampling, Inspection, Rejection, Certification, Packaging and Package Marking, Shipping, Handling and Storage

8.1 The sampling, inspection, rejection, certification, packaging and package marking, shipping, handling and storage shall be conducted in accordance with Specification C 1264.

9. Keywords

9.1 gypsum; gypsum concrete; gypsum formboard; gypsum panel product; roof decks

SUMMARY OF CHANGES

Committee C11 has identified the location of selected changes to this specification since the last issue, C 318/C 318M – 96, that may impact the use of this specification. (Approved July 10, 2000)

(*1*) SI values in paragraphs 5.1.2 and 5.1.4 were rationalized to the nearest 5N.

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Designation: C330/C330M – 09

Standard Specification for Lightweight Aggregates for Structural Concrete[1]

This standard is issued under the fixed designation C330/C330M; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

This standard has been approved for use by agencies of the Department of Defense.

1. Scope*

1.1 This specification covers lightweight aggregates intended for use in structural concrete in which prime considerations are reducing the density while maintaining the compressive strength of the concrete. Procedures covered in this specification are not intended for job control of concrete.

1.2 The values stated in either SI units or inch-pound units are to be regarded separately as standard. The values stated in each system may not be exact equivalents; therefore, each system shall be used independently of the other. Combining values from the two systems may result in non-conformance with the standard.

1.2.1 With regard to other units of measure, the values stated in inch-pound units are to be regarded as standard.

1.3 The text of this standard references notes and footnotes which provide explanatory material. These notes and footnotes (excluding those in tables and figures) shall not be considered as requirements of the standard.

NOTE 1—This specification is regarded as adequate to ensure satisfactory lightweight aggregates for most concrete. It is recognized that it may be either more or less restrictive than needed for some conditions and for special purposes, such as fire resistance, fill, and concrete constructions, the use of which is based on load tests rather than conventional design procedures.

2. Referenced Documents

2.1 *ASTM Standards:*[2]

C29/C29M Test Method for Bulk Density ("Unit Weight") and Voids in Aggregate

C31/C31M Practice for Making and Curing Concrete Test Specimens in the Field

C33 Specification for Concrete Aggregates

C39/C39M Test Method for Compressive Strength of Cylindrical Concrete Specimens

C40 Test Method for Organic Impurities in Fine Aggregates for Concrete

C114 Test Methods for Chemical Analysis of Hydraulic Cement

C136 Test Method for Sieve Analysis of Fine and Coarse Aggregates

C142 Test Method for Clay Lumps and Friable Particles in Aggregates

C151 Test Method for Autoclave Expansion of Hydraulic Cement

C157/C157M Test Method for Length Change of Hardened Hydraulic-Cement Mortar and Concrete

C192/C192M Practice for Making and Curing Concrete Test Specimens in the Laboratory

C496/C496M Test Method for Splitting Tensile Strength of Cylindrical Concrete Specimens

C567 Test Method for Determining Density of Structural Lightweight Concrete

C641 Test Method for Iron Staining Materials in Lightweight Concrete Aggregates

C666/C666M Test Method for Resistance of Concrete to Rapid Freezing and Thawing

C702 Practice for Reducing Samples of Aggregate to Testing Size

D75 Practice for Sampling Aggregates

2.2 *ACI Standards:*

ACI 211.2 Standard Practices for Selecting Proportions for Structural Lightweight Concrete [3]

3. Aggregate Types

3.1 Two general types of lightweight aggregates are covered by this specification, as follows:

3.1.1 Aggregates prepared by expanding, pelletizing, or sintering products such as blast-furnace slag, clay, diatomite, fly ash, shale, or slate, and

3.1.2 Aggregates prepared by processing natural materials, such as pumice, scoria, or tuff.

[1] This specification is under the jurisdiction of ASTM Committee C09 on Concrete and Concrete Aggregates and is the direct responsibility of Subcommittee C09.21 on Lightweight Aggregates and Concrete.

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[2] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

[3] Available from American Concrete Institute (ACI), P.O. Box 9094, Farmington Hills, MI 48333-9094, http://www.concrete.org.

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3.2 The aggregates shall be composed predominately of lightweight-cellular and granular inorganic material.

4. Chemical Composition

4.1 Lightweight aggregates shall not contain excessive amounts of deleterious substances, as determined by the following limits:

4.1.1 *Organic Impurities (Test Method C40)*—Lightweight aggregates that, upon being subjected to test for organic impurities, produce a color darker than the standard shall be rejected, unless it is demonstrated that the discoloration is due to small quantities of materials not harmful to the concrete.

4.1.2 *Staining (Test Method C641)*—An aggregate producing a stain index of 60 or higher shall be rejected when the deposited stain is found upon chemical analysis to contain an iron content, expressed as Fe_2O_3 equal to or greater than 1.5 mg/200 g of sample.

4.1.3 *Loss on Ignition (Test Methods C114)*—The loss on ignition of lightweight aggregates shall not exceed 5 %.

NOTE 2—Some aggregates may contain carbonates or water of hydration that contribute to loss on ignition but may not affect the quality of the product. Therefore, when evaluating an aggregate, consideration should be given to the material characteristics that cause the ignition loss.

5. Physical Properties

5.1 Lightweight aggregate under test shall meet the following requirements:

5.1.1 *Clay Lumps and Friable Particles*—The total amount of clay lumps and friable particles shall not exceed 2 % by dry mass.

5.1.2 *Grading*—The grading shall conform to the requirements shown in Table 1.

NOTE 3—The surfaces of pyro-processed lightweight aggregate particles finer than 75 µm (No. 200) sieves are not deleterious and may be moderately pozzolanic.

5.1.3 *Uniformity of Grading*—To ensure reasonable uniformity in the grading of successive shipments of lightweight aggregate, fineness modulus shall be determined on samples taken from shipments at intervals stipulated by the purchaser. If the fineness modulus of the aggregate in any shipment differs by more than 7 % from that of the sample submitted for acceptance tests, the aggregate in the shipment shall be rejected, unless the supplier demonstrates that it will produce concrete of the required characteristics.

5.1.4 *Loose Bulk Density (Test Method C29/C29M)*—The dry loose bulk density of lightweight aggregates shall conform to the requirements shown in Table 2 using a 14 L [½ cubic foot] measure.

5.1.5 *Uniformity of Loose Bulk Density*—The dry loose bulk density of lightweight aggregate shipments sampled and tested, shall not differ by more than 10 % from that of the sample submitted for acceptance tests, and shall not exceed the limits in Table 2.

5.1.6 *Density Factor*—When specified, the density factor shall be determined in accordance with 8.10.

5.2 Concrete specimens containing lightweight aggregate under test shall meet the following requirements:

5.2.1 *Compressive Strength (Test Method C39/C39M), Density (Test Method C567), and Splitting Tensile Strength (Test Method C496/C496M)* —Compressive strength and density shall be an average of three specimens and the splitting tensile strength shall be the average of eight specimens. It shall be possible to produce structural concrete using the lightweight aggregates under test, so that from the same batch of concrete one or more of the compressive strength requirements and splitting tensile strength requirements in Table 3 will be satisfied without exceeding the corresponding maximum density values.

NOTE 4—Intermediate values for strength and corresponding density values shall be established by interpolation. Materials that do not meet the minimum average splitting tensile strength requirement may be used provided the design is modified to compensate for the lower value.

5.2.2 *Natural Aggregates*— Natural aggregates, when used to replace part, or all, of the lightweight-aggregates shall comply with the applicable requirements of Specification C33. The test report shall record the proportion of all ingredients and the characteristics of the natural aggregates to ensure compliance with these minimum requirements.

5.2.3 *Drying Shrinkage*— The drying shrinkage of concrete specimens prepared, cured, and tested in accordance with 8.4 shall not exceed 0.07 %.

5.2.4 *Popouts*—Concrete specimens prepared in accordance with 8.4 and 8.5, and tested in accordance with Test Method C151 shall show no surface popouts.

5.2.5 *Resistance to Freezing and Thawing*—When required, the aggregate supplier shall demonstrate by test or proven field performance that the lightweight aggregate when used in

TABLE 1 Grading Requirements for Lightweight Aggregate for Structural Concrete

Nominal Size Designation	Percentages (Mass) Passing Sieves Having Square Openings									
	25.0 mm (1 in.)	19.0 mm (¾ in.)	12.5 mm (½ in.)	9.5 mm (⅜ in.)	4.75 mm (No. 4)	2.36 mm (No. 8)	1.18 mm (No. 16)	300 µm (No. 50)	150 µm (No. 100)	75 µm (No. 200)
Fine aggregate:										
4.75 mm to 0	...	...	...	100	85–100	...	40–80	10–35	5–25	...
Coarse aggregate:										
25.0 m to 4.75 mm	95–100	...	25–60	...	0–10	...	...	...	...	0–10
19.0 mm to 4.75 mm	100	90–100	...	10–50	0–15	...	...	...	...	0–10
12.5 mm to 4.75 mm	...	100	90–100	40–80	0–20	0–10	...	...	...	0–10
9.5 mm to 2.36 mm	...	...	100	80–100	5–40	0–20	0–10	...	...	0–10
Combined fine and coarse aggregate:										
12.5 mm to 0	...	100	95–100	...	50–80	...	...	5–20	2–15	0–10
9.5 mm to 0	...	...	100	90–100	65–90	35–65	...	10–25	5–15	0–10

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TABLE 2 Maximum Dry Loose Bulk Density Requirements of Lightweight Aggregates for Structural Concrete

Size Designation	Maximum Dry Loose Bulk Density kg/m³ [lb/ft³]
Fine aggregate	1120 [70]
Coarse aggregate	880 [55]
Combined fine and coarse aggregate	1040 [65]

TABLE 3 Compressive Strength and Splitting Tensile Strength Requirements

Calculated Equilibrium Density max, kg/m³ [lb/ft³]	Average 28-day Splitting Tensile Strength, min, MPa [psi]	Average 28-day Compressive Strength, min, MPa [psi]
All Lightweight Aggregate		
1760 [110]	2.2 [320]	28 [4000]
1680 [105]	2.1 [300]	21 [3000]
1600 [100]	2.0 [290]	17 [2500]
Combination of Normal Weight and Lightweight Aggregates		
1840 [115]	2.3 [330]	28 [4000]
1760 [110]	2.1 [310]	21 [3000]
1680 [105]	2.1 [300]	17 [2500]

concrete, had the necessary resistance to freezing and thawing to perform satisfactorily in its intended use.

6. Sampling

6.1 Sample lightweight aggregates in accordance with Practice D75.

6.2 Reduce sample to test sizes in accordance with Practice C702.

7. Number of Tests

7.1 *Tests on Aggregates*—One representative sample is required for each test for organic impurities, staining, loss on ignition, grading, bulk density, and clay lumps.

7.2 *Tests on Concrete*—At least three specimens are required for each of the following tests of concrete: compressive strength, shrinkage, density, resistance to freezing and thawing, and presence of popout materials. At least eight concrete specimens are required for splitting tensile strength tests.

8. Test Methods

8.1 *Compressive Strength (Test Method C39/C39M)*—Make test specimens in accordance with Practice C192/C192M and Practice C31/C31M. Unless otherwise specified, cure specimens in accordance with Practice C192/C192M or Practice C31/C31M, until the time of test. When specified, an alternative curing method is allowed. The alternative method shall be in accordance with Practice C192/C192M or the standard curing procedure in Practice C31/C31M for the first 7 days, after which the specimens shall be removed from moist curing and stored at 23 ± 2 °C [73.5 ± 3.5 °F] with a relative humidity of 50 ± 5 % until the time of test.

8.2 *Splitting Tensile Strength*—Make 152 by 305 mm [6 by 12 in.] cylindrical test specimens in accordance with Practice C192/C192M, cure, and test in accordance with Test Method C496/C496M.

8.3 *Density of Concrete (Test Method C567)*—Follow the procedures in Test Method C567.

8.4 *Shrinkage of Concrete (Test Method C157/C157M)*—Follow the procedures of Test Method C157/C157M with the following exceptions:

8.4.1 Prepare the concrete mixture using 335 kg of cement/m³ [564 lb/yd³], admixture (if any), and with an air content of 6 ± 1 %. Adjust the water content so as to produce a slump of 50 to 100 mm [2 to 4 in.]. Thoroughly consolidate the concrete in steel molds not smaller than 50 by 50 mm [2 by 2 in.] nor larger than 100 by 100 [4 by 4 in.] in cross section, and long enough to provide a 250 mm [10 in.] gauge length. The surface of the concrete shall be steel troweled.

8.4.2 *Curing*—To prevent evaporation of water from the unhardened concrete, cover the specimen with a nonabsorptive, nonreactive plate or sheet of tough, durable, impervious plastic or wet burlap. When wet burlap is used for covering, the burlap must be kept wet until the specimens are removed from the molds (see Note 5). Remove specimens from the molds not less than 20 nor more than 48 h after casting and store in a moist room maintained at 23 ± 2 °C [73.5 ± 3.5 °F] with a relative humidity of not less than 95 %. At the age of 7 days, remove the specimens from the moist room, measure for length, and store in a curing cabinet maintained at 37.8 ± 1.1 °C [100 ± 2 °F] with a relative humidity of 32 ± 2 %.

NOTE 5—Placing a sheet of plastic over the burlap will facilitate keeping it wet.

NOTE 6—The air immediately above a saturated solution of magnesium chloride ($MgCl_2$) at 37.8 °C [100 °F] is approximately 32 % relative humidity.

8.4.3 *Report*—After storage in the cabinet for 28 days, remove each specimen and within 15 s, determine its change in length to the nearest 0.01 % of the effective gauge length. Report the change in length as the drying shrinkage of the specimen; report the average drying shrinkage of the specimens as the drying shrinkage of the concrete.

8.5 *Test for Popout Materials*—Prepare concrete specimens for the test for popout materials as described in method for preparation of samples for shrinkage of concrete. Cure and autoclave the specimens in accordance with Test Method C151. Visually inspect the autoclaved specimens for the number of popouts that have developed on the surface. Report the number of popouts per specimen.

8.6 *Test for Freezing and Thawing*— Make freezing and thawing tests of concrete, when required, in accordance with Test Method C666/C666M, with the following modification to the section on Test Specimens and on Procedure. Unless otherwise specified, remove the lightweight aggregate concrete specimens from moist curing at an age of 14 days and allow to dry in air for another 14 days exposed to a relative humidity of 50 ± 5 % and a temperature of 23 ± 2 °C [73.5 ± 3.5 °F]. Then submerge the specimens in water for 24 hours, prior to the freezing and thawing test.

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8.7 *Grading (Test Method* C136*)*—Follow the procedures of Test Method C136, except that the mass of the test sample for fine aggregate shall be in accordance with Table 4. The test sample for coarse aggregate shall consist of 2830 cm^3 [0.1 ft^3] or more of the material used for the determination of bulk density. Mechanical sieving of aggregate shall be for 5 minutes.

8.8 *Bulk Density (Loose) (Test Method* C29/C29M*)*—The aggregate shall be tested in an oven dry condition utilizing the shoveling procedure.

TABLE 4 Mass of Sieve Test Sample for Fine Lightweight Aggregates

Nominal Bulk Density (Loose) of Aggregate		Mass of Test Sample, g
kg/m^3	lb/ft^3	
80–240	5–15	50
240–400	15–25	100
400–560	25–35	150
560–720	35–45	200
720–880	45–55	250
880– 1040	55–65	300
1040–1120	65–70	350

8.9 *Clay Lumps and Friable Particles in Aggregate*, shall be in accordance with Test Method C142.

8.10 *Density Factor*—Determine the Density ("Specific Gravity") Factor in accordance with ACI 211.2.

9. Rejection

9.1 Material that fails to conform to the requirements of this specification shall be subject to rejection. The reason for rejection shall be reported to the producer or supplier promptly and in writing.

10. Certification

10.1 When specified in the purchase order or contract, a producer's or supplier's certification shall be furnished to the purchaser that the material was sampled and tested in accordance with this specification and has been found to meet the requirements. When specified in the purchase order or contract, a report of the test results shall be furnished.

SUMMARY OF CHANGES

Committee C09 has identified the location of selected changes to this specification since the last issue, C330–05, that may impact the use of this specification. (Approved December 15, 2009)

(*1*) Revised 8.4.3.

(*2*) Moved the tabular information from 5.2.1 into new Table 3 and renumbered subsequent tables.

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Designation: C 331 – 05

Standard Specification for Lightweight Aggregates for Concrete Masonry Units[1]

This standard is issued under the fixed designation C 331; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

This standard has been approved for use by agencies of the Department of Defense.

1. Scope*

1.1 This specification covers lightweight aggregates intended for use in concrete masonry units when a prime consideration is to reduce the density of the units.

1.2 The values stated in SI units are to be regarded as the standard. The values shown in parentheses are for information purposes only.

1.3 The text of this specification references notes and footnotes which provide explanatory material. These notes and footnotes (excluding those in tables and figures) shall not be considered as requirements of the standard.

2. Referenced Documents

2.1 *ASTM Standards:* [2]

C 29/C 29M Test Method for Bulk Density ("Unit Weight") and Voids in Aggregate

C 40 Test Method for Organic Impurities in Fine Aggregates for Concrete

C 114 Test Methods for Chemical Analysis of Hydraulic Cement

C 136 Test Method for Sieve Analysis of Fine and Coarse Aggregates

C 142 Test Method for Clay Lumps and Friable Particles in Aggregates

C 151 Test Method for Autoclave Expansion of Hydraulic Cement

C 157/C 157M Test Method for Length Change of Hardened Hydraulic-Cement Mortar and Concrete

C 641 Test Method for Iron Staining Materials in Lightweight Concrete Aggregates

C 702 Practice for Reducing Samples of Aggregate to Testing Size

C 1262 Test Method for Evaluating the Freeze-Thaw Durability of Manufactured Concrete Masonry Units and Related Concrete Units

D 75 Practice for Sampling Aggregates

3. Aggregate Types

3.1 Three general types of lightweight aggregates are covered by this specification, as follows:

3.1.1 Aggregates prepared by expanding, pelletizing, or sintering products such as blast-furnace slag, clay, diatomite, fly ash, shale, or slate, and

3.1.2 Aggregates prepared by processing natural materials, such as pumice, scoria, or tuff, and

3.1.3 Aggregates consisting of end products of coal or coke combustion.

3.2 The aggregates shall be composed predominately of lightweight-cellular and granular inorganic material.

4. Chemical Composition

4.1 Lightweight aggregates shall not contain excessive amounts of deleterious substances, as determined by the following limits:

4.1.1 *Organic Impurities (Test Method C 40)*—Lightweight aggregates subjected to the test for organic impurities that produce a color darker than the standard shall be rejected, unless it is demonstrated that the discoloration is due to small quantities of materials not harmful to the concrete.

4.1.2 *Staining (Test Method C 641)*—An aggregate producing a stain index of 60 or higher shall be rejected when the deposited stain is found upon chemical analysis to contain an iron content, expressed as Fe_2O_3 equal to or greater than 1.5 mg/200 g of sample.

4.1.3 *Loss on Ignition (Test Methods C 114)*—Loss on ignition of aggregates, consisting of end products of coal or coke combustion, shall not exceed 12 %. Loss on ignition of other aggregates shall not exceed 5 %.

NOTE 1—Some aggregates may contain carbonates or water of hydration that contribute to loss on ignition but may not affect the quality of the product. Therefore, when evaluating an aggregate, consideration should be given to the material characteristics that cause the ignition loss.

[1] This specification is under the jurisdiction of ASTM Committee C09 on Concrete and Concrete Aggregates and is the direct responsibility of Subcommittee C09.21 on Lightweight Aggregates and Concrete.

Current edition approved Dec. 15, 2005. Published January 2006. Originally approved in 1953. Last previous edition approved in 2004 as C 331–04.

[2] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

***A Summary of Changes section appears at the end of this standard.**

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5. Physical Properties

5.1 Lightweight aggregate under test shall meet the following requirements:

5.1.1 *Clay Lumps and Friable Particles*— The amount of clay lumps and friable particles shall not exceed 2 % by dry mass.

5.1.2 *Grading*—Aggregate grading shall be by mutual agreement between interested parties. See Appendix X1 for aggregate grading guidance.

5.1.3 *Uniformity of Grading*—To ensure reasonable uniformity in the gradation of successive shipments of lightweight aggregate, fineness modulus shall be determined on samples taken from shipments at intervals stipulated by the purchaser. If the fineness modulus of the aggregate in any shipment differs by more than 7 % from that of the sample submitted for acceptance tests, the aggregate in the shipment shall be rejected, unless the supplier demonstrated that it will produce concrete of the required characteristics.

5.1.4 *Loose Bulk Density (Test Method C 29/C 29M)*—The loose bulk density of lightweight aggregates shall conform to the requirements in Table 1 using a 14 L (½ cubic foot) measure.

5.1.5 *Uniformity of Loose Bulk Density*— The dry loose bulk density of lightweight aggregate shipments sampled and tested shall not differ by more than ±50 kg/m^3 (3 lb/ft^3) or 7 %, whichever is greater, from that of the sample submitted for acceptance tests, and shall not exceed the limits in Table 1.

5.2 Concrete specimens containing lightweight aggregate under test shall meet the following requirements:

5.2.1 *Popouts*—Concrete specimens prepared and tested in accordance with 8.1 shall show no surface popouts.

5.2.2 *Resistance to Freezing and Thawing*— When required, the aggregate supplier shall demonstrate by test or proven field performance that the lightweight aggregate when used in manufactured concrete masonry units and related concrete units has the necessary resistance to freezing and thawing to perform satisfactorily in its intended use.

NOTE 2—Methods are available to evaluate the performance of manufactured concrete masonry products made with lightweight aggregates. For example, Test Method C 1262 includes procedures for evaluating manufactured concrete masonry units and related concrete units, but does not include criteria for determining compliance. Care should be used in evaluating the results of Test Method C 1262 or any other method since the results are affected by other characteristics of the concrete mixture in addition to the characteristics of the lightweight aggregate, including, but not limited to the following: cement content, cement type, admixtures, and water content.

TABLE 1 Maximum Bulk Density (Dry Loose) Requirements of Lightweight Aggregates for Concrete Masonry Units

Nominal Size Designation	Maximum Dry Loose Bulk Density kg/m^3(lb/ft^3)
Fine aggregate 4.75 mm (No. 4) to 0	1120 (70)
Coarse aggregate 9.5 to 2.36 mm (⅜ in. to No. 8)	880 (55)
Combined fine and coarse aggregate	1040 (65)

5.2.3 *Drying Shrinkage*—Drying shrinkage of concrete specimens prepared and tested in accordance with 8.6 shall not exceed 0.10 %.

6. Sampling

6.1 Sample lightweight aggregates in accordance with Practice D 75.

6.2 Reduce sample to test sizes in accordance with Practice C 702.

7. Number of Tests

7.1 *Tests on Aggregate*—One representative sample is required for each test for organic impurities, staining, clay lumps, loss on ignition, grading, and bulk density.

7.2 *Tests on Concrete Masonry Units*— Three specimens are required for the test for popout materials.

8. Test Methods

8.1 *Test for Popout Materials*—Obtain test specimens by one of the following methods: (*1*) Whole concrete masonry units, free of visible cracks or other structural defects; (*2*) Portions of concrete masonry units cut from whole units and having a surface area of at least 580 cm^2(90 in. ^{2}); (*3*) Specimens prepared as described in 8.6. Autoclave test specimens in accordance with Test Method C 151. Visually inspect the autoclaved specimens for the number of popouts that have developed on the surface and report the average number of popouts per specimen.

8.2 *Test for Resistance to Freezing and Thawing*—Make tests for resistance to freezing and thawing of manufactured concrete masonry units and related concrete units in accordance with Test Method C 1262.

8.3 *Grading*—Follow the procedures of Test Method C 136 except that the mass of the test sample for fine aggregate shall be in accordance with Table 2. The test sample for coarse aggregate shall consist of 2830 cm^3 (0.1 ft^3) or more of the material used for determination of bulk density. Mechanical sieving of aggregate shall be for 5 min.

8.4 *Bulk Density (Loose)* (Test Method C 29/C 29M)—The aggregate shall be tested in an oven-dry condition utilizing the shoveling procedure.

8.5 *Clay Lumps and Friable Particles in Aggregates*, shall be in accordance with Test Method C 142.

8.6 *Shrinkage of Concrete*, shall be in accordance with Test Method C 157/C 157M, with the following exceptions:

TABLE 2 Mass of Sieve Test Sample for Fine Lightweight Aggregates

Nominal Bulk Density (Loose) of Aggregate		Mass of Test Sample, g
kg/m^3	lb/ft^3	
80–240	5–15	50
240–400	15–25	100
400–560	25–35	150
560–720	35–45	200
720–880	45–55	250
880–1040	55–65	300
1040–1120	65–70	350

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8.6.1 Prepare a concrete mix in the proportions of one part portland cement to six parts combined aggregates, measured by dry loose volume. Adjust the water content so as to produce a slump of 50 to 75 mm (2 to 3 in.) and thoroughly consolidate the concrete in steel molds 50 by 50 by 285 mm (2 by 2 by 11¼ in.). The surface of the concrete shall be steel-troweled.

8.6.2 Cure the test specimens in a moist condition for 7 days at a temperature of 23 ± 2 °C (73.5 ± 3.5 °F) and a relative humidity of not less than 95 %. Make the initial length measurements immediately after removal of specimens from moist storage. Store the specimens in an atmosphere of 23 ± 2 °C (73.5 ± 3.5 °F) and a relative humidity of 50 ± 5 % for the duration of the test. Make subsequent measurements at 28 and 100 days.

8.6.3 Calculate the difference in length of the specimens, when removed from moist storage at an age of 7 days and at the final measurement at the age of 100 days, to the nearest 0.01 % of the effective gage length, and report as the drying shrinkage of the specimen. Report the average drying shrinkage of the specimens tested as the drying shrinkage of the concrete.

9. Rejection

9.1 Material that fails to conform to the requirements of this specification shall be subject to rejection. The reason for rejection shall be reported to the producer or supplier promptly and in writing.

10. Certification

10.1 When specified in the purchase order or contract, a producer's or supplier's certification shall be furnished to the purchaser that the material was sampled and tested in accordance with this specification and has been found to meet the requirements. When specified in the purchase order or contract, a report of the test results shall be furnished.

APPENDIX

(Nonmandatory Information)

X1. AGGREGATE GRADING GUIDE FOR CONCRETE MASONRY UNITS WITH LOWER DENSITIES

X1.1 Concrete masonry units with lower densities are manufactured with lightweight aggregate, with a blend of lightweight aggregates, or a blend of lightweight and normal-weight aggregates. Because the aggregates being blended may come from several different sources, the proper combined aggregate grading (see Fig. X1.1 and Table X1.1) is important, and is one of the essential ingredients in producing quality concrete masonry units. The combined aggregate grading range shown optimizes the particle size distribution which, in turn, optimizes the quality of the CMU in the following ways:

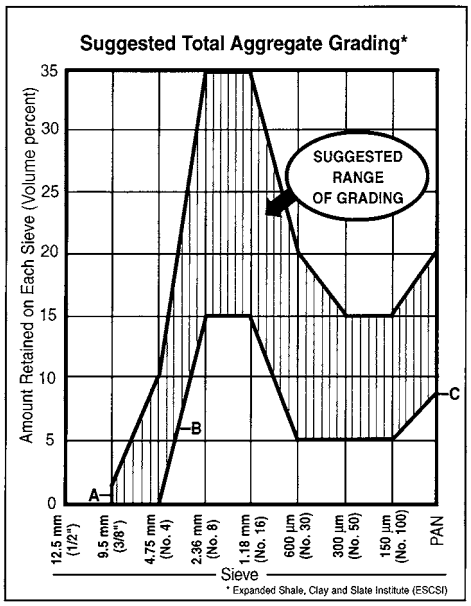

FIG. X1.1 Suggested Total Aggregate Grading

TABLE X1.1 Suggested Total Aggregate Grading

Sieve Size	Amount Retained On Each Sieve (Volume %) (see Fig. X1.1 and [A])
9.5 mm (⅜ in.)	0-2
4.75 mm (No. 4)	0-10
2.36 mm (No. 8)	15-35
1.18 mm (No. 16)	15-35
600 µm (No. 30)	5-20
300 µm (No. 50)	5-15
150 µm (No. 100)	5-15
Pan	8-20

[A] Volume % and mass % retained on each sieve are essentially equal when the particle density of the retained fractions are approximately the same. Volumetric analysis of particle sizes of blended aggregates composed of aggregates of different densities is accomplished by considering the proportions of each aggregate.

X1.1.1 Compactibility and high strengths are obtained without excessive amounts of cementitious materials.

X1.1.2 Shrinkage is reduced by maximizing aggregate packing.

X1.1.3 Water absorption and penetration are reduced because of improved compaction.

X1.1.4 Resistance to freezing and thawing is improved because better compaction results in fewer interconnected voids.

X1.2 Comments

X1.2.1 Keep particles retained on the 9.5 mm (⅜ in.) sieve to a minimum. ("0" is optimum.) (Refer to Letter "A" in Fig. X1.1.)

X1.2.2 A uniform, fine textured surface is controlled by limiting the material on 4.75 mm (No. 4) and 2.36 mm (No. 8) sieves. (Refer to Letter "B" in Fig. X1.1.)

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X1.2.3 A minimum of 8 % passing the 150 μm (No. 100) sieve is desirable for green strength, moldability and compaction. Less than 8 % is acceptable when using mixtures with high cementitious material content. (Refer to Letter "C" in Fig. X1.1.)

SUMMARY OF CHANGES

Committee C09 has identified the location of selected changes to this specification since the last issue, C 331–04, which may impact the use of this specification. (Approved December 15, 2005)

(*1*) Revised 5.1.4.

Committee C09 has identified the location of selected changes to this specification since the last issue, C 331–03a, which may impact the use of this specification. (Approved January 1, 2004)

(*1*) Revised X1.1.
(*2*) Changed "Mass %" to "Volume %" in Fig. X1.1 and Table X1.1.
(*3*) Added footnote to Table X1.1.

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Designation: C332 – 09

Standard Specification for Lightweight Aggregates for Insulating Concrete[1]

This standard is issued under the fixed designation C332; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

This standard has been approved for use by agencies of the Department of Defense.

1. Scope*

1.1 This specification covers lightweight aggregates intended for use in concrete not exposed to the weather, in which the prime consideration is the thermal insulating property of the resulting concrete.

1.2 The text of this standard references notes and footnotes which provide explanatory material. These notes and footnotes (excluding those in tables and figures) shall not be considered as requirements of the standard.

1.3 With regard to sieve size and the size of aggregate as determined by the use of testing sieves, the values in inch-pound units are shown for the convenience of the user; however, the standard sieve designation shown in parentheses is the standard value as stated in Specification E11.

1.3.1 With regard to other units of measure, the values stated in inch-pound units are to be regarded as standard. The values given in parentheses are mathematical conversions to SI units that are provided for information only and are not considered standard.

1.4 The following precautionary caveat pertains only to the test method portion, Section 6, of the specification: *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

2. Referenced Documents

2.1 *ASTM Standards:*[2]

C29/C29M Test Method for Bulk Density ("Unit Weight") and Voids in Aggregate

C136 Test Method for Sieve Analysis of Fine and Coarse Aggregates

C177 Test Method for Steady-State Heat Flux Measurements and Thermal Transmission Properties by Means of the Guarded-Hot-Plate Apparatus

D75 Practice for Sampling Aggregates

E11 Specification for Woven Wire Test Sieve Cloth and Test Sieves

3. Classification

3.1 Two general types of lightweight aggregate are covered by this specification as follows:

3.1.1 *Group I*—Aggregates prepared by expanding products such as perlite or vermiculite.

NOTE 1—These aggregates generally produce concrete having a density from 15 to 50 lb/ft^3 (240 to 800 kg/m^3), the thermal conductivity of which may be expected to range from 0.45 to 1.50 Btu·in/h·ft^2·°F (0.065 to 0.22 W/m·K).

3.1.2 *Group II*—Aggregates prepared by expanding, calcining, or sintering products such as blast-furnace slag, clay, diatomite, fly ash, shale, or slate; and aggregates prepared by processing natural materials, such as pumice, scoria, or tuff.

NOTE 2—These aggregates generally produce concrete having a density from 45 to 90 lb/ft^3 (720 to 1440 kg/m^3), the thermal conductivity of which may be expected to range from 1.05 to 3.00 BTU·in/h·ft^2· °F (0.15 to 0.43 W/m·K).

3.2 The aggregate shall be composed predominantly of lightweight cellular and granular inorganic material.

4. Physical Properties

4.1 *Insulating Properties*—The thermal insulating properties of concrete made from the lightweight aggregate under test shall conform to the following limits:

Maximum Average 28-Day Oven-Dry Bulk Density, lb/ft^3 (kg/m^3)	Maximum Average Thermal Conductivity, Btu·in/h·ft^2·°F (W/m·K)
50 (800)	1.50 (0.22)
90 (1440)	3.00 (0.43)

4.2 *Grading*—The grading shall conform to the requirements shown in Table 1.

[1] This specification is under the jurisdiction of ASTM Committee C09 on Concrete and Concrete Aggregates and is the direct responsibility of Subcommittee C09.21 on Lightweight Aggregates and Concrete.

Current edition approved Nov. 1, 2009. Published December 2009. Originally approved in 1954. Last previous edition approved in 2007 as C332 – 07. DOI: 10.1520/C0332-09.

[2] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

***A Summary of Changes section appears at the end of this standard.**

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TABLE 1 Grading Requirements for Lightweight Aggregates for Insulating Concrete

Nominal Size Designation	Percentages (Mass) Passing Sieves Having Square Openings								
	19.0-mm (¾-in.)	12.5-mm (½-in.)	9.5-mm (⅜-in.)	4.75-mm (No. 4)	2.36-mm (No. 8)	1.18-mm (No. 16)	600-µm (No. 30)	300-µm (No. 50)	150-µm (No. 100)
Group I									
Perlite	...	...	...	100	85 to 100	40 to 85	20 to 60	5 to 25	0 to 10
Vermiculite[A] (Coarse)	...	...	100	98 to 100	60 to 100	30 to 85	2 to 45	1 to 20	0 to 10
Vermiculite (Fine)	...	...	...	...	100	85 to 100	35 to 85	2 to 40	0 to 10
Group II									
Fine aggregate: 4.75-mm (No. 4) to 0	...	...	100	85 to 100	...	40 to 80	...	10 to 35	5 to 25
Coarse Aggregate: 12.5 to 4.75-mm (½-in. to No. 4)	100	90 to 100	40 to 80	0 to 20	0 to 10	...	...	...	...
9.5 to 2.36-mm (⅜-in. to No. 8)	...	100	80 to 100	5 to 40	0 to 20	...	...	...	...
4.75 to 2.36-mm (No. 4 to No. 8)	...	...	100	90 to 100	0 to 20	...	...	...	...
Combined Fine and Coarse Aggregate:									
12.5-mm (½-in.) to 0	100	95 to 100	...	50 to 80	...	...	...	5 to 20	2 to 15
9.5-mm (⅜-in.) to 0	... 100	90 to 100	65 to 90	35 to 65	...	...	10 to 25	5 to 15	

[A] Attention is directed to the need for adjustment in water content and air entrainment to achieve comparable oven-dry unit weights for the two gradings.

4.2.1 *Uniformity of Grading*—To ensure reasonable uniformity in the gradation of successive shipments of lightweight aggregates, fineness modulus determination shall be made periodically. If the fineness modulus of the aggregate differs by more than 7 % from that of the sample submitted for acceptance, the aggregate is subject to rejection, unless the supplier demonstrates that it will produce concrete of the required characteristics.

4.3 *Loose Bulk Density (Test Method C29/C29M)*—The dry loose bulk density of lightweight aggregates shall conform to the requirements shown in Table 2.

4.3.1 *Uniformity of Loose Bulk Density*—The dry loose bulk density of successive shipments of lightweight aggregates shall not differ by more than 10 % from that of the sample submitted for acceptance.

5. Sampling and Testing for Aggregate Properties

5.1 Sample lightweight aggregates and determine the properties enumerated in this specification in accordance with the following methods:

5.1.1 *Sampling*—Practice D75, except sample bagged materials by riffling and then quartering.

TABLE 2 Bulk Density Requirement for Lightweight Aggregates of Insulating Concrete

Size Designation	Dry Loose Bulk Density lb/ft³ (kg/m³)	
	Min	Max
Group I:		
Perlite	7.5 (120)	12 (196)
Vermiculite	5.5 (88)	10 (160)
Group II:		
Fine aggregate	...	70 (1120)
Coarse aggregate	...	55 (880)
Combined fine and coarse aggregate	...	65 (1040)

5.1.2 *Grading*—Method C136, except that when a mechanical sieving device is used, the sieving time shall be 5 min and the following modification shall apply:

5.1.2.1 *Fine aggregate*—The mass of the test sample shall be in accordance with the following table:

Nominal Density lb/ft³ (kg/m³)	Mass of Test Sample, g
5 to 15 (80 to 240)	50
15 to 25 (240 to 400)	100
25 to 35 (400 to 560)	150
35 to 45 (560 to 720)	200
45 to 55 (720 to 880)	250
55 to 65 (880 to 1040)	300
65 to 70 (1040 to 1120)	350

5.1.2.2 *Coarse Aggregate*—The sample shall be not less than 0.1 ft³ (2830 cm³) of the material obtained in making the bulk density determination.

5.1.3 *Loose Bulk Density*—Test Method C29/C29M utilizing the shoveling procedure described in Test Method C29/C29M, except test the aggregate in an oven-dry condition.

5.1.4 *Fineness Modulus*—Calculate as described in Test Method C136.

6. Test Methods for Insulating Concrete Properties

6.1 Determine the density and thermal conductivity of the concrete in accordance with the following methods:

6.1.1 *Specimen Preparation*—Prepare three specimens for each type of test, applying the same composition and fabrication procedure as is proposed for use. Moist-cure the specimens for 7 days and then remove them from the moist room and store at a temperature of 73.4 ± 3 °F (23 ± 1.7 °C) and at a relative humidity of 50 ± 5 % until the time of test. Dry the specimens at the age of 28 days in an oven at 230 ± 18 °F (110 ± 10 °C) and weigh them at 24-h intervals until the loss in mass does not exceed 1 % in a 24-h period.

6.1.2 *Concrete Density*—Determine the density from specimens each of which has a volume of not less than 0.1 ft³ (2 L).

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Determine the mass and dimensions of the oven-dry specimens and compute the volume and the density from the average data obtained.

6.1.3 *Thermal Conductivity*—Determine the thermal conductivity in accordance with Test Method C177, except prepare and cure the specimens in accordance with 6.1.1. The dimensions of the specimens shall be as required for the testing equipment available. Report the details of the composition and fabrication procedure used in preparing the specimens.

7. Rejection and Rehearing

7.1 Material that fails to conform to the requirements of this specification is subject to rejection. Rejection shall be reported to the producer or supplier promptly and in writing. In case of dissatisfaction with the result of the test, the producer or supplier shall make claim for a rehearing.

7.2 The purchaser of materials covered by this specification shall have the option of evaluating these materials for rejection by either minimum mass or approximate volume as stated.

7.3 Individual packages are subject to rejection when:

7.3.1 The contents, on a mass basis, are 5 % less than that indicated on the package, or

7.3.2 The contents, on a volume basis, are 10 % less than that indicated on the package.

7.4 The entire shipment is subject to rejection.

7.4.1 On a mass basis when the average contents of two packages for each 100, but not less than 6 packages selected at random, in any one shipment, are less than that indicated on the package.

7.4.2 On a volume basis when the average contents of two packages for each 100, but not less than 6 packages selected at random, in any one shipment differ by more than 5 % from that indicated on the package.

7.5 The net mass of the contents shall be determined by weighing the package or packages and deducting the mass of the container.

7.6 The bulk volume of the contents in a package shall be calculated by determining the mass of the contents of the package and dividing by the bulk density of the aggregate. The bulk density of the aggregate shall be determined in accordance with the shoveling procedure given in Test Method C29/C29M using material from one or more of the packages selected in 7.4.2.

8. Certification

8.1 When specified in the purchase order or contract, a producer's or supplier's certification shall be furnished to the purchaser that the material was manufactured, sampled, tested, and inspected in accordance with this specification and has been found to meet the requirements. When specified in the purchase order or contract, a report of the test results shall be furnished.

9. Packaging and Package Marking

9.1 When lightweight aggregates covered by this specification are delivered in packages, the name of the manufacturer, type of aggregate, and minimum mass and approximate volume of the contents shall be plainly indicated thereon.

10. Keywords

10.1 insulating concrete; lightweight aggregate; thermal properties

SUMMARY OF CHANGES

Committee C09 has identified the location of selected changes to this specification since the last issue, C332 – 07, that may impact the use of this specification. (Approved November 1, 2009)

(*1*) Revised 7.6.

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Designation: C 341/C 341M – 06

Standard Practice for Length Change of Cast, Drilled, or Sawed Specimens of Hydraulic-Cement Mortar and Concrete[1]

This standard is issued under the fixed designation C 341/C 341M; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope*

1.1 This practice covers the determination of the length changes of cast, drilled, or sawed specimens of hydraulic-cement mortar and concrete due to causes other than externally applied forces and temperature changes. It can be readily adapted, if desired, to studies of length change involving different schedules or environmental treatment than the standard procedures prescribed by this practice.

1.2 The values stated in either inch-pound units or SI units shall be regarded separately as standard. The units stated in each system may not be exact equivalents; therefore, each system must be used independently of the other, without combining in any way. The inch-pound units are shown in brackets.

1.3 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

2. Referenced Documents

2.1 *ASTM Standards:* [2]

A 276 Specification for Stainless Steel Bars and Shapes

C 31/C 31M Practice for Making and Curing Concrete Test Specimens in the Field

C 42/C 42M Test Method for Obtaining and Testing Drilled Cores and Sawed Beams of Concrete

C 157/C 157M Test Method for Length Change of Hardened Hydraulic-Cement Mortar and Concrete

C 192/C 192M Practice for Making and Curing Concrete Test Specimens in the Laboratory

C 490 Practice for Use of Apparatus for the Determination of Length Change of Hardened Cement Paste, Mortar, and Concrete

C 666/C 666M Test Method for Resistance of Concrete to Rapid Freezing and Thawing

3. Terminology

3.1 *Definition*

3.1.1 *length change, n*—an increase or decrease in a linear dimension of a test specimen, which has been caused to change by any factor other than externally applied forces and temperature changes.

4. Significance and Use

4.1 Measurements of length change permit assessment of the potential for volumetric expansion or contraction of cast, drilled, or sawed specimens of hydraulic-cement mortar, and concrete due to various causes other than externally applied forces and temperature changes. This practice is particularly useful for comparative evaluation of this potential in different mortar or concrete specimens.

5. Apparatus

5.1 *Length Comparator*—The length comparator shall generally conform to the requirements of Specification C 490, except that it shall be constructed to accommodate the specimens to be tested under this practice, which shall have gauge lengths of 75 mm [3 in.] or more.

5.1.1 *Gauge Studs in Ends of Specimens*—When the comparator is to be used to measure between gauge studs in the ends of specimens, the gauge length for computing percentage length change shall be considered to be the distance between the innermost ends of the gauge studs, and the contact terminals of the comparator shall be plane, polished, heat-treated surfaces as described in Specification C 490. Fig. 3 of Specification C 490 shows one type of comparator that has been found suitable for such specimens. A horizontal comparator is desirable for specimens that are considered too large to be handled by the type of comparator illustrated in Fig. 3 of Specification C 490.

5.1.2 *Gauge Studs on Sides of Specimen*—When the comparator is to be used to measure between gauge studs on the sides of specimens, the contact terminals shall be conical,

[1] This practice is under the jurisdiction of ASTM Committee C09 on Concrete and Concrete Aggregates and is the direct responsibility of Subcommittee C09.68 on Volume Change.

Current edition approved June 1, 2006. Published June 2006. Originally approved in 1954. Last previous edition approved in 2005 as C 341/C 341M – 05.

[2] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

***A Summary of Changes section appears at the end of this standard.**

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heat-treated surfaces as shown in Fig. 1, which illustrates a type of comparator that has been found satisfactory for this type of specimen. In this case, the gauge length shall be the distance between the reference points located in the exposed ends of the gauge studs (see 5.2).

5.2 *Gauge Studs*—Gauge studs shall be Type 316 stainless steel, meeting Specification A 276.

5.2.1 *For Ends of Specimens*—Gauge studs that are to be located in the ends of specimens shall have a rounded surface to provide point contact with the terminals of the comparator. The types of studs described in Specification C 490 are suitable for insertion in drilled holes. Spherical studs having a diameter of 6 to 10 mm [¼ to ⅜ in.], or studs that are sections of spheres of similar diameter, are suitable for cementing to the ends of specimens.

5.2.2 *For Sides of Specimens*—The exposed end of gauge studs that are to be located on the sides of specimens shall have a plane surface with a diameter or diagonal of 10 to 13 mm [⅜ to ½ in.]. For dry setting, the length of the stud shall be 13 to 16 mm [½ to ⅝ in.]. Shorter lengths of stud, including plane disks, shall be satisfactory for studs that are to be cemented.

5.3 *Drying Room and Controls*—A drying room and controls as described in Test Method C 157/C 157M shall be used for storing specimens in air.

6. Sampling

6.1 Samples of drilled or sawed hydraulic cement mortar or concrete shall be obtained in accordance with the section on Sampling of Test Method C 42/C 42M.

6.2 Samples of field cast hydraulic cement mortar or concrete shall be cast in accordance with Practice C 31/C 31M.

6.3 Constituent materials for concrete or mortar specimens made in the laboratory for use in this practice shall be sampled using applicable standard methods.

6.3.1 The specimens for use in this practice prepared from the constituent materials in the laboratory shall be cast prisms or cylinders made and cured in accordance with the applicable requirements of Practice C 192/C 192M and Practice C 490.

7. Test Specimens

7.1 Test specimen geometry shall be either cylindrical or rectangular prisms. Specimens shall be either cast from freshly mixed materials or drilled or sawn from existing concrete or mortar structures. Specimens shall be free from reinforcing steel, visible cracks, or other structural defects. They shall be of any size but specimens that are to be compared shall not differ in their cross-sectional dimensions by more than 10 % or in length by more than 20 % (Note 1). The gauge length shall be at least six times the maximum nominal size of the coarse aggregate but not less than 75 mm [3 in.], and that the minimum cross-sectional dimension be at least three times the maximum nominal size of the coarse aggregate but not less than 50 mm [2 in.]. When the gauge studs are to be located on the sides of the specimen, the over-all length of the specimen shall exceed the gauge length by at least 50 mm [2 in.].

NOTE 1—Specimens used for length change measurements during freeze thaw resistance testing as described in Test Method C 666/C 666M should follow the dimensional requirements of that method.

8. Setting Gauge Studs

8.1 Gauge studs shall either be cast in place, dry-set or cemented in drilled holes, or cemented directly to the surface of the specimen.

8.2 *Drilling Holes*—For gauge studs that are to be cemented, holes shall be drilled (Note 2) only slightly larger than the studs. For gauge studs that are to be dry-set, holes shall be drilled about 0.1 mm [0.005 in.] smaller in diameter than the studs. In the case of small specimens, take care that the

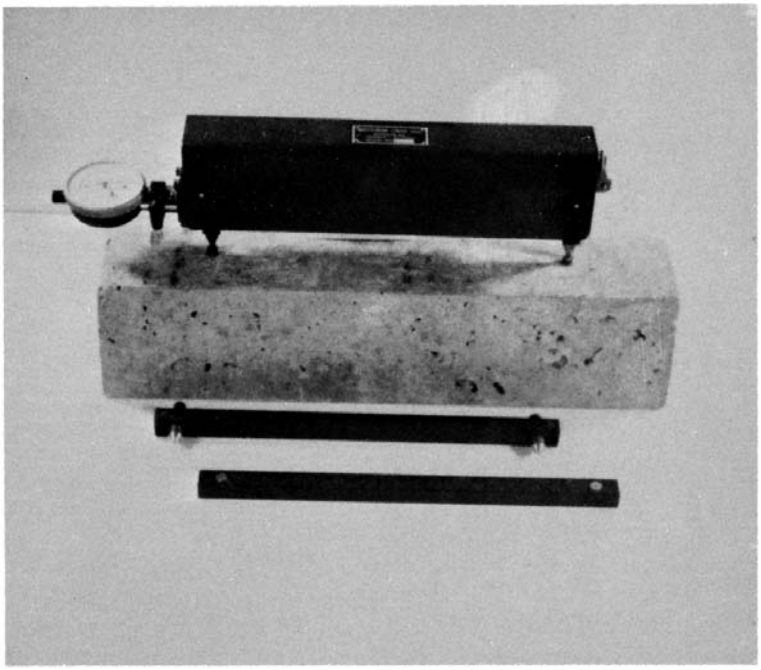

FIG. 1 Type of Suitable Extensometer for Measurement of Length Change of Specimens Having Gauge Studs on Sides

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specimens are not damaged by the drilling operation. The location and depth of holes shall be as given in 8.2.1 and 8.2.2.

NOTE 2—Carbide-tipped masonry drills have been found most suitable for this purpose.

8.2.1 *For Gauge Studs in Ends of Specimen*—Drill holes in the ends of a specimen so that their longitudinal axes coincide with the longitudinal axis of the specimen. The depth of the holes shall be such that the gauge studs will project from 3 to 5 mm [⅛ in. to 3⁄16 in.] beyond the ends of the specimen.

8.2.2 *For Gauge Studs in Sides of Specimen*—Drill a pair of holes in each of two opposite sides of the specimen to compensate for warping and to provide a better average for length change. Position both pairs of holes in a plane containing the longitudinal axis of the specimen and space to conform to the length of the comparator. The center of each hole shall be at least 25 mm [1 in.] from the end of the specimen. The depth of the holes shall preferably be such that the top surfaces of the gauge studs can be set about 3 mm [0.1 in.] below the surface of the specimen.

8.3 *Cementing Methods*:

8.3.1 *Studs Set in Holes*—Position gauge studs in holes at the depth specified in 8.2.1 or 8.2.2, as appropriate, with the exposed end parallel to the surface of the specimen in the case of studs having plane end surfaces. The cementing material shall be stable and effective in either a wet or dry environment and at temperatures up to 120 °C [250 °F]. The following cementing materials have been found satisfactory:

8.3.1.1 *Epoxy Resin*—Epoxy resins for this purpose shall cure at room temperatures and not soften upon exposure to water immersion. Holes shall be free of loose particles and visually dry to ensure good bond.

8.3.1.2 *Portland-Cement Paste*—Use a thick paste of Type III Portland cement. Moisten each hole with about 5 mL of water, cement the studs in place after the water has been absorbed, and moist-cure the paste for approximately 24 h.

8.3.1.3 *Other Cementing Media*—Sulfur and Rose metal have also proven satisfactory.

8.3.2 *Studs Cemented to Surface*—An epoxy resin system that cures at room temperature and does not soften at a temperature of 120 °C [250 °F] or soften upon exposure to water immersion is the most satisfactory material for cementing studs to the surface of a specimen. To ensure good bond, it is essential that the surface be clean. Acid etching followed by flushing with water and drying is a satisfactory preparation of the surface for bonding. The locations of the studs on the specimen are the same as those prescribed for drilled holes in 8.2.1 and 8.2.2. The exposed end surface of each stud having a plane end surface shall be parallel to the surface of the specimen.

8.4 *Dry-Setting Method*—Drive the gauge studs to the depth specified in 8.2.1 or 8.2.2, as appropriate, into holes that are approximately 0.1 mm [0.005 in.] smaller in diameter than the gauge studs, being careful not to deform the exposed ends of the gauge studs during the driving operation.

8.5 *Reference Points on Gauge Studs*—On each gauge stud located on the side of a specimen, establish a reference point by drilling a hole approximately 1 mm in diameter (see Note 3) in the end of the stud to a depth sufficient to provide clearance between the bottom of the hole and the point of the comparator, as shown in Fig. 1. A template (Fig. 1) will aid in spacing the holes at proper gauge length, which shall be as nearly equal to the mean gauge length of the comparator as practicable. Remove burred edges from the reference point holes.

NOTE 3—A No. 56 American Standard Twist Drill or other bit suitable to drill a hole approximately 1 mm or 0.046 in. in diameter is suitable for this purpose.

9. Determination of Gauge Length of Specimens

9.1 Determine the gauge length of each specimen to an accuracy of 1 %. In the case of specimens having gauge studs on the sides, determine the gauge length by direct measurement between the reference points with a suitable scale. Determine the gauge length of specimens having gauge studs in the ends by first measuring the distance between the ends of the gauge studs with suitable calipers and subtracting the lengths of the two gauge studs.

10. Conditioning of Specimens for Measurement of Base Length

10.1 Prior to the initial measurement for length, condition specimens by immersion in lime-saturated water.

10.2 Maintain the temperature of the conditioning water at 23 ± 2 °C [73.5 ± 3.5 °F], except that during the last 1 h of immersion immediately before making any measurement for length maintain the temperature at 23.0 ± 0.5 °C [73.4 ± 1.0 °F] (Note 4). When measuring for length, remove the specimens from water one at a time, wipe with a damp cloth, and immediately measure for length using the comparator specified in 5.1. Make length measurements at 7-day intervals and continue conditioning until the change in length over a 7-day period is less than 0.001 %. Use the length measurement that determines that this criterion is met as the basis for calculating length change occurring during the air or water storage period.

NOTE 4—Specimens used for length change measurements during freeze thaw resistance testing as described in Test Method C 666/C 666M should follow the conditioning of that method.

11. Storage of Specimens

11.1 After measurement at the end of the conditioning period, store the specimens as described in either 11.2 or 11.3, unless another condition of storage is specified.

11.2 *Water Storage*—Immerse specimens in lime-saturated water at 23 ± 2 °C [73.5 ± 3.5 °F]. Take observations of the length of each specimen after 1, 2, 4, 8, 16, 32, and 64 weeks unless otherwise specified. Make these observations immediately after the specimens have been subjected to storage in water at 23.0 ± 0.5 °C [73.4 ± 1.0 °F] for a period of at least 1 h. When measuring for length, remove the specimens from water one at a time, wipe with a damp cloth, and immediately measure for length using the comparator specified in 5.1.

11.3 *Air Storage*—Store the specimens in circulating air maintained at a temperature of 23 ± 2 °C [73.5 ± 3.5 °F] and a relative humidity of 50 ± 4 % unless some other condition of storage is specified. See 5.3 for reference to a suitable drying room. The air movement past all specimens shall be such that the rate of evaporation is 77 ± 30 mL/24 h from the atmometer referenced in 5.3 or 13 ± 5 mL/24 h from a 400-mL Griffin

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low-form beaker filled initially to 20 mm [¾ in.] from the top. Unless otherwise specified, measure specimens for length at weekly intervals and continue them in air storage until their change in length over a 7-day period is less than 0.001 %. Preferably, make these observations in a room maintained at a relative humidity of 50 ± 4 % while the specimens are at a temperature of 23 ± 2 °C [73.5 ± 3.5 °F].

12. Report

12.1 Report the following information:

12.1.1 Sources of specimen in terms of the structure and particular location in the structure from which the specimen was obtained,

12.1.2 Dimensions of the test specimen,

12.1.3 Maximum size and mineral character of aggregate in concrete,

12.1.4 Description of conditioning, either by indication that the type of conditioning outlined in Section 10 was followed, or by giving details of any procedure not conforming to that condition. In either case, give the total length of the conditioning period,

12.1.5 Description of the storage condition, either by indicating that the type of storage outlined in Section 11 was followed or by giving details of any procedure not conforming to that condition,

12.1.6 Total length of the period of storage, exclusive of the conditioning period, up to each length measurement,

12.1.7 Length change data, measured in accordance with the Procedure for Calculating Length Change in Test Method C 157/C 157M and typically reported to 0.001 %, except the gauge length is defined in terms of Section 9 above, based on the initial measurement made at the end of the conditioning period,

12.1.8 Any condition or characteristic of the concrete of interest to the study, and

12.1.9 Any other pertinent information.

13. Keywords

13.1 comparator; concrete; conditioning; length change; mortar

SUMMARY OF CHANGES

Committee C09 has identified the location of selected changes to this practice since the last issue, C 341/C 341M – 05, that may impact the use of this practice. (Approved June 1, 2006)

(*1*) Revised 8.3.2.

Committee C09 has identified the location of selected changes to this practice since the last issue, C 341/C 341M – 03a, that may impact the use of this practice. (Approved May 1, 2005)

(*1*) Revised 8.3.1.1 and 8.3.2.

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Designation: C 348 – 08

Standard Test Method for Flexural Strength of Hydraulic-Cement Mortars[1]

This standard is issued under the fixed designation C 348; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope*

1.1 This test method covers the determination of the flexural strength of hydraulic-cement mortars.

1.2 The values stated in SI units are to be regarded as standard. No other units of measurement are included in this standard.

1.3 Values in SI units shall be obtained by measurement in SI units or by appropriate conversion, using the Rules for Conversion and rounding given in Standard IEEE/ASTM SI 10, of measurements made in other units.

1.4 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.* (**Warning—**Fresh hydraulic cementitious mixtures are caustic and may cause chemical burns to skin and tissue upon prolonged exposure.[2])

2. Referenced Documents

2.1 *ASTM Standards:*[3]

C 109/C 109M Test Method for Compressive Strength of Hydraulic Cement Mortars (Using 2-in. or [50-mm] Cube Specimens)

C 230/C 230M Specification for Flow Table for Use in Tests of Hydraulic Cement

C 305 Practice for Mechanical Mixing of Hydraulic Cement Pastes and Mortars of Plastic Consistency

C 349 Test Method for Compressive Strength of Hydraulic-Cement Mortars (Using Portions of Prisms Broken in Flexure)

C 670 Practice for Preparing Precision and Bias Statements for Test Methods for Construction Materials

C 778 Specification for Standard Sand

C 1005 Specification for Reference Masses and Devices for Determining Mass and Volume for Use in the Physical Testing of Hydraulic Cements

C 1437 Test Method for Flow of Hydraulic Cement Mortar

IEEE/ASTM SI 10 Standard for Use of the International System of Units (SI): The Modern Metric System

3. Summary of Test Method

3.1 The test mortar used consists of 1 part cement and 2.75 parts of sand proportion by mass. Portland or air-entraining portland cements are mixed at specified water-cement ratios. Water content of other cements is that sufficient to obtain a flow of 110 ± 5 % with 25 drops of the flow table. Test prisms, 40 by 40 by 160-mm are molded by tamping in two layers. Prisms are cured one day in the molds and stripped until tested by center point loading.

4. Significance and Use

4.1 This test method provides a means for determining the flexural strength of hydraulic cement mortars. Portions of the mortar prisms tested in flexure according to this test method may be used for the determination of compressive strength in accordance with Test Method C 349.

4.2 The values are determined from this test method for research or reference purposes only and are not used for determining compliance with specification requirements.

5. Apparatus

5.1 *Weights, Weighing Devices and Glass Graduates*, shall conform to the requirements of Specification C 1005. The balance shall be evaluated for precision and accuracy at 2000 g.

5.2 *Mixer, Bowl and Paddle*, an electrically driven mechanical mixer of the type equipped with paddle and mixing bowl, as specified in the Apparatus Section of Practice C 305.

5.3 *Flow Table and Flow Mold*, shall conform to Specification C 230/C 230M.

5.4 *Specimen Molds*—Molds for the 40 by 40 by 160-mm prism specimens shall be triple-gang molds and shall be so designed that the specimens will be molded with their longitudinal axes in a horizontal position. The molds shall be made of a hard metal, not attacked by cement mortar, and with a Rockwell hardness of not less than HRB 55. The parts of the

[1] This test method is under the jurisdiction of ASTM Committee C01 on Cement and is the direct responsibility of Subcommittee C01.27 on Strength.

Current edition approved Dec. 1, 2008. Published January 2009. Originally approved in 1954. Last previous edition approved in 2002 as C 348 – 02.

[2] See the section on Safety, Manual of Cement Testing, *Annual Book of ASTM Standards*, Vol 04.01.

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molds shall be matchmarked and, when assembled, shall be tight-fitting and positively held together. The sides of the molds shall be sufficiently rigid to prevent spreading or warping. The interior faces of the molds shall be plane surfaces with a permissible variation, in any 50-mm line on a surface, of 0.03 mm for new molds and 0.05 mm for molds in use. The distance between opposite sides shall be 40 ± 0.13 mm for new molds and 40 ± 0.3 mm for molds in use. The height of the molds shall be 40 mm with permissible variations of +0.25 and −0.15 mm for new molds, and +0.25 and −0.40 mm for molds in use. The inside length of the molds shall be 160 ± 2.5 mm. The angle between adjacent interior faces and top and bottom planes of the mold shall be 90 ± 0.5°, measured at points slightly removed from the intersections of the faces. The base plate shall be approximately 10 mm in thickness and shall have a plane surface 200 by 180 mm with a permissible variation in any 50-mm line on the surface of 0.03 mm.

5.5 *Tamper*—The tamper (see Fig. 1) shall be made of nonabsorptive, nonabrasive material, such as a rubber compound having a Shore A durometer hardness of 80 ± 10 or seasoned oak wood rendered nonabsorptive by immersion for 15 min in paraffin at approximately 200 °C. The face of the tamper shall be 22 by 85 mm.

5.6 *Tamper Guide*—The tamper guide (see Fig. 2), shall be made of metal (such as brass of Rockwell hardness not less than HRB 55) not attacked by the cement mortar. It shall lie flat on the mold and shall not protrude over any interior edge of the form more than 0.40 mm. The height of the guide shall be 25 mm.

5.7 *Trowel*—The trowel shall have a steel blade 115 by 250 mm in length, with straight edges.

5.8 *Flexure Testing Device*—The centerpoint loading method shall be used in making flexure tests on the prism specimens. The device used shall be designed such that the forces applied to the specimen will be vertical only and applied without eccentricity. A device that accomplishes this purpose, for use in a compression testing machine, is shown in Fig. 3. Apparatus for making flexure tests of mortar specimens shall be designed to incorporate the following principles:

5.8.1 The distance between supports and points of load application shall remain constant.

5.8.2 The load shall be applied normal to the loaded surface of the specimen and in such a manner as to avoid all eccentricity of loading.

5.8.3 The direction of the reactions should be parallel to the direction of the applied load at all times during the test.

5.8.4 The load should be applied at a uniform rate and in a manner to avoid shock.

5.9 *Compression Testing Machine*—The compression testing machine used with the flexure testing device, as shown in Fig. 3, shall be of the hydraulic type and conform to the requirements prescribed in Test Method C 109/C 109M.

NOTE 1—Most hydraulic compression machines designed for breaking 50-mm cubes have a relatively small diameter lower bearing surface directly centered below the upper spherically seated head, on which close-fitting pedestals of appropriate heights are set for breaking 50-mm cubes and 50 by 100-mm or 75 by 150-mm cylinders. The base plate of the flexure testing apparatus shown in Fig. 3 is designed to rest on the low pedestal intended for tests on 75 by 150-mm.

NOTE 2—In the absence of self-centering arrangements on machines with large lower bearing surfaces, the center of this surface directly below the center of the upper spherically seated head shall be accurately located. A circle or concentric circles of appropriate diameters shall be scribed on the lower bearing surface around this point. A cylindrical pedestal of appropriate diameter and height shall be obtained. End faces of the pedestal must be plane and parallel and at 90° to the axis of the cylinder. The upper face shall have a diameter of 77.5 mm.

6. Materials

6.1 *Graded Standard Sand*:

6.1.1 The sand used for making test specimens shall be natural silica sand and conform to Specification C 778.

7. Number of Specimens

7.1 Three or more specimens shall be made for each period of test specified.

8. Preparing Specimen Molds

8.1 Prepare the specimen molds as prescribed in Test Method C 109/C 109M.

9. Procedure

9.1 *Proportioning, Consistency, and Mixing of Mortars*—The proportioning, consistency, and mixing of the standard

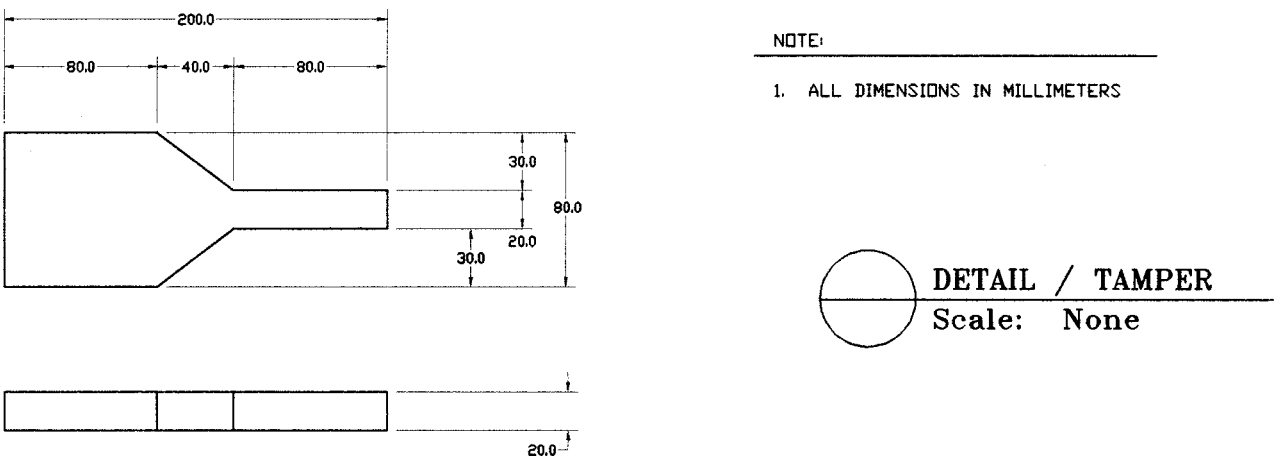

FIG. 1 Tamper

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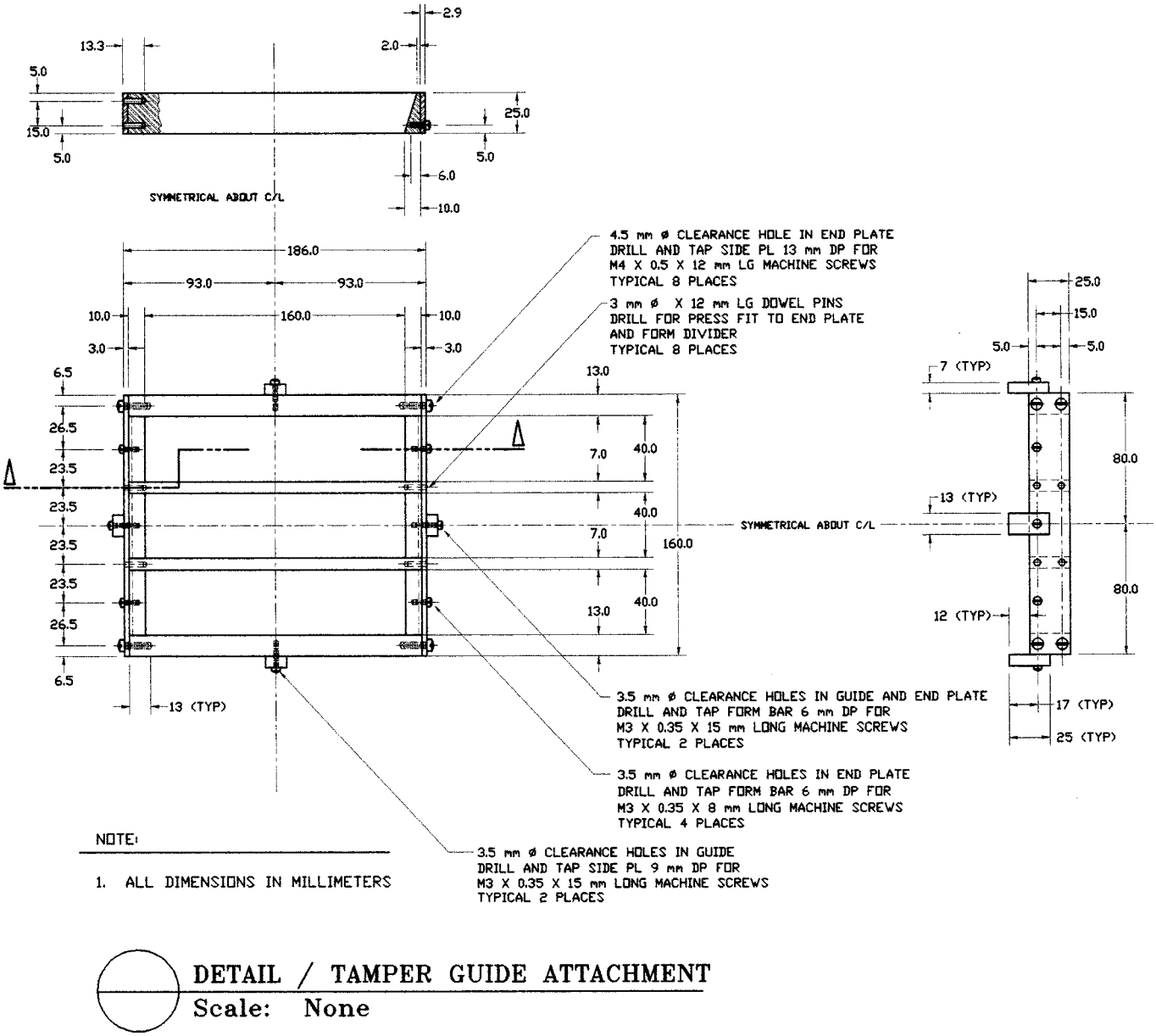

FIG. 2 Tamper Guide Attachment

mortar shall be in accordance with the Procedure Section of Test Method C 109/C 109M.

9.2 *Determination of Flow*—The flow shall be determined in accordance with Test Method C 1437.

9.3 *Molding Test Specimens*:

9.3.1 Immediately following completion of the flow test, return the mortar from the flow table to the mixing bowl. Quickly scrape down into the batch the mortar that may have collected on the side of the bowl and then remix the entire batch 15 s at medium speed. Upon completion of mixing, the mixing paddle shall be shaken to remove excess mortar into the mixing bowl.

9.3.2 When a duplicate batch is to be made immediately for additional specimens, the flow test may be omitted and the mortar allowed to remain in the mixing bowl for 90 s without covering. During the last 15 s of this interval, quickly scrape down into the batch the mortar that may have collected on the side of the bowl. Then remix for 15 s at medium speed.

9.3.3 Start molding the specimens within a total elapsed time of not more than 2 min and 30 s after completion of the original mixing of the mortar batch.

9.3.4 Evenly distribute a layer of mortar about 20 mm in thickness in each of the three molds with the tamper guide in place. Then compact the mortar in each mold by twelve strokes of the tamper, applied in three rounds of four strokes each, as shown in Fig. 4. Complete the twelve strokes in about 15 s. For each stroke hold the tamper face in horizontal position about 25 mm above the mortar level and then thrust directly downward with sufficient force to squeeze out a small amount of mortar from under the tamping surface. Fill the molds with mortar which shall be uniformly distributed and tamped in the same manner as the bottom layer. Then remove the tamper guide and

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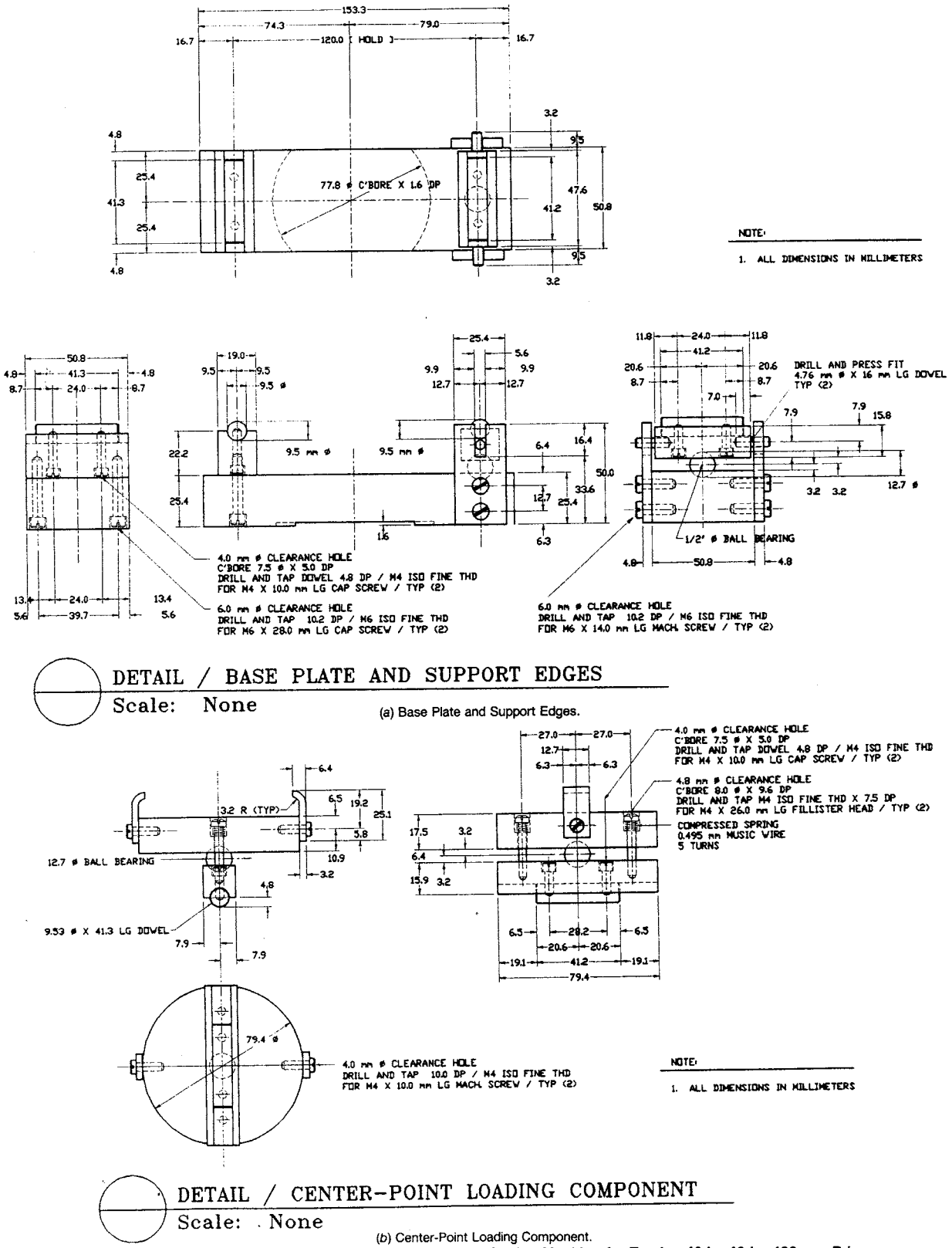

FIG. 3 Special Components for Adapting Compression Testing Machine for Testing 40 by 40 by 160-mm Prisms

smooth off the specimens by drawing the flat side of the trowel (with the leading edge slightly raised) once along the length of the molds. Cut the mortar off flush with the top of the molds by the straight edge of the trowel (held nearly perpendicular to the molds) with a sawing motion over the length of the molds. Following the cutting operation repair tears or cracks in the top

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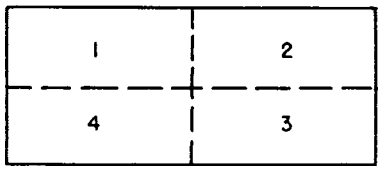

FIG. 4 Order of Tamping in Molding of Specimens (Three Rounds)

surfaces and then make the surfaces of the specimens plane by two or three light longitudinal strokes of the trowel held with the leading edge slightly raised.

9.4 *Storage of Test Specimens*—Store the test specimens in accordance with Test Method C 109/C 109M.

9.5 *Determination of Flexural Strength*:

9.5.1 Test the specimens immediately after their removal from the moist closet in the case of 24-h specimens and from the storage water in the case of all other specimens. All test specimens for a designated test age shall be broken within the permissible tolerance prescribed below:

Test Age	Permissible Tolerance, h
24 h	±½
3 days	±1
7 days	±3
28 days	±12

When the portions of prisms are tested as modified cubes in accordance with Test Method C 349, test the prisms early enough so that the modified cubes are also broken within the above tolerances. If more than one specimen at a time is removed from the moist closet for the 24-h test, cover these specimens with waterproof plastic until the time of test. For older specimens, if more than one specimen at a time is removed from the storage water for testing, place these specimens in water at a temperature of 23 ± 2.0 °C and of sufficient depth to completely immerse each specimen until time of test.

NOTE 3—The flexural strength of prisms is quickly affected by drying which produces skin tension in the specimens and yields low strengths. Specimens for test at 24 h should, therefore, be removed from molds preferably at that age and tested immediately. If there is a delay in testing, specimens shall be wrapped in waterproof plastic and placed in the moist closet until immediately before testing. After breaking, rewrap in plastic until compressive tests are made.

9.5.2 Wipe each prism to a surface-dry condition, and remove any loose sand grains or incrustations from the faces that will be in contact with the bearing surfaces of the points of support and load application. Check these faces by applying a straightedge. If there is appreciable curvature, grind the face or faces to plane surfaces or discard the specimen. Cloths used for wiping 24-h specimens shall be not more than faintly damp.

9.5.3 Center the pedestal on the base plate of the machine directly below the center of the upper spherical head, and place the bearing plate and support edge assembly on the pedestal. Attach the center-loading device to the spherical head. Turn the specimen on its side with respect to its position as molded and place it on the supports of the testing device. The longitudinal center line of the specimen shall be set directly above the midpoint of both supports. Adjust the center-point loading device so that its bearing edge is at exactly right angles to the length of the prism and parallel to its top face as placed, with the center of the bearing edge directly above the center line of the prism and at the center of the span length. Take care to ensure that contact between the specimen and loading edge is continuous when the load is applied. Apply the load at the rate of 2640 ± 110 N which shall be indicated within an accuracy of ±1 % on a dial graduated in increments of not more than 44 N. Estimate the total maximum load to the closest 22 N.

10. Calculation

10.1 Record the total maximum load indicated by the testing machine and calculate the flexural strength (for the particular size of specimen and conditions of test herein described) in MPa as follows:

$$S_f = 0.0028\,P \quad (1)$$

where:

S_f = flexural strength, MPa, and
P = total maximum load, N.

11. Faulty Specimens and Retests

11.1 Test specimens that are manifestly faulty or that result in strengths differing by more than 10 % from the average value of all test specimens made from the same sample and tested at the same period shall not be considered in determining the flexural strength. After discarding specimens or strength values, if less than two strength values are left for determining the flexural strength at any given period a retest shall be made.

12. Precision and Bias

12.1 *Precision*:

12.1.1 The following precision statements are applicable when a test result is the average of flexural strength tests of three prisms molded from a single batch of mortar and tested at the same age. They are applicable to mortars made with Type I, IA, IS, or III cement tested at 3, 7, or 28 days (1, 3, or 7 days for Type III cement).

12.1.1.1 *Multilaboratory Precision*—The multilaboratory coefficient of variation has been found to be 8.4 %. Therefore, results of properly conducted tests of single batches by two different laboratories should not differ by more than 23.8 % of their average.

NOTE 4—These numbers represent, respectively, the (1s %) and (d2s %) limits as described in Practice C 670.

12.1.1.2 *Single-Laboratory Precision*—The single-laboratory coefficient of variation has been found to be 5.1 %. Therefore, results of two properly conducted tests of single batches of mortar made with the same materials either on the same day or within the same week should not differ from each other by more than 14.4 % of their average (see Note 4).

12.2 *Bias*—No statement on bias is being made since there is no accepted reference material suitable for determining the bias of this test method.

13. Keywords

13.1 compressive strength; flexural strength; hydraulic-cement mortar; hydraulic-cement strength; mortar strength; strength

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For additional information on details of cement test methods, reference may be made to the "Manual of Cement Testing," which appears in the *Annual Book of ASTM Standards,* Vol 04.01.

SUMMARY OF CHANGES

Committee C01 has identified the location of selected changes to this test method since the last issue, C 348 – 02, that may impact the use of this test method. (Approved December 1, 2008)

(*1*) Revised the standard to delete informational units.
(*2*) Revised 5.1 to add reference to Specification C 1005.
(*3*) Revised 9.2 to add reference to Test Method C 1437.

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Designation: C 349 – 08

Standard Test Method for Compressive Strength of Hydraulic-Cement Mortars (Using Portions of Prisms Broken in Flexure)[1]

This standard is issued under the fixed designation C 349; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope*

1.1 This test method covers the determination of the compressive strength of hydraulic-cement mortars, using for the test specimens portions of prisms made and broken in flexure in accordance with Test Method C 348.

1.2 The values stated in SI units are to be regarded as standard. No other units of measurement are included in this standard.

1.3 Values in SI units shall be obtained by measurement in SI units or by appropriate conversion, using the Rules for Conversion and rounding given in Standard IEEE/ASTM SI 10, of measurements made in other units.

1.4 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use. (***Warning—**Fresh hydraulic cementitious mixtures are caustic and may cause chemical burns to skin and tissue upon prolonged exposure.[2])

2. Referenced Documents

2.1 *ASTM Standards:*[3]

C 109/C 109M Test Method for Compressive Strength of Hydraulic Cement Mortars (Using 2-in. or [50-mm] Cube Specimens)

C 348 Test Method for Flexural Strength of Hydraulic-Cement Mortars

C 670 Practice for Preparing Precision and Bias Statements for Test Methods for Construction Materials

IEEE/ASTM SI 10 Standard for Use of the International System of Units (SI): The Modern Metric System

3. Significance and Use

3.1 This method provides a means of obtaining compressive strength values from the same specimens previously used for flexural strength determinations by Test Method C 348. The compressive strength values are for reference purposes, and not as substitutes for values obtained by Test Method C 109/C 109M for cement acceptance.

4. Apparatus

4.1 *Bearing Plates*—The bearing plates shall be not less than 25 mm in thickness and shall be made of a hard metal. The surfaces of the bearing plates that are placed in contact with the specimens shall be 40.0 ± 0.1-mm by 50.8-mm rectangles, with the 50.8-mm dimension at right angles to the longitudinal axis of the prism. The bearing plate surfaces in contact with the specimen shall have a Rockwell hardness of not less than 60 HRC. These surfaces shall not depart from plane surfaces by more than 0.01 mm when the plates are new and shall be maintained within a permissible variation of 0.03 mm.

4.2 *Device for Aligning Bearing Plates*—A device for aligning the bearing plates to ensure the proper location of the upper plate with reference to the lower plate is shown in Fig. 1. If the upper bearing plate does not have free movement within the aligning plates, these shall be separated from the bottom plate by insertion of 0.05-mm shims on each side of the bottom bearing plate, and the two 6-mm pins in the upper bearing plate filed down just sufficiently to permit free up and down movement in the slots at the top of the aligning plates.

4.3 *Testing Machine*—The testing machine shall conform to the requirements prescribed in Test Method C 109/C 109M, except that the testing machine shall be of the hydraulic type.

5. Test Specimens

5.1 Both portions from each prism broken in flexure shall be used for compression testing, except that the broken portions of prisms selected for the compression test shall have a length of

[1] This test method is under the jurisdiction of ASTM Committee C01 on Cement and is the direct responsibility of Subcommittee C01.27 on Strength.

Current edition approved Dec. 1, 2008. Published January 2009. Originally approved in 1954. Last previous edition approved in 2002 as C 349 – 02.

[2] See the section on Safety, Manual of Cement Testing, *Annual Book of ASTM Standards*, Vol 04.01.

[3] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

***A Summary of Changes section appears at the end of this standard.**

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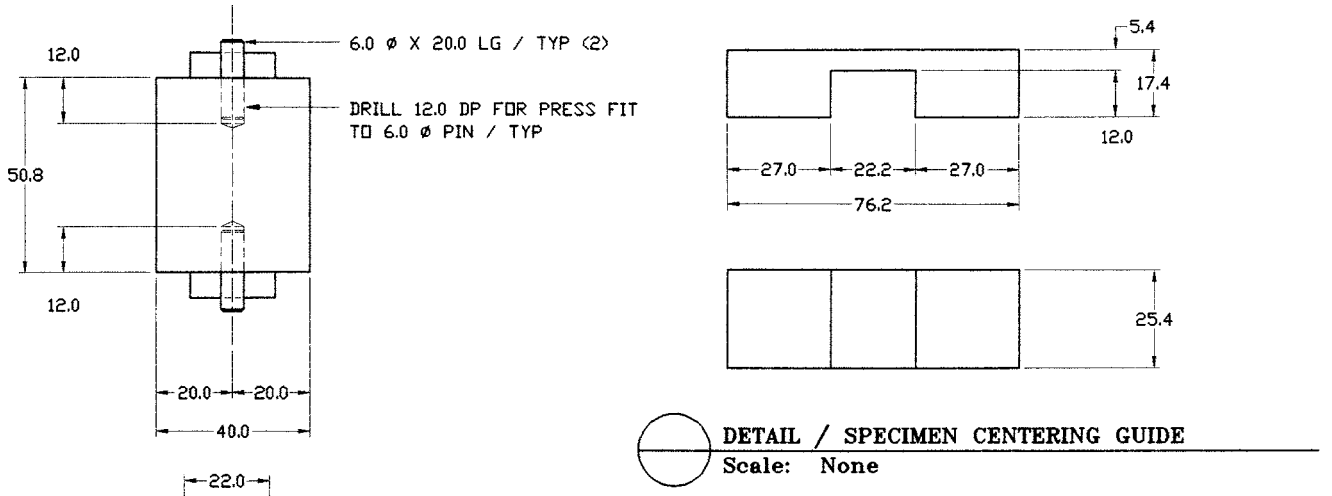

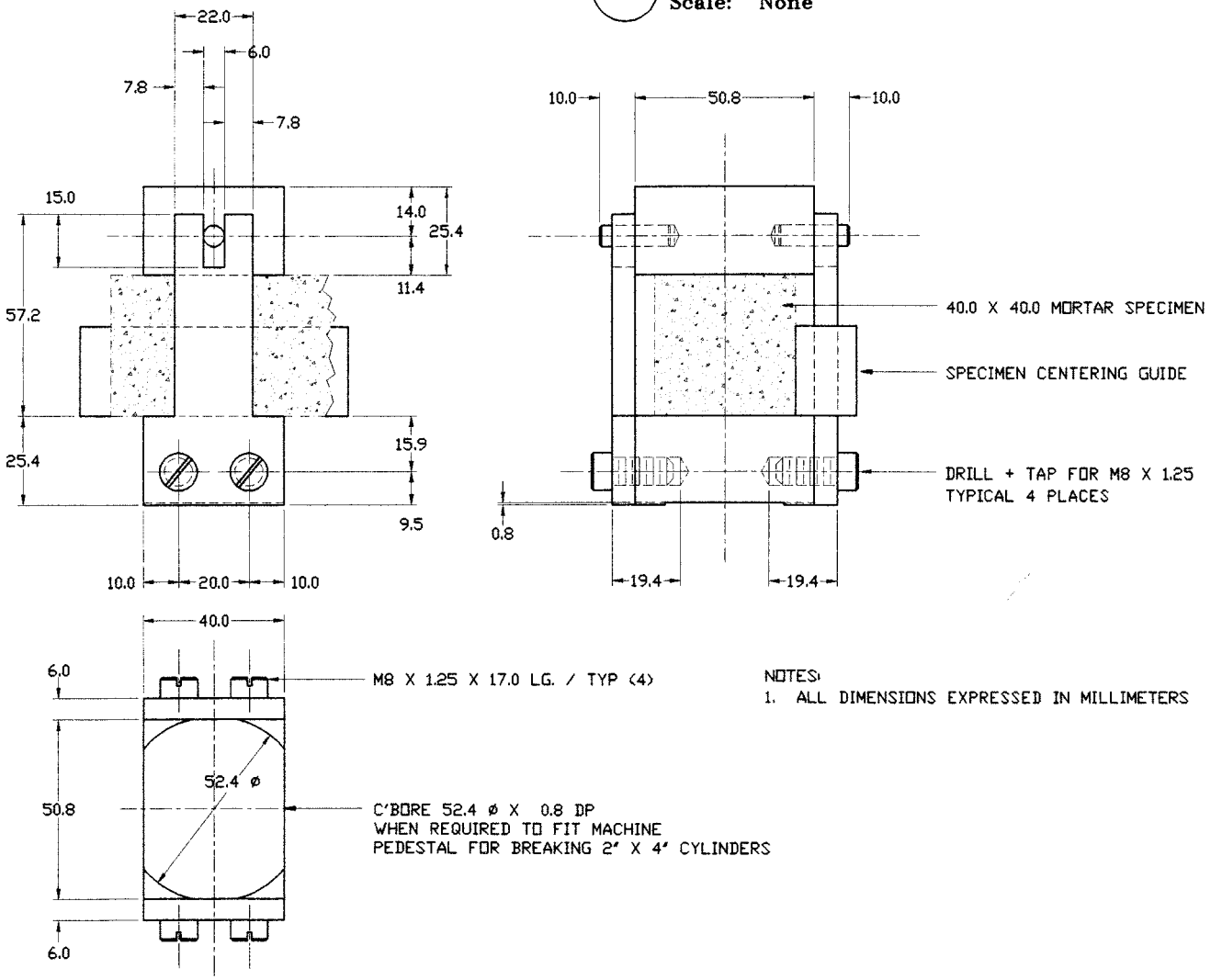

SI Equivalents

in.	1/32	1/4	5/16	3/8	0.462	1/2	9/16	5/8	3/4	7/8	1	1 1/16	1 3/4	2	2 1/16	2 1/2	3
mm	0.8	6.4	7.9	9.5	11.7	13	14.3	16	19	22.2	25	27	44.5	51	52.4	64	76

FIG. 1 Bearing Plates and Bearing Plate Aligning Device for Testing 40 by 40 by 160-mm Mortar Prisms as Modified Cubes

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not less than 65 mm and shall be free of cracks, chipped surfaces, or other obvious defects.

6. Procedure

6.1 *Determination of Compressive Strength*—During the interval between flexure tests of the prisms and testing the broken portions as modified cubes, cover the specimens for the 24-h test with waterproof plastic and completely immerse all other specimens in water at a temperature of 23 ± 2.0 °C until the time of testing. Wipe the specimen to a surface-dry condition, and remove any sand grains or incrustations from the faces that will be in contact with the bearing plates of the testing apparatus. Check these faces by application of a straightedge. If there is appreciable curvature, grind the face or faces to plane surfaces or discard the specimen (Note 1). Center the pedestal usually provided for breaking 50 by 100-mm cylinders on the base bearing block of the machine, and center the bearing plate assembly on top of this pedestal. If the testing machine has no provisions for automatic accurate centering of a pedestal exactly below the center of its upper spherical bearing head, a hardened steel cylinder of suitable diameter and height and with parallel plane end faces may be used, provided that the bearing plate assembly is centered accurately below the center of the upper bearing head after the specimen has been placed in proper position in the bearing plate assembly. Apply the specimen aligning guide to the outside of one of the aligning plates of the bearing plate assembly, with the lugs at each end resting on or slightly above the edge of the bearing face of the bottom plate. Turn the specimen on its side with respect to its position as molded and place it in the device with the bottom as molded in contact with the aligning lugs, holding the aligning guide against the aligning plate firmly with one hand. Then remove the aligning guide without disturbing the position of the specimen and apply the load in accordance with the Procedure section of Test Method C 109/C 109M. The testing of the broken portions as modified cubes shall follow breaking in flexure within 10 min for 24-h specimens and within 30 min for all other specimens.

NOTE 1—*Modified Cube Faces*—Results much lower than the true strength will be obtained by loading faces of the modified cube that are not truly plane surfaces. It is essential, therefore, that molds be kept scrupulously clean, as otherwise large irregularities in the surfaces will occur. Instruments for cleaning molds should always be softer than the metal in the molds to prevent wear. In case grinding of modified cube faces is necessary, it can be accomplished best by rubbing the specimen on a sheet of fine emery paper or cloth glued to a plane surface, using only moderate pressure. Since such grinding is tedious for more than a few thousandths of an inch or hundredth of a millimetre, it is recommended that where more than this is found necessary, the specimen be discarded.

7. Calculation

7.1 Record the total maximum load indicated by the testing machine and calculate the compressive strength in megapascals to the nearest 0.1 MPa, as follows:

$$S_c = 0.00062\,P \quad (1)$$

where:

S_c = compressive strength, MPa, and
P = total maximum load, N.

8. Faulty Specimens and Retests

8.1 Specimens that are manifestly faulty or that result in strengths differing by more than 10 % from the average value of all test specimens made from the same sample and tested at the same period shall not be considered in determining the compressive strength. After discarding strength values, if less than two strength values are left for determining the compressive strength at any given period a retest shall be made.

NOTE 2—Reliable strength results depend upon careful observance of all of the specified requirements and procedures. Erratic results at a given test period indicate that some of the requirements and procedures have not been carefully observed; for example, those covering the testing of the modified cubes, as prescribed in Sections 5 and 6. Specimens exhibiting oblique fractures on breaking, due to improper centering in the compression machine or to lateral movement of one of the testing machine heads during loading, will often indicate lower strengths than specimens showing a normal pyramidal fracture.

9. Precision and Bias

9.1 *Precision*—The following precision statements are applicable when a test result is the average of compressive strength tests of six modified cubes (using portions of prisms broken in flexure) molded from a single batch of mortar and tested at the same age. They are applicable to mortars made with Type I, IA, IS, or III cement tested at 3, 7, or 28 days (1, 3, or 7 days for Type III cement).

9.1.1 *Multilaboratory Precision*—The multilaboratory coefficient of variation has been found to be 6.3 %. Therefore, results of properly conducted tests of single batches by two different laboratories should not differ by more than 17.8 % of their average (Note 3).

NOTE 3—These numbers represent, respectively, the (1s%) and (d2s%) limits as described in Practice C 670.

9.1.2 *Single-Laboratory Precision*—The single-laboratory coefficient of variation has been found to be 3.5 %. Therefore, results of two properly conducted tests of single batches of mortar made with the same materials either on the same day or within the same week should not differ from each other by more than 9.9 % of their average (Note 3).

9.2 *Bias*—The procedure in this test method has no bias because the value of compressive strength is defined in terms of the test method.

10. Keywords

10.1 compressive strength; hydraulic-cement mortar; hydraulic-cement strength; mortar strength; strength

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For additional useful information on details of cement test methods, reference may be made to the "Manual of Cement Testing," which appears in the *Annual Book of ASTM Standards* Vol 04.01.

SUMMARY OF CHANGES

Committee C01 has identified the location of selected changes to this test method since the last issue, C 349 – 02, that may impact the use of this test method. (Approved December 1, 2008)

(*1*) Revised 1.2, 3.1, and 6.1 to remove informational units.

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Designation: C 359 – 08

Standard Test Method for Early Stiffening of Hydraulic Cement (Mortar Method)[1]

This standard is issued under the fixed designation C 359; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope*

1.1 This test method covers the determination of early stiffening in hydraulic-cement mortar.

1.2 The values stated in SI units are to be regarded as standard. The values given in parentheses are mathematical conversions to inch-pound units that are provided for information only and are not considered standard.

1.3 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.* (**Warning**—Fresh hydraulic cementitious mixtures are caustic and may cause chemical burns to skin and tissue upon prolonged exposure. The use of gloves, protective clothing, and eye protection is recommended. Wash contact area with copious amounts of water after contact. Wash eyes for a minimum of 15 min. Avoid exposure of the body to clothing saturated with the liquid phase of the unhardened material. Remove contaminated clothing immediately after exposure.[2])

1.4 The text of this standard references notes and footnotes which provide explanatory material. These notes and footnotes (excluding those in tables and figures) shall not be considered as requirements of the standard.

2. Referenced Documents

2.1 *ASTM Standards:* [3]

C 183 Practice for Sampling and the Amount of Testing of Hydraulic Cement

C 185 Test Method for Air Content of Hydraulic Cement Mortar

C 187 Test Method for Normal Consistency of Hydraulic Cement

C 305 Practice for Mechanical Mixing of Hydraulic Cement Pastes and Mortars of Plastic Consistency

C 670 Practice for Preparing Precision and Bias Statements for Test Methods for Construction Materials

C 778 Specification for Standard Sand

C 1005 Specification for Reference Masses and Devices for Determining Mass and Volume for Use in the Physical Testing of Hydraulic Cements

D 1193 Specification for Reagent Water

E 2251 Specification for Liquid-in-Glass ASTM Thermometers with Low-Hazard Precision Liquids

3. Terminology

3.1 *Definitions:*

3.1.1 *early stiffening*, *n*—the early development of stiffness in the working characteristics of a hydraulic-cement paste, mortar, or concrete; varieties include false set and flash set.

3.1.2 *false set*, *n*—the early development of stiffness in the working characteristics of a hydraulic-cement paste, mortar, or concrete without the evolution of much heat, which stiffness can be dispelled and plasticity regained by further mixing without addition of water; also known as "grab set," " premature stiffening," "hesitation set," and "rubber set."

3.1.3 *flash set*, *n*—the early development of stiffness in the working characteristics of a hydraulic-cement paste, mortar, or concrete, usually with the evolution of considerable heat, which stiffness cannot be dispelled nor can the plasticity be regained by further mixing without addition of water; also known as "quick set."

4. Summary of Test Method

4.1 A mortar is prepared with the cement to be tested, using specified quantities of cement, standard sand, and an amount of water that will produce a mortar with an initial penetration of 46 ± 3 mm, using the modified Vicat apparatus. Measurements of penetration are made at stipulated intervals after the beginning of the mixing procedure. Upon completion of the first series of penetration measurements, the mortar is returned to the mixer to be remixed. Following the remix procedure, an

[1] This test method is under the jurisdiction of ASTM Committee C01 on Cement and is the direct responsibility of Subcommittee C01.30 on Time of Set.

Current edition approved June 1, 2008. Published June 2008. Originally approved in 1955. Last previous edition approved in 2007 as C 359 – 07.

[2] Section on Safety, Manual of Cement Testing, *Annual Book of ASTM Standards*, Vol 04.01.

[3] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

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additional penetration, termed the remix penetration, is determined. The report is a tabulation of the penetration measurements and the amount of mixing water used.

5. Significance and Use

5.1 The purpose of this test method is to determine the degree to which a cement mortar develops early stiffening. It is intended for use by those interested in methods for determining the potential early stiffening of hydraulic cement.

5.2 When used for estimating the relative tendency of a cement to manifest early stiffening, a judgment may be made by comparing the behavior in the penetration series (see 10.4.1 and 10.4.2) and the remix procedure (see 10.4.3) to differentiate a relatively less serious and less persistent tendency to early stiffening (false set) from one that is more persistent and, consequently, more serious (flash set).

5.3 Severe false setting in a cement may cause difficulty from a placing and handling standpoint, but it is not likely to cause difficulties where concrete is mixed for a longer time than usual, as usually occurs in transit mixing, or where it is remixed prior to placing or transporting, in concrete pumping operations. It is most likely noticed where concrete is mixed for a short period of time in stationary mixers and transported to the forms in non-agitating equipment, as on some paving jobs, and when concrete is made in an on-site batch plant.

5.4 Cements with severe false setting usually require slightly more mixing water to produce the same consistency, which may result in slightly lower strengths and increased drying shrinkage.

5.5 Early stiffening resulting from false set is not likely to cause a cement to fail the applicable time of setting requirement.

5.6 Early stiffening resulting from flash set, depending on severity, can cause a cement to fail the applicable time of setting requirement.

6. Apparatus

6.1 *Vicat Apparatus*, conforming to the requirements of Fig. 1 in Test Method C 187, with the following modifications:

6.1.1 The 1-mm needle shall be replaced by a mass, such that the total mass of the 10-mm plunger, indicator, and added mass shall be 400 ± 0.5 g.

6.2 *Spoon*, conforming to the requirements of Test Method C 185.

6.3 *Mixer, Bowl, Paddle, and Scraper*, conforming to the requirements of Practice C 305.

6.4 *Glass Graduates*, 200 or 250 mL capacity, conforming to the requirements of Specification C 1005.

6.5 *Masses and Mass Determining Devices*, conforming to the requirements of Specification C 1005. The devices for determining mass shall be evaluated for precision and accuracy at a total load of 1000 g.

6.6 *Thermometer*, ASTM No. S12C or S12F, conforming to the requirements of Specification E 2251.

6.7 *Flat Trowel*, having a sharpened straight-edged steel blade 100 to 150 mm in length. The edges when placed on a plane surface shall not depart from straightness by more than 1 mm.

6.8 *Clock Timer*, having a readability to the nearest second.

6.9 *Containers*, approximately 50 by 50 by 150 mm (2 by 2 by 6 in.) inside dimensions (Fig. 1). These containers, which may be made of any suitable materials such as sheet metal or plastic, shall be rigid, watertight, and at least 50 mm (2 in.) deep.

7. Reagents and Materials

7.1 *Standard Sand, 20-30 and Graded*, conforming to the requirements of Specification C 778.

7.2 *Mixing Water*—Potable water is satisfactory for routine tests. For all referee and cooperative tests, reagent water conforming to the requirements of Specification D 1193 for Type III or Type IV grades of reagent water shall be used.

8. Sampling

8.1 When the test is part of acceptance testing, sample the cement in accordance with Practice C 183.

9. Conditioning

9.1 Maintain the temperature of the room, dry materials, paddle, bowl, and containers at 23.0 ± 3.0 °C.

9.2 The relative humidity of the mixing room shall not be less than 50 %.

10. Procedure

10.1 *Batch*—Mix at one time 600 g of cement, 300 g of graded standard sand, 300 g of 20-30 standard sand, and an amount of water that produces a mortar with an initial penetration of 46 ± 3 mm.

10.2 *Mixing of Mortar*—Mix in the mechanical mixer as follows:

10.2.1 Place the sand and cement in the dry bowl, and mix the dry materials for a few seconds with the spoon.

10.2.2 Place the bowl in the mixer, set the paddle in place, and mix the dry materials for 10 s at a slow speed (140 ± 5 r/min).

10.2.3 With the mixer operating at a slow speed (140 ± 5 r/min), add the entire quantity of mixing water within 5 s. Stop the mixer, quickly change to a medium speed (285 ± 10 r/min), and continue the mixing for 1 min, timing from the first addition of water.

10.2.4 Stop the mixer, scrape the sides of the mixing bowl with the rubber scraper, and quickly place the thermometer in the mortar. Allow it to stand undisturbed for the remainder of a 45-s interval from the time of stopping the mixer.

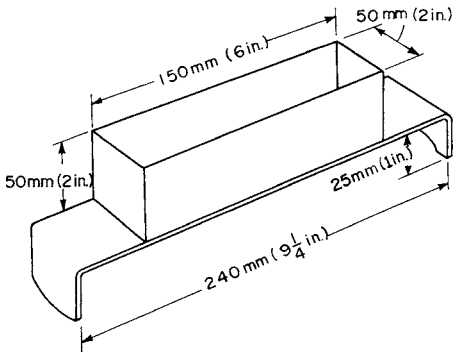

FIG. 1 Container for Early Stiffening Tests

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10.2.5 Read the temperature, remove the thermometer, start the mixer, and mix for 15 s at a medium speed (285 ± 10 r/min). If the mortar temperature is not in the range from 23 ± 2.0 °C, discard the batch and adjust the temperature of the water or sand, or both, to give the required temperature.

10.3 *Filling Container*:

10.3.1 Immediately after completion of the mixing, remove the bowl from the mixer and with a spoon, uniformly distribute a portion of the mortar into the container until the container is heaping full. Quickly and gently place each spoonful of mortar in the container. When removing the mortar from the bowl, do not remove the material pushed up on the side of the bowl by the paddle. After the container has been filled, reassemble the mixer, cover the bowl with a lid, and retain the remaining mortar for a remix test to be performed later. To compact the mortar in the container, lift the container approximately 80 mm (3 in.) from the table with both hands and rap it twice against the surface of the table.

10.3.2 With the leading edge slightly raised, strike off the mortar with one stroke of the trowel along the length of the container. Then remove the excess mortar by means of a sawing motion with the straightedge of the trowel along the length of the container in a direction opposite to that used in striking off. Then, smooth the surface of the mortar with a single stroke of the trowel.

10.4 *Penetration Tests*:

10.4.1 After filling the container, immediately place the 10-mm plunger of the modified Vicat apparatus in contact with the surface of the mortar at the midpoint of the container on the longitudinal center line. Set the movable indicator at zero. Release the plunger 3 min after the beginning of the wet mixing and record, as the initial penetration, the depth in millimetres to which the plunger has settled below the surface 10 s after being released. If the plunger does not settle to a depth of 46 ± 3 mm, discard the batch and adjust the quantity of water to produce the required consistency.

10.4.2 Immediately withdraw and clean the plunger. In a similar manner, determine, after moving the Vicat apparatus to the desired location, the penetrations at intervals of 5, 8, and 11 min after the beginning of mixing. Do not move the filled container until these measurements are completed. Make all penetrations along the longitudinal center line of the container. Obtain 5 and 8-min penetrations at a distance of approximately 40 mm (1½ in.) from each end of the container, respectively, and determine the 11-min penetration at a point approximately midway between the points at which the initial and 5-min penetrations were determined.

10.4.3 At the completion of the measurement of the 11-min penetration, immediately return the mortar in the container to the bowl. Start the mixer, raise the bowl into mixing position, and remix the contents of the bowl at medium speed (285 ± 10 r/min) for 1 min. Fill a clean container as outlined in 10.3.1 and 10.3.2, and determine the penetration 45 s after completion of mixing.

11. Calculation

11.1 *Early Stiffening Amount*—The change in penetration from the initial penetration to the 11 min penetration.

11.1.1 Calculate as follows: A – D, where:

A = Initial Penetration
B = Penetration at 5 min
C = Penetration at 8 min
D = Penetration at 11 min
E = Penetration after REMIX

11.1.2 Report to the nearest mm.

11.2 *Average Early Stiffening Rate*—An average of the rate of penetration change between each set of measurements.

11.2.1 Calculate as follows:

$$\frac{\frac{A-B}{2}+\frac{B-C}{3}+\frac{C-D}{3}}{3}$$

where A,B,C,D are as defined in 11.1.1.

11.2.2 Report to the nearest 0.1 mm/min.

11.3 *Early Stiffening Recovery*—The percent penetration recovery accomplished with the REMIX procedure.

11.3.1 Calculate as follows:

$$100 * \frac{E}{A}$$

where E and A are as defined in 11.1.1. (See Note 2)

11.3.2 Report to the nearest percent.

12. Report

12.1 Report the measured and calculated values as shown below:

Mixing Water	___mL
Initial penetration	___mm
5-min penetration	___mm
8-min penetration	___mm
11-min penetration	___mm
Remix penetration	___mm
Early Stiffening Amount	___mm
Average Early Stiffening Rate	___mm/min
Early Stiffening Recovery	___%

13. Precision and Bias [4]

13.1 Early Stiffening Amount

13.1.1 The single-operator standard deviation has been found to be 1.8 mm over a range from 35 to 49 mm. Therefore, results of two properly conducted tests by the same operator on the same material are not expected to differ by more than 5 mm. (See Note 3)

13.1.2 The multilaboratory standard deviation has been found to be 2.5 mm over a range from 35 to 49 mm. Therefore, results of two properly conducted tests from two different laboratories on samples of the same cement are not expected to differ by more than 7 mm. (See Note 3)

13.2 Average Early Stiffening Rate

13.2.1 The single-operator standard deviation has been found to be 0.50 mm/min over a range from 4.0 to 8.0 mm/min. Therefore, results of two properly conducted tests by the same operator on the same material are not expected to differ by more than 1.4 mm/min. (See Note 3)

13.2.2 The multilaboratory standard deviation has been found to be 0.86 mm/min over a range from 4.0 to 8.0 mm/min. Therefore, results of two properly conducted tests from two

[4] Supporting data have been filed at ASTM International Headquarters and may be obtained by requesting Research Report RR: C01-1008.

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different laboratories on samples of the same cement are not expected to differ by more than 2.4 mm/min. (See Note 3)

13.3 Early Stiffening Recovery

13.3.1 The single-operator standard deviation has been found to be 6.6 % over a range from 40 to 100+ %. (See Note 2) Therefore, results of two properly conducted tests by the same operator on the same material are not expected to differ by more than 19 %. (See Note 3)

13.3.2 The multilaboratory standard deviation has been found to be 16.8 % over a range from 40 to 100+ %. (See Note 2) Therefore, results of two properly conducted tests from two different laboratories on samples of the same cement are not expected to differ by more than 48 %. (See Note 3)

13.4 Bias

13.4.1 Since an acceptable reference material suitable for determining any bias of the method does not exist, no statement on bias is being made.

NOTE 1—For additional useful information on details of cement test methods, reference may be made to the "Manual of Cement Testing," which appears in the *Annual Book of ASTM Standards*, Vol 04.01.

NOTE 2—Since it is possible for the remix penetration to exceed the initial penetration, this number may exceed 100 %.

NOTE 3—These numbers represent, respectively, the (1s) and (d2s) limits as described in ASTM Practice C 670.

14. Keywords

14.1 early stiffening; false set; flash set; hydraulic-cement mortar

SUMMARY OF CHANGES

Committee C01 has identified the location of selected changes to this test method since the last issue, C 359 – 07, that may impact the use of this test method. (Approved June 1, 2008)

(*1*) Revised 6.5, 6.7, and 9.2.

Committee C01 has identified the location of selected changes to this test method since the last issue, C 359 – 06, that may impact the use of this test method. (Approved June 1, 2007)

(*1*) Revised 6.6.

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Designation: C 387/C 387M – 09

Standard Specification for Packaged, Dry, Combined Materials for Mortar and Concrete[1]

This standard is issued under the fixed designation C 387/C 387M; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope*

1.1 This specification covers the production, properties, packaging, and testing of packaged, dry, combined materials for concrete and mortars. The classifications of concrete and mortar covered are defined in Section 3.

1.2 The values stated in either SI units or inch-pound units are to be regarded separately as standard. The values stated in each system may not be exact equivalents; therefore, each system shall be used independently of the other. Combining values from the two systems may result in non-conformance with the standard.

1.3 The following safety hazards caveat pertains only to the test method portion of this specification. *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

2. Referenced Documents

2.1 *ASTM Standards:*[2]

C 33 Specification for Concrete Aggregates
C 39/C 39M Test Method for Compressive Strength of Cylindrical Concrete Specimens
C 91 Specification for Masonry Cement
C 109/C 109M Test Method for Compressive Strength of Hydraulic Cement Mortars (Using 2-in. or [50-mm] Cube Specimens)
C 125 Terminology Relating to Concrete and Concrete Aggregates
C 138/C 138M Test Method for Density (Unit Weight), Yield, and Air Content (Gravimetric) of Concrete
C 143/C 143M Test Method for Slump of Hydraulic-Cement Concrete
C 144 Specification for Aggregate for Masonry Mortar
C 150 Specification for Portland Cement
C 173/C 173M Test Method for Air Content of Freshly Mixed Concrete by the Volumetric Method
C 185 Test Method for Air Content of Hydraulic Cement Mortar
C 192/C 192M Practice for Making and Curing Concrete Test Specimens in the Laboratory
C 207 Specification for Hydrated Lime for Masonry Purposes
C 231 Test Method for Air Content of Freshly Mixed Concrete by the Pressure Method
C 260 Specification for Air-Entraining Admixtures for Concrete
C 270 Specification for Mortar for Unit Masonry
C 305 Practice for Mechanical Mixing of Hydraulic Cement Pastes and Mortars of Plastic Consistency
C 330 Specification for Lightweight Aggregates for Structural Concrete
C 494/C 494M Specification for Chemical Admixtures for Concrete
C 566 Test Method for Total Evaporable Moisture Content of Aggregate by Drying
C 595 Specification for Blended Hydraulic Cements
C 618 Specification for Coal Fly Ash and Raw or Calcined Natural Pozzolan for Use in Concrete
C 702 Practice for Reducing Samples of Aggregate to Testing Size
C 989 Specification for Slag Cement for Use in Concrete and Mortars
C 1157 Performance Specification for Hydraulic Cement
C 1240 Specification for Silica Fume Used in Cementitious Mixtures
C 1329 Specification for Mortar Cement
C 1437 Test Method for Flow of Hydraulic Cement Mortar
C 1438 Specification for Latex and Powder Polymer Modifiers for Hydraulic Cement Concrete and Mortar
C 1506 Test Method for Water Retention of Hydraulic Cement-Based Mortars and Plasters

[1] This specification is under the jurisdiction of ASTM Committee C09 on Concrete and Concrete Aggregates and is the direct responsibility of Subcommittee C09.43 on Packaged Dry Combined Materials.

Current edition approved Feb. 1, 2009. Published February 2009. Originally approved in 1956. Last previous edition approved in 2008 as C 387/C 387M – 08.

[2] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

***A Summary of Changes section appears at the end of this standard.**

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E 96/E 96M Test Methods for Water Vapor Transmission of Materials

3. Terminology

3.1 *Definitions*—For definitions of terms used in this specification, refer to Terminology C 125.

3.2 Definitions of Terms Specific to This Standard:

3.2.1 *concrete, high-early strength*, *n*—in packaged, dry, combined materials, a product for building and repair requiring a more rapid than normal strength development such as required for the earlier removal of forms.

3.2.2 *concrete, normal strength* , *n*—in packaged, dry, combined materials, a product for general building and repair where thickness exceeds 50 mm [2 in.].

3.2.2.1 *Discussion*—Typical uses include building or repairing sidewalks, patios, steps, footings, and for setting posts.

3.2.3 *concrete, normal strength, lightweight*, *n*—in packaged, dry, combined materials, a concrete product for building and repair where the lightest concrete density is desirable.

3.2.3.1 *Discussion*—These mixtures will produce concrete that is about 25 to 35 % lower in density than normal weight concrete.

3.2.4 *concrete, normal strength, lightweight using normal weight sand*, *n*—in packaged, dry, combined materials, a concrete product for building and repair where a lower density is desirable.

3.2.4.1 *Discussion*—These mixtures will produce concrete that is about 15 to 25 % lower in density than normal weight concrete.

3.2.5 *mortar for unit masonry*, *n*—in packaged, dry, combined materials, a packaged mortar for laying brick, block, and stone, and for masonry repairs.

3.2.5.1 *Discussion*—These products are packaged versions of the masonry mortars that are specified in Specification C 270.

3.2.6 *mortar, high-strength* , *n*—in packaged, dry, combined materials, a product for building or repair requiring a thickness of less than 50 mm [2 in.], or where a high strength mortar mixture is required.

3.2.6.1 *Discussion*—Typical uses include topping and patching existing concrete structures. Often referred to as "sand mix."

4. Ordering Information

4.1 The purchaser shall specify the material desired as concrete, high strength mortar, or mortar for use with unit masonry, and the respective physical requirements as specified in Table 1 shall govern.

5. Materials

5.1 Materials used as ingredients in packaged, dry, combined materials for mortar and concrete shall conform to at least one of the following requirements:

5.1.1 *Aggregates*, shall conform to Specification C 33, Specification C 144, or Specification C 330.

5.1.2 *Air-Entraining Admixtures*, shall conform to Specification C 260.

5.1.3 *Blended Cement*, shall conform to Specification C 595 or Performance Specification C 1157.

5.1.4 *Chemical Admixtures*, shall conform to Specification C 494/C 494M.

5.1.5 *Flyash*, shall conform to Specification C 618.

5.1.6 *Ground Granulated Blast-Furnace Slag*, shall conform to Specification C 989.

5.1.7 *Hydrated Lime*, shall conform to Type S or Type SA of Specification C 207.

5.1.8 *Latex and Powder Polymer Modifiers*, shall conform to Specification C 1438.

NOTE 1—Type II latex polymers should not be used in applications that may be more than superficially wet in service.

5.1.9 *Masonry Cement*, shall conform to Specification C 91.

5.1.10 *Mortar Cement*, shall conform to Specification C 1329.

5.1.11 *Portland Cement*, shall conform to Type I, IA, II, IIA, III or IIIA of Specification C 150.

5.1.12 *Silica Fume*, shall conform to Specification C 1240.

6. Preparation of Aggregate

6.1 All aggregates prepared in the laboratory for the purpose of establishing the correct proportions for the product shall be dried, without disintegration, to a moisture content of less than 0.1 % by mass. Verify moisture content using a ventilated oven in accordance with Test Method C 566.

TABLE 1 Physical Requirements

Kind of Material	Compressive Strength, MPa [psi] min		
	3 days	7 days	28 days
Concrete:			
High-early strength	17.0 [2500]	24.0 [3500]	. . .
Normal strength:			
Normal weight	. . .	17.0 [2500]	24.0 [3500]
Lightweight using normal weight sand[A]	. . .	17.0 [2500]	24.0 [3500]
Lightweight	. . .	17.0 [2500]	24.0 [3500]
Mortar:			
High-strength mortar		20.0 [3000]	35.0 [5000]
Mortar for unit masonry:			
Type M		Shall comply with property requirements of Specification C 270[B]	
Type S			
Type N			

[A] Lightweight concrete using normal weight sand may contain some portion of lightweight fines.

[B] The performance requirements for 28-day compressive strength, water retention, and air content are those for mortars made from masonry cement unless otherwise specified. Manufacturers wishing to comply with the air content requirements for mortar-cement mortar or cement-lime mortar must specify the ingredients used and comply with the applicable portions of Specification C 270.

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7. Proportioning

7.1 The proportions of cementitious material and aggregate shall be such that the strength requirements will be met when an amount of mixing water is used that produces for concrete the slump specified in 13.3 and for mortar the flow specified in 15.2.

8. Physical Properties

8.1 Packaged, dry, combined materials for concrete, high strength mortar, and mortar for use with unit masonry shall conform to the respective physical requirements as given in Table 1 for the material specified when the prescribed amount of water is added.

9. Packaging and Package Marking

9.1 All packages shall be identified as conforming to Specification C 387, and as to kind and type of material listed in Table 1 and the net mass in each bag printed thereon.

9.2 The yield in liters (or cubic feet), and the amount of water recommended for mixing shall be marked on the package.

NOTE 2—The amount of water recommended should be the amount required to produce a slump of 50 to 75 mm [2 to 3 in.].

9.3 *Container Construction*—The material from which the containers are made shall have water vapor transmission not greater than 100 g/m^2 in 24 h as determined in accordance with Procedure B of Test Methods E 96. The strength of the container shall be adequate for the mass of concrete or mortar it is intended to contain.

10. Rejection

10.1 The purchaser has the right to reject material that fails to conform to the requirements of this specification. Rejection shall be reported to the Producer or supplier promptly and in writing.

SAMPLING AND TESTING

11. Accuracy of Measurement

11.1 Use scales conforming to the applicable sections of *Handbook 44*.[3] New and reconditioned scales shall be accurate to ±0.1 % of the total capacity of the scale. When scales have been in use, they shall be accurate to ±0.4 % of the total capacity of the scale.

11.2 Record the mass of concrete in kilograms (pounds) to a minimum accuracy of 0.05 kg [0.1 lb.]. Record the mass of mortar in grams to an accuracy of within 1 g or 0.1 %, whichever is greater.

12. Sampling Concrete

12.1 Use a sufficient quantity of whole packages to conduct all testing from a single batch.

13. Mixing and Testing Concrete

13.1 Determine the net mass of concrete in the package (or packages), then empty into a clean, watertight container.

13.2 Mix the concrete, determine the properties of the fresh concrete, and mold and cure the specimens in accordance with the applicable provisions of Practice C 192/C 192M, or modifications of them as outlined herein. Test the strength of the concrete in accordance with Test Method C 39/C 39M.

13.3 Mix the entire sample of the combined, dry material for concrete either by hand or by machine, except that hand mixing is not applicable to air-entrained concrete. Add mixing water in sufficient amount to produce a slump of 50 to 75 mm [2 to 3 in.].

13.4 Use a watertight, clean metal container for hand mixing, using either a blunted bricklayer's trowel, hands protected by rubber gloves, or a shovel, whichever is more convenient. Mix the dry batch until the materials appear to be uniformly distributed. Add water while mixing until the concrete is homogeneous in appearance and has the desired slump. If prolonged mixing is required because of the addition of mixing water in increments while adjusting the slump, the batch must be discarded and a new batch made without interrupting the mixing to make trial slump tests.

13.5 Place all materials in the mixer to be used for machine mixing. A mixing period of 3 min followed by a 3-min rest, followed by 2-min final mixing is suggested, unless a different procedure is better adapted to the mixer being used. Cover the open end of the mixer during the rest period to reduce evaporation. Test the slump in accordance with Test Method C 143/C 143M upon completion of the mixing. If the slump test of the mixed batch shows that additional water is required, return the sample used for the slump test promptly to the mixer, add additional water, and remix the batch for 2 min. Retest the slump. If the slump is not from 50 to 75 mm [2 to 3 in.], discard the batch.

13.6 Discharge the mixed batch into a clean, watertight container that has been predampened, then remix the batch by hand, using a scoop or trowel, until the batch appears to be uniform. Promptly determine the density in kilograms per cubic meter (or pound per cubic foot) in accordance with Test Method C 138/C 138M. Return samples used for the slump and unit weight test to the container, then remix the batch by hand and mold the specimens.

13.7 Mold six cylinders from each batch, using three cylinders for test at 7 days and three at 28 days, except that in the case of high early strength concrete, three cylinders shall be tested at 3 days and three at 7 days. Compression test specimens shall be cylindrical with a length equal to twice the diameter. The minimum specimen diameter shall be 75 mm [3 in.], but the maximum diameter is not limited, provided the number of specimens for a test as required in this section are molded from a single batch and the sample taken in accordance with 12.1. For acceptance, the average of the strengths of the three specimens tested at each age shall not be less than the

[3] *Specifications, Tolerances, and Other Technical Requirements of Weighing and Measuring Devices, Handbook 44,* National Bureau of Standards.

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compressive strength required in Table 1 for the type of concrete under test and no individual specimen shall have a strength less than 90 % of the required strength.

13.8 The report of the tests of the concrete shall include the following:

13.8.1 Net mass of dry, combined material in the bag or bags determined by subtracting the mass of the empty bag or bags from the gross mass of the package.

13.8.2 Amount of mixing water (*W*) calculated in terms of kilograms (or pounds) per bag, based on mass of the bag.

$$W=(W_b/A)B$$

W_b = mass of water added to batch,
A = mass of dry material in batch, and
B = printed mass of bag contents.

13.8.3 Slump in millimetres (or inches) in accordance with Test Method C 143/C 143M.

13.8.4 Density (*D*) in kilograms per cubic meter (or pounds per cubic foot) in accordance with Test Method C 138/C 138M.

13.8.5 Yield (*Y*) of concrete as determined by Test Method C 138/C 138M in terms of liters (or cubic feet) per bag, based on printed mass of bag contents.

13.8.6 Air content, if required, shall be determined by one of the following Test Methods: C 138/C 138M, C 173/C 173M, (suggested for lightweight concrete); or C 231. The method used to determine the air content shall be reported.

13.8.7 Compressive strength at the ages specified in Table 1; report the method of mixing the concrete. State the size of the cylinder used in the report.

14. Sampling Mortar

14.1 The contents of an entire package of dry, combined material for mortar for unit masonry or for concrete mortar shall be used as a sample. Determine the gross mass of the package and contents to the nearest 0.05 kg [0.1 lb.]. Empty the entire contents of the package into a clean, watertight container. Determine the mass of the empty package and calculate the net mass of the package from the gross mass of the package and contents. Reduce the sample to the proper size for testing in accordance with Practice C 702.

15. Mixing and Testing Mortar

15.1 Mortar mixing equipment shall be as specified in Practice C 305, except that the mixer must be provided with a bowl positioning adapter (Note 3) to ensure clearance for the largest size aggregate in the mix being tested. The mixing procedure shall be modified as given in 15.2.

NOTE 3—Description of such an adapter may be obtained from the Cement and Concrete Reference Laboratory of the National Institute of Standards Technology.

15.2 Mix 3000 ± 3 g [6.61 ± 0.01 lbs.] of mortar in accordance with Practice C 305 with the exception that the combined material is added at the time of cement addition in Practice C 305. Additional water may be added in the final mix period to adjust the flow. Determine the flow in accordance with Test Method C 1437. Use sufficient water to produce a flow of 110 ± 5 %.

15.3 *Compressive Strength*—Specimens shall be 50-mm [2-in.] cubes molded, cured, and tested in accordance with procedures in Specification C 270 for mortars for unit masonry and in accordance with Test Method C 109/C 109M for high-strength mortars.

15.4 *Density and Yield*—Determination of density of the mixed mortar and yield per package of mortar.

15.4.1 Vigorously remix the remaining mortar by hand for 10 s using a spoon. Consolidate the mortar into a 400-mL measure in accordance with Test Method C 185.

15.4.2 Determine the net mass (M) of the mortar in the 400-mL measure to the nearest 1 g.

15.4.3 Calculate the density of the mortar in kilograms per cubic metre (or pounds per cubic foot) using the equations:

$$D_k = 2.5M \text{ or } (D_p = 0.156M) \quad (1)$$

where:
D_k = density in kilograms per cubic metre
D_p = density in pounds per cubic foot

15.4.4 Calculate the yield (Y) per package in litres (cubic feet) as follows:

$$Y = (1 + R)PC/D \quad (2)$$

where:
R = ratio of mass (or weight) of mixing water to mass (or weight) of dry combined material in the batch of mortar.
P = the net mass (or weight) printed on the package.
C = Conversion factor. To determine the yield in litres, P must be in kilograms per cubic metre. The conversion factor is 1000. To determine the yield in pounds per cubic foot; P must be in pounds and D must be in pounds per cubic foot. The conversion factor is 1.

15.5 *Water Retention*—For mortars for unit masonry, determine the water retention in accordance with Test Method C 1506.

15.6 *Air Content* (required for mortars for unit masonry and optional for high-strength mortars)—If the mixture proportions are known, calculate the air content in accordance with Specification C 270. If the proportions are not known, use Test Method C 138/C 138M, or Test Method C 173/C 173M, or Test Method C 231 to determine air content.

15.7 The report of the tests shall include:

15.7.1 Net mass (or weight) of dry, combined material in the bag determined to 0.05 kg [0.1 lb],

15.7.2 Amount of mixing water (*W*) calculated in accordance with the formula specified in 13.8.2,

15.7.3 Flow, in accordance with Test Method C 1437,

15.7.4 Density (D) in kilograms per cubic metre (or pounds per cubic foot) as determined in 15.4 in accordance with Test Method C 138/C 138M,

15.7.5 Yield (*Y*) of mortar in liters (or cubic feet) as determined in 15.4,

15.7.6 Air content, if measured, and test method used to determine air content,

15.7.7 Water retention in percent, if measured, and

15.7.8 Compressive strength at ages specified in Table 1.

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16. Keywords

16.1 aggregate-cement aggregate combinations; cement mortars; combined concrete/mortar materials; concrete admixtures; concrete, packaged; concrete specifications; dry combined concrete/mortar materials; mortar-cement mortar; mortar, packaged; packaged dry combined materials; packaged concrete/mortar materials

SUMMARY OF CHANGES

Committee C09 has identified the location of selected changes to this specification since the last issue, C 387/C 387M – 08, that may impact the use of this specification. (Approved February 1, 2009)

(*1*) Revised Section 1.

(*2*) Added new Section 3 Terminology and renumbered subsequent sections.

Committee C09 has identified the location of selected changes to this specification since the last issue, C 387/C 387M – 06a, that may impact the use of this specification. (Approved December 1, 2008)

(*1*) Revised 6.1.

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Designation: C 400 – 98 (Reapproved 2006)

Standard Test Methods for Quicklime and Hydrated Lime for Neutralization of Waste Acid[1]

This standard is issued under the fixed designation C 400; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope

1.1 This test method covers the testing of quicklime and hydrated lime for use in the treatment of waste acid solutions and includes the characterization of the liming material and of the acid waste.

NOTE 1—When agreed upon by the manufacturer and the purchaser, this method may be used directly to evaluate the lime requirement for a plant waste acid and in the preparation of the lime slurry; the pH, the time, temperature, and other conditions of treatment may be adjusted to conform to plant practice. Otherwise the test shall be performed as described in this method.

NOTE 2—Under some conditions of test the lime requirement may vary substantially from that indicated by ultimate chemical analysis or by the use of a determination of available alkalinity by titration to a stoichiometric end point.

1.2 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

2. Referenced Documents

2.1 *ASTM Standards:* [2]

C 50 Practice for Sampling, Sample Preparation, Packaging, and Marking of Lime and Limestone Products

E 70 Test Method for pH of Aqueous Solutions With the Glass Electrode

3. Terminology

3.1 *Definitions:*

3.1.1 *neutralization coefficient*—the number of parts of lime required to neutralize one million parts by weight of sulfuric acid solution (1.5 %) to a pH of 4.4 in 30 min (see Note 1).

3.1.2 *pH*—a measure of the hydrogen ion concentration of a sample and representing the logarithm of the reciprocal (negative logarithm) of the activity of hydrogen ions, calculated as follows:

$$pH = \log \frac{1}{(H)^{+}} = -\log(H^{+})$$

where:

H^{+} = activity of hydrogen ions.

4. Significance and Use

4.1 Since all limes and waste acid solutions are different, this test method evaluates the relative quantity of a given lime needed for the neutralization of a specific quantity of acid.

4.2 Liming materials have a specific basicity factor or measure of alkalinity which can be used for comparing their relative neutralizing power. It avoids dependence on chemical analysis and is determined as grams of calcium oxide equivalents per kilogram of liming material.

4.3 Likewise, specific waste acids have an acid value that can be expressed as grams of hydrochloric acid equivalent per litre of acid waste. This value is related on a stoichiometric basis to lime neutralization requirements of a liquid acid waste.

5. Apparatus

5.1 *pH Measuring Apparatus,* conforming to the requirements of Section 5, Apparatus, and Section 6, Reagents and Materials, of Test Method E 70. A time-pH recording device or attachment is desirable but not required.

5.2 *Analytical Balance,* capable of reproducing results within 0.005 g.

5.3 *Stirrer*, motorized, capable of rotating at speeds from 120 to 600 r/min.

5.4 *Miscellaneous Equipment*—Chemically resistant glassware,[3] metal stands for support of the equipment, etc.

6. Purity of Reagents

6.1 Reagent grade chemicals shall be used in all tests. Unless otherwise indicated, it is intended that all reagents shall

[1] These test methods are under the jurisdiction of ASTM Committee C07 on Lime and are the direct responsibility of Subcommittee C07.05 on Chemical Tests.

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[2] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

[3] Borosilicate glass has been found satisfactory for this purpose.

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conform to the specifications of the Committee on Analytical Reagents of the American Chemical Society, where such specifications are available.[4] Other grades may be used, provided it is first ascertained that the reagent is of sufficiently high purity to permit its use without lessening the accuracy of the determination.

6.2 Unless otherwise indicated, references to water shall be understood to mean distilled water.

7. Test Method A—for Determining Lime Requirement for the neutralization of a standard sulfuric acid or waste acid solution within a time limit of thirty minutes.

7.1 *Reagents*:

7.1.1 *Sulfuric Acid, Standard Solution* (1.5 ± 0.05 %)—Thoroughly mix 15.8 g of concentrated sulfuric acid (95 % H_2SO_4) with water, dilute to 1 L, analyze to within 0.005 % H_2SO_4, and store in a suitable stoppered bottle.

7.2 *Preparation of Sample*:

7.2.1 Take samples of quicklime and hydrated lime in accordance with Methods C 50.

7.2.2 *Quicklime*—Weigh a sample of quicklime (2.50 ± 0.01 g) ground to pass a No. 50 mesh sieve. Add to a 500-mL tall-form beaker containing 50 mL of boiling water and continue to boil for 2 min. Remove from hot plate and continue stirring with a magnetic stirrer until the slurry reaches room temperature (at least 10 min).

7.2.3 *Hydrated Lime*—Mix a sample of hydrated lime (2.50 ± 0.01 g) with 50 mL of water in a 500-mL tall-form beaker for at least 10 min.

7.3 *Procedure*:

7.3.1 Place the pH electrodes within the beaker about ½ in. (13 mm) above the surface of the lime slurry sample. Set the motor stirrer to the highest speed at which splattering or immersion of the electrodes does not occur. Measure 250 g of H_2SO_4 (1.5 ± 0.05 %) into a separate 500-mL beaker. Add this acid to the sample in a single motion and record the pH as a function of time for a period of 30 min (see Note 1).

7.3.2 Test a second slurry sample using more or less than 250 g of H_2SO_4 (1.5 ± 0.05 %), as indicated by the pH value observed after 30 min reaction in the first test. Repeat the procedure at least four times or until sufficient data are available to give a family of curves that indicate pH at 30 min as a function of grams of lime per 1000 g of H_2SO_4 (1.5 %), with particular emphasis in the region of pH equals 4.4.

7.4 *Results*:

7.4.1 *Neutralization Rate Curves*:

7.4.1.1 Plot pH versus time in minutes for each of the lime-acid ratios used in the initial series of tests. This family of curves serves as the basis for calculation of the lime requirements.

7.4.2 *Lime Requirement Curve*:

7.4.2.1 Plot the pH in 30 min, as determined from the neutralization rate curves described in Section 10, against grams of lime used per 1000 g of H_2SO_4 (1.5 %).

7.4.3 *Neutralization Coefficient*:

7.4.3.1 Interpolate the quantity of lime required to achieve a pH of 4.4 in 30 min from the lime requirement curve (Section 11), correct for the actual acid concentration, and calculate as parts of lime required per million parts of H_2SO_4 (1.5 %) as follows:

$$N=(1.5/Z)\times X\times 1000$$

where:

N = neutralization coefficient (see 3.1.1),
X = grams of lime per 1000 g of H_2SO_4(1.5 %), and
Z = concentration of the H_2SO_4 to the nearest 0.005 %, as determined by analysis.

7.5 *Precision and Bias*:

7.5.1 The precision and bias of this test method has not been determined at this time. Replicate samples are recommended.

8. Test Method B—For Determining Acid Value-Basicity Factor Relationship

8.1 *Procedure*:

8.1.1 *Basicity Factor*—Weigh 2.804 g ± 1 mg of the sample that has been prepared to pass a No. 100 (150-µm) sieve and transfer to a 500-mL Erlenmeyer flask containing approximately 20 mL of cold water. (For quicklime samples, heat to boiling to ensure complete slaking). Add from a buret 100 mL of 1.0 *N* hydrochloric acid and stopper with a two-hole rubber stopper (Note 3). The quantity of acid may be increased or decreased depending on the equivalent strength of the material being tested. Place the flask on a hot plate and boil for 15 min. (Glass beads may be added to prevent bumping.) Remove the flask from the hot plate and cool in water. Add several drops of phenolphthalein indicator solution and titrate the excess acid with 0.5 *N* sodium hydroxide solution. Calculate the basicity factor as follows:

$$\text{Basicity factor} = [(V_1N_1 - V_2N_2)/W] \times 0.02804$$

where:

V_1 = HCl (mL) required for titration of the sample,
N_1 = normality of HCl,
V_2 = NaOH solution (mL) required for titration of the excess acid,
N_2 = normality of NaOH solution, and
W = sample (g).

NOTE 3—A water-cooled condenser with a tapered, ground-glass joint and a magnetic stir plate may be used during the boiling step.

8.1.2 *Acid Value*—Pipet 10 mL of the sample of acidic waste into a 250-mL Erlenmeyer flask. This quantity may be increased or decreased depending on the strength of the acidic waste. Add an excess of 25 to 30 mL of 0.5 *N* sodium hydroxide solution and boil for 3 min. Filter through a small Büchner funnel with the aid of vacuum. Wash the residue on the funnel with water. Add several drops of phenolphthalein indicator solution to the filtrate and titrate the excess sodium hydroxide with 1.0 *N* hydrochloric acid solution. Calculate acid value as follows:

[4] "Reagent Chemicals, American Chemical Society Specifications," Am. Chemical Soc., Washington, DC. For suggestions on the testing of reagents not listed by the American Chemical Society, see "Reagent Chemicals and Standards," by Joseph Rosin, D. Van Nostrand Co., Inc., New York, NY, and the "United States Pharmacopeia."

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$$\text{Acid value} = [(V_1N_1 - V_2N_2)/V] \times 0.03646$$

where:

V_1 = NaOH solution (mL) required for titration of the sample,
N_1 = normality of NaOH solution,
V_2 = HCl (mL) required for titration of the excess NaOH solution,
N_2 = normality of HCl, and
V = sample (mL).

8.1.3 *Relationship of Acid Value to Basicity Factor*—Calculate the acid value-basicity factor relationship as follows:

$$\frac{\text{Acid value}}{\text{Basicity factor}} \times 0.7691 = \text{lime or limestone product (kg) per litre of Acidic Waste.}$$

NOTE 4—When agreed upon between the manufacturer and the purchaser, Test Method A may also be used.

8.2 *Precision and Bias*:

8.2.1 The precision and bias of this test method has not been determined at this time. Replicate samples are recommended.

9. Keywords

9.1 acid value; alkalinity; basicity; lime requirement; liming material; neutralization; neutralization coefficient; pH; waste acid

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Designation: C 403/C 403M – 08

Standard Test Method for Time of Setting of Concrete Mixtures by Penetration Resistance[1]

This standard is issued under the fixed designation C 403/C 403M; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

This standard has been approved for use by agencies of the Department of Defense.

1. Scope*

1.1 This test method covers the determination of the time of setting of concrete, with slump greater than zero, by means of penetration resistance measurements on mortar sieved from the concrete mixture.

1.2 This test method is suitable for use only when tests of the mortar fraction will provide the information required.

1.3 This test method may also be applied to prepared mortars and grouts.

1.4 This test method is applicable under controlled laboratory conditions, as well as under field conditions.

1.5 The values stated in either SI units or inch-pound units are to be regarded separately as standard. The values stated in each system may not be exact equivalents; therefore, each system shall be used independently of the other. Combining values from the two systems may result in non-conformance with the standard.

1.6 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

2. Referenced Documents

2.1 *ASTM Standards:* [2]

C 125 Terminology Relating to Concrete and Concrete Aggregates

C 143/C 143M Test Method for Slump of Hydraulic-Cement Concrete

C 172 Practice for Sampling Freshly Mixed Concrete

C 173/C 173M Test Method for Air Content of Freshly Mixed Concrete by the Volumetric Method

C 192/C 192M Practice for Making and Curing Concrete Test Specimens in the Laboratory

C 231 Test Method for Air Content of Freshly Mixed Concrete by the Pressure Method

C 670 Practice for Preparing Precision and Bias Statements for Test Methods for Construction Materials

D 1558 Test Method for Moisture Content Penetration Resistance Relationships of Fine-Grained Soils

E 11 Specification for Wire Cloth and Sieves for Testing Purposes

E 2251 Specification for Liquid-in-Glass ASTM Thermometers with Low-Hazard Precision Liquids

3. Terminology

3.1 *Definitions*—Definitions are given in Terminology C 125.

4. Summary of Test Method

4.1 A mortar sample is obtained by sieving a representative sample of fresh concrete. The mortar is placed in a container and stored at a specified ambient temperature. At regular time intervals, the resistance of the mortar to penetration by standard needles is measured. From a plot of penetration resistance versus elapsed time, the times of initial and final setting are determined.

5. Significance and Use

5.1 Since the setting of concrete is a gradual process, any definition of time of setting must necessarily be arbitrary. In this test method, the times required for the mortar to reach specified values of resistance to penetration are used to define times of setting.

[1] This test method is under the jurisdiction of ASTM Committee C09 on Concrete and Concrete Aggregates and is the direct responsibility of Subcommittee C09.23 on Chemical Admixtures.

Current edition approved April 1, 2008. Published May 2008. Originally approved in 1957. Last previous edition approved in 2006 as C 403/C 403M–06.

[2] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

***A Summary of Changes section appears at the end of this standard.**

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5.2 This test method can be used to determine the effects of variables, such as water content; brand, type and amount of cementitious material; or admixtures, upon the time of setting of concrete. This test method may also be used to determine compliance with specified time-of-setting requirements.

5.3 This test method may also be applied to prepared mortars and grouts. However, when the setting time of concrete is desired, the test shall be performed on mortar sieved from the concrete mixture and not on a prepared mortar intended to simulate the mortar fraction of the concrete; it has been shown that the initial and final setting times may be increased when using the prepared mortar.

6. Apparatus

6.1 *Containers for Mortar Specimens*—The containers shall be rigid, watertight, nonabsorptive, free of oil or grease, and either cylindrical or rectangular in cross section. Mortar surface area shall be provided for ten undisturbed readings of penetration resistance in accordance with clear distance requirements specified in Procedure. The lateral dimension shall be at least 6 in. [150 mm] and the height at least 6 in. [150 mm].

6.2 *Penetration Needles*—Needles shall be provided which can be attached to the loading apparatus and which have the following bearing areas: 1, ½ , ¼ , 1/10 , 1/20 , and 1/40 in.^{2} [645, 323, 161, 65, 32, and 16 mm^2]. Each needle shank shall be scribed circumferentially at a distance 1 in. [25 mm] from the bearing area. The length of the 1/40 in.^{2}[16-mm^2] needle shall be not more than 3½ in. [90 mm].

6.3 *Loading Apparatus*—A device shall be provided to measure the force required to cause penetration of the needles. The device shall be capable of measuring the penetration force with an accuracy of ±2 lbf [10 N] and shall have a capacity of at least 130 lbf [600 N].

NOTE 1—Suitable loading apparatus can be of the spring-reaction type as described in Test Method D 1558, or of other types with a calibrated force measuring device, such as an electronic load cell or a hydraulic pressure gage.

6.4 *Tamping Rod*—The tamping rod shall be a round, straight, steel rod 5/8 in. [16 mm] in diameter and approximately 24 in. [600 mm] in length, having the tamping end or both ends rounded to a hemispherical tip, the diameter of which is 5/8 in. [16 mm].

6.5 *Pipet*—A pipet or other suitable instrument shall be used for drawing off bleed water from the surface of the test specimen.

6.6 *Thermometer*—The thermometer shall be capable of measuring the temperature of the fresh mortar to ±1 °F [±0.5 °C]. ASTM liquid-in-glass thermometers having a temperature range from 0 to 120 °F [–20 to 50 °C], and conforming to the requirements of Thermometer 97F (or 97C) as prescribed in Specification E 2251 are satisfactory. Other thermometers of the required accuracy, including the metal immersion type, are acceptable.

7. Sampling, Test Specimens, and Test Units

7.1 For tests under field conditions, prepare three specimens from each sample of concrete.

7.2 For tests under laboratory conditions, the requirements depend upon the purpose of the tests.

7.2.1 For testing to prove compliance of a material with performance requirements, make at least three separate concrete batches for each variable under investigation. Perform one time of setting test on each batch. Make an equal number of batches for each variable on any one day. When it is impossible to perform at least one test for each variable on any one day, mix the entire series of batches in as few days as possible, and repeat one of the mixtures each day as a standard for comparison.

7.2.2 For other tests, prepare three test specimens from one batch of concrete for each test variable.

7.3 Record the time at which initial contact was made between cement and mixing water.

7.4 For tests under field conditions, obtain a representative sample of the fresh concrete in accordance with Practice C 172. For tests under laboratory conditions, make the concrete in accordance with Practice C 192/C 192M. Determine and record the slump (Test Method C 143/C 143M) and air content (Test Method C 173/C 173M or C 231) of the fresh concrete.

7.5 From the concrete not used in the slump and air content tests, select a representative portion of sufficient volume to provide enough mortar to fill the test container, or containers, to a depth of at least 5½ in. [140 mm].

7.6 Using the procedure in Practice C 172, obtain a mortar sample by wet-sieving the selected portion of concrete through a 4.75-mm sieve[3] and onto a nonabsorptive surface.

7.7 Thoroughly remix the mortar by hand methods on the nonabsorptive surface. Measure and record the temperature of the mortar. Place the mortar in the container, or containers, using a single layer. Consolidate the mortar to eliminate air pockets in the specimen and level the top surface. This may be accomplished by rocking the container back and forth on a solid surface, by tapping the sides of the container with the tamping rod, by rodding the mortar, or by placing the container on a vibrating table (see Note 2). If rodding is used, rod the mortar with the hemispherical end of the tamping rod. Rod the mortar once for each 1 in.^{2} [645 mm^2] of top surface area of the specimen and distribute the strokes uniformly over the cross section of the specimen. After completion of the rodding, tap the sides of the containers lightly with the tamping rod to close voids left by the tamping rod and to further level the surface of the specimen. Upon completion of specimen preparation, the mortar surface shall be at least ½ in. [10 mm] below the top edge of the container to provide space for the collection and removal of bleed water and to avoid contact between the mortar surface and the protective covering specified in Section 8.

NOTE 2—Sieved mortar is generally of fluid consistency and air pockets are readily removed by the listed consolidation methods. The user should exercise judgment in the selection of the consolidation method. Rocking the container or tapping of the sides should be sufficient for fluid mortars. Rodding or using a vibrating table may be desirable for stiffer mortars. When using a vibrating table, use low-amplitude vibration so that portions of the sample are not ejected from the container.

[3] Detailed requirements for this sieve are given in Specification E 11.

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8. Conditioning

8.1 For tests under laboratory conditions, the storage temperature for specimens shall be within the range 68 to 77 °F [20 to 25 °C], or as specified by the user.

8.2 For tests under field conditions, store the specimens under ambient conditions, or as specified by the user. Shield the specimens from direct sunlight.

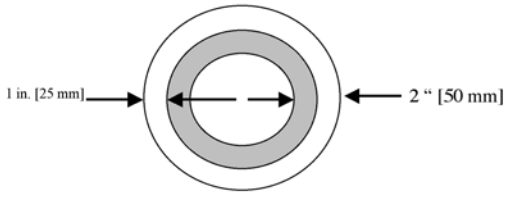
8.3 Measure and record the ambient air temperature at the start and finish of the test. To prevent excessive evaporation of moisture, keep the specimens covered with a suitable material such as damp burlap or a tight-fitting, water-impermeable cover for the duration of the test, except when bleed water is being removed or penetration tests are being made.

9. Procedure

9.1 Just prior to making a penetration test, remove bleed water from the surface of the mortar specimens by means of a pipet or suitable instrument. To facilitate collection of bleed water, tilt the specimen carefully to an angle of about 10° from the horizontal by placing a block under one side 2 min prior to removal of the water.

9.2 Insert a needle of appropriate size, depending upon the degree of setting of the mortar, in the penetration resistance apparatus and bring the bearing surface of the needle into contact with the mortar surface. Gradually and uniformly apply a vertical force downward on the apparatus until the needle penetrates the mortar to a depth of 1 ± 1⁄16 in. [25 ± 2 mm], as indicated by the scribe mark (Note 4). The time required to penetrate to the 1-in. [25-mm] depth shall be 10 ± 2 s. Record the force required to produce the 1-in. [25-mm] penetration and the time of application, measured as elapsed time after initial contact of cement and water. Calculate the penetration resistance by dividing the recorded force by the bearing area of the needle, and record the penetration resistance. In subsequent penetration tests take care to avoid areas where the mortar has been disturbed by previous tests. The clear distance between needle impressions shall be at least two diameters of the needle being used, but not less than ½ in. [15 mm]. The clear distance between any needle impression and the side of the container shall be at least 1 in. [25 mm], but not more than 2 in. [50 mm], as depicted in Fig. 1.

NOTE 3—For a cylindrical container with the smallest allowable outer diameter of 6 in., the operator can reasonably expect to achieve approximately eight penetrations before impinging upon previous penetrations. This is based on using needles of the following surface areas: 1 @ ½ [13], 2 @ ¼ [6], 2 @ 1⁄10 [2.5], 2 @ 1⁄20 [1.3], and 1 @ 1⁄40 [0.6] in.^{2}[mm^2].



NOTE 1—Dark-colored areas define where needle penetrations are permitted.

FIG. 1 Top View of Mortar Test Specimen

NOTE 4—To facilitate determination of when the required penetration has been attained, a sliding marker may be attached to the needle shaft. For example, a paper clip or masking tape may be placed on the shaft so that it coincides with the scribe mark. The marker should not interfere with the penetration of the needle into the mortar. The position of the marker should be checked prior to making a penetration.

9.3 For conventional concrete mixtures at laboratory temperatures of 68 to 77 °F [20 to 25 °C], make the initial test after an elapsed time of 3 to 4 h after initial contact between cement and water. Subsequent tests should be made at ½- to 1-h intervals. For concrete mixtures containing accelerators, or at temperatures higher than laboratory, it is advisable to make the initial test after an elapsed time of 1 to 2 h and subsequent tests at ½-h intervals. For concrete mixtures containing retarders, or at temperatures lower than laboratory, the initial test may be deferred until an elapsed time of 4 to 6 h. In all cases, time intervals between subsequent tests may be adjusted as necessary, depending upon the rate of setting, to obtain the required number of penetrations.

9.4 Make at least six penetrations for each time-of-setting test, with time intervals of such duration as to provide a satisfactory curve of penetration resistance versus elapsed time (Note 5). Continue testing until one at least penetration resistance reading equals or exceeds 4000 psi [27.6 MPa].

NOTE 5—A satisfactory curve is one which represents the overall development of penetration resistance and includes points before and after the times of initial and final setting to improve the accuracy of the required interpolation. For normal setting mixtures, test points are usually at equally spaced time intervals. Premature penetration testing will result in too many data points earlier than the initial setting time. This may decrease the accuracy of the estimated setting time by biasing the best fit line when regression analysis is used to analyze the penetration resistance data.

9.5 *Plotting Test Results*—One of the following alternative procedures may be used to plot the test results and obtain times of setting (Note 6). Appendix X1 illustrates the application of these procedures.

NOTE 6—The plot of penetration resistance versus elapsed time provides information on the rate of setting. The plot may be used to select the time for subsequent penetration tests and it can assist in identifying spurious test results. Therefore, it is recommended that the data be plotted as they are being accumulated.

9.5.1 Use the following plotting procedure to determine the times of setting by hand-fitting a smooth curve through the data. Prepare a graph of penetration resistance, as the ordinate, versus elapsed time, as the abscissa, using a scale such that 500 psi [3.5 MPa] and 1 h are each represented by a distance of at least ½ in. [15 mm]. Plot the values of penetration resistance as a function of elapsed time.

9.5.2 Use the following plotting procedure to determine the times of setting by linear regression analysis of the logarithms of the data by using a suitable calculator. Using log-log graph paper, prepare a graph of penetration resistance, as the ordinate, versus elapsed time in minutes, as the abscissa. The limits of penetration resistance on the ordinate should extend from 10 psi [0.1 MPa] to 10 000 psi [100 MPa], and the limits of elapsed time on the abscissa should extend from 10 to 1000 min. If slow setting mixtures are used, the time limits may have

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to be 100 to 10 000 min. Plot the values of penetration resistance as a function of elapsed time (Note 5).

9.5.3 Use the following procedure if a computer is used to plot test results and obtain the times of setting by regression analysis of the data. As the test results are obtained, enter the time and penetration resistance into the computer and plot the penetration resistance as the ordinate and the elapsed time as the abscissa. For software that permits only linear regression analysis, convert the data by taking their logarithms. The converted data will be fitted by a straight line[4] (see Eq 1):

$$\text{Log}\,(PR) = a + b\,\text{Log}\,(t) \quad (1)$$

where:

PR = penetration resistance
t = elapsed time
a and b = regression constants

The data do not have to be converted if the software permits direct fitting of a power function:

$$PR = ct^d \quad (2)$$

where:

c and d = regression constants

9.5.4 The procedures in 9.5.2 and 9.5.3 assume that the data obey (Eq 1) or (Eq 2). Verify that the data obey one of these relationships. If the correlation coefficient for the regression analysis, after removal of outliers (see Note 7), is less than 0.98, use the procedure in 9.5.1.

10. Calculation

10.1 For each variable under investigation, separately plot the results of three or more time-of-setting tests. For each plot prepared according to 9.5.1, hand fit a smooth curve to the data points. For each plot prepared according to 9.5.2 or 9.5.3, use the method of least squares to obtain the constants of the best-fit relationship given by (Eq 1) or (Eq 2), whichever is applicable. Disregard data points that are obvious outliers from the trend defined by the rest of the points (Note 7).

NOTE 7—Outliers may occur because of factors such as: interferences due to the larger particles in the mortar; presence of large voids within the penetration zone; interferences from the impressions created by adjacent penetrations; failure to maintain the instrument perpendicular to the test surface during penetration; errors in reading the load; variations in the penetration depths; or variations in rate of loading. Judgement of the operator is required to identify those points that should not be included in the data analysis.

10.2 For each plot, determine the times of initial and final setting as the times when the penetration resistance equals 500 psi [3.5 MPa] and 4000 psi [27.6 MPa], respectively. For plots made according to 9.5.1, determine times of setting by visual inspection of the drawn curves. For plots made according to 9.5.2 or 9.5.3, determine the times of setting by interpolation using the best-fit regression equation. Record the times of setting in hours and minutes to the nearest 5 min.

10.3 For each variable under investigation, calculate the times of initial and final setting as the average values of the individual test results. Record the average times in hours and minutes to the nearest 5 min.

11. Report

11.1 *Data on Concrete Mixture*—Report the following information on the concrete mixture:

11.1.1 Brand and type of cementitious materials, amounts (mass) of cementitious materials, fine aggregate and coarse aggregate per cubic yard [per cubic metre] of concrete, nominal maximum aggregate size, and water-cement or water-cementitious material ratio,

11.1.2 The name, type, and amount of admixture(s) used,

11.1.3 Air content of fresh concrete and method of determination,

11.1.4 Slump of concrete,

11.1.5 Temperature of mortar after sieving,

11.1.6 Record of ambient temperature during the test period, and

11.1.7 Date of test.

11.2 *Time of Setting Results*—Report the following information on the time of setting tests:

11.2.1 A plot of penetration resistance versus elapsed time for each time of setting test,

11.2.2 The times of initial and final setting for each test, reported in hours and minutes to the nearest minute, and

11.2.3 The average times of initial and final setting for each test condition, reported in hours and minutes to the nearest 5 min.

12. Precision and Bias

12.1 The data used to develop the precision statement were obtained using the inch-pound version of this test method. Estimates of time of setting were determined by both graphical methods and regression analysis. The temperature of the laboratory, where the concrete mixtures were sieved and the resulting mortar fraction measured for penetration resistance, was maintained at 73 ± 2 °F [23 ± 1 °C] for the duration of the round robin test.

12.2 The following precision values were obtained from an interlaboratory study[5] involving five operators and three concrete mixtures. The average time of initial setting varied between 169 and 252 min., and the average time of final setting varied between 240 and 341 min. Three replicate determinations were made by each operator on specimens made from a single batch of each mixture.

12.3 *Single-Operator Precision*—The single-operator standard deviations of a single test result are shown in Table 1.[A] The results of two properly conducted tests by the same operator are not expected to differ by more than the values shown in the third column of Table 1.[A] The test method calls for reporting three test results. The range (difference between highest and lowest) of the three test results obtained by the same operator on specimens from the same batch of concrete are not expected to exceed the values shown in the fourth column of Table 1.[B]

[4] Popovics, S., 1971, "Physical Aspects of the Setting of Portland Cement Concrete," *Journal of Materials*, JMLSA, Vol. 6, No. 1, March, pp. 150–162.

[5] Supporting data have been filed at ASTM International Headquarters and may be obtained by requesting Research Report RR: C09-1032.

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12.4 *Multi-Operator Precision*—The multi-operator standard deviations of a single test result are shown in Table 2.[A] The results of two properly-conducted tests by different operators on the same material are not expected to differ by more than the values shown in the third Column of Table 2.[A] The averages of three test results by two different operators obtained on specimens from a single batch of the same concrete are not expected to differ by more than the values in the fourth column of Table 2.[B]

TABLE 1 Single-Operator Precision

Time of Setting	Single-Operator Standard Deviation, min[A]	Acceptable Difference Between Two Results, min[A]	Acceptable Range of Three Results, min[B]
Initial	3.5	9.8	11.4
Final	4.4	12.5	14.6

[A]These numbers represent, respectively, the (1s) and (d2s) limits as described in Practice C 670.
[B]Calculated as described in the section "*acceptable range of more than two results*" of Practice C 670.

TABLE 2 Multi-Operator Precision

Time of Setting	Multi-Operator Standard Deviation, min[A]	Acceptable Difference Between Two Results, min[A]	Acceptable Difference Between Average of Three Results, min[B]
Initial	6.9	19.4	11.1
Final	10.1	28.7	16.4

[A]These numbers represent, respectively, the (1s) and (d2s) limits as described in Practice C 670.
[B]Calculated as described in the section "*multilaboratory precision expressed as a maximum allowable differences between two averages*" of Practice C 670.

12.5 The bias of this test method cannot be determined because times of setting can be defined only in terms of the test method.

13. Keywords

13.1 concrete; mortar; penetration resistance; time of final setting; time of initial setting

APPENDIX

(Nonmandatory Information)

X1. ILLUSTRATIVE EXAMPLES

X1.1 The penetration resistance (*PR*) and the elapsed time (*t*) data in Table X1.1 will be used to illustrate the procedures for determining times of setting.

X1.2 *Hand Fit*—Fig. X1.1 is a plot of the penetration resistance versus elapsed time values in Table X1.1. The smooth curve was drawn by-hand using a flexible drawing curve. The curve was drawn so as to achieve the visual best-fit to the data. Note that the penetration resistance at an elapsed time of 335 min is an obvious outlier, and this point was disregarded in drawing the best-fit curve. Horizontal lines are drawn at penetration resistance values of 500 and 4000 psi. The intersections of the horizontal lines with the curve define the times of initial and final setting, which in this case are 289 min and 389 min, respectively.

X1.3 *Regression Analysis:*

TABLE X1.1 Penetration Resistance

Penetration Resistance (*PR*) (psi)[A]	Elapsed Time (*t*) (min)	Log(*PR*)	Log(*t*)
44	200	1.643	2.301
110	230	2.041	2.362
216	260	2.334	2.415
540	290	2.732	2.462
1000	320	3.000	2.505
1000	335	3.000	2.525
2000	350	3.301	2.544
2560	365	3.408	2.562
3520	380	3.547	2.580
4440	395	3.647	2.597

[A]MPa = psi × 0.00689.

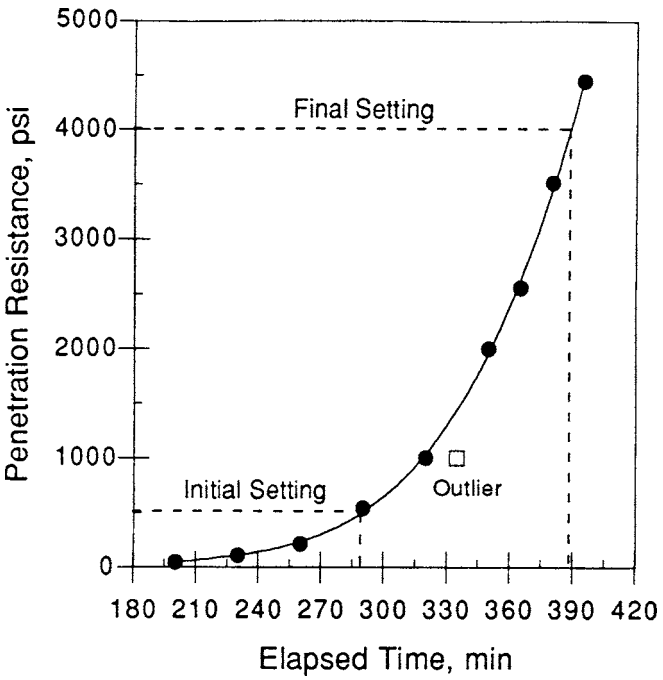

FIG. X1.1 Plot of Penetration Resistance Values Versus Elapsed Time and Hand Fit Curve Used to Determine Time of Setting (Note: Not drawn to actual scale)

X1.3.1 Fig. X1.2 is a log-log plot of the penetration resistance versus elapsed time values. The plot shows that, with the exception of the outlier, there is approximately a straight line relationship between the logarithms of penetration resistance

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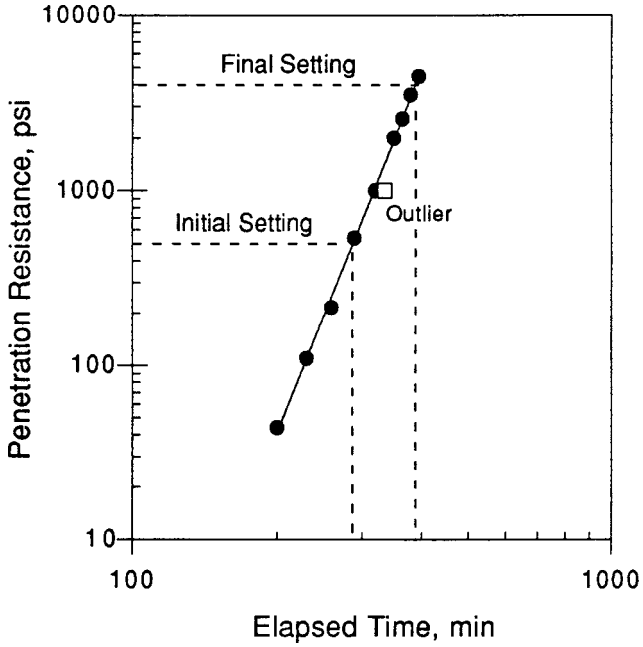

FIG. X1.2 Log-Log Plot Showing Straight Line to Determine Times of Setting by Using Regression Analysis

and elapsed time. The straight line is obtained by linear regression analysis using the logarithms shown in the third and fourth columns of Table X1.1. The equation for this line is:

$$\text{Log}\,(PR) = -14.196 + 6.871\,\text{Log}\,(t) \quad \text{(X1.1)}$$

where:
PR = penetration resistance, and
t = elapsed time.

The correlation coefficient is 0.999, and it is, therefore, acceptable to use linear regression analysis.

X1.3.2 To obtain the times of setting, the equation is rewritten as:

$$\text{Log}\,(t) = \frac{\text{Log}(PR) + 14.196}{6.871} \quad \text{(X1.2)}$$

X1.3.3 For time of initial setting, substitute the value 500 for PR:

$$\text{Log}\,(t) = \frac{\text{Log}(500) + 14.196}{6.871} = \frac{2.699 + 14.196}{6.871} = 2.458 \quad \text{(X1.3)}$$

therefore:
$t = (10)^{2.458} = 287$ min.

X1.3.4 For time of final setting, substitute the value 4000 for PR:

$$\text{Log}\,(t) = \frac{\text{Log}(4000) + 14.196}{6.871} = \frac{3.602 + 14.196}{6.871} = 2.590 \quad \text{(X1.4)}$$

therefore:
$t = (10)^{2.590} = 389$ min.

SUMMARY OF CHANGES

Committee C09 has identified the location of selected changes to this test method since the last issue, C 403/C 403M – 06, that may impact the use of this test method. (Approved April 1, 2008)

(*1*) Replaced Specification E 1 with Specification E 2251 in Referenced Documents and 6.6.

Committee C09 has identified the location of selected changes to this test method since the last issue, C 403/C 403M – 05, that may impact the use of this test method. (Approved December 15, 2006)

(*1*) Revised Section 12 and added new Table 1 and Table 2.

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Designation: C 418 – 05

Standard Test Method for Abrasion Resistance of Concrete by Sandblasting[1]

This standard is issued under the fixed designation C 418; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

This standard has been approved for use by agencies of the Department of Defense.

1. Scope

1.1 This test method covers determination of the abrasion resistance characteristics of concrete by subjecting it to the impingement of air-driven silica sand. It is intended for use as a basis for the development of informed judgment.

1.2 The values stated in SI units are to be regarded as the standard. Inch-pound units are shown for information purposes in parentheses.

1.3 *This standard does not purport to address the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

NOTE 1—Users of this test method are advised that there are known safety hazards associated with the use of silica as a blasting media. Consult the silica manufactures MSDS to insure that the latest recommended health and safety practices are being followed.

NOTE 2—Other procedures are available for measuring abrasion resistance of concrete surfaces in addition to subjecting it to air driven silica sand. Consideration should be given to other methods of testing as outlined in ASTM C 779/C 779M, ASTM C 944, and ASTM C 1138. The test method most closely representing service conditions should be used.

1.4 The text of this standard references notes and footnotes which are provided as explanatory material. These notes and footnotes (excluding those in tables and figures) shall not be considered as requirements of this standard.

2. Referenced Documents

2.1 *ASTM Standards:* [2]

C 127 Test Method for Density, Relative Density (Specific Gravity), and Absorption of Coarse Aggregate

C 778 Specification for Standard Sand

C 779/C 779M Test Method for Abrasion Resistance of Horizontal Concrete Surfaces

C 944 Test Method for Abrasion Resistance of Concrete or Mortar Surfaces by the Rotating-Cutter Method

C 1138 Test Method for Abrasion Resistance of Concrete (Underwater Method)

3. Significance and Use

3.1 This test method covers the laboratory evaluation of the relative resistance of concrete surfaces to abrasion. This procedure simulates the action of waterborne abrasives and abrasives under traffic on concrete surfaces. It performs a cutting action that tends to abrade more severely the less resistant components of the concrete.

4. Apparatus

4.1 *Scales*—The scale shall have a capacity of 5000 g or more. The permissible variation at a load of 5000 g (11 lb) shall be ± 0.5 g (0.2 oz).

4.2 *Weights*—The permissible variations on weights used in weighing shall be as prescribed in Table 1. The permissible variations on new weights shall be one half of the values given in Table 1.

4.3 *Sand Blast Apparatus*—The sand blast apparatus shall consist of an injector-type gun. The gun shall have a high-velocity air jet fed by a suitably controlled rate of flow for the abrasive material. The nozzle shown in Fig. 1 shall consist of cold-rolled bar stock, 40 mm (1.5 in.) long, or hardened tool steel HRC 48 ± 2 as determined by Test Methods E 18, drilled to 6.40 ± 0.02 mm (0.250 ± 0.001 in.) approximately 700 kPa (100 psi) through the center. The walls of the nozzle shall have a 45° bevel on the inside at the upper end. A compressed air supply of approximately 100 psi (690 kPa) shall be available and equipped with a pressure-control device. Provision shall be made to collect the spent abrasive and dust. Suitable jigs and clamps shall be provided to hold the test specimen in a fixed position with relation to the discharge end of the nozzle. For laboratory wear testing of concrete specimens a commercial sand blast cabinet may be selected similar to that shown in Fig. 2.

[1] This test method is under the jurisdiction of ASTM Committee C09 on Concrete and Concrete Aggregates and is the direct responsibility of Subcommittee C09.62 on Abrasion Testing of Concrete.

Current edition approved Feb. 1, 2005. Published February 2005. Originally approved in 1958. Last previous edition approved in 1998 as C 418 – 98.

[2] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

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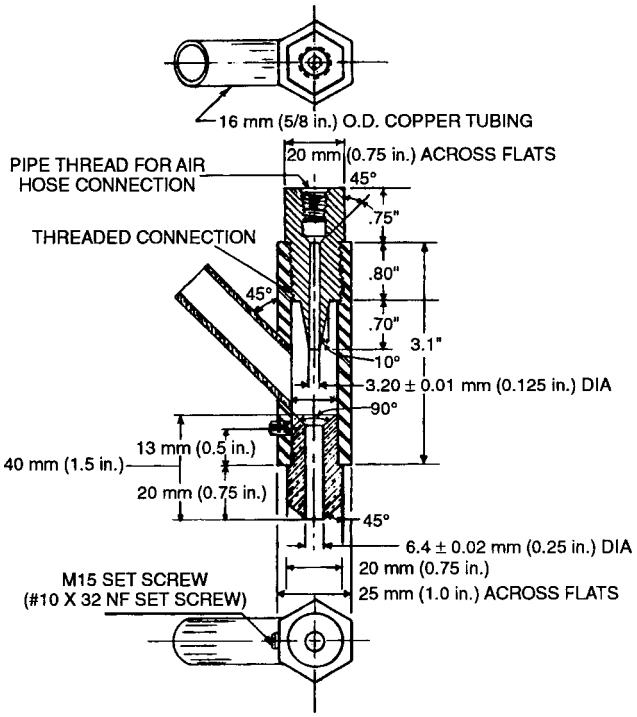
TABLE 1 Permissible Variations on Weights

Weight, g	Permissible Variations on Weights in Use, g
1000	±0.50
500	±0.35
300	±0.30
250	±0.25
200	±0.20



NOTE—All dimensions are approximate except where tolerances are shown. Inch-pound dimensions shown here for clarity purposes only.

FIG. 1 Gun Nozzle Assembly

4.4 *Shield*—The shield shall be square or circular, 150 mm (6 in.) on a side or diameter, made from zinc-coated steel sheet or equivalent, having a thickness in the range of 0.90 to 1.90 mm (0.035 to 0.075 in.). The shield shall have an opening 28.70 ± 0.25 mm (1.13 ± 0.01 in.) in diameter in the center (See Note 3).

NOTE 3—An opening of 28.7 mm (1.13 in.) is equivalent to 6.45 cm^2 (1 $in.^2$). The purpose of the opening in the shield is to limit the abraded area to approximately 1 $in.^2$

4.5 *Abrasive*—The abrasive shall conform to Specification C 778 for 20–30 sand (predominantly graded to pass an 850-µm (No. 20) sieve and be retained on a 600-µm (No. 30) sieve).

5. Preparation of Specimens

5.1 Immerse the specimens in water for 24 h and then surface dry with a damp cloth to obtain a saturated, surface-dry condition at the time of test.

6. Calibration of Apparatus

6.1 Adjust the air pressure to 410 ± 1 kPa (59.5 ± 1 psi) and collect the abrasive for a period of 1 min. Adjust the rate of flow of abrasive to 600 ± 25 g/min (See Note 4).

NOTE 4—A ball valve between the abrasive supply and the gun inlet has been found satisfactory for adjusting the flow of abrasive.

6.2 The abrasive shall be regraded or replaced after every 60 min of operating time in order to maintain a uniform grading.

6.3 A cold-rolled steel nozzle shall be replaced every 60 min of operating time. A hardened tool steel nozzle shall be changed as required to maintain the original uniform flow and original blast pattern.

7. Procedure

7.1 Place the specimen with the surface to be tested normal to the nozzle axis and at a distance of 75 ± 2.5 mm (3.0 ± 0.1 in.) from the end. Clamp the specimen, with shield attached, firmly in place. Expose the surface to the blast for a period of 1 min. Repeat this on at least eight different spots on the surface. Determine the abraded volume by filling the abrasion cavities with an oil base modeling clay. Press the clay into the cavities manually with a moderate amount of finger pressure and level flush with a straight edge. Determine the mass of the clay supply before and after the cavities are filled to the tolerance listed in Table 1 instead of removing the clay from the filled cavities. Repeat filling with clay at least once on each specimen to ensure reproducible results.

8. Calculation

8.1 Calculate the mass of clay, W_c, as follows:

$$W_c = W_i - W_f$$

where:
W_i = mass, initial supply, and
W_f = mass, final supply.

8.2 Calculate the specific gravity of clay, D, as follows:

$$D = B / (B - C)$$

where:
B = mass of clay in air, g, and
C = mass of clay in water, g.

NOTE 5—Appendix X1 of Test Method C 127 provides guidance on the development of the equations used in the calculation of specific gravity (relative density to water) using the mass of clay in air and the mass of clay when suspended in water.

8.3 Calculate the volume of clay, V, per cavity in cubic centimetres, as follows:

$$V = W / D$$

where:
W = mass of clay in cavity, and
D = specific gravity of clay.

8.4 Calculate the abrasion coefficient loss on a volumetric basis, expressed in cubic centimetres per square centimetre, in order to compensate for variable densities of specimens, as follows:

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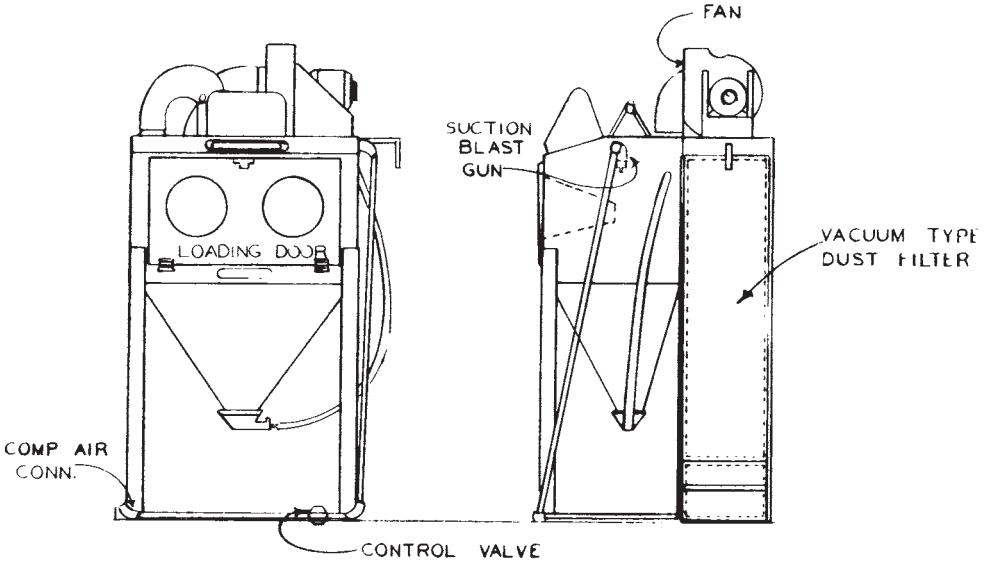

FIG. 2 Sand Blast Cabinet

$$A_c = V / A$$

where:

A_c = abrasion coefficient, cubic centimetres per square centimetre, and

A = area of surface abraded, square centimetres.

9. Report

9.1 Report the following information:

9.2 Report the abrasion coefficient loss to the nearest 0.01 cm^3/cm^2.

9.3 Report the location of the concrete where the specimen was obtained and other characteristics of the concrete, if known.

10. Precision and Bias

10.1 On a limited sampling (Note 6), the single-operator coefficient of variation has been found to be 9.1 %.[3] Therefore, results of two properly conducted tests by the same operator on the same material using the same equipment should not differ by more than 25.8 %[3] of their average.

10.2 On a limited sampling (Note 6), the multi-operator coefficient of variation has been found to be 10.3 %.[3] Therefore, results of two properly conducted tests by two operators on the same material using the same equipment should not differ from each other by more than 29.1 %[3] of their average.

NOTE 6—The data, on file at ASTM Headquarters, involve two operators performing the tests on samples made from the same batch and repeated on another day. Two concrete mixtures having different expected abrasion resistance were also used. The tests were conducted in one laboratory using the same equipment. As more laboratories become more equipped and capable of performing the test, a more detailed interlaboratory test program will be conducted.

10.3 Since there is no acceptable reference material suitable for determining bias for the procedure in this test method, no statement of bias is being made.

[3] These numbers represent, respectively, the (1s %) and (d2s %) limits as described in Practice C 670 for Preparing Precision and Bias Statements for Test Methods for Construction Materials.

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Designation: C 430 – 08

Standard Test Method for Fineness of Hydraulic Cement by the 45-μm (No. 325) Sieve[1]

This standard is issued under the fixed designation C 430; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope*

1.1 This test method covers the determination of the fineness of hydraulic cement by means of the 45-μm (No. 325) sieve.

1.2 The values stated in SI units are to be regarded as the standard. The inch-pound equivalents of SI units may be approximate.

1.3 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

2. Referenced Documents

2.1 *ASTM Standards:*[2]

E 11 Specification for Wire Cloth and Sieves for Testing Purposes

E 161 Specification for Precision Electroformed Sieves

E 177 Practice for Use of the Terms Precision and Bias in ASTM Test Methods

3. Apparatus

3.1 *Sieve*:

3.1.1 *Sieve Frame*—The sieve frame shall be of metal not subject to corrosion by water and shall be circular, either 51 ± 6 mm (2.0 ± 0.25 in.) when woven-wire cloth is mounted in the frame or 76 ± 6 mm (3.0 ± 0.25 in.) in diameter when an electroformed sheet is mounted in the frame. The depth of the sieve from the top of the frame to the cloth or sheet shall be 76 ± 6 mm (3.0 ± 0.25 in.). The frame shall have either side walls of 89 ± 6 mm (3.5 ± 0.25 in.) in total height, or legs at least 12 mm (0.5 in.) in length, sufficient to allow air circulation beneath the sieve cloth or electroformed sheet.

3.1.2 *Sieve Cloth or Electroformed Sheet*—The sieve frame shall be fitted with either a 45-μm (No. 325) stainless steel AISI Type 304 woven-wire sieve cloth, conforming to the requirements of Specification E 11 or a 45-μm electroformed reinforced nickel sieve sheet conforming to the requirements of Specification E 161 with the exception that the number of openings shall be 71 ± 2 per linear centimetre (180 ± 5 per linear inch).

3.1.3 *Cloth or Sheet Mounting*:

3.1.3.1 *Woven-Wire Cloth Mounting*—Type 304 stainless steel woven-type cloth shall be mounted in the frame without distortion, looseness, or wrinkling. For a sieve fabricated by soldering the cloth to the frame, the joint shall be made smooth to prevent the cement from catching in the joints between the sieve cloth and the frame. Two-piece sieves shall clamp tightly on the cloth to prevent the cement from catching in the joints between the sieve cloth and the frame.

3.1.3.2 *Electroformed Sieve Sheet Mounting*—Electroformed reinforced nickel sieve sheet shall be mounted in the frame without distortion, looseness, or wrinkling. The joint between the sieve cloth and the frame shall be made smooth with a material impervious to water.

3.2 *Spray Nozzle*—The spray nozzle (Fig. 1) shall be constructed of metal not subject to corrosion by water and shall be 17.5 mm (0.69 in.) in inside diameter with a central hole drilled in line with the longitudinal axis, an intermediate row of eight holes drilled 6 mm (0.23 in.) center-to-center at an angle of 5° from the longitudinal axis, and an outer row of eight holes drilled 11 mm (0.44 in.) center-to-center at an angle of 10° from the longitudinal axis. All holes shall be 0.5 mm (0.02 in.) in diameter. The spray nozzle shall have been checked within six months prior to testing a cement sample to ensure that the flow rate is between 1500 and 3000 g/min at 69 ± 3 kPa (10 ± 0.4 psi).

3.3 *Pressure Gage*—The pressure gage shall be 76 mm (3.0 in.) minimum diameter, and shall be graduated in 7-kPa (1-psi) increments, and shall have a maximum capacity of 207 kPa (30 psi). The accuracy at 69 kPa (10 psi) shall be ±2 kPa (±0.25 psi).

4. Calibration of 45-μm (No. 325) Sieve

4.1 Place 1.000 g of the current lot of National Institute of Standards and Technology standard sample No. 114 or No. 46h on the clean, dry, 45-μm (No. 325) sieve and proceed as in Section 5. The sieve correction factor is the difference between

[1] This test method is under the jurisdiction of ASTM Committee C01 on Cement and is the direct responsibility of Subcommittee C01.25 on Fineness.

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[2] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

***A Summary of Changes section appears at the end of this standard.**

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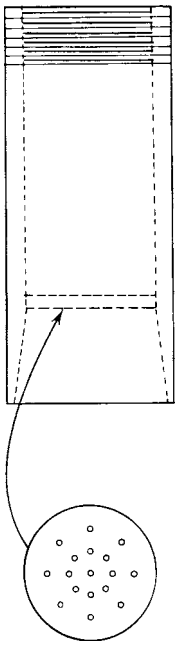

FIG. 1 Spray Nozzle with Seventeen 0.02-in. (0.51-mm) Holes

the test residue obtained and the assigned residue value indicated by the electroformed sheet sieve fineness specified for the standard sample, expressed as a percentage of the test residue.

NOTE 1—It should be observed that the sieve correction as specified is a factor to be multiplied by the residue obtained and that the amount to be added to or subtracted from the residue in any given test is therefore proportional to the amount of residue.

Example of Determination of Sieve Correction Factor:

Residue on 45-μm (No. 325) Sieve, sample No. 114 or No. 46h		12.2 %
Residue for a 1-g sample		0.122 g
Residue on sieve being calibrated		0.093 g
Difference	=	+ 0.029 g
Correction factor = + 0.029/0.093 × 100 = + 31.18	=	+ 31.2 %

5. Procedure

5.1 Place a 1.000 g sample of the cement on the clean, dry 45-μm (No. 325) sieve. Wet the sample thoroughly with a gentle stream of water. Remove the sieve from under the nozzle and adjust the pressure on the spray nozzle to 69 ± 4 kPa (10 ± 0.5 psi). Return the sieve to its position under the nozzle and wash for 1 min, moving the sieve with a circular motion in a horizontal plane at the rate of one motion per second in the spray. The bottom of the spray nozzle should extend below the top of the sieve frame about 12 mm (0.5 in.). Immediately upon removing the sieve from the spray, rinse once with about 50 cm^3 of distilled or deionized water, using caution not to lose any of the residue, and then blot the lower surface gently upon a damp cloth. Dry the sieve and residue in an oven or over a hot plate (see Note 2), supporting the sieve in such a manner that air may pass freely beneath it. Cool the sieve; then brush the residue from the sieve and weigh on an analytical balance capable of reproducing results within 0.0005 g.

NOTE 2—Care should be taken not to heat the sieve hot enough to soften the solder.

6. Cleaning of 45-μm (No. 325) Sieves

6.1 *Frequency of Cleaning and Calibration*—Sieves fitted with woven wire sieve cloth shall be cleaned after no more than five determinations. Sieves fitted with an electroformed reinforced sieve sheet having 71 openings per linear centimetre shall be cleaned after no more than three determinations. Both types of sieves shall be recalibrated after no more than 100 determinations.

6.2 *Acceptable Cleaning Procedures*—One option for cleaning is to place the sieve in a low-power (150 W maximum power input) ultrasonic bath containing an appropriate laboratory cleaning solution. The bath is to be operated for sufficient time (approximately 10 to 15 min at room temperature) to remove particles lodged in the openings. Be apprised that electroformed sieve sheets containing more than 71 openings per linear centimetre may well be damaged by ultrasonic cleaning. An option for cleaning which does not require an ultrasonic bath can also be employed. Immerse the sieve in a bath of appropriate laboratory cleaning solution heated to just below boiling point. Cover with a watch glass to reduce evaporation. Continue this soaking for a time sufficient to loosen lodged particles with a rinse following the bath. Overnight soaking in similar but unheated cleaning solutions is also acceptable, provided a rinse following the bath is able to wash away lodged particles. Cleaning or rinsing with dilute hydrochloric or acetic acid solutions is to be avoided. Appropriate cleaning solutions are restricted to soap or detergent-type solutions.

7. Calculation

7.1 Calculate the fineness of the cement to the nearest 0.1 % as follows:

$$R_c = R_s \times (100 + C) \quad (1)$$

$$F = 100 - R_c \quad (2)$$

where:

F = fineness of the cement expressed as the corrected percentage passing the 45-μm (No. 325) sieve,
R_c = corrected residue, %,
R_s = residue from the sample retained on the 45-μm (No. 325) sieve, g, and
C = sieve correction factor (determined as prescribed in Section 4) which may be either plus or minus.

Example:

Sieve correction factor, C	=	+31.2 %
Residue from sample being tested, R_s	=	0.088 g
Corrected residue, R_c	=	0.088 × (100 + 31.2)
	=	11.5 %
Corrected amount passing, F	=	100 – 11.5 % = 88.5 %

8. Precision and Bias

8.1 *Normal Fineness Product*—The multilaboratory precision has been found to be ±0.75 % (IS) as defined in Practice E 177, therefore, results of properly conducted tests from two different laboratories on identical samples of cement should agree 95 % of the time within ±2.1 %.

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8.2 *High Fineness Product*—The multilaboratory precision has been found to be ±0.50 % (IS) as defined in Practice E 177; therefore, results of properly conducted tests from two different laboratories on identical samples of cement should agree 95 % of the time within ±1.4 %.

NOTE 3—The use of outside threads instead of inside threads as shown in this figure is permissible.

8.3 Since there is no accepted reference material suitable for determining the bias for the procedure in this test method, no statement on bias is being made.

9. Keywords

9.1 fineness of hydraulic cement

SUMMARY OF CHANGES

Committee C01 has identified the location of selected changes to this test method since the last issue, C 430 – 96(2003), that may impact the use of this test method. (Approved December 1, 2008)

(*1*) Revised 4.1.

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Designation: C 441 – 05

Standard Test Method for Effectiveness of Pozzolans or Ground Blast-Furnace Slag in Preventing Excessive Expansion of Concrete Due to the Alkali-Silica Reaction[1]

This standard is issued under the fixed designation C 441; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope

1.1 This test method covers the determination of the effectiveness of pozzolans or slag in preventing the excessive expansion caused by reaction between aggregates and alkalies in portland cement mixtures. The evaluation is based on the expansion developed in mortar bars by a combination of portland cement and a pozzolan or slag, made with reactive aggregates (borosilicate glass), during storage under prescribed conditions of test.

1.2 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

2. Referenced Documents

2.1 *ASTM Standards:* [2]

C 125 Terminology Relating to Concrete and Concrete Aggregates

C 150 Specification for Portland Cement

C 227 Test Method for Potential Alkali Reactivity of Cement-Aggregate Combinations (Mortar-Bar Method)

C 618 Specification for Coal Fly Ash and Raw or Calcined Natural Pozzolan for Use in Concrete

C 989 Specification for Ground Granulated Blast-Furnace Slag for Use in Concrete and Mortars

C 1240 Specification for Use of Silica Fume Used in Cementitious Mixtures

C 1437 Test Method for Flow of Hydraulic Cement Mortar

3. Terminology

3.1 *Definitions*—For definitions of terms used in this test method, refer to Terminology C 125.

4. Significance and Use

4.1 This test method may be used as a preliminary or screening test to evaluate the relative effectiveness of a number of different materials being considered for use to prevent excessive expansion due to alkali-silica reaction.

4.2 This test method may also be used to evaluate materials proposed for use on a particular job to prevent excessive expansion due to alkali-silica reaction, by testing in the quantity and in combination with the cement or cements to be used on the job.

4.3 This test method does not assess the suitability of pozzolans or slag for use in concrete. These materials should comply with Specification C 618, Specification C 989 or Specification C 1240.

5. Apparatus

5.1 The apparatus shall be as described in Test Method C 227.

6. Materials

6.1 *Borosilicate Glass* [3] —Borosilicate glass granules graded according to Table 1 or crushed Pyrex Glass No. 7740 cullet or solid glass rod crushed and graded according to Table 1. After the glass cullet or rod has been crushed and separated into the various sieve sizes, wash with a water spray over the sieve to remove adhering dust and fine particles from the aggregate. Dry the portions retained on the various sieves and, unless used immediately, store each such portion individually in a clean container provided with a tight-fitting cover.

6.2 *High-Alkali Cement*—For the preparation of mortar bars for the preliminary or screening tests, use a blend of cement or cements that conform to Specification C 150 and contain between 0.95 and 1.05 % total alkalies as sodium oxide (Na_2O)

[1] This test method is under the jurisdiction of ASTM Committee C09 on Concrete and Concrete Aggregates and is the direct responsibility of Subcommittee C09.26 on Chemical Reactions .

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[2] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

[3] The sole source of supply of borosilicate glass granules in the specific sizes called for in this test method known to the committee at this time is Enviroglass International, Caldwell, ID, http://www.enviroglass.net/. If you are aware of alternative suppliers, please provide this information to ASTM International Headquarters. Your comments will receive careful consideration at a meeting of the responsible technical committee,[1] which you may attend.

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TABLE 1 Grading Requirements

Sieve Size		Mass, %
Passing	Retained on	
4.75-mm (No. 4)	2.36-mm (No. 8)	10
2.36-mm (No. 8)	1.18-mm (No. 16)	25
1.18-mm (No. 16)	600-µm (No. 30)	25
600-µm (No. 30)	300-µm (No. 50)	25
300-µm (No. 50)	150-µm (No. 100)	15

calculated as % Na_2O + 0.658 × % potassium oxide (K_2O). If blending is needed, introduce the individual cements into the batch separately.

7. Proportioning and Consistency of Mortar

7.1 *Control Mixture*—The quantities of dry materials for the control mixture shall be 400 g of high-alkali cement and 900 g of glass aggregate made by recombining the portions retained on the various sieves in the prescribed grading (Table 1). Test specimens made from the control mixture shall have a 14-day increase in length of at least 0.250 %.

7.2 *Test Mixture Using Pozzolans*—The quantities of dry materials for the test mixture shall be 300 g of high-alkali cement, a mass of pozzolan having an absolute volume equal to the absolute volume of 100 g of portland cement (100 × density of pozzolan/3.15) and 900 g of glass aggregate made as described for the control mixture.

7.3 *Test Mixture Using Slag*—The quantities of dry materials for this test mixture shall be 200 g of high-alkali cement, a mass of slag having an absolute volume of 200 g of portland cement (200 × density of slag/3.15) and 900 g of glass made in accordance with 7.1.

7.4 A smaller quantity of the pozzolan or slag and a proportionately large quantity of cement may be used if there is evidence that it is unusually effective in reducing expansion due to the alkali-silica reaction and that the use of a smaller quantity is likely to produce a large reduction of expansion of the test mixture as compared to that of the control mixture.

7.5 *Job Mixture*—The quantities of dry materials used for the job mixture shall be in accordance with the requirements given above, except that the cement or cements to be used on the job shall be used instead of the high-alkali cement. Also, the quantity of pozzolan or slag, by mass, used with the portland cement shall be equivalent to that proposed for use on the job.

7.6 *Flow*—The amount of mixing water, measured in millilitres, shall be such as to produce a flow of between 100 and 115 as determined in accordance with Test Method C 1437.

8. Temperature and Humidity

8.1 The temperature of the dry materials, water, molding room, and moist cabinet and the humidity of the laboratory and moist cabinet shall conform to the requirements of Test Method C 227.

9. Test Specimen

9.1 *Preparation of Molds*—Prepare the molds as specified in Test Method C 227.

9.2 *Mixing of Mortar*—Mix the mortar as specified in Test Method C 227, except add the admixture or slag with the cement to the water.

9.3 *Molding Test Specimens*—Mold the specimens as specified in Test Method C 227.

9.4 *Dimensions and Number of Test Specimens*—Make three 1 by 1 by 11¼-in. or 25 by 25 by 285-mm test specimens having an effective gage length of 10 ± 0.1 in. or 254 ± 2.5 mm from each batch of each mortar mixture. One set of three specimens shall represent each test mixture or each job mixture. On the same day that the test specimens are made, make one set of three specimens representing the control mixture and store in the same container with the corresponding test specimens. Make all specimens stored in a given container on the same day. If more specimens from test or job mixtures, or both, are made on a given day than can be stored in a single container with the specimens from the control mixture made on that day, make additional control mixture specimens for each additional storage container used.

10. Procedure

10.1 Store and measure the test specimens in accordance with the applicable requirements of Test Method C 227.

11. Calculation

11.1 For tests of mixtures proportioned as prescribed, calculate the reduction of mortar expansion resulting from the use of a pozzolan or slag and report the result to the nearest 0.1 % as follows.

$$R_e = (E_r - E_t) \times 100/E_r$$

where:

R_e = reduction of mortar expansion, %,
E_t = average increase in length of mortar bars from the test mixture, and
E_r = average increase in length of mortar bars from the control mixture.

11.2 For test mixtures proportioned in accordance with the job mixture procedure, report the average length increase of the mortar bars as the length increase of the combination proposed for use in the work. Indicate contraction (length decrease) by prefixing a minus sign to the value of the length change reported.

12. Interpretation

12.1 Information pertaining to this procedure and to the significance of the results obtained has been published[4,5,6,7]

[4] Moran, W. T., and Gilliland, J. L., "Summary of Methods for Determining Pozzolanic Activity," *Symposium on Use of Pozzolanic Materials in Mortars and Concretes, ASTM STP 99,* ASTM International, 1950, p. 109.

[5] Gilliland, J. L., and Bartley, T. R., "Water-Solubility of Alkalies in Portland Cement," *Journal of the American Concrete Institute,* American Concrete Institute, Vol 47, 1951, p. 153 (especially Fig. number 2 and Table number 3).

[6] Mielenz, R. C., Greene, K. T., Benton, E. J., and Geier, F. H., "Chemical Test for Alkali Reactivity of Pozzolans," *Proceedings,* ASTM International, Vol 52, 1952, p. 1128.

[7] Pepper, L., and Mather, B., "Effectiveness of Mineral Admixtures in Preventing Excessive Expansion of Concrete Due to Alkali-Aggregate Reaction," *Proceedings,* ASTM International, Vol 59, 1959, p. 1178–1203.

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and should be reviewed before results of the test are used as a basis for conclusions and recommendations concerning the properties and use of pozzolans, or slag combinations for concrete.

12.2 Minimum values for the reduction of mortar expansion (R_e) have been selected for use in specifications as a basis for acceptance of pozzolan or slag proposed for use in combination with high-alkali cement and an aggregate known to be potentially deleteriously alkali reactive.

13. Report

13.1 Report the following information:

13.1.1 Type and source of glass used.

13.1.2 The type of portland cement used and its total alkali content as Na_2O in percent. If the test is applied to a cement-pozzolan or cement-slag combination to be used in specific work, the type, brand, and manufacturing plant of the cement.

13.1.3 The type and proportion of pozzolan or slag used. If the test is applied to a cement-pozzolan or cement-slag combination to be used in specific work, the type, brand, source, proportion, and the nature of the pozzolan or slag.

13.1.4 If the control mixture and the test mixture are prepared as specified, the average increase in length of the mortar bars prepared from the control mixture and the average increase in length of the mortar bars from the test mixture, in percent. Also, the reduction in mortar length change resulting from the use of the pozzolan or slag (R_e), in percent.

13.1.5 The average increase in length of the mortar bars prepared from the job mixtures, in percent.

14. Precision and Bias

14.1 *Precision*—Repeatability shall be considered satisfactory if the percentage length increase of each specimen made from the same cement-aggregate combination is within 0.003 of the average, except that, if the average length increase exceeds 0.02 %, the repeatability shall be considered satisfactory if the percentage length increase of each specimen molded from the same cement-aggregate combination is within 15 % of the average.

14.2 *Bias*—This procedure has no bias because the effectiveness is defined in terms of this test method.

15. Keywords

15.1 alkali-silica reaction; concrete; expansion; fly ash; ground blast-furnace slag; mortar; pozzolan; silica fume

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Designation: C 451 – 08

Standard Test Method for Early Stiffening of Hydraulic Cement (Paste Method)[1]

This standard is issued under the fixed designation C 451; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope*

1.1 This test method covers the determination of early stiffening in hydraulic-cement paste.

1.2 The values stated in SI units are to be regarded as standard. No other units of measurement are included in this standard.

1.3 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

Warning—Fresh hydraulic-cementitious mixtures are caustic and may cause chemical burns to skin and tissue upon prolonged exposure. The use of gloves, protective clothing, and eye protection is recommended. Wash contact area with copious amounts of water after contact. Wash eyes for a minimum of 15 min. Avoid exposure of the body to clothing saturated with the liquid phase of the unhardened material. Remove contaminated clothing immediately after exposure.

1.4 The text of this standard references notes and footnotes which provide explanatory material. These notes and footnotes (excluding those in tables and figures) shall not be considered as requirements of the standard.

2. Referenced Documents

2.1 *ASTM Standards:* [2]

C 150 Specification for Portland Cement

C 183 Practice for Sampling and the Amount of Testing of Hydraulic Cement

C 187 Test Method for Normal Consistency of Hydraulic Cement

C 219 Terminology Relating to Hydraulic Cement

C 305 Practice for Mechanical Mixing of Hydraulic Cement Pastes and Mortars of Plastic Consistency

C 670 Practice for Preparing Precision and Bias Statements for Test Methods for Construction Materials

C 1005 Specification for Reference Masses and Devices for Determining Mass and Volume for Use in the Physical Testing of Hydraulic Cements

D 1193 Specification for Reagent Water

3. Terminology

3.1 *Definitions:*

3.1.1 *early stiffening*, *n*—the early development of stiffness in the working characteristics of a hydraulic-cement paste, mortar, or concrete; varieties include false set and flash set.

3.1.2 *false set*, *n*—the early development of stiffness in the working characteristics of a hydraulic-cement paste, mortar, or concrete without the evolution of much heat, which stiffness can be dispelled and plasticity regained by further mixing without addition of water; also known as "grab set," "premature stiffening," " hesitation set," and "rubber set."

3.1.3 *flash set*, *n*—the early development of stiffness in the working characteristics of a hydraulic-cement paste, mortar, or concrete, usually with the evolution of considerable heat, which stiffness cannot be dispelled nor can the plasticity be regained by further mixing without addition of water; also known as "quick set."

3.1.4 Refer to Terminology C 219 for definitions of other terms.

4. Summary of Test Method

4.1 A paste is prepared with the cement to be tested, using sufficient water to give a required initial penetration as measured by the Vicat apparatus at a stipulated time after completion of mixing. A second penetration, termed the final penetration, is measured at a later stipulated time. The ratio of final penetration to initial penetration is calculated as a percentage.

5. Significance and Use

5.1 The purpose of this test method is to determine the degree to which a cement paste develops early stiffening or to establish whether or not a cement complies with a specification limit on early stiffening.

5.2 When used for establishing compliance with a specification limit, the specification requirement is customarily stated in terms of the minimum allowable final penetration, in

[1] This test method is under the jurisdiction of ASTM Committee C01 on Cement and is the direct responsibility of Subcommittee C01.30 on Time of Set.

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[2] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

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percent, calculated in accordance with the Calculation Section. When used for estimating the relative tendency of a cement to manifest early stiffening, additional information of value may be obtained if the remix procedure described in the Procedure Section is employed. Under some conditions, a judgment may be made by comparing the behavior in the initial test and in the remix procedure to differentiate a relatively less serious and less persistent tendency to early stiffening (false set) from one that is more persistent and, consequently, more serious (flash set).

5.3 Severe false setting in a cement may cause difficulty from a placing and handling standpoint, but it is not likely to cause difficulties where concrete is mixed for a longer time than usual, as usually occurs in transit mixing, or where it is remixed prior to placing or transporting, as occurs in concrete pumping operations. It is most likely to be noticeable where concrete is mixed for a short period of time in stationary mixers and transported to the forms in non-agitating equipment, such as on some paving jobs, and when concrete is made in an on-site batch plant.

5.4 Cements with severe false setting usually require slightly more water to produce the same consistency, which may be expected to result in slightly lower strengths and increased drying shrinkage.

5.5 Early stiffening resulting from false set is not likely to cause a cement to fail the applicable time of setting requirement.

5.6 Early stiffening resulting from flash set, depending on severity, can cause a cement to fail the applicable time of setting requirement.

6. Apparatus

6.1 *Vicat Apparatus*, conforming to the requirements of Test Method C 187.

6.2 *Flat Trowel*, having a sharpened straight-edged steel blade 100 to 150 mm in length. The edges when placed on a plane surface shall not depart from straightness by more than 1 mm.

6.3 *Mixer, Bowl, Paddle, and Scraper*, conforming to the requirements of Practice C 305.

6.4 *Glass Graduates*, 200 or 250 ml capacity, conforming to the requirements of Specification C 1005.

6.5 *Masses and Mass Determining Devices*, conforming to the requirements of Specification C 1005. The devices for determining mass shall be evaluated for precision and accuracy at a total load of 1000 g.

6.6 *Conical Ring*, made of a rigid, non-corroding, non-absorbernt material, having a height of 40 ± 1 mm, an inside diameter at the bottom of 70 ± 3 mm, and an inside diameter at the top of 60 ± 3 mm (see Test Method C 187, Fig. 1 item G).

6.7 *Plane Non-Absorptive Plate*, 100 ± 5 mm square, of similar planeness, corrosivity, and absorptivity to that of glass (see Test Method C 187, Fig. 1 item H).

6.8 Inspect and document Section 6 apparatus conformance to the requirements of this test method at least every 2 ½ years.

7. Reagent

7.1 *Mixing Water*—Potable water is satisfactory for routine tests. For all referee and cooperative tests, use reagent water conforming to the requirements of Specification D 1193 for Type III or Type IV grades of reagent water.

8. Sampling

8.1 When the test is part of acceptance testing, sample the cement in accordance with Practice C 183.

9. Conditioning

9.1 Maintain the temperature of the room, dry materials, paddle, bowl, conical ring, and base plate at 23.0 ± 3.0 °C. Maintain the temperature of the mixing water at 23.0 ± 2.0 °C.

9.2 Maintain the relative humidity of the mixing room at not less than 50 %.

10. Procedure

10.1 *Preparation of Cement Paste*—Mix 500 g of cement with sufficient water to produce a paste with an initial penetration of 32 ± 4 mm using the following procedure.

10.1.1 Place the dry paddle and the dry bowl in the mixing position in the mixer.

10.1.2 Introduce the materials for a batch into the bowl and mix in the following manner:

10.1.2.1 Place all the mixing water in the bowl.

10.1.2.2 Add the cement to the water and allow 30 s for the water to absorb.

10.1.2.3 Start the mixer and mix at a slow speed (140± 5 r/min) for 30 s.

10.1.2.4 Stop the mixer for 15 s, and during this time scrape down into the batch any paste that may have collected on the sides of the bowl.

10.1.2.5 Start the mixer at a medium speed (285 ±10 r/min) and mix for 2½ min.

10.2 *Molding Test Specimens*—Quickly form the cement paste into a ball with gloved hands. Press the ball, resting in the palm of one hand, into the larger end of the conical ring held in the other hand, completely filling the ring with paste. Remove the excess at the larger end by a single movement of the palm of the hand. Place the ring on its larger end on the non-absorptive plate and slice off the excess paste at the smaller end at the top of the ring by a single oblique stroke of a sharp-edged trowel held at a slight angle with the top of the ring. Smooth the top of the specimen, if necessary, with one or two light touches of the pointed end of the trowel. During the operation of cutting and smoothing, take care not to compress the paste.

10.3 *Determination of Initial Penetration*—Set the paste confined in the ring resting on the plate, H, under the rod, B, Fig. 1 of Test Method C 187, about one third of the diameter from the edge, and bring the plunger end, C, in contact with the surface of the paste and the tightened setscrew, E. Then set the movable indicator, F, to the upper zero mark of the scale, and release the rod exactly 20 s after completion of the mixing. Keep the apparatus free of all vibrations during the penetration test. Consider the paste to have proper consistency when the rod settles to a point 32 ± 4 mm below the original surface in

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30 s after being released. Make trial pastes with varying percentages of water until this consistency is obtained. This consistency is the initial penetration. During the 30-s interval for the initial penetration, return the excess paste to the bowl and cover the bowl and mixing paddle with a lid.

10.4 *Determination of Final Penetration*—After completion of the initial reading, remove the plunger from the paste, clean it, and reset the ring and plate in a new position. Perform this operation with as little disturbance as possible to the paste confined in the Vicat ring. Then bring the plunger again in contact with the surface of the paste, tighten the setscrew, and set the movable indicator to the upper zero mark of the scale. Release the plunger a second time 5 min ± 10 s after completion of the mixing period, and determine the final penetration 30 s after the plunger is released.

10.5 *Determination of Remix Penetration*—If the penetrations determined by the foregoing procedure show the cement to be stiffening rapidly, at the option of the tester, obtain information as to the nature of the stiffening by testing as follows:

10.5.1 After completing the measurement of the 5-min penetration, immediately return the paste in the ring to the bowl.

10.5.2 Start the mixer, raise the bowl into mixing position, and remix the contents of the bowl at a medium speed (285 ±10 r/min) for 1 min.

10.5.3 Fill the ring and determine the penetration following the procedures specified in 10.2 and 10.3.

11. Calculation

11.1 Calculate the percent final penetration, based on the ratio of final penetration to initial penetration, as follows:

$$P, \% = \frac{B}{A} \times 100 \quad (1)$$

where:
P = percent final penetration,
A = initial penetration, mm, and
B = final penetration, mm.

12. Report

12.1 Report the results of the test as follows:

Initial penetration	___ mm
Final penetration	___ mm
Percent final penetration	___ %
Remix penetration	___ mm

13. Precision and Bias

13.1 Precision

13.1.1 On samples testing between 8 % and 89 % Paste False Set, the single-operator (within laboratory) standard deviation has been found to be 10 % (1s), therefore, results of two properly conducted tests by the same operator on samples of the same cement should not differ from each other by more than 28 % (1s and d2s are defined in Practice C 670).

13.1.2 On samples testing between 8 % and 89 % Paste False Set, the multi-laboratory standard deviation has been found to be 12 % (1s), therefore, results of two properly conducted tests from two different laboratories on samples of the same cement should not differ by more than 34 % (1s and d2s are defined in Practice C 670). (See Note 1.)

13.2 Bias

13.2.1 Since an acceptable reference material suitable for determining any bias of this method does not exist, no statement on bias is being made.

NOTE 1—This data is based upon CCRL Portland Cement round robin test samples 47 to 138. The data indicates that precision decreases as the false set values fall below approximately 60 %. These decreases are not clearly statistically significant, however they do indicate the duplication difficulties on cements which exhibit false set tendencies severe enough to fail or possibly fail Specification C 150 optional limits.

14. Keywords

14.1 early stiffening; false set; flash set; hydraulic-cement paste; Vicat.

SUMMARY OF CHANGES

Committee C01 has identified the location of selected changes to this test method since the last issue, C 451 – 07, that may impact the use of this test method. (Approved June 1, 2008)

(*1*) Revised 6.2, 6.5, and 9.2.

Committee C01 has identified the location of selected changes to this test method since the last issue, C 451 – 05, that may impact the use of this test method. (Approved July 15, 2007)

(*1*) Added new 6.8.

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Designation: C 452 – 06

Standard Test Method for Potential Expansion of Portland-Cement Mortars Exposed to Sulfate[1]

This standard is issued under the fixed designation C 452; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope*

1.1 This test method, which is applicable only to portland cements, covers the determination of the expansion of mortar bars made from a mixture of portland cement and gypsum in such proportions that the mixture has a sulfur trioxide (SO_3) content of 7.0 mass %.

1.2 The values stated in SI units (IEEE/ASTM SI-10) are to be regarded as the standard.

1.3 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

Warning—Fresh hydraulic cementitious mixtures are caustic and may cause chemical burns to skin and tissue upon prolonged exposure.[2]

2. Referenced Documents

2.1 *ASTM Standards:* [3]

C 109/C 109M Test Method for Compressive Strength of Hydraulic Cement Mortars(Using 2-in. or [50-mm] Cube Specimens)

C 150 Specification for Portland Cement

C 230/C 230M Specification for Flow Table for Use in Tests of Hydraulic Cement

C 305 Practice for Mechanical Mixing of Hydraulic Cement Pastes and Mortars of Plastic Consistency

C 471M Test Methods for Chemical Analysis of Gypsum and Gypsum Products [Metric]

C 490 Practice for Use of Apparatus for the Determination of Length Change of Hardened Cement Paste, Mortar, and Concrete

C 511 Specification for Mixing Rooms, Moist Cabinets, Moist Rooms, and Water Storage Tanks Used in the Testing of Hydraulic Cements and Concretes

C 778 Specification for Sand

C 1005 Specification for Reference Masses and Devices for Determining Mass and Volume for Use in the Physical Testing of Hydraulic Cements

D 1193 Specification for Reagent Water

IEEE/ASTM SI-10 Practice for Use of the International System of Units (SI): The Modern Metric System

3. Significance and Use

3.1 This test method is used primarily by those interested in research on methods for determining the potential sulfate resistance of portland cement. This test method is also used to establish that a sulfate-resisting portland cement meets the performance requirements of Specification C 150.

4. Apparatus

4.1 *Weights and Weighing Devices*, conforming to the requirements of Specification C 1005.

4.2 *Flow Table*, conforming to the requirements of Specification C 230/C 230M.

4.3 *Mixer, Bowl, and Paddle*, conforming to the requirements of Practice C 305.

4.4 *Trowel and Tamper*, conforming to the requirements of Test Method C 109/C 109M.

4.5 *Glass Graduates, Molds, and Length Comparator*, conforming to the requirements of Practice C 490.

5. Temperature and Humidity

5.1 *Molding Room, Dry Materials, and Mixing Water*—Maintain the temperature of the molding room, dry materials, and mixing water at 23.0 ± 4.0 °C (73.5 ± 7 °F) and the relative humidity of the molding room at not less than 50 %.

5.2 *Moist Cabinet or Room*, conforming to the requirements of Specification C 511.

[1] This test method is under the jurisdiction of ASTM Committee C01 on Cement and is the direct responsibility of Subcommittee C01.29 on Sulfate Resistance.

Current edition approved May 15, 2006. Published June 2006. Originally approved in 1960. Last previous edition approved in 2002 as C 452 – 02.

[2] Section on Safety, Manual of Cement Testing, *Annual Book of ASTM Standards*, Vol 04.01.

[3] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

***A Summary of Changes section appears at the end of this standard.**

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6. Materials

6.1 Use graded sand that conforms to Specification C 778 Table 1 Standard Sand Requirements for making the test mortar.

6.2 For the gypsum addition to portland cement, use high grade natural gypsum[4] with 100 % passing the 150-µm (No. 100) sieve, at least 94 % passing the 75-µm (No. 200) sieve, and at least 90 % passing the 45-µm (No. 325) sieve. Calculate the percentage of cement and gypsum required to provide a mixture containing 7.0 mass % SO_3 as follows:

$$\text{Cement, \%} = [(g - 7.0)/(g - c)] \times 100 \quad (1)$$

$$\text{Gypsum, \%} = [(7.0 - c)/(g - c)] \times 100 \quad (2)$$

where:

c = SO_3 content of the portland cement, %,
g = SO_3 content of the gypsum, %, and
7.0 = SO_3 content of the cement-gypsum mixture, %.

6.3 If the SO_3 content of the gypsum is unknown, analyze the gypsum for SO_3 content using Test Methods C 471M. Determine the SO_3 content to the nearest 0.1 %.

6.4 *Purity of Water*—Unless otherwise indicated, references to water mean reagent water conforming to Type IV of Specification D 1193.

7. Number and Dimensions of Test Specimens

7.1 Make six 25 by 25 by 285-mm (or 1 by 1 by 11¼-in.) test specimens, three from each of two batches, for each cement.

7.2 In routine tests, 25 by 25 by 160-mm (or 1 by 1 by 6¼-in.) specimens may be used, but in case of dispute, results obtained with 25 by 25 by 285-mm (or 1 by 1 by 11¼-in.) specimens govern.

8. Preparing Specimen Molds

8.1 Prepare the molds in accordance with Practice C 490.

9. Proportioning, Consistency, and Mixing of Mortar

9.1 Use 400 g (cement plus gypsum) and 1100 g of sand for each batch. Use 194 mL of mixing water for all non-air-entraining portland cements, and 184 mL of mixing water for all air-entraining portland cements.

9.2 Mix the mortar according to the procedure for mixing mortars of Practice C 305, except after placing the mixing water in the bowl, add the gypsum and mix at the slow speed for 15 s, then stop the mixer, add the cement, and continue as prescribed in Practice C 305.

10. Procedure

10.1 *Molding Test Specimens:*

10.1.1 Immediately upon completion of the flow test, return the mortar to the bowl, scrape down into the batch any mortar on the side of the bowl, and remix at the medium speed (285 ± 10 r/min) for 15 s. Remove the paddle and the bowl from the mixer and shake the excess mortar from the paddle into the bowl. Fill the mold in two layers, each layer being compacted with the tamper. Work the mortar into the corners, around the gage studs, and along the surfaces of the mold with the tamper until a homogeneous specimen is obtained. After the top layer has been compacted, cut the mortar off flush with the top of the mold and smooth the surface with a few strokes of the trowel.

10.2 *Storage of Test Specimens:*

10.2.1 *Initial Storage*—Cure the specimens in the molds in the moist closet at 23 ± 2 °C (73.5 ± 3.5 °F) for 22 to 23 h. Then remove them from the molds, properly identify, and place in water at 23 ± 2 °C (73.5 ± 3.5 °F) for at least 30 min prior to making the initial length measurement.

10.2.2 *Subsequent Storage*—After the bars have been removed from the molds and measured, store them horizontally in water at 23 ± 2 °C (73.5 ± 3.5 °F). Store the specimens with at least 6-mm (¼-in.) clearance on all sides except for the necessary supports. Cover the specimens with at least 13 mm (½ in.) of water. Use a volume of water that does not exceed 5 times the volume of the bars to prevent excessive leaching. Replenish the water with fresh water every 7 days for the first 28 days and every 28 days thereafter.

11. Length Measurement

11.1 Measure the specimens for length by means of the length comparator. Remove them from the water storage, one at a time, and wipe with a damp cloth before measuring.

11.2 Make the first reading at the age of 24 h ± 15 min from the time the cement and water are mixed together. Measure the specimen again at the age of 14 days.

NOTE 1—Additional information of value may be obtained by returning the specimen to water storage after the 14-day test and making additional measurements at later ages.

12. Calculation

12.1 Calculate the difference in length of the specimen at 24 h and at 14 days to the nearest 0.001 % of the effective gage length and report as the expansion of the specimen at that period. All specimens remaining after 14 days must comprise a set having at least three specimens with a permissible range depending on the number of the remaining specimens, as follows:

No. of Specimens	Maximum Permissible Range, %
3	0.010
4	0.011
5	0.012
6	0.012

13. Report

13.1 Report the average of the specimens comprising the set to the nearest 0.001 %.

14. Precision and Bias

14.1 *Precision*:

14.1.1 The single-operator standard deviation has been found to be: 0.003 % for expansions between 0.01 and 0.04 %. Therefore, results of two properly conducted tests by the same operator on the same material should not differ from each other by more than 0.009 %.

[4] The sole source of supply of the apparatus known to the committee at this time is Terra Alba No. 1, available from the U.S. Gypsum Co., Southard, OK plant. If you are aware of alternative suppliers, please provide this information to ASTM International Headquarters. Your comments will receive careful consideration at a meeting of the responsible technical committee,[1] which you may attend.

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14.1.2 The multilaboratory standard deviation has been found to be 0.005 % for expansions between 0.01 and 0.04 %. Therefore, results of two properly conducted tests on the same material in two different laboratories should not differ from each other by more than 0.014 %.

14.1.3 The precision of this test method has been evaluated by cooperative testing.[5]

14.2 *Bias*—Since there is no accepted reference material suitable for determining the bias for this test method, no statement on bias is being made.

15. Keywords

15.1 calcium sulfate; expansion; gypsum; portland cement; sulfate resistance

[5] Supporting data have been filed at ASTM International Headquarters and may be obtained by requesting Research Report RR: 001–1004.

For additional useful information on details of cement test methods, reference may be made to the "Manual of Cement Testing," which appears in the *Annual Book of ASTM Standards*, Vol 04.01.

SUMMARY OF CHANGES

Committee C01 has identified the location of selected changes to this test method since the last issue, C 452 – 06, that may impact the use of this test method. (Approved May 15, 2006)

(*1*) Revised 6.1.

(*2*) Added keywords.

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Designation: C 457 – 09

Standard Test Method for Microscopical Determination of Parameters of the Air-Void System in Hardened Concrete[1]

This standard is issued under the fixed designation C 457; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope*

1.1 This test method describes procedures for microscopical determinations of the air content of hardened concrete and of the specific surface, void frequency, spacing factor, and paste-air ratio of the air-void system in hardened concrete (**1**).[2] Two procedures are described:

1.1.1 *Procedure A,* the linear-traverse method (**2, 3**).

1.1.2 *Procedure B,* the modified point-count method (**3, 4, 5, 6**).

1.2 This test method is based on prescribed procedures that are applied to sawed and lapped sections of specimens of concrete from the field or laboratory.

1.3 It is intended to outline the principles of this test method and to establish standards for its adequate performance but not to describe in detail all the possible variations that might be used to accomplish the objectives of this test method.

1.4 The values stated in SI units are to be regarded as standard. The values given in parentheses are mathematical conversions to inch-pound units that are provided for information only and are not considered standard.

1.5 *This standard does not purport to address all of the safety concerns associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.* For specific hazard statements see 8.3 and 10.1.

2. Referenced Documents

2.1 *ASTM Standards:*[3]

C 42/C 42M Test Method for Obtaining and Testing Drilled Cores and Sawed Beams of Concrete

C 125 Terminology Relating to Concrete and Concrete Aggregates

C 138/C 138M Test Method for Density (Unit Weight), Yield, and Air Content (Gravimetric) of Concrete

C 173/C 173M Test Method for Air Content of Freshly Mixed Concrete by the Volumetric Method

C 231 Test Method for Air Content of Freshly Mixed Concrete by the Pressure Method

C 666/C 666M Test Method for Resistance of Concrete to Rapid Freezing and Thawing

C 670 Practice for Preparing Precision and Bias Statements for Test Methods for Construction Materials

C 672/C 672M Test Method for Scaling Resistance of Concrete Surfaces Exposed to Deicing Chemicals

C 823 Practice for Examination and Sampling of Hardened Concrete in Constructions

C 856 Practice for Petrographic Examination of Hardened Concrete

D 92 Test Method for Flash and Fire Points by Cleveland Open Cup Tester

2.2 *American Concrete Institute Standards:*

201.2R Guide to Durable Concrete[4]

211.1 Recommended Practice for Selecting Proportions for Normal, Heavyweight, and Mass Concrete[4]

3. Terminology

3.1 For definitions of terms used in this test method, refer to Terminology C 125.

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *average chord length ($\bar{l}$), n*—the average length of the chords formed by the transection of the voids by the line of traverse; the unit is a length.

3.2.2 *paste-air ratio (p/A), n*—the ratio of the volume of hardened cement paste to the volume of the air voids in the concrete.

3.2.3 *paste content (p), n*—the proportion of the total volume of the concrete that is hardened cement paste expressed as percentage by volume.

[1] This test method is under the jurisdiction of ASTM Committee C09 on Concrete and Concrete Aggregates and is the direct responsibility of Subcommittee C09.65 on Petrography.

Current edition approved July 1, 2009. Published August 2009. Originally approved in 1960. Last previous edition approved in 2008 as C 457 – 08d.

[2] The boldface numbers in parentheses refer to the list of references at the end of this test method.

[3] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

[4] Available from American Concrete Institute (ACI), P.O. Box 9094, Farmington Hills, MI 48333-9094, http://www.aci-int.org.

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3.2.3.1 *Discussion*—When this parameter is calculated, it is the sum of the proportional volumes of the cement, the net mixing water (including the liquid portions of any chemical admixtures), and any supplementary cementitious materials present (**7, 8**).

3.2.4 *spacing factor ($\bar{L}$), n*—a parameter related to the maximum distance in the cement paste from the periphery of an air void, the unit is a length.

3.2.5 *specific surface (α), n*—the surface area of the air voids divided by their volume, expressed in compatible units so that the unit of specific surface is a reciprocal length.

3.2.6 *void frequency (n), n*—voids per unit length of traverse; the number of air voids intercepted by a traverse line divided by the length of that line; the unit is a reciprocal length.

3.2.6.1 *Discussion*—The value for void frequency *(n)* cannot be directly determined by the paste-air ratio method as this value refers to the voids per unit measure of traverse in the total concrete (including aggregate).

3.2.7 *water void, n*—a space enclosed by the cement paste that was occupied by water at the time of setting and frequently found under an aggregate particle or reinforcing bar. A water-void is usually identified by its irregular shape or evidence that a channel or cavity has been created by bleed water trapped in the concrete at the time it hardened.

4. Summary of Test Method

4.1 *Procedure A, Linear-Traverse Method*—This procedure consists of the determination of the volumetric composition of the concrete by summing the distances traversed across a given component along a series of regularly spaced lines in one or more planes intersecting the sample. The data gathered are the total length traversed *(T_t)*, the length traversed through air voids *(T_a)*, the length traversed through paste *(T_p)*, and the number of air voids intersected by the traverse line *(N)*. These data are used to calculate the air content and various parameters of the air-void system. If only the air content is desired, only T_a and T_t need be determined.

4.2 *Procedure B, Modified Point-Count Method*—This procedure consists of the determination of the volumetric composition of the concrete by observation of the frequency with which areas of a given component coincide with a regular grid system of points at which stops are made to enable the determinations of composition. These points may be in one or more planes intersecting the sample. The data gathered are the linear distance between stops along the traverse *(I),* the total number of stops *(S_t)*, the number of stops in air voids *(S_a)*, the number of stops in paste *(S_p)*, and the number of air voids *(N)* intersected by the line of traverse over which the component data is gathered. From these data the air content and various parameters of the air-void system are calculated. If only the air content is desired, only S_a and S_t need be determined.

4.3 *Paste-Air Ratio Modification*—In some instances the sample is not representative of the concrete as a whole, so T_t and S_t lose their significance and cannot be used as a basis for calculations. The most common examples are concrete with large coarse aggregate and samples from the finished surface region, for both of which the examined sample consists of a disproportionately large amount of the mortar fraction. In such instances the usual procedure must be changed, and the paste-air ratio modification must be used (see 5.5).

5. Significance and Use

5.1 The parameters of the air-void system of hardened concrete determined by the procedures described in this test method are related to the susceptibility of the cement paste portion of the concrete to damage by freezing and thawing. Hence, this test method can be used to develop data to estimate the likelihood of damage due to cyclic freezing and thawing or to explain why it has occurred. The test method can also be used as an adjunct to the development of products or procedures intended to enhance the resistance of concrete to cyclic freezing and thawing (**1**).

5.2 Values for parameters of the air-void system can be obtained by either of the procedures described in this test method.

5.3 No provision is made for distinguishing among entrapped air voids, entrained air voids, and water voids. Any such distinction is arbitrary, because the various types of voids intergrade in size, shape, and other characteristics. Reports that do make such a distinction typically define entrapped air voids as being larger than 1 mm in at least one dimension being irregular in shape, or both. The honey-combing that is a consequence of the failure to compact the concrete properly is one type of entrapped air void (**9, 10**).

5.4 Water voids are cavities that were filled with water at the time of setting of the concrete. They are significant only in mixtures that contained excessive mixing water or in which pronounced bleeding and settlement occurred. They are most common beneath horizontal reinforcing bars, pieces of coarse aggregate and as channelways along their sides. They occur also immediately below surfaces that were compacted by finishing operations before the completion of bleeding.

5.5 Application of the paste-air ratio procedure is necessary when the concrete includes large nominal maximum size aggregate, such as 50 mm (2 in.) or more. Prepared sections of such concrete should include a maximum of the mortar fraction, so as to increase the number of counts on air voids or traverse across them. The ratio of the volume of aggregate to the volume of paste in the original mix must be accurately known or estimated to permit the calculation of the air-void systems parameters from the microscopically determined paste-air ratio.

NOTE 1—The air-void content determined in accordance with this test method usually agrees closely with the value determined on the fresh concrete in accordance with Test Methods C 138/C 138M, C 173/C 173M, or C 231 (**11**). However, significant differences may be observed if the sample of fresh concrete is consolidated to a different degree than the sample later examined microscopically. For concrete with a relatively high air content (usually over 7.5 %), the value determined microscopically may be higher by one or more percentage points than that determined by Test Method C 231.

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SAMPLING AND SECTION PREPARATION

6. Apparatus and Materials for Sample Preparation (for either procedure)

6.1 Apparatus and materials for the preparation of surfaces of concrete samples for microscopical observation are described in Practice C 856; other apparatus may be equally suitable.

NOTE 2—Apparatus for measurement of prepared samples is described in the two following procedures.

7. Sampling (for either procedure)

7.1 Samples of concrete can be obtained from specimens cast in the field or laboratory, or by coring, sawing, or otherwise removing concrete from structures or products. The procedure followed and the location from which the samples are obtained will depend on the objectives of the program. In general, secure samples of hardened concrete in accordance with Test Method C 42 or Practice C 823 or both. Provide at least the minimum area of finished surface given in Table 1 in each sample. A sample may be composed of any number of specimens.

7.2 For referee purposes or to determine the compliance of hardened concrete with requirements of specifications for the air-void system, obtain samples for analysis by this test method from at least three randomly selected locations over the area or throughout the body of concrete to be tested, depending upon the objectives of the investigation.

8. Preparation of Sections (for either procedure)

8.1 Unless the objectives of the program dictate otherwise, saw the section for observation approximately perpendicular to the layers in which the concrete was placed or perpendicular to the finished surface. Individual sections should be as large as can be ground and examined with the available equipment. The required area may consist of more than one prepared section. Spread the selected traverse length uniformly over the available surface so as to compensate for the heterogeneity of the concrete.

TABLE 1 Minimum Area of Finished Surface for Microscopical Measurement

Nominal or Observed Maximum Size of Aggregate in the Concrete, mm (in).	Total Area to be Traversed for Determination of α or $\bar{L}$ [A], min, cm^2(in.^{2}) Based on Direct Measurement of:	
	Total Air-Void Content,[A,B]	Paste-Air Ratio, *p/A*
150 (6)	1613 (250)	645 (100)
75 (3)	419 (65)	194 (30)
37.5 (1½)	24 (155)	97 (15)
25.0 (1)	77 (12)	77 (12)
19.0 (¾)	71 (11)	71 (11)
12.5 (½)	65 (10)	65 (10)
9.5 (⅜)	58 (9)	58 (9)
4.75 (No. 4)	45 (7)	45 (7)

[A] See Section 3 for the interpretation of symbols employed.

[B] The indicated values refer to reasonably homogeneous, well-compacted concrete. The microscopical measurement should be made on proportionately larger area of sections if the concrete is markedly heterogeneous in distribution of aggregate or large air voids. If more than one finished surface is taken from a single portion of the concrete, the finished surfaces shall be separated by a distance greater than one half of the nominal or observed maximum size of aggregate.

8.2 If gross irregularities are present, begin the surface preparation by lapping (grinding on a flat surface) with nominal 150 µm (No. 100) silicon carbide abrasive. Lap the surface with successively finer abrasives until it is suitable for microscopical observation. An appropriate series of abrasives would include nominal 75, 35, 17.5 and 12.5 µm grit sizes (No. 220, 320, 600, and 800, respectively), and perhaps 5-µm aluminum oxide (Note 3). From time to time during lapping, and when changing to a finer abrasive and when lapping is complete, clean all surfaces of the specimen gently and thoroughly to remove the grinding compound. Use of ultrasonic cleaners may be harmful to the surface. Such treatment should not be used without care and experimentation. Cleaning with a soft cosmetic brush under running water, or by a pressurized dental spray has been successful. A surface that is satisfactory for microscopical examination will show an excellent reflection of a distant light source when viewed at a low incident angle and there shall be no noticeable relief between the paste and the aggregate surfaces. Areas that are scratched or imperfect indicate the need for additional preparation; use special techniques if required (see 8.3). The edges of the sections of the air voids will be sharp and not eroded or crumbled, and air-void sections including those as small as 10 µm ($3.94\ 10^{-5}$ in.) in diameter will be clearly distinguishable. (See Fig. 1.) Do not include scratched or broken portions of the surface in the analyzed area. If needed to meet the requirements of Table 1, prepare additional surfaces.

NOTE 3—Grit numbers of abrasives can denote slightly different particle sizes, depending on the manufacturer. The suggested sizes will usually be appropriate, but others may be selected according to the experience of the user.

8.3 Sometimes difficulty will be encountered in preparing the lapped surfaces. The usual cause is a weak cement-paste matrix. The problem is manifested by the plucking of sand grains from the surface during the lapping, with consequent scratching of the surface, and by undercutting of the paste around the harder aggregate particles. Friable particles of aggregate can also cause difficulty. In such instances the following procedure is helpful. Heat the partially prepared specimen of concrete to about 150 °C (300 °F) in an oven. (**Warning**—If the specimen was sawn with a lubricant other than water, heating must be done so as to avoid inhaling the fumes and to preclude fire or explosion. Some lubricants have a flash point as low as 140 °C (285 °F). (The flash point of the lubricant may be found by use of Test Method D 92.) Unless other precautions are taken, the temperature must not be allowed to approach the flash point. If this cannot be avoided, heating must be done in the open air on a hot plate or in an explosion-proof hood.)

Remove the specimen from the oven and immediately brush melted carnauba wax that was heated to the same temperature onto the surface. Repeat the application as the wax is absorbed by the concrete, so that when the temperature of the concrete falls below the melting point of the wax, a perceptible film remains on the surface. After the specimen has cooled, scrape off any excess wax and repeat the lapping. After completion of lapping, remove the residue of wax from the surface air voids by reheating the concrete to about 150 °C (300 °F) to allow

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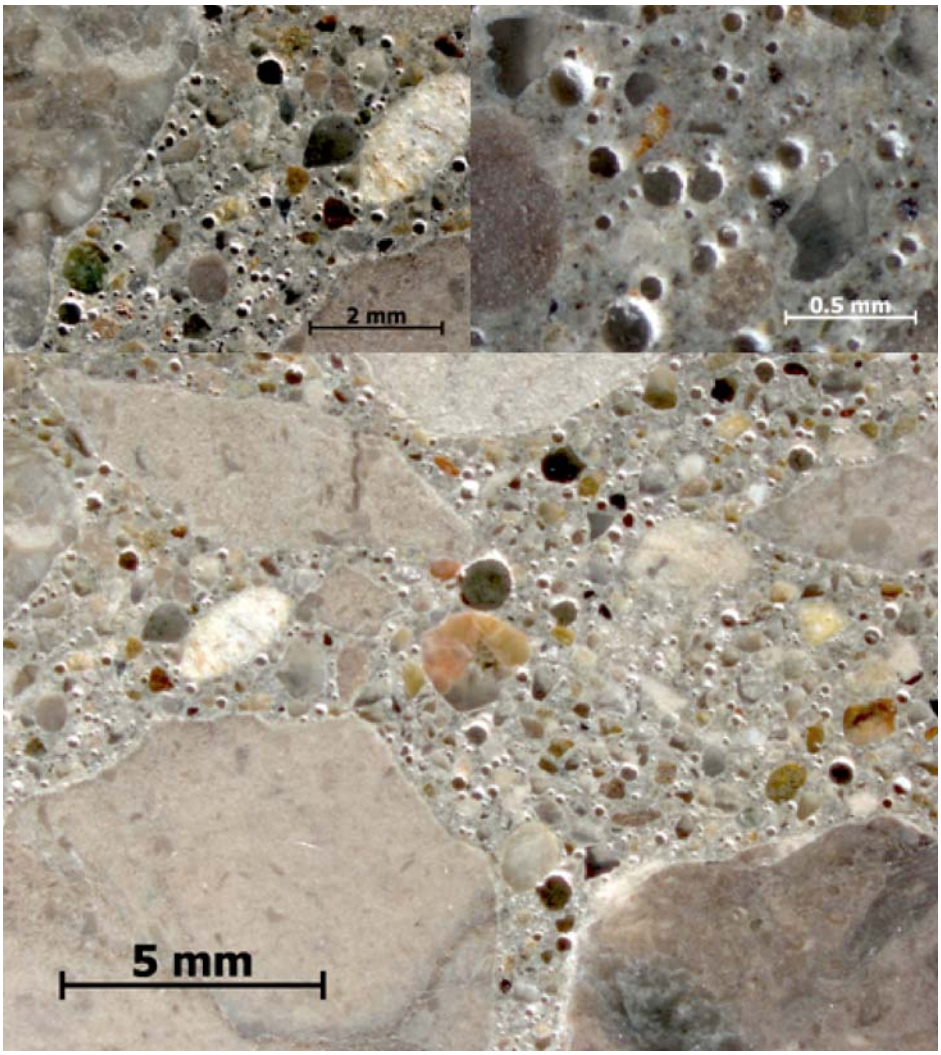

FIG. 1 Photographs of a Satisfactory Surface

absorption of the molten wax into the specimen. Again take care to avoid approaching the flash point of the wax or of any cutting oil present. Protect the surface from dust during heating. The time to remove the wax from the surface air voids varies with the properties and thickness of the specimen, but heating for about an hour is usually sufficient. Exceptionally fragile concrete may require repetition of this process. Substances other than carnauba wax have been used successfully to impregnate and strengthen the surfaces of concrete specimens before grinding.

NOTE 4—If performing a microscopic examination of the cement paste, using Practice C 856, on the same test sample that will be coated with wax or other paste strengthening media, perform the microscopic examination prior to heating the sample and application of the strengthening materials. The application of such materials and exposure to oven temperatures of 150 °C will alter the physical characteristics and appearance of the cement paste.

8.4 If the parameters of the air-void system near a finished or formed surface are desired, then prepare the section examined in such a manner as to allow for the fact that the parameters of the air-void system may vary greatly with the distance from such a surface. Therefore, measure the distance between the section to be examined and the original surface accurately, to at least the nearest 1.2 mm (0.05 in.). Use the following procedure: (*1*) Prepare a specimen that includes a portion of the finished or formed surface to be investigated, and of convenient thickness, but not less than 12 mm (½ in.) or one-half of the nominal maximum size of the aggregate, whichever is greater. (*2*) Lap the surface with a coarse abrasive until the last portion of the original surface is just removed, then complete the lapping operation as described above. Use this surface as the reference plane, to which later measurements are referenced. (*3*) Lap the back surface of the specimen so as to produce a plane section. (*4*) Measure the thickness of the specimen to the nearest 1.2 mm (0.05 in.) at four or more points uniformly spaced around the periphery. Average the results, and record the average to the nearest 1.2 mm. (*5*) Determine the parameters of the air-void system on any plane desired or specified. If nearest surface values are desired, make the determination on the reference plane; if values for the bulk concrete are desired, make the determination on the back plane. If values for some other plane are desired, repeat the grinding process to the desired depth. Redetermine the thickness of the

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sample as specified above so that the parameters of the air-void system can be correlated with the distance of the examined surface from the reference plane.

8.5 The composition of the near-surface zone differs from that of the concrete as a whole. Therefore, whenever the design of the mixture is known, use the paste-air ratio method for the determination of the air-void system parameters in this region.

PROCEDURE A—LINEAR TRAVERSE METHOD

9. Apparatus for Measurement of Specimens

9.1 The apparatus listed in 9.1.1 to 9.1.5 comprises a recommended minimum selection. Apparatus other than that described has been used and may be equally satisfactory. Apparatus that uses electronic switches and totalizers has been constructed. Computerized apparatus is commercially available. Image analyzers have frequently been used.

9.1.1 *Linear-Traverse Device*—Provide a platform, on which the specimen is carried mounted on lead screws by means of which it can be smoothly translated in two perpendicular directions. Provide one lead screw for movement in the N-S direction and at least two for movement in the E-W direction (Note 5). One of these latter is called the "main" lead screw and the other(s) the "upper" lead screw(s). Ensure that the capacity of the main (E-W) lead screw is at least 100 mm (4 in.), that of each (E-W) lead screw at least 65 mm (2.5 in.), and that of the N-S lead screw at least 75 mm (3.0 in.). Ensure that the pitch of the upper lead screw does not exceed 0.265 mm (0.0105 in.) per revolution. Determine the pitch of all E-W lead screws to the nearest 0.03 mm (0.001 in.). Attach rotation counters readable to the nearest 0.01 of revolution to all E-W lead screws. Provide a manually operated tally counter. For the determination of the paste content, provide a third E-W lead screw complete with rotation counter, unless each traverse is to be repeated, that is, performed once for the air content and again for the paste content. Photographs of satisfactory linear-traverse devices are shown in Figs. 2 and 3.

NOTE 5—In the descriptions of the linear-traverse and point-count devices the term "E-W direction" refers to the direction from the operator's right to his left, and "N-S" means the direction perpendicular to E-W, that is, the directions are analogous to those on a map.

9.1.2 *Stereoscopic Microscope and Support,* with objectives and eyepieces to give final magnification in the range from about 50× to about 125×. While it is possible to use a microscope with a single, fixed magnification, it is more convenient to be able to vary the magnification within the above range by replacing eyepieces or objectives or, better, by means of a zoom attachment. Arrange the microscope so as to permit continuous observations of the surface of the specimen mounted on the platform of the linear-traverse device. Include cross hairs, scale, or some other reticle device to provide an index point in one eyepiece. Since an index point is dimensionless it shall be a point such as the intersection of one pair of edges of the cross hairs or one corner of the end of a line of a scale. Use the same index point throughout any examination.

9.1.3 *Microscope Lamp*, spotlight-type, arranged to provide sufficient illumination at a low and variable incident angle to the surface. The spot of evenly lit area on the specimen surface should be slightly larger than the field of view of the microscope.

9.1.4 *Spirit Level*, the small circular type is convenient.

9.1.5 *Leveling Device*—Provide a means to level the examined surface. This can be done by the insertion of small pieces of modeling clay. A better way is by means of a platform that is mounted on three adjustable leveling screws and that supports the sample on the stage of the traverse device.

10. Procedure

10.1 Place the prepared specimen of concrete on the stage of the linear-traverse device. Level the prepared surface with the leveling device and the spirit level so that the surface may be traversed and microscopically examined with a minimum of refocusing. Adjust the lamp so that the beam evenly illuminates the field of view of the microscope and is incident on the surface at a low angle, so the air voids are demarked by a shadow. Superimpose the index point on the surface to be examined. Do not use a magnification of less than 50× and do not change it during the course of the analysis. For a rectangular section, place the index near an upper corner; for a circular section, place it near the top and at one end of the initial traverse. Engage and adjust all drives so as to remove all play from the gear systems. Set all counters to zero. By operation of the main lead screw move the assembly and specimen in the E-W direction while scrutinizing the prepared surface as it moves beneath the microscope. When the index point is exactly superimposed on the periphery of a section of an air void (Notes 6 and 7) in the prepared surface of the specimen, stop the movement of the carriage, actuate the tally counter once, and by means of the upper lead screw, move the concrete under the microscope until the index point is exactly superimposed upon the opposite periphery of the same air-void section. Stop the rotation of the upper lead screw, and resume the movement by means of the main lead screw. Take extreme care to determine whether or not a section of an air void is intersected by the index point when the line of traverse is nearly tangent to the void section. The results can be affected significantly by consistent error in this respect. If the periphery of an air void is crumbled or rounded, estimate the position of the true periphery in the plane of the surface by extrapolation of the surface contour of the air void. If the paste content is being determined, as will usually be the case, carry out the above procedure for traverses across paste regions, except use the second upper lead screw and do not use the tally counter. Proceed in this way along the E-W traverse line, traversing all chords across air voids with the upper lead screw, all sections of paste with the second upper lead screw (if paste content is being determined), and all other sections with the main lead screw. Stop the traverse at the end of the line, which should be just within the examined area, not at its edge. By means of the N-S lead screw shift the sample an appropriate distance to the next traverse line. Space the segments of the traverse so as to cover the entire prepared surface with at least the minimum required traverse length. If the rotation counters operate in both directions, the next line of traverse can begin just below the

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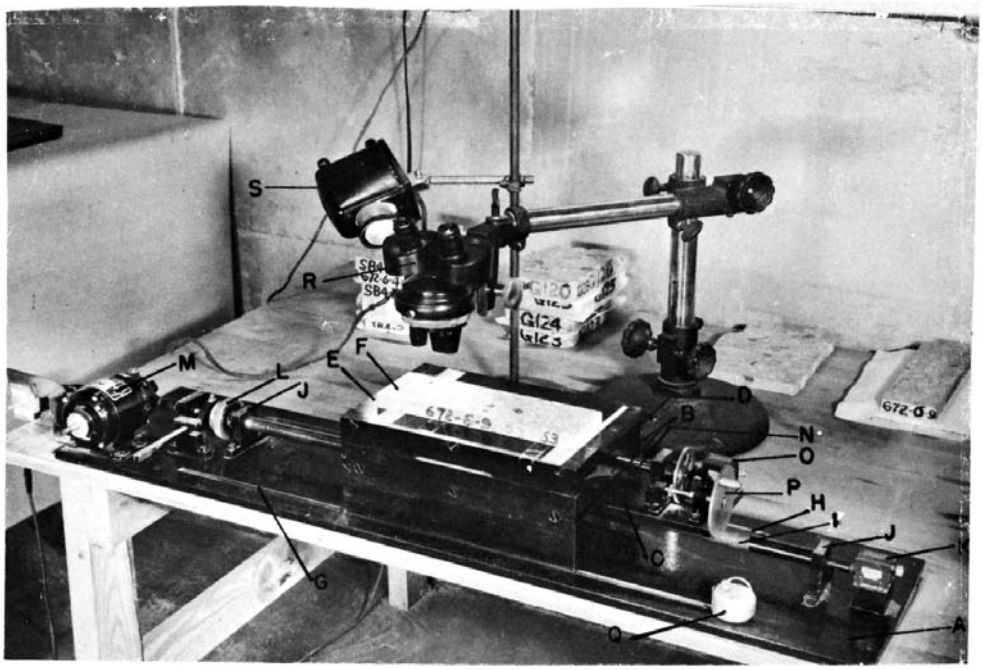

A = Base plate.
B = Front and back rails supporting the middle plate *C*
C = Middle plate.
D = Upper front and back rails carrying the stage *E*
E = Stage.
F = Concrete specimen
G = Rectangular front groove in the base plate.
H = V-shaped back groove in the base plate.
I = Main lead screw.
J = Two bearing blocks for the main lead screw.
K = Revolution counter on main lead screw.
L = Manually operated knurled wheel.
M = Electric motor for driving the main lead screw.
N = Upper lead screw.
O = Revolution counter for upper lead screw.
P = Hand-driven wheel for moving the stage.
Q = Ratchet counter to tally the number of air voids encountered.
R = Stereoscopic microscope.
S = Microscope lamp.

NOTE 1—Not shown are a third lead screw and a disengaging clutch; the former is necessary if a determination of the air-paste ratio is required, and the latter may be required (see 9.1.1).

FIG. 2 Photograph of a Linear-Traverse Device Meeting the Requirements of This Test Method

end of the previous one; if not, return the stage so the new line will begin just below the beginning of the previous one. Start each segment of the traverse just within the prepared area and on the satisfactory plane surface of the specimen rather than at the edge of the surface itself. The length of the segments of the traverse may vary. Superimpose the index point at the beginning of the new line, and perform the traverse as before. Repeat this process for all segments of the total traverse. Accumulate the total rotation on each counter, or read and record each at the end of each traverse line, so that the total will be the summation of such records. If more than one specimen has been prepared from the sample of concrete, repeat the procedure on each such specimen as to comply with the requirements of Table 1. Electronic or computerized equipment will require that the procedures specified by the fabricator be followed but the principles will remain as detailed above. The minimum length of traverse shall be as specified in Table 2.

NOTE 6—Surfaces examined may exhibit features that resemble air voids, but are not: *(a)* Occasionally a transparent section of a grain of quartz sand will look like an air void. *(b)* The socket left when a section of a nearly spherical and smooth sand grain is lost from the surface during grinding looks much like an air void, but can be distinguished by differences in the luster and sheen of the film lining the hole. *(c)* Cenospheres, hollow particles of fly ash, or hollow plastic spheres will

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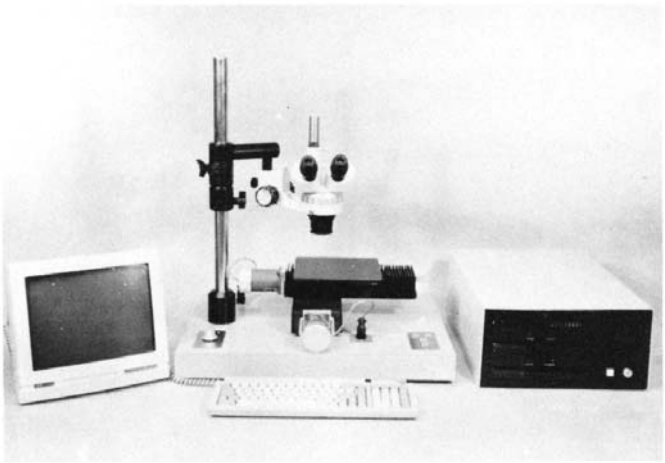

FIG. 3 Photograph of a Computerized Linear-Traverse/Point-Count Device Meeting the Requirements of This Test Method

TABLE 2 Minimum Length of Traverse for the Linear Traverse Method

Nominal or Observed Maximum Size of Aggregate in the Concrete, (mm) in.	Length of Traverse for Determination of[A], α, or $\bar{L}$, min, mm (in.)[A]
6 (150)	4064 (160)
3 (75)	3048 (120)
1½ (37.5)	2540 (100)
1 (25.0)	2413 (95)
¾ (19.0)	2286 (90)
½ (12.5)	2032 (80)
⅜ (9.5)	1905 (75)
4.75 (No. 4)	1397 (55)

[A] The limits of uncertainty of results obtained for air-void content depend upon the length of traverse and the air-void content of the concrete. Based on experience, the recommended minimum length of traverse shown in this table should produce limits of uncertainty such that up to 3 % air-void content the standard deviation is not greater than 0.5 %, which at 3 % air-void content corresponds to a coefficient of variation of 17 %. For traverse lengths greater than 1375 mm (55 in.) and air-void contents greater than 3 % the coefficient of variation is correspondingly reduced. The data obtained can be analyzed by statistical methods to determine the limits of uncertainty to be applied.

also have a different sheen, and are unaffected when the surrounding paste is etched with dilute (10 %) hydrochloric acid.

Warning—Do not acid-etch the sample under the microscope, as the effervescent spatter may damage the lens.

NOTE 7—Occasionally, air voids may become filled, during the service exposure of the concrete, with secondary products. Whether such voids are counted as belonging to the air-void system or not depends on the purposes of the investigation.

11. Calculation

11.1 When based on the air content of the total concrete:

11.1.1 The data will consist of:

where:

N = total number of air voids intersected,
R_i = number of rotations of the respective lead screws, and
P_i = pitch of the corresponding lead screws.

11.1.2 Calculate:

$$T_t = \text{total length of traverse} = \text{sum of } P_i \times R_i \quad (1)$$

$$T_a = \text{traverse length through air} = P_a \times R_a \quad (2)$$

$$T_p = \text{traverse length through paste} = P_p \times R_p \quad (3)$$

11.1.3 *Air Content (A),* in %:

$$A = \frac{T_a \cdot 100}{T_t} \quad (4)$$

11.1.4 *Void Frequency (n)*:

$$n = \frac{N}{T_t} \quad (5)$$

11.1.5 *Average Chord Length* ($\bar{l}$):

$$\bar{l} = \frac{T_a}{N} \quad (6)$$

or

$$\bar{l} = \frac{A}{100n} \quad (7)$$

11.1.6 *Specific Surface* (α):

$$\alpha = \frac{4}{\bar{l}} \quad (8)$$

or

$$\alpha = \frac{4N}{T_a} \quad (9)$$

11.1.7 *Paste Content (p),* in %:

$$p = \frac{T_p \cdot 100}{T_t} \quad (10)$$

11.1.8 *Paste-Air Ratio (p/A)*:

$$\frac{p}{A} = \frac{T_p}{T_a} \quad (11)$$

11.1.9 *Spacing Factor* ($\bar{L}$):

11.1.9.1 When *p/A* is less than or equal to 4.342

$$\bar{L} = \frac{T_p}{4N} \quad (12)$$

11.1.9.2 When *p/A* is greater than 4.342

$$\bar{L} = \frac{3}{\alpha}\left[1.4\left(1 + \frac{p}{A}\right)^{1/3} - 1\right] \quad (13)$$

11.2 If the calculations are based on the paste-air ratio method, the design of the mixture must be known. The microscopically determined data will consist of T_p, T_a, and N. Proceed as follows:

11.2.1 Calculate the *paste-air ratio (r):*

$$r = \frac{T_p}{T_a} \quad (14)$$

11.2.2 From the mixture design calculate the ratio of *aggregate volume* to *paste volume (M):*

$$M = \frac{G_c}{p_c} \quad (15)$$

where:

G_c = sum of the masses of the aggregates; each divided by its specific gravity (Note 8), and
p_c = sum of mass of cement divided by specific gravity of cement + mass of mineral admixture divided by the specific gravity of the mineral admixture + mass of water (including the fluid portion of any admixture) divided by the specific gravity of the fluids (Note 8):

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NOTE 8—The values used for the calculated G_c and p_c must accurately reflect the differing densities of the constituents and the proportions of the masses of each.

11.2.3 The *percent air (A):*

$$A=\frac{100}{r(1+M)+1} \tag{16}$$

11.2.4 *Paste* expressed as percent *(p):*

$$p=A\cdot r \tag{17}$$

11.2.5 *Average chord length* ($\bar{l}$):

$$\bar{l}=\frac{T_a}{N} \tag{18}$$

11.2.6 *Specific Surface* (α): Use Eqs 8 or 9.

11.2.7 *Spacing Factor* ($\bar{L}$):

11.2.7.1 When *r* is equal to or less than 4.342 use Eq 12.

11.2.7.2 When *r* is greater than 4.342 use Eq 13 with the substitution of *r* for the *p/A* ratio.

11.3 If desired, the spacing factor ($\bar{L}$) may be estimated graphically by use of Fig. 4 rather than calculated directly.

PROCEDURE B—MODIFIED POINT-COUNT METHOD

12. Apparatus for Measurement of Specimens

12.1 The apparatus listed in 12.1.1 to 12.1.5 comprises a recommended minimum selection. Apparatus other than that described has been used and may be equally satisfactory. Apparatus that uses electronic switches and totalizers has been constructed. Computerized apparatus is commercially available. Image analyzers have frequently been used.

12.1.1 *Point-Count Device*, comprising a stage or platform connected to E-W and N-S (Note 5) lead screws and designed in such a way that a specimen of concrete placed on the stage can be moved smoothly and uniformly through equal distances by turning of the screws. Ensure that the total possible translation of the stage is at least 100 mm (4.0 in.) in each direction. Fit lead screws with notched wheels and stopping devices, such that with each rotation of the screws a click can be detected by the operator when a stop position is reached. Ensure that the intervals between the stops correspond to a translation of the stage a distance of 0.025 to 0.64 to 5.0 mm (0.025 to 0.200 in.). Determine the magnitude of the average translation of the stage between stops to the nearest 0.03 mm (0.001 in.). Provide at least four digital counters; more may be better. It may be convenient to attach one counter to the stopping device of the E-W lead screw, so as to register automatically the total number of stops in that direction. A photograph of a satisfactory device for the modified point-count method is given in Fig. 5.

12.1.2 *Stereoscopic Microscope and Support*, as described in 9.1.2.

12.1.3 *Microscope Lamp*, as described in 9.1.3.

12.1.4 *Spirit Level*, as described in 9.1.4.

12.1.5 *Leveling Device*, as described in 9.1.5.

13. Procedure

13.1 Place the prepared surface of concrete on the stage of the point-count device. Using the spirit level, level the prepared surface with the leveling device so that the surface may be traversed and microscopically examined with a minimum of refocusing. Adjust the lamp so the beam evenly illuminates the field of view of the microscope and is incident upon the surface at a low angle, so the air voids are demarked by a shadow. Superimpose the index point of the cross hairs (or other reticle device) on the surface to be examined. Use a magnification not less than 50× and do not change it during the course of the analysis. For a rectangular section, place the index near an upper corner; for a circular section, place it near the top and at one end of the initial traverse. Position the stopping device at a stop or click position at the beginning of the traverse. Do not include the initial stops for each traverse line in the total number of stops or in the number of stops for any component. Zero all counters. By operation of the E-W lead screw, cause movement of the stage and specimen while simultaneously scrutinizing the surface. At each click stop, except not at the beginning of any traverse line, pause and examine the field of view, and record on the appropriate counter the material or phase on which the index point is superimposed (Notes 5, 6 and 7). Normally use one counter for air voids, one for paste, and one for all other phases (or a totaling counter). Other components (fine and coarse aggregate, for example—if they are lithologically distinguishable) of the concrete can be determined with the use of additional counters. Continue in this way along the line until a last stop is reached just within the prepared area, but close to its edge. When the end of the line is reached, turn off the totaling counter. Reverse the E-W lead screw and proceed back along the same line, recording on another counter each air void intersected, whether or not a stop occurred within the air void. Terminate the void counting just before the initial stop. Take extreme care to determine whether a section of an air void is intersected by the movement of the index when the line of traverse is nearly tangent to the void section. The results can be affected significantly by consistent error in this respect. If the periphery of an air void is crumbled or rounded, estimate the position of the true periphery in the plane of the surface by extrapolation of the surface contour of the air void. If the examination is being made to determine only the air content of the concrete, the number of air voids intersected by the line of traverse need not be determined. By means of the N-S lead screw, shift the concrete specimen at right angles to the direction of traverse an appropriate distance. Space the segments of the traverse so as to cover the whole prepared surface and achieve at least the minimum length of traverse and the minimum number of points specified in Table 3. Proceed along the new line of traverse as before, and so on, for all segments of the total traverse and for all sections prepared from a sample of concrete so as to comply with the requirements of this test method. Electronic or computerized equipment will require that the procedures specified by the fabricator be followed but the principles will remain as detailed above. When calculations are based on the paste-air ratio, the minimum length of traverse shall be as shown in Table 3, and the minimum number of points shall comply with the following equation:

$$S_a=\frac{10\,000}{V^2} \tag{19}$$

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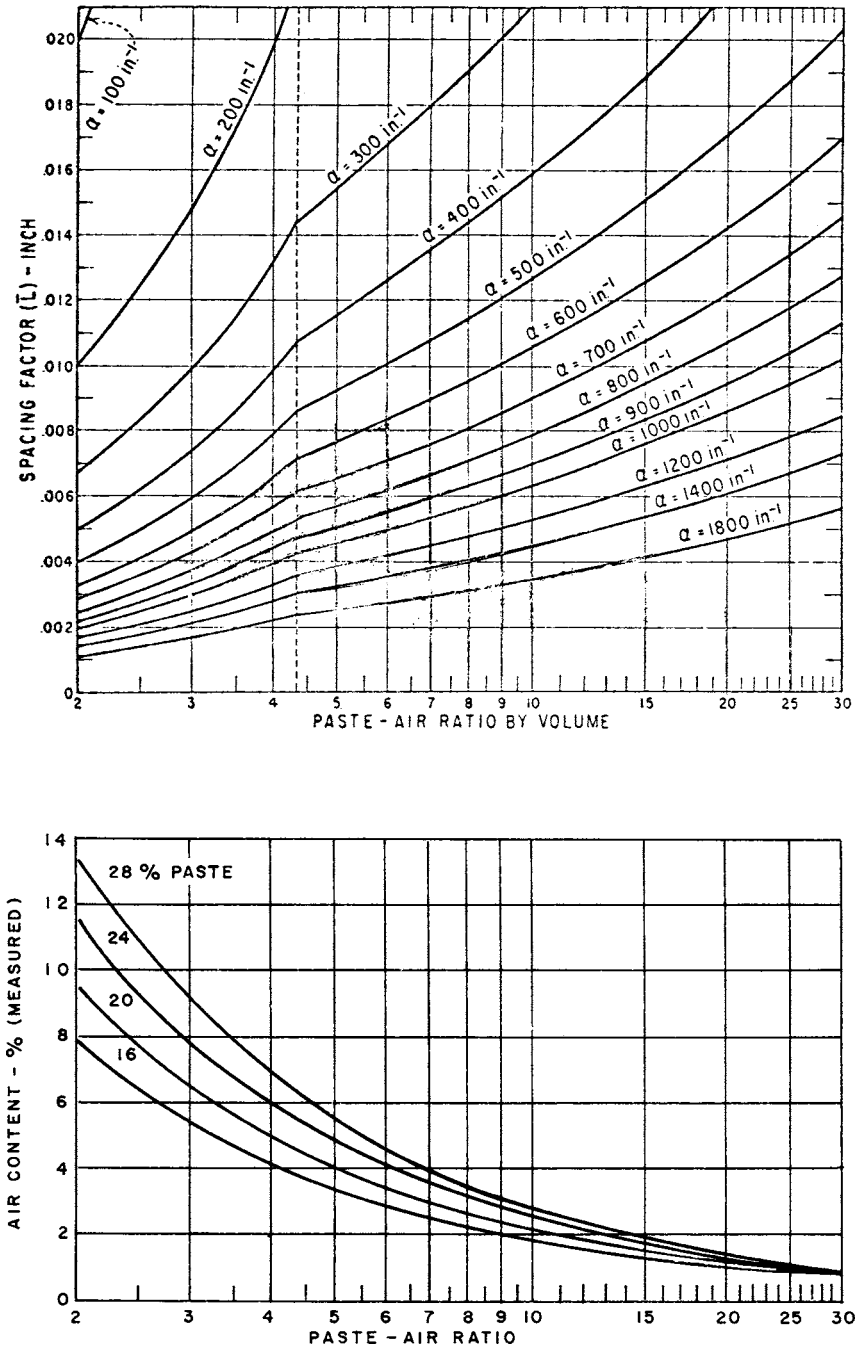

NOTE 1—Estimate the spacing factor; $\bar{L}$, as follows:

(*1*) If air content was measured, selected appropriate value in lower diagram, follow horizontally to calculated or estimated paste content. Now move vertically to upper diagram to calculated specific surface, α, and then horizontally to corresponding spacing factor, $\bar{L}$, or

(*2*) If paste-air ratio was measured, select the appropriate value in the upper diagram, move vertically upward to calculated specific surface, α, and then horizontally to corresponding factor, $\bar{L}$

FIG. 4 Graphs for Estimating the Spacing Factor, $\bar{L}$

where:

S_a = number of stops at which the index point is superimposed on a section of an air void, and

V = the desired coefficient of variation of the air content expressed as a percent of the average air content.

14. Calculation

14.1 hen based on data collected from a sample of the total concrete; the data will consist of:

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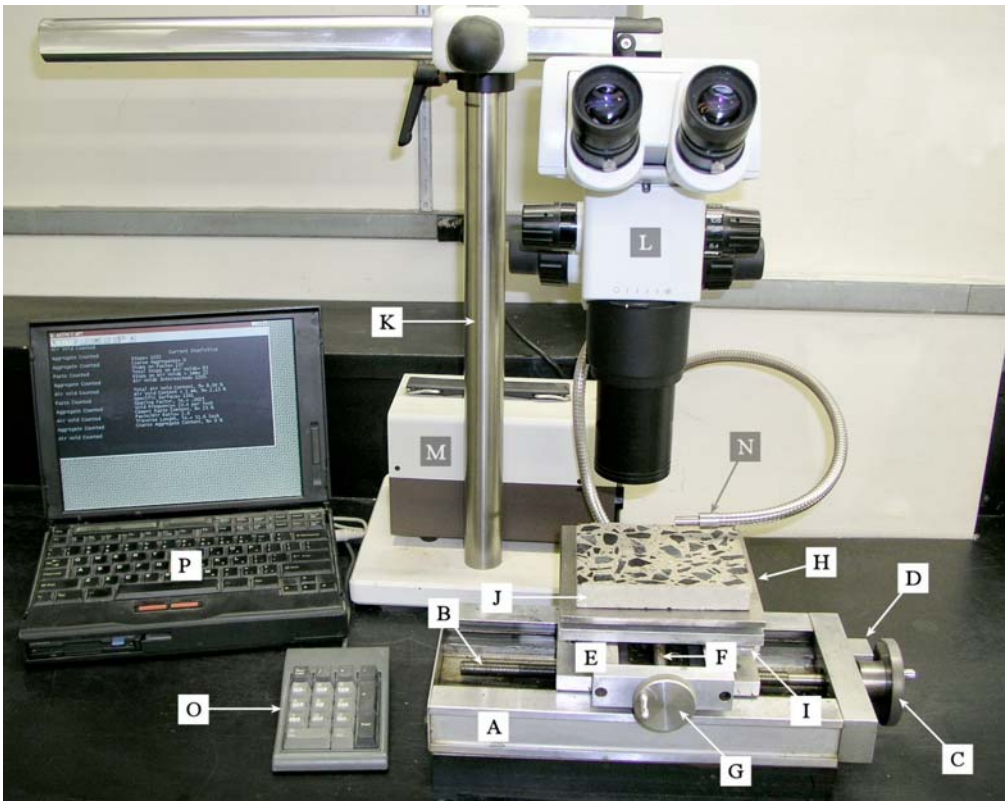

A = Lower stage assembly
B = Lower lead screw (E-W)
C = Manually operated crank for turning lower lead screw
D = Stopping device for indicating point-count positions on the line of traverse
E = Upper stage assembly
F = Cross feed screw for lateral movement of upper stage (N-S)
G = Manually operated knurled knob for turning cross feed screw
H = Plate supporting concrete specimen
I = Screws for leveling surface of concrete specimen
J = Concrete specimen
K = Support for microscope
L = Stereoscopic microscope
M = Fiber optic light source
N = Fiber optic light guide
O = Keypad to enter number of points counted, points superimposed on sections of air voids, cement paste, and the number of air-void sections intercepted by the line of traverse
P = Computer for calculations and storage of results

FIG. 5 Photograph of a Point-Count Device Meeting the Requirements of This Test Method

N	=	total number of air voids intersected,
S_t	=	total number of stops,
S_a	=	number of stops in air voids,
S_p	=	number of stops in paste, and
I	=	the E-W translation distance between stops.

NOTE 9—S_i, etc. may be used to denote other constituents tallied on other counters.

14.1.1 Calculate the *total traverse length* (T_t):

$$T_t = S_t \cdot I \tag{20}$$

14.1.2 *Air Content (A)*:

$$A = \frac{S_a \cdot 100}{S_t} \tag{21}$$

14.1.3 *Void Frequency (n)*:

$$n = \frac{N}{T_t} \tag{22}$$

14.1.4 *Paste Content (p)* in %:

$$p = \frac{S_p \cdot 100}{S_t} \tag{23}$$

14.1.5 *Paste-Air ratio (p/A)*:

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TABLE 3 Minimum Length of Traverse and Minimum Number of Points for the Modified Point-Count Method[A]

Nominal or Observed Maximum Size of Aggregate in the Concrete, mm (in.)	Length of Traverse for Determination of[A], α, or $\bar{L}$, min, mm (in.)	Number of Points for Determination of[A], α, or $\bar{L}$, min
150 (6)	4064 (160)	2400
75 (3)	3048 (120)	1800
37.5 (1½)	2540 (100)	1500
25.0 (1)	2413 (95)	1425
19.0 (¾)	2286 (90)	1350
12.5 (½)	2032 (80)	1200
9.5 (⅜)	1905 (75)	1125
4.25 (No. 4)	1397 (55)	1000

[A] The limits of uncertainty of results obtained for air-void content depend upon the number of points and the air-void content of the concrete. The recommended minimum number of points shown in this table should produce limits of uncertainty such that up to 3 % air-void content the standard deviation is not greater than 0.5 % which at 3 % air-void content corresponds to a coefficient of variation of 17 %. For number of points greater than 1000 and air-void contents greater than 3 % the coefficient of variation is correspondingly reduced. The data obtained can be analyzed by statistical methods to determine the limits of uncertainty to be applied.

$$\frac{p}{A}=\frac{S_p}{S_a} \tag{24}$$

14.1.6 *Average chord length* ($\bar{l}$):

$$\bar{l}=\frac{S_a \cdot I}{N} \tag{25}$$

or

$$\bar{l}=\frac{A}{100n} \tag{26}$$

14.1.7 *Specific Surface* (α):

$$\alpha=\frac{4}{\bar{l}} \tag{27}$$

or

$$\alpha=\frac{400n}{A} \tag{28}$$

14.1.8 *Spacing Factor* ($\bar{L}$):

14.1.8.1 If *p/A* is less than or equal to 4.342

$$\bar{L}=\frac{p}{400n} \tag{29}$$

14.1.8.2 If *p/A* is greater than 4.342

$$\bar{L}=\frac{3}{\alpha}\left[1.4\left(1+\frac{p}{A}\right)^{1/3}-1\right] \tag{30}$$

14.2 If the calculations are based on the paste-air ratio method, the data will consist of S_a, S_p, N, and I (the distance between stops). Calculate the following:

14.2.1 The *paste-air ratio (r):*

$$r=\frac{S_p}{S_a} \tag{31}$$

14.2.2 From the mixture design, calculate the ratio of *aggregate volume to paste volume (M):*

$$M=\frac{G_c}{p_c} \tag{32}$$

where:

G_c = sum of the masses of the aggregates; each divided by its specific gravity (Note 8), and,

p_c = sum of mass of cement divided by specific gravity of cement + mass of mineral admixture divided by the specific gravity of the mineral admixture + mass of water (including the fluid portion of any admixture) divided by the specific gravity of the fluids (Note 8).

14.2.3 The *percent air (A):*

$$A=\frac{100}{r(1+M)+1} \tag{33}$$

14.2.4 *Paste* expressed as percent *(p):*

$$p=A \cdot r \tag{34}$$

14.2.5 *Specific Surface* (α):

$$\alpha=\frac{4N}{S_a \cdot I} \tag{35}$$

14.2.6 *Average chord length* ($\bar{l}$):

$$\bar{l}=\frac{S_a \cdot I}{N} \tag{36}$$

14.2.7 *Spacing Factor* ($\bar{L}$):

14.2.7.1 When r is equal to or less than 4.342

$$\bar{L}=\frac{S_p \cdot I}{4N} \tag{37}$$

14.2.7.2 When r is greater than 4.342, use Eq 12 with the substitution of r for the *p/A* ratio.

14.3 If desired, the spacing factor *(L)* may be estimated graphically by use of Fig. 4 rather than calculated directly.

15. Report

15.1 Report the following information from the results of the linear-traverse or modified point-count method:

15.1.1 Method used, Procedure A or Procedure B,

15.1.2 Identification of the source of the samples,

15.1.3 Location from which the samples were taken and their orientation with respect to the sources,

15.1.4 Orientation and position of the surfaces cut from the samples for traversing,

15.1.5 The length of traverse, the area traversed, and, if the modified point-count method is employed, the number of stops,

15.1.6 The determined values of air content and, if measured, void frequency, specific surface, spacing factor, and paste-air ratio, and

15.1.7 Method by which the paste content was determined.

15.2 If the parameters of the air-void system have been determined on near-surface sections, the relationship of such parameters to the depth from the reference surface.

16. Precision and Bias

16.1 *Precision*:

16.1.1 The estimates of precision for this test method are given in Table 4 for determinations made on a series of four lapped specimens prepared in one laboratory and then circulated to nine laboratories where a number of determinations were made in each laboratory, usually involving at least two operators per laboratory and two or three determinations per operator. The range of properties covered by the four prepared surfaces used in this study was: for air content, 2 to 9 %; for voids intersected, 79 to 512 voids/m (2 to 13 voids/in.); and for paste content average, in the range of 20 to 22 %. The

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TABLE 4 Average Precision Data Based on a Set of Four Prepared Specimens Circulated to Nine Laboratories[A]

Item	Standard Deviation (1s)[B]	Range of Two Test Results (D2s)[B]	Percent of Average	
			Coefficient of Variation (1s %)[C]	Range of Two Test Results (D2s %)[C]
Air Content, %:				
Within Lab	0.29	0.82	. . .	. . .
Between Lab	0.41	1.16	. . .	. . .
Voids/in.:				
Within Lab	. . .	. . .	3.7	10.3
Between Lab	. . .	. . .	12.4	35.0
Paste Content, %:				
Between Operator (Each in Their Own Laboratory)	3.1	8.8	. . .	. . .

[A] Includes determinations using both point count and linear traverse. In all, 19 operators participated with a total of 41 determinations on each specimen. For point count: 6 labs; 12 operators; and 26 determinations. For linear traverse: 3 labs; 7 operators; and 15 determinations. Paste content determinations were made by 13 operators representing 8 different laboratories. Eleven were by point count and 2 by linear traverse procedures.

[B] These numbers represent, respectively, the (1s) and (D2s) limits as described in Practice C 670.

[C] These numbers represent, respectively, the (1s %) and (D2s %) limits as described in Practice C 670.

variability of the test method would be higher in actual practice for specimens sampled and prepared from in-place concrete since additional variation due to sample selection and surface preparation in different laboratories would increase the coefficient of variation. Additional data are still being gathered on these four prepared specimens and additional statistical analyses will be done on the data to arrive at precision estimates for spacing factor calculated from the results of each determination. Table 5 compares the actual variation from this study with theoretical estimates.

TABLE 5 Comparison of Actual Variation with Theoretical Estimates Based on Binomial and Poisson's Distribution

Specimen Number	Average Value	Standard Deviation		Coefficient of Variation %	
		Actual[A]	Theoretical[B]	Actual	Theoretical
Air Content, % Based on Counts of 1500 Points					
1	2.98	0.45	0.44	15.1	14.8
2	3.65	0.49	0.48	13.4	13.2
3	5.55	0.40	0.59	7.2	10.6
4	8.02	0.64	0.70	8.0	8.7
Voids Per Inch Based on 100 in. Traverses					
1	2.31	0.27	0.15	11.7	6.5
2	5.77	0.78	0.24	13.5	4.2
3	7.69	0.86	0.28	11.2	3.6
4	12.69	1.63	0.36	12.8	2.8

[A] Includes all data—all labs and all operators. Includes both point count and linear traverse data.

[B] Theoretical Standard Deviation:—For air content: Binomial Distribution; Standard deviation in points on air = $\sqrt{npq}$ using an assumed 1500 point count, where n is number of points, p is decimal fraction of air, and q is decimal fraction not-on-air. To convert to units of percent air content, divide by n and multiply by 100 to get percent. For voids per in.: Poisson's Distribution; S.D. = $\sqrt{np}$ where np is the mean number of occurrences (counts per 100 in. of traverse based on results of 100-in. traverses).

16.1.2 Table 6 provides an estimate of precision for air content and spacing factor from a European study **(12)** using predominantly the same procedures as contained in this test method. The great majority of these determinations were made by linear traverse with a magnification of 50×. Two hardened concrete beam specimens with nominal air contents of about 3 and 6.5 % were sampled by one laboratory. A pair of surfaces were sawn from the beams for each participating laboratory; one surface was lapped in the originating laboratory, and the adjacent surface was lapped in the participating laboratory.

16.2 *Bias*:

16.2.1 There is no accepted reference material suitable for determining bias from the true air-void parameters of concrete.

16.2.2 From the results of the interlaboratory study referenced in 16.1.1 and Table 4 there was very little bias between Procedure A and Procedure B for the average results for air content and voids intersected measured on each of the four specimens. The overall averages are given in Table 7. Two few determinations of paste content were made by Procedure A to make any comparison for that property.

17. Keywords

17.1 air content; air void parameters of hardened concrete; area-prepared surface required; average chord-length of voids; determination of air-void parameters; entrained void; entrapped void; grits for lapping hardened concrete; index point; lapping; length of traverse required; linear-traverse method; microscopical; number of points required; paste-air ratio; paste-air ratio modification; paste content; point-count method (modified); sample preparation for microscopical analysis; spacing factor; specific surface; void frequency; water void

TABLE 6 Estimate of Average Precision from a European Study Where Both Prepared Specimens and Companion Unprepared Specimens Were Sent to Participating Laboratories to Determine Air Content and Spacing Factor

Item	Standard Deviation (1s)[A]	Range of Two Test Results (D2s)[A]	Percent of Average	
			Coefficient of Variation (1s %)[B]	Range of Two Test Results (D2s %)[C]
Slabs Prepared in Originating Lab and Measured in Originating Lab				
Air Content, %	0.57	1.61	. . .	. . .
Spacing Factor	. . .	. . .	8.0	22.6
Slabs Prepared in Originating Lab But Measured in Participating Labs				
Air Content, %	0.71	2.01	. . .	. . .
Spacing Factor	. . .	. . .	20.1	56.9
Slabs Lapped and Measured in Participating Labs				
Air Content, %	0.73	2.07	. . .	. . .
Spacing Factor	. . .	. . .	17.5	49.5

[A] These numbers represent, respectively, the (1s) and (D2s) limits as described in Practice C 670.

[B] These numbers represent, respectively, the (1s %) and (D2s %) limits as described in Practice C 670.

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TABLE 7 Comparison of Overall Average Data on the Set of Four Prepared Specimens Circulated to Different Laboratories and Operators

Specimen	Air Content, %		Voids/in.	
	Point Count[A]	Linear Tr.[B]	Point Count[A]	Linear Tr.[B]
No. 1	3.00	2.91	2.24	2.33
No. 2	3.70	3.59	5.69	5.39
No. 3	5.66	5.46	7.44	7.44
No. 4	8.20	7.97	12.42	12.17

[A] Modified Point Count: 6 labs; 12 operators; and 26 determinations.
[B] Linear Traverse: 3 labs; 7 operators; and 15 determinations.

APPENDIX

(Nonmandatory Information)

X1. Interpretation of Results

X1.1 The question of whether or not the determined air-void system parameters are acceptable to provide protection in water-saturated cyclic freezing and thaw conditions shall be made by the specifier, or be determined from actual freeze-thaw testing of the concrete (that is, Test Method C 666/C 666M, Test Method C 672/C 672M, field results). The following text provides useful information on air-void system parameters of known freeze-thaw durable concrete and explains guidelines and specifications from other respected specifying agencies.

X1.2 For air-entrained concrete designed in accordance with ACI 201.2R and ACI 211.1, the paste-air ratio *(p/A)* is usually in the range 4 to 10, the specific surface (α) is usually in the range 24 to 43 mm^{-1} (600 to 1100 $in.^{-1}$), and the spacing factor ($\bar{L}$) is usually in the range 0.1 to 0.2 mm (0.004 to 0.008 in.).

X1.3 Of the parameters determined with this test method, the spacing factor ($\bar{L}$) is generally regarded as the most significant indicator of the durability of the cement paste matrix to freezing and thawing exposure of the concrete. The maximum value of the spacing factor for moderate exposure of the concrete is usually taken to be 0.20 mm (0.008 in.). Somewhat larger values may be adequate for mild exposure, and smaller ones may be required for severe exposure, especially if the concrete is in contact with deicing chemicals. Care should be exercised in using spacing factor values in specifications since the standard deviation of that property has been found to approach one-fifth of the average when determinations are made in different laboratories. Hence, substantial differences in spacing factor may be caused solely by sampling and between laboratory variation. The factors affecting the variability of the test method are discussed in the section on Precision and Bias.

X1.4 The air content and the parameters of the air-void system in hardened concrete depend primarily on the kind and dosage of the air entraining agent used, the degree of consolidation of the concrete, and its water-cement ratio. The values of the specific surface (α) and the void frequency *(n)* decrease rapidly with an increase of the water-cement ratio or the paste content if other conditions are not altered. Satisfactory values of specific surface (α) and spacing factor ($\bar{L}$) require that the void frequency be larger than about 315/m (8/in.). An increase in the water-cement ratio or the paste content must be accompanied by an increase in the air content, if the spacing factor ($\bar{L}$) is not to increase. The air content can be reduced substantially by extended vibration of the concrete, without a significant increase of the spacing factor ($\bar{L}$), provided the concrete was adequately air entrained originally. Extended vibration is not, however, recommended as a field practice because of the dangers of excessive bleeding and segregation.

X1.5 The void frequency *(n)* is a critical parameter in determining the magnitude of the specific surface (α) and the spacing factor ($\bar{L}$). Consequently, utmost care must be taken in conducting either microscopical method to observe and record all air-void sections intersected by the line of traverse. Recognition of air-void sections of small size, for example, 10 μm (3.94 by 10^{-5} in.) is essential to securing a correct evaluation of these parameters. For this reason, care must be taken to prepare extremely smooth and plane sections, the magnification employed should be not less than 50×, and the index point in the cross hairs (or other reticle device) must be observed precisely in relation to the area and periphery of the air-void section.

X1.6 Provided the value of the specific surface (α) or the void frequency *(n)* is sufficiently high, a suitable spacing factor ($\bar{L}$) will be obtained even when the air content is low. However, in order to obtain an air-void system that has both the volume capacity and the geometric parameters necessary to protect saturated mature cement paste during exposure to freezing, it is important to obtain concrete with an acceptably high air content *(A)* and a low enough spacing factor ($\bar{L}$) to provide protection **(12)**.

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X1.7 For concrete exposed to freezing and thawing while critically saturated, a minimum-compressive strength must be developed prior to the freezing exposure, in addition to the securing of adequate air entrainment if the concrete is to be protected properly. Such compressive strength must be at least 28 MPa (4000 psi).

REFERENCES

(1) Powers, T. C. "The Air Requirement of Frost-Resistant Concrete," *Proceedings*, Highway Research Board, Vol 29, 1949, pp. 184–202 and discussion by T. E. Willis, pp. 203–211.

(2) Brown, L. S., and Pierson, C. U. "Linear Traverse Technique for Measurement of Air in Hardened Concrete," *Proceedings*, Am. Concrete Inst., PACIA, Vol 47, 1950, pp. 117–123.

(3) Chayes, F. *Petrographic Modal Analysis, An Elementary Statistical Appraisal*, John Wiley and Sons, Inc., New York, NY, 1956.

(4) Chayes, F. "A Simple Point-Counter for Thin Section Analysis," *American Mineralogist*, AMMIA, Vol 34, 1949, pp. 1–11.

(5) Chayes, F., and Fairbairn, H. W. "A Test of the Precision of Thin Section Analysis by Point Counter," *American Mineralogist*, AMMIA, Vol 36, 1951, pp. 704–712.

(6) Mielenz, R. C., Wolkodoff, V. E., Backstrom, J. E., and Burrows, R. H. "Origin, Evolution, and Effects of the Air-Void System in Concrete. Part 4—The Air Void System in Job Concrete," *Proceedings*, Am. Concrete Inst., PACIA, Vol 55, 1958, pp. 507–517.

(7) Mielenz, R. C. "Petrography Applied to Portland-Cement Concrete," *Reviews in Engineering Geology*, Geol. Soc. Am., Vol 1, 1962, pp. 1–38.

(8) Mielenz, R. C. "Diagnosing Concrete Failures," Stanton Walker Lecture Series on the Material Sciences, Lecture No. 2, Univ. of Maryland, College Park, MD, 1964, p. 47.

(9) Lord, G. W., and Willis, T. F. "Calculation of Air Bubble Size Distribution from Results of Rosiwal Traverse of Aerated Concrete," *ASTM Bulletin*, ASTBA, No. 177, October 1951, pp. 56–61.

(10) Walker, H. N. "Formula for Calculating Spacing Factor for Entrained Air Voids," *Cement, Concrete, and Aggregates*, Vol 2, No. 2, Winter 1980, pp. 63–66.

(11) Whiting, D., and Stark, D. "Control of Air Content in Concrete;" National Cooperative Highway Research Program Report #258, Transportation Research Board, Washington DC 1983.

(12) Sommer, Hermann, "The Precision of the Microscopical Determination of the Air-Void System in Hardened Concrete," *ASTM, Cement, Concrete, and Aggregate*, Vol 1, No. 2, 1979, pp. 49–55.

SUMMARY OF CHANGES

Committee C09 has identified the location of selected changes to this test method since the last issue, C 457 – 08d, that may impact the use of this test method. (Approved July 1, 2009)

(*1*) Revised Section 3 Terminology according to ASTM Form and Style.

Committee C09 has identified the location of selected changes to this test method since the last issue, C 457 – 08c, that may impact the use of this test method. (Approved December 15, 2008)

(*1*) Revised Fig. 5.

(*2*) Added new 15.1.7.

Committee C09 has identified the location of selected changes to this test method since the last issue, C 457 – 08b, that may impact the use of this test method. (Approved October 1, 2008)

(*1*) Revised Section 5 and moved some subsections into new Appendix X1.

Committee C09 has identified the location of selected changes to this test method since the last issue, C 457 – 08a, that may impact the use of this test method. (Approved July 1, 2008)

(*1*) Revised Fig. 1.

Committee C09 has identified the location of selected changes to this test method since the last issue, C 457 – 08, that may impact the use of this test method. (Approved May 1, 2008)

(*1*) Revised 3.1.5.1.

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Designation: C465 – 10

Standard Specification for Processing Additions for Use in the Manufacture of Hydraulic Cements[1]

This standard is issued under the fixed designation C465; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope*

1.1 This specification pertains to the criteria and tests to be used for determining whether a(n) organic or inorganic processing addition, when used in the recommended amount at the option of the cement producer in the manufacture of hydraulic cements, meets the requirements as prescribed by definition in Specifications C150, C1157, C845, and C595. The materials listed in the following former ASTM Specifications shall be considered as meeting the organic processing additions requirements of this specification:

C150 – 62, for Portland Cement
C205 – 58 T, for Portland Blast-Furnace Slag Cement
C340 – 58 T, for Portland Pozzolan Cement
C358 – 58, for Slag Cement

1.2 The following safety hazards caveat pertains only to the test methods described in this specification. *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

1.3 The values stated in SI units are to be regarded as standard. No other units of measurement are included in this standard.

2. Referenced Documents

2.1 *ASTM Standards:*[2]

C33 Specification for Concrete Aggregates
C39/C39M Test Method for Compressive Strength of Cylindrical Concrete Specimens
C78 Test Method for Flexural Strength of Concrete (Using Simple Beam with Third-Point Loading)
C109/C109M Test Method for Compressive Strength of Hydraulic Cement Mortars (Using 2-in. or [50-mm] Cube Specimens)
C114 Test Methods for Chemical Analysis of Hydraulic Cement
C115 Test Method for Fineness of Portland Cement by the Turbidimeter
C138/C138M Test Method for Density (Unit Weight), Yield, and Air Content (Gravimetric) of Concrete
C143/C143M Test Method for Slump of Hydraulic-Cement Concrete
C150 Specification for Portland Cement
C151 Test Method for Autoclave Expansion of Hydraulic Cement
C173/C173M Test Method for Air Content of Freshly Mixed Concrete by the Volumetric Method
C185 Test Method for Air Content of Hydraulic Cement Mortar
C187 Test Method for Normal Consistency of Hydraulic Cement
C191 Test Methods for Time of Setting of Hydraulic Cement by Vicat Needle
C192/C192M Practice for Making and Curing Concrete Test Specimens in the Laboratory
C204 Test Methods for Fineness of Hydraulic Cement by Air-Permeability Apparatus
C205 Specification for Portland Blast- Furnace Cement[3]
C226 Specification for Air-Entraining Additions for Use in the Manufacture of Air-Entraining Hydraulic Cement
C231 Test Method for Air Content of Freshly Mixed Concrete by the Pressure Method
C293 Test Method for Flexural Strength of Concrete (Using Simple Beam With Center-Point Loading)
C340 Specification for Corkboard Thermal Insulation[3]
C358 Specification for Slag Cement[3]
C595 Specification for Blended Hydraulic Cements
C596 Test Method for Drying Shrinkage of Mortar Containing Hydraulic Cement
C617 Practice for Capping Cylindrical Concrete Specimens

[1] This specification is under the jurisdiction of ASTM Committee C01 on Cement and is the direct responsibility of Subcommittee C01.20 on Additions.

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[2] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

[3] Withdrawn. The last approved version of this historical standard is referenced on www.astm.org.

***A Summary of Changes section appears at the end of this standard.**

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C845 Specification for Expansive Hydraulic Cement
C1157 Performance Specification for Hydraulic Cement
D891 Test Methods for Specific Gravity, Apparent, of Liquid Industrial Chemicals
E203 Test Method for Water Using Volumetric Karl Fischer Titration

3. Materials

3.1 *Cements*:

3.1.1 In cases where it is desired that the proposed organic processing addition be accepted for general use in portland cement, tests shall be made on cements prepared from at least five different clinkers. As a minimum, these clinkers shall represent two Type I cements containing not less than 9.0 % C_3A, one Type II cement, and two Type III cements, all conforming to Specification C150.

3.1.2 In cases where it is also desired that the proposed organic processing addition be used in blended cements, the test and test procedures shall be as specified with a control and an addition for cement conforming to the appropriate Specification C595 or C1157.

3.1.3 Organic processing additions which have been shown to meet the requirements of this specification may also be used in cements conforming to Specification C845. Testing of the addition with these special cements, where desired, shall be done using the tests and test procedures as specified with a control cement and a cement containing the addition, both conforming to Specification C845.

3.1.4 In cases where it is desired that the proposed organic processing addition be limited in use to specific types of cement less in number than required in 3.1.1, the tests and test procedures shall be as specified, and at least two pairs of cements shall be prepared from two clinkers from different plants for each type under specific consideration.

3.1.5 For inorganic processing additions, or in cases where it is desired that the proposed organic processing addition be limited in use to a single plant, the tests and test procedures shall be as specified and at least two pairs of cements shall be prepared from clinker representing each type under specific consideration.

3.1.6 The two companion cements to be made from any one clinker shall be ground to the same fineness within 7 m^2/kg when tested in accordance with Test Method C115 or within 13 m^2/kg when tested in accordance with Test Method C204, and the SO_3 content, expressed as a percentage of the cement mass and reported to the nearest 0.01 %, shall differ by not more than 0.3, so as to afford comparable samples for indicating the effect of the addition on the cement. Each control cement shall comply with all requirements in the specification applicable to that type of cement, and shall not contain the proposed addition when tested by the method furnished by the producer or seller of the addition.

3.1.7 The percentage of each of the following shall be determined for each lot of cement tested: silicon dioxide (SiO_2), aluminum oxide (Al_2O_3), ferric oxide (Fe_2O_3), calcium oxide (CaO), magnesium oxide (MgO), sulfur trioxide (SO_3), ignition loss, insoluble residue, sodium oxide (Na_2O), and potassium oxide (K_2O). There shall also be calculated the potential percentages of the following compounds: tricalcium silicate, dicalcium silicate, tricalcium aluminate, and tetracalcium aluminoferrite. Determinations for the percentage of the addition shall be made, both on the control cements and on those with which the addition was interground, using the method proposed therefore by the sponsor.

3.2 *Aggregates*—The fine and coarse aggregates shall comply with Specification C33; the coarse aggregate shall comply with the grading requirements for Size No. 57 or Size No. 67. A sufficient quantity from a single lot of coarse aggregate and from a single lot of fine aggregate shall be provided to complete all tests. To prevent the segregation of particle sizes in the fine aggregate, a single lot of sand sufficient for all tests shall either (*1*) be separated on the 4.75-mm (No. 4), 1.18-mm (No. 16), 300 µm (No. 50), and 150 µm (No. 100) sieves and then be recombined in the required quantity for each batch; or (*2*) be blended while in a damp condition, and maintained in that condition for the duration of the tests. Under option (*2*), lots of appropriate size for single mortar and concrete batches shall be carefully split or quartered from the entire batch.

4. General Requirements

4.1 Processing additions shall conform to the respective requirements in this specification.

4.2 The trade name, source, character of the material, and means for the quantitative determination of the addition in the finished cement shall be furnished by the sponsor, manufacturer, or supplier of the addition, and the information shall form a part of the record of tests of the addition. If the processing addition is a liquid, the specific gravity and percent water content shall also be part of the record. If the processing addition is an inorganic solid, the allowable ranges of chemical analysis of the addition shall also be part of the record.

4.2.1 The specific gravity, run in accordance with 7.1.1 shall be within ±0.05 units of the value reported in 4.2.

4.2.2 The chemical analysis in 7.2.1 shall be within the ranges given in 4.2.

4.3 Processing additions shall be evaluated by comparing cements containing the addition to otherwise identical cements from the same source without the addition, or containing a processing addition which has been shown to comply with this specification using control cements without any additions, hereinafter designated the “control” cement.

4.4 The amount of the processing addition to be interground with the cement for evaluation purposes shall be determined by the sponsor of the addition.

4.4.1 The amount of the addition in the cement containing the addition and showing compliance with the requirements of this specification shall be determined quantitatively by means of the quantitative determination required by 4.2.

4.4.2 The amount of addition, so determined, shall be used to state the amount of addition that shows compliance with this specification.

4.4.3 When tests on cements containing the addition show compliance with the requirements of this specification, the addition in cement may be used in any amount up to the maximum amount showing compliance.

4.5 The cement produced for evaluation purposes with the processing addition shall comply with the appropriate Specifications C150, C845, C1157, or C595, except that it contains

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the addition under test. The effect of the addition on the properties of the cement shall also be within the following limits:

4.5.1 The percentage of water by mass of cement required for normal consistency of cement containing the addition shall not exceed that required by the corresponding control cement by more than 1.0. For those cements not limited to a fixed water requirement, the percentage of water by mass of cement required for standard consistency of the mortar used for strength determinations as described in 4.5.4 shall not be increased by more than 2.0 by the addition over that required for the control cement.

4.5.2 The time of setting of cement containing the addition shall not vary from the time of setting of the corresponding control cement by more than 1 h or 50 %, whichever is the lesser.

4.5.3 The autoclave expansion of cement containing the addition, expressed as a percentage change in length, shall be not more than 0.10 greater than that of the corresponding control cement.

4.5.4 The compressive strength of mortar cubes made with cement containing the addition, in accordance with Test Method C109/C109M, and tested at 1, 3, 7, and 28 days for all types, shall be compared with strengths obtained with the control cement at similar ages. The grand average of these individual strength percentages shall be not less than 95 % of the control cement values. It is required that cubes for companion cements be made and tested on the same days, with storage of specimens side by side in the same section of the moist cabinet during the 24-h curing period. Retesting of companion cements on the same, or a following, day is required in order to provide six, rather than three, test specimens for each cement and age of test.

4.5.5 The ultimate drying shrinkage (percent) of mortar made with cement containing the addition shall not be more than 0.025 greater than that of similar mortar made with the corresponding control cement when tested in accordance with Test Method C596.

4.5.6 The compressive strength of the concrete made with cement containing the addition shall be compared with strengths obtained with the control cement at similar ages. The grand average of these individual strength percentages shall be not less than 90 % of the values for the control cement.

4.5.7 The flexural strength of concrete made with cement containing the addition shall be compared with strengths obtained with the control cement at similar ages. The grand average of these individual strength percentages shall be not less than 90 % of the values for the control cement.

4.5.8 The amount of air-entraining addition required to produce 19 ± 3 % air in the mortar test made in accordance with Test Method C185, with the cement containing the addition under test, shall be not greater than 120 % of the amount required to produce, within ±1 %, the air content obtained with the control cement. The air-entraining addition used shall meet the requirements of Specification C226.

4.6 Processing additions which provide maximum effects as grinding aids or pack set inhibitors may increase cement flowability to a point where mill retention time is reduced sufficiently to affect significantly the particle size distribution of the resulting cement and its physical-chemical properties. Mill retention times are controllable by mechanical means in full-scale grinding mills. Hence, the true physical-chemical effects of the test additive may be determined for acceptance purposes by making supplementary laboratory or pilot-mill grinds, in instances where full-scale tests have shown mill retention time reductions to have significant effects on the properties of the resulting cement.

4.7 In the event that the effect of the addition on the properties of cement are determined on the basis of laboratory or pilot mill grinds, this fact shall be entered in the report specified in Section 13, and the specific tests shall be indicated.

5. Sampling Cement

5.1 Samples of the plant-ground cement shall be taken from the product stream during grinding. Prior to the start of sampling a given lot of cement, the mill shall have run for 4 h or long enough to have reached equilibrium under the general conditions that are to govern during the sampling period.

NOTE 1—Records should be kept as to the rate and continuity of feed of the addition, the form in which the addition is used, strength of solution (if applicable), magnitude of circulating loads, mill discharge temperature, and feed rate of clinker and gypsum. Product fineness should be determined during the grinding immediately subsequent to sampling.

5.2 As the cement samples are taken, they shall be placed in sealable containers which shall be sealed immediately at the end of the sampling period. Prior to use, the samples of a given lot of cement shall be thoroughly blended to form a uniform, representative composite.

6. Test Methods

6.1 Determine the properties enumerated in this specification in accordance with the test methods prescribed in Sections 7-12.

7. Tests on Processing Additions

7.1 Test the liquid, organic processing addition, in the form normally marketed, in accordance with the following test methods:

7.1.1 *Specific Gravity*—Use Test Methods D891, Test Method A or B.

7.1.2 *Water Content*—Use Test Method E203.

7.2 Conduct the following tests on solid, inorganic processing addition in accordance with the following test methods:

7.2.1 *Chemical Analysis*—Use Test Methods C114, and determine silicon dioxide (SiO_2), aluminum oxide (Al_2O_3), ferric oxide (Fe_2O_3), calcium oxide (CaO), magnesium oxide (MgO), sulfur trioxide (SO_3), ignition loss, insoluble residue, sodium oxide (Na_2O), and potassium oxide (K_2O).

8. Tests on Cement

8.1 Test cement in accordance with the following standards:

8.1.1 *Chemical Analysis of Cement*—Test Methods C114.

8.1.2 *Compound Composition*—Specification C150.

8.1.3 *Fineness of Cement*—Test Method C115 or C204.

8.1.4 *Normal Consistency*—Test Method C187.

8.1.5 *Time of Setting (Vicat)*—Test Method C191.

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8.1.6 *Autoclave Expansion*—Test Method C151.

8.1.7 *Air Content of Mortar*—Test Method C185.

8.1.8 *Compressive Strength of Mortar*— Test Method C109/C109M.

8.1.9 *Drying Shrinkage of Mortar*—Test Method C596.

9. Concrete Mixtures

9.1 *Preparation and Weighing*—Prepare all materials used in making the concrete mixtures and make all weighings as prescribed in Practice C192/C192M. Report the amount of mixing water used in each batch on the basis of saturated, surface-dry aggregates.

9.2 *Proportions*—Design one basic concrete mixture having an actual cement content of 307 ± 3 kg/m^3 (517± 5 lb/yd^3), and use in all concrete tests herein specified. Adjust the water content of mixtures to provide concrete having a consistency equal to a 64 ± 13-mm (2½ ± ½-in.) slump in each case. Adjust the ratio of fine to coarse aggregate to the optimum for concrete to be consolidated by hand rodding. Recommended trial values for the percentage of fine aggregate in the total aggregate, by absolute volume, are as follows:

Coarse Aggregate, Maximum 25.0 mm (1 in.)	Concrete Without Entrained Air
Angular	45
Rounded	40

9.3 *Mixing of Concrete*—Mix the concrete in accordance with Practice C192/C192M except as follows: Hand mixing will not be permitted. The rated capacity of the machine mixer shall not be more than twice the size of the batch used.

10. Tests on Freshly Mixed Concrete

10.1 Test samples of the freshly mixed concrete for slump in accordance with Test Method C143/C143M; unit weight in accordance with Test Method C138/C138M; and air content in accordance with Test Method C138/C138M, C231, or C173/C173M.

11. Test Specimens of Hardened Concrete

11.1 *Number of Specimens*—At least three specimens shall be made for each test condition. For each cement containing an addition and its companion control cement, make three rounds of concrete mixed on different days. One round of mixes on a given day shall include both the cement containing the addition and its companion control cement. From each round, make at least one test specimen for each test condition. If necessary, to obtain enough concrete for all test specimens to be made in any one round, it may be necessary to make more than one concrete batch for each round.

11.2 *Types of Specimens*:

11.2.1 *Compressive Strength*—Compressive strength test specimens shall be cylinders made and cured as prescribed in Practice C192/C192M. Cylinders shall be capped as prescribed in Practice C617.

11.2.2 *Flexural Strength*—Flexural strength test specimens shall be beams made and cured as prescribed in Practice C192/C192M.

12. Test on Hardened Concrete

12.1 Test the specimens on hardened concrete, as specified in Section 11, in accordance with the following methods and at the specified ages:

12.1.1 *Compressive Strength*—Test specimens in accordance with Test Method C39/C39M at ages 3, 7, and 28 days, except also test Type III cement at 24 h.

12.1.2 *Flexural Strength*—Test specimens in accordance with Test Method C293, or Test Method C78, ages at 3, 7, and 28 days, except also test Type III cement at 24 h. By either method of test, turn the specimen on its side with respect to its position as molded and center it on the bearing blocks.

13. Report

13.1 The report covering the results of the evaluation of a material proposed for use as a processing addition in the manufacture of portland cement under this specification shall include the following information:

13.1.1 Trade name, source and character of the material, and the amount recommended for use, together with means for determination of the proposed addition in the finished cement, all as furnished by the sponsor, manufacturer, or seller of the addition,

13.1.2 If the proposed processing addition is an organic liquid, the specific gravity and percent water content by mass,

13.1.3 If the proposed processing addition is an inorganic solid, report chemical analysis,

13.1.4 Detailed results of all analyses and tests prescribed by this specification, and the amount of the addition used, as well as other pertinent information required,

13.1.5 Comparison of test results to determine compliance with the requirements prescribed in 4.4,

13.1.6 Name and location of the laboratory or laboratories that made the tests covered by the report,

13.1.7 Include as an appendix to the report, letters of certification from the various cement manufacturers stating the name of the addition, the amount used, and the type of cement in which used, and

13.1.8 The highest amount of addition that has demonstrated compliance with the specification in a particular type of cement (see 4.4.3).

14. Manufacturer's Certification Processing Additions

14.1 *Organic Processing Additions*—Upon request of the purchaser in the contract or order, a manufacturer's report shall be furnished at the time of shipment stating the water content and specific gravity of the samples of the material taken during production or transfer and certifying that the specific gravity value is within the specified limits of the originally qualified product and that the product meets the requirements of this Specification.

14.2 *Inorganic Processing Additions*—Upon request of the purchaser in the contract or order, a manufacturer's report shall be furnished at time of shipment stating the chemical analysis of the samples of the material taken during production or transfer and certifying that they are within the specified limits of the originally qualified product and that the product meets the requirements of this specification.

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15. Keywords

15.1 additions; hydraulic cements; processing

SUMMARY OF CHANGES

Committee C01 has identified the location of selected changes to this specification since the last issue, C465–09, that may impact the use of this specification. (Approved February 1, 2010)

(*1*) Revised 4.2, 4.2.2, 13.1.3, and 14.2. Deleted 7.2.2.

Committee C01 has identified the location of selected changes to this specification since the last issue, C465–99(2005), that may impact the use of this specification. (Approved May 15, 2009)

(*1*) Revised the Scope to include inorganic processing additions.
(*2*) Revised Section 3 to differentiate requirements for organic and inorganic processing additions.
(*3*) Revised Section 4 to include requirements for chemical analysis and specific gravity of the inorganic processing addition being tested and to clarify that a maximum of two processing additions can be used (an inorganic and an organic for example).
(*4*) Revised Section 7 to include requirements for chemical analysis and specific gravity of the inorganic processing addition being tested.
(*5*) Revised Section 12 to require hardened concrete testing through 28 days instead of 3 months, per the NCHRP 18-11 report.
(*6*) Revised Section 13 to include requirements for reporting of results of chemical analyses and specific gravity determination of the inorganic processing addition being tested.
(*7*) Renamed Section 14 and added new 14.2 for manufacturer's certification for inorganic processing additions.

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Designation: C 469 – 02$^{\epsilon 1}$

Standard Test Method for Static Modulus of Elasticity and Poisson's Ratio of Concrete in Compression[1]

This standard is issued under the fixed designation C 469; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

ε[1] NOTE—Adjunct references were corrected editorially in April 2006.

1. Scope

1.1 This test method covers determination of (*1*) chord modulus of elasticity (Young's) and (*2*) Poisson's ratio of molded concrete cylinders and diamond-drilled concrete cores when under longitudinal compressive stress. Chord modulus of elasticity and Poisson's ratio are defined in Terminology E 6.

1.2 The values stated in inch-pound units are to be regarded as the standard.

1.3 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

2. Referenced Documents

2.1 *ASTM Standards:* [2]

C 31/C 31M Practice for Making and Curing Concrete Test Specimens in the Field

C 39/C 39M Test Method for Compressive Strength of Cylindrical Concrete Specimens

C 42/C 42M Test Method for Obtaining and Testing Drilled Cores and Sawed Beams of Concrete

C 174/C 174M Test Method for Measuring Thickness of Concrete Elements Using Drilled Concrete Cores

C 192/C 192M Practice for Making and Curing Concrete Test Specimens in the Laboratory

C 617 Practice for Capping Cylindrical Concrete Specimens

E 4 Practices for Force Verification of Testing Machines

E 6 Terminology Relating to Methods of Mechanical Testing

E 83 Practice for Verification and Classification of Extensometer System

E 177 Practice for Use of the Terms Precision and Bias in ASTM Test Methods

2.2 *ASTM Adjuncts:*

Compressometers (two drawings) and Extensometers (two drawings)[3]

3. Significance and Use

3.1 This test method provides a stress to strain ratio value and a ratio of lateral to longitudinal strain for hardened concrete at whatever age and curing conditions may be designated.

3.2 The modulus of elasticity and Poisson's ratio values, applicable within the customary working stress range (0 to 40 % of ultimate concrete strength), are used in sizing of reinforced and nonreinforced structural members, establishing the quantity of reinforcement, and computing stress for observed strains.

3.3 The modulus of elasticity values obtained will usually be less than moduli derived under rapid load application (dynamic or seismic rates, for example), and will usually be greater than values under slow load application or extended load duration, given other test conditions being the same.

4. Apparatus

4.1 *Testing Machine*—Use a testing machine capable of imposing a load at the rate and of the magnitude prescribed in 6.4. The machine shall conform to the requirements of Practices E 4 (Constant-Rate of-Traverse CRT-Type Testing Machines section). The spherical head and bearing blocks shall conform to the Apparatus Section of Test Method C 39/C 39M.

4.2 *Compressometer*[3]—For determining the modulus of elasticity use a bonded (Note 1) or unbonded sensing device that measures to the nearest 5 millionths the average deformation of two diametrically opposite gage lines, each parallel to the axis, and each centered about midheight of the specimen.

[1] This test method is under the jurisdiction of ASTM Committee C09 on Concrete and Concrete Aggregates and is the direct responsibility of Subcommittee C09.61 on Testing for Strength.

Current edition approved Aug. 10, 2002. Published October 2002. Originally approved in 1961. Last previous edition approved in 1994 as C469 – 94$^{\epsilon 1}$.

[2] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

[3] Available from ASTM International Headquarters. Order Adjunct No. ADJC0469.

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The effective length of each gage line shall be not less than three times the maximum size of the aggregate in the concrete nor more than two thirds the height of the specimen; the preferred length of the gage line is one half the height of the specimen. Either use gage points embedded in or cemented to the specimen, and read deformation of the two lines independently; or use a compressometer (such as is shown in Fig. 1) consisting of two yokes, one of which (see *B*, Fig. 1) is rigidly attached to the specimen and the other (see *C*, Fig. 1) attached at two diametrically opposite points so that it is free to rotate. At one point on the circumference of the rotating yoke, midway between the two support points, use a pivot rod (see *A*, Fig. 1) to maintain a constant distance between the two yokes. At the opposite point on the circumference of the rotating yoke, the change in distance between the yokes (that is, the gage reading) is equal to the sum of the displacement due to specimen deformation and the displacement due to rotation of the yoke about the pivot rod (see Fig. 2).

4.2.1 Measure deformation by a dial gage used directly or with a lever multiplying system, by a wire strain gage, or by a linear variable differential transformer. If the distances of the pivot rod and the gage from the vertical plane passing through the support points of the rotating yoke are equal, the deformation of the specimen is equal to one-half the gage reading. If these distances are not equal, calculate the deformation as follows:

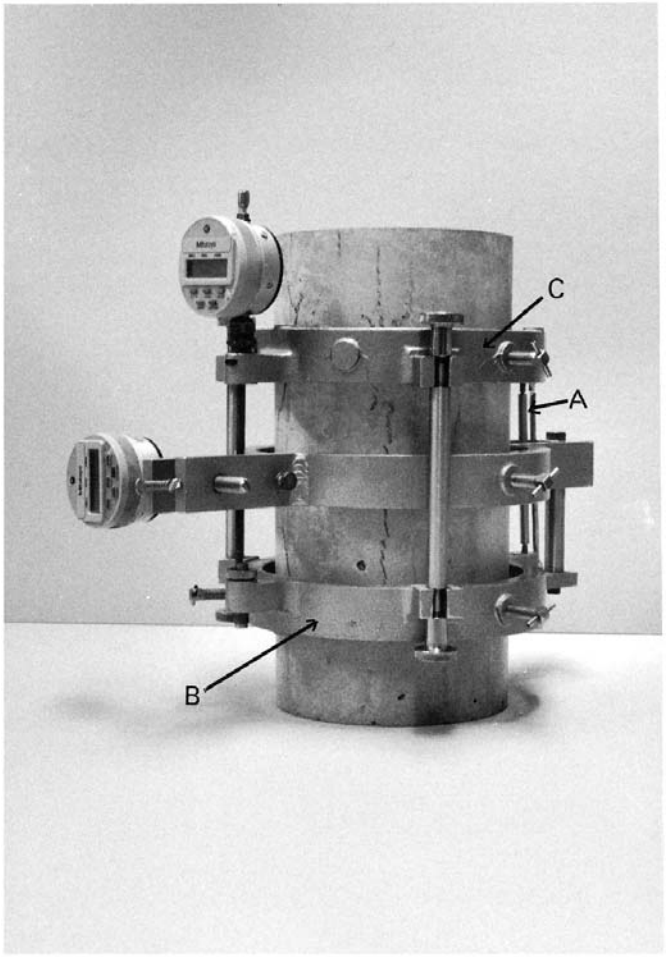
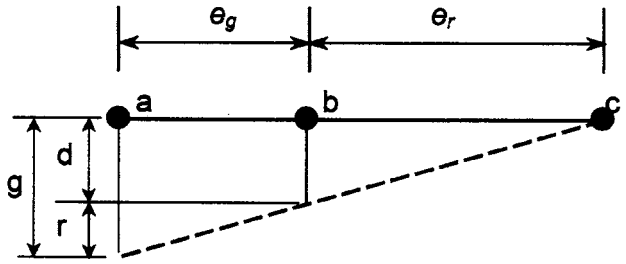


FIG. 1 Suitable Compressometer



d = displacement due to specimen deformation
r = displacement due to rotation of the yoke about the pivot rod
a = location of gage
b = support point of the rotating yoke
c = location of pivot rod
g = gage reading

FIG. 2 Diagram of Displacements

$$d = g e_r / (e_r + e_g) \quad (1)$$

where:

d = total deformation of the specimen throughout the effective gage length, μin. (μm),
g = gage reading, μin. (μm),
e_r = the perpendicular distance, measured in inches (millimetres) to the nearest 0.01 in. (0.254 mm) from the pivot rod to the vertical plane passing through the two support points of the rotating yoke, and
e_g = the perpendicular distance, measured in inches (millimetres) to the nearest 0.01 in. (0.254 mm) from the gage to the vertical plane passing through the two support points of the rotating yoke.

Procedures for calibrating strain-measuring devices are given in Practice E 83.

NOTE 1—Although bonded strain gages are satisfactory on dry specimens, they may be difficult, if not impossible, to mount on specimens continually moist-cured until tested.

4.3 *Extensometer*[3]—If Poisson's ratio is desired, the transverse strain shall be determined (*1*) by an unbonded extensometer capable of measuring to the nearest 25 μin. (0.635 μm) the change in diameter at the midheight of the specimen, or (*2*) by two bonded strain gages (Note 1) mounted circumferentially at diametrically opposite points at the midheight of the specimen and capable of measuring circumferential strain to the nearest 5 millionths. A combined compressometer and extensometer (Fig. 3) is a convenient unbonded device. This apparatus shall contain a third yoke (consisting of two equal segments) located halfway between the two compressometer yokes and attached to the specimen at two diametrically opposite points. Midway between these points use a short pivot rod (*A′*, see Fig. 3), adjacent to the long pivot rod, to maintain a constant distance between the bottom and middle yokes. Hinge the middle yoke at the pivot point to permit rotation of the two segments of the yoke in the horizontal plane. At the opposite point on the

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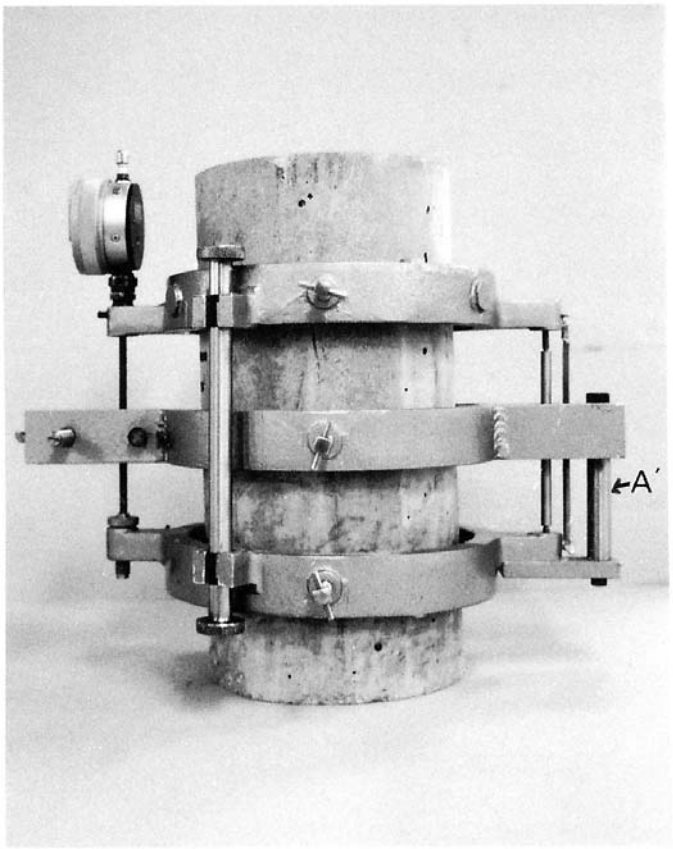

FIG. 3 Suitable Combined Compressometer-Extensometer

circumference, connect the two segments through a dial gage or other sensing device capable of measuring transverse deformation to the nearest 50 µin. (1.27 µm). If the distances of the hinge and the gage from the vertical plane passing through the support points of the middle yoke are equal, the transverse deformation of the specimen diameter is equal to one-half the gage reading. If these distances are not equal, calculate the transverse deformation of the specimen diameter in accordance with Eq 2.

$$d' = g'e'_h/(e'_h + e'_g) \quad (2)$$

where:

d' = transverse deformation of the specimen diameter, µin. (µm),
g' = transverse gage reading, µin. (µm),
e'_h = the perpendicular distance, measured in inches (millimeters) to the nearest 0.01 in. (0.254 mm) from the hinge to the vertical plane passing through the support points of the middle yoke, and
e'_g = the perpendicular distance, measured in inches (millimeters) to the nearest 0.01 in. (0.254 mm) from the gage to the vertical plane passing through the support points of the middle yoke.

4.4 *Balance or Scale*, accurate to 0.1 lb (0.045 kg) shall be used if necessary.

5. Test Specimens

5.1 *Molded Cylindrical Specimens*—Mold test cylinders in accordance with the requirements for compression test specimens in Practice C 192/C 192M, or in Practice C 31/C 31M. Subject specimens to the specified curing conditions and test at the age for which the elasticity information is desired. Test specimens within 1 h after removal from the curing or storage room. Specimens removed from a moist room for test shall be kept moist by a wet cloth covering during the interval between removal and test.

5.2 *Drilled Core Specimens*—Cores shall comply with the requirements for drilling, and moisture conditioning applicable to compressive strength specimens in Test Method C 42/C 42M, except that only diamond-drilled cores having a length-to-diameter ratio greater than 1.50 shall be used. Requirements relative to storage and to ambient conditions immediately prior to test shall be the same as for molded cylindrical specimens.

5.3 The ends of the test specimens shall be made perpendicular to the axis (± 0.5°) and plane (within 0.002 in.). If the specimen as cast does not meet the planeness requirements, planeness shall be accomplished by capping in accordance with Practice C 617, or by lapping, or by grinding. It is not prohibited to repair aggregate popouts that occur at the ends of specimens, provided the total area of popouts does not exceed 10 % of the specimen area and the repairs are made before capping or grinding is completed (Note 2). Planeness will be considered within tolerance when a 0.002 in. (0.05 mm) feeler gage will not pass between the specimen surface and a straight edge held against the surface.

NOTE 2—Repairs may be made by epoxying the dislodged aggregate back in place or by filling the void with capping material and allowing adequate time for it to harden.

5.4 Measure the diameter of the test specimen by caliper to the nearest 0.01 in. (0.25 mm) by averaging two diameters measured at right angles to each other near the center of the length of the specimen. Use this average diameter to calculate the cross-sectional area. Measure and report the length of a molded specimen, including caps, to the nearest 0.1 in. (2.54 mm). Measure the length of a drilled specimen in accordance with Test Method C 174/C 174M; report the length, including caps, to the nearest 0.1 in. (2.54 mm).

6. Procedure

6.1 Maintain the ambient temperature and humidity as constant as possible throughout the test. Record any unusual fluctuation in temperature or humidity in the report.

6.2 Use companion specimens to determine the compressive strength in accordance with Test Method C 39/C 39M prior to the test for modulus of elasticity.

6.3 Place the specimen, with the strain-measuring equipment attached, on the lower platen or bearing block of the testing machine. Carefully align the axis of the specimen with the center of thrust of the spherically-seated upper bearing block. Note the reading on the strain indicators. As the spherically-seated block is brought slowly to bear upon the specimen, rotate the movable portion of the block gently by hand so that uniform seating is obtained.

6.4 Load the specimen at least twice. Do not record any data during the first loading. Base calculations on the average of the results of the subsequent loadings (Note 3).

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NOTE 3—At least two subsequent loadings are recommended so that the repeatability of the test may be noted.

During the first loading, which is primarily for the seating of the gages, observe the performance of the gages (Note 4) and correct any unusual behavior prior to the second loading. Obtain each set of readings as follows: Apply the load continuously and without shock. Set testing machines of the screw type so that the moving head travels at a rate of about 0.05 in. (1.25 mm)/min when the machine is running idle. In hydraulically operated machines, apply the load at a constant rate within the range 35 ± 5 psi (241 ± 34 kPa)/s. Record, without interruption of loading, the applied load and longitudinal strain at the point (*1*) when the longitudinal strain is 50 millionths and (*2*) when the applied load is equal to 40 % of the ultimate load (see 6.5). Longitudinal strain is defined as the total longitudinal deformation divided by the effective gage length. If Poisson's ratio is to be determined, record the transverse strain at the same points. If a stress-strain curve is to be determined, take readings at two or more intermediate points without interruption of loading; or use an instrument that makes a continuous record. Immediately upon reaching the maximum load, except on the final loading, reduce the load to zero at the same rate at which it was applied. If the observer fails to obtain a reading, complete the loading cycle and then repeat it. Record the extra cycle in the report.

NOTE 4—Where a dial gage is used to measure longitudinal deformation, it is convenient to set the gage before each loading so that the indicator will pass the zero point at a longitudinal strain of 50 millionths.

6.5 It is not prohibited to obtain the modulus of elasticity and strength on the same loading provided that the gages are expendable, removable, or adequately protected so that it is possible to comply with the requirement for continuous loading given in Test Method C 39/C 39M. In this case record several readings and determine the strain value at 40 % of the ultimate by interpolation.

6.6 If intermediate readings are taken, plot the results of each of the three tests with the longitudinal strain as the abscissa and the compressive stress as the ordinate. Calculate the compressive stress by dividing the quotient of the testing machine load by the cross-sectional area of the specimen determined in accordance with 5.4.

7. Calculation

7.1 Calculate the modulus of elasticity, to the nearest 50 000 psi (344.74 MPa) as follows:

$$E = (S_2 - S_1)/(\epsilon_2 - 0.000050) \quad (3)$$

where:

E = chord modulus of elasticity, psi,
S_2 = stress corresponding to 40 % of ultimate load,
S_1 = stress corresponding to a longitudinal strain, ϵ_1, of 50 millionths, psi, and
ϵ_2 = longitudinal strain produced by stress S_2.

7.2 Calculate Poisson's ratio, to the nearest 0.01, as follows:

$$\mu = (\epsilon_{t2} - \epsilon_{t1})/(\epsilon_2 - 0.000050) \quad (4)$$

where:

μ = Poisson's ratio,
ϵ_{t2} = transverse strain at midheight of the specimen produced by stress S_2, and
ϵ_{t1} = transverse strain at midheight of the specimen produced by stress S_1.

8. Report

8.1 Report the following information:
8.1.1 Specimen identification number,
8.1.2 Dimensions of specimen, in inches (or millimetres),
8.1.3 Curing and environmental histories of the specimen,
8.1.4 Age of the specimen,
8.1.5 Strength of the concrete, if determined,
8.1.6 Unit weight of the concrete, if determined,
8.1.7 Stress-strain curves, if plotted,
8.1.8 Chord modulus of elasticity, and
8.1.9 Poisson's ratio, if determined.

9. Precision and Bias

9.1 *Precision*—The single-operator-machine multibatch precision is ± 4.25 % (R1S %) max, as defined in Practice E 177, over the range from 2.5 to 4×10^6 psi (17.3 to 27.6×10^9 Pa); therefore, the results of tests of duplicate cylinders from different batches should not depart more than 5 % from the average of the two.

9.2 *Bias*—This test method has no bias because the values determined can only be defined in terms of the test method.

10. Keywords

10.1 compression testing; concrete; modulus of elasticity; Poisson's ratio

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Designation: C470/C470M – 09

Standard Specification for Molds for Forming Concrete Test Cylinders Vertically[1]

This standard is issued under the fixed designation C470/C470M; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope*

1.1 This specification covers molds for use in forming cylindrical concrete specimens. The provisions of this specification include the requirements for both reusable and single-use molds.

NOTE 1—Sizes included are molds having diameters from 50 mm [2 in.] to 900 mm [36 in.].

1.2 The values stated in either SI units or inch-pound units are to be regarded separately as standard. The values stated in each system may not be exact equivalents; therefore, each system shall be used independently of the other. Combining values from the two systems may result in non-conformance with the standard. The inch-pound units are shown in brackets.

1.3 The following safety hazards caveat pertains only to the test method described in this specification: *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

1.4 The text of this standard references notes and footnotes which provide explanatory material. These notes and footnotes (excluding those in tables and figures) shall not be considered as requirements of the standard.

2. Referenced Documents

2.1 *ASTM Standards:*[2]

C31/C31M Practice for Making and Curing Concrete Test Specimens in the Field

C33 Specification for Concrete Aggregates

C192/C192M Practice for Making and Curing Concrete Test Specimens in the Laboratory

C1077 Practice for Laboratories Testing Concrete and Concrete Aggregates for Use in Construction and Criteria for Laboratory Evaluation

D256 Test Methods for Determining the Izod Pendulum Impact Resistance of Plastics

D570 Test Method for Water Absorption of Plastics

3. General Requirements

3.1 The following provisions apply to both reusable and single-use molds:

3.1.1 Molds shall be constructed in the form of right circular cylinders which stand with the cylindrical axis vertical and the top open to receive the concrete. They shall be made of materials that do not react with concrete containing portland or other hydraulic cements. They shall be watertight and sufficiently strong and tough to permit their use without tearing, crushing, or deforming.

NOTE 2—Reusable lids may be used on molds to reduce moisture loss.

3.1.2 Molds shall have a nominal inside height equal to twice the nominal inside diameter. The diameter of a mold, consisting of the average of two measurements taken at right angles to each other at the top of the mold, shall not differ from the nominal diameter by more than 1 %. The height, determined by averaging two measurements taken 180° apart, shall not differ from the nominal height by more than 2 %. The planes of the top rim of the mold and the bottom shall be perpendicular to the axis of the mold within 0.5 degrees—approximately equivalent to 3 mm in 300 mm [⅛ in. in 12 in.]. No diameter of a mold shall differ from any other diameter of the same mold by more than 2 % except that molds that fail to meet this requirement may be used when the user is able to demonstrate that no diameter of hardened concrete specimen produced in a similar mold differs from any other diameter on the same specimen by more than 2 % (see Note 3).

NOTE 3—Certain single-use molds may require the use of a special device such as a tube of heavy-gage metal around the mold during molding to maintain the dimensional tolerances specified in 3.1.2.

[1] This specification is under the jurisdiction of ASTM Committee C09 on Concrete and Concrete Aggregates and is the direct responsibility of Subcommittee C09.61 on Testing for Strength.

Current edition approved Oct. 1, 2009. Published November 2009. Originally approved in 1961. Last previous edition approved in 2008 as C470/C470M-08. DOI: 10.1520/C0470_C0470M-09.

[2] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

***A Summary of Changes section appears at the end of this standard.**

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3.1.3 The bottom inside surface of the mold shall not depart from a plane by more than 2 mm in 150 mm [1/16 in. in 6 in.] (1 % of the diameter of the mold).

4. Reusable Molds

4.1 Reusable molds are those which are designed to be used more than a single time. Reusable molds shall be made of nonabsorptive materials, and constructed as either one piece or several pieces (see Note 4).

4.2 Reusable molds shall be provided with a closure or base on the lower end at right angles to the axis of the cylinder. Molds may be single piece molds or made from castings with a separate detachable base plate or a base that is an integral part of the sidewall. The mold shall be either coated or made of a material that will prevent adherence to the concrete. At the time of use, molds shall not leak water. An inside fillet, if any, at the bottom of the side wall shall have an indentation around the circumference no more than 3 mm [1/8 in.] in the vertical direction or no more than 5 mm [3/16 in.] in the horizontal direction.

4.3 Reusable molds shall be tested for water leakage as described in 6.4, for resistance to damage as described in 6.3.1, and for dimensional stability in accordance with 3.1.2 and 3.1.3 initially and after every 50 uses or every six months, whichever comes first.

NOTE 4—Satisfactory molds can be made from lengths of steel tubing or pipe that is slit on one side parallel to the axis and fitted with a means of closing the vertical slit as well as a means of attaching a base plate. The required dimensional tolerances must be maintained after slitting, clamping, and attaching the base plate. Other nonabsorptive materials which have been used include iron, brass, steel, and various plastics. Although aluminum and magnesium alloys have been used, some of these alloys may be reactive with cement constituents and are therefore unacceptable.

5. Single-Use Molds

5.1 Single-use molds are molds designed to be used once and discarded. They are permitted to be made of sheet metal, plastic, suitably treated paper products, or other materials and shall conform to the requirements of this specification.

5.2 *Physical Requirements*—The molds as prepared for use shall comply with the following:

5.2.1 *Water Leakage*—When tested as described in Section 6, there shall be no visible leakage.

5.2.2 *Absorptivity*—When tested as described in Section 6, the absorption shall not exceed the values given in Table 1. Intermediate values are proportional to the square of the height.

5.2.3 *Elongation*—When tested as described in Section 6, the elongation after test shall not exceed 0.2 % of height.

TABLE 1 Limits for Absorption and Elongation

Nominal Mold Height, mm [in.]	Absorption, max g	Elongation, max mm [in.]
100 [4]	2.7	0.2 [0.008]
150 [6]	6.0	0.3 [0.012]
200 [8]	11	0.4 [0.016]
300 [12]	24	0.6 [0.024]
450 [18]	54	0.9 [0.036]
600 [24]	96	1.2 [0.048]
900 [36]	216	1.8 [0.072]

5.3 *Single-use Plastic Molds*—Molds shall conform to the following additional requirements when plastic is the predominant material used in construction:

5.3.1 *Wall Thickness*—The side walls shall be of sufficient stiffness to meet the requirements of 3.1 (See Note 5).

NOTE 5—This can be achieved through sufficient side wall thickness alone, or in combination with a stiffened top.

5.3.2 *Bottom Design*—The bottom shall be designed so that it will be flush with the bottom of the sidewall within a tolerance of 2 mm [1/16 in.]. An inside fillet, if any, at the bottom of the sidewall shall have an indentation around the circumference no more than 4 mm [1/8 in.] in the vertical direction or no more than 5 mm [3/16 in.] in the radial direction. The bottom shall be of adequate rigidity to prevent permanent deformation when specimens are molded in accordance with the applicable provisions of Practice C31/C31M or C192/C192M.

5.3.3 *Material*—The mold manufacturer shall certify that: (*1*) the plastic material used in molds has a maximum water absorption of less than 0.5 % in 24 h when tested in accordance with Test Method D570; (*2*) the plastic has an Izod impact toughness of at least 117 J/m [2.2 ft lb/in.] of notch for a 4 mm [1/8 in.] thick specimen tested in accordance with Test Methods D256; and (*3*) after being held at 12 °C [10 °F] for 24 h, the plastic shall not fracture when subject to tapping and jarring that is judged to be typical of what occurs when specimens are molded in accordance with the applicable provisions of Practice C31/C31M or C192/C192M.

5.4 *Paper Molds*—When paper or other potentially absorptive fiber material is used as the primary structural material in the construction of the side walls or bottom of the mold, the mold shall conform to the following additional requirements:

5.4.1 *Side Walls*—The side walls of paper molds shall be made with a minimum of three plies having a combined thickness of not less than 2 mm [0.070 in.]. Seams on the inside of the mold shall not be open by more than 2 mm [1/16 in.].

NOTE 6—The minimum thickness of material used in side walls and bottoms is considered adequate for cylinders up to 150 mm [6 in.] in diameter. For larger cylinders thicker material may be required to meet requirements of 3.1.

5.4.2 *Bottom Caps*—The bottom cap of the mold shall be made of either metal or paper. If metal, it shall not be less than 0.23 mm [0.009 in.] in thickness and coated to prevent corrosion (Note 6). It shall be designed so that it will be flush with the bottom edge of the side wall within a tolerance of 2 mm [1/16 in.] and the inside crimp, if any, shall produce an indentation around the circumference of the cylinder no more than 5 mm [3/16 in.] in the radial, and no more than 4 mm [1/8 in.] in the vertical direction. If made of paper, the bottom cap of the mold shall be of parchment-lined cap stock not less than 0.7 mm [0.028 in.] thick (Note 6). It shall be glued to the outside of the walls by means of a flange not less than 19 mm [3/4 in.] high. The glue shall be water-insoluble adhesive of the resin type that will not react with fresh concrete. Only the practicable minimum amount of adhesive shall be exposed on the inner side of the bottom of the mold.

5.4.3 *Waterproofing*—The mold made from paper or fiber shall be completely coated on inside and outside, side walls,

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and bottom with a suitable waterproofing medium (Note 7). The top edge shall be waterproofed, or coated, to limit absorption. The surfaces of metal bottoms, which must comply with 5.4.2, need not be coated. Any waterproofing coating used in this application shall have a melting point not less than 49 °C [120 °F] (Note 8). The coating shall provide a film over the inside that will minimize adherence of the concrete to the side walls and the bottom.

NOTE 7—Paraffin coating for this use may be of the grade known to the trade as crude scale wax or of any superior grade. In general, a film of paraffin of sufficient thickness to accomplish the intended purposes will permit one to raise a curl of paraffin with the thumbnail.

NOTE 8—Such coatings may be unsuitable for molds that are subjected to temperatures above 49 °C [120 °F], either before or after filling with concrete.

5.5 *Single-Use Sheet Metal Molds*—Molds shall conform to the following additional requirements when light-gage sheet metal is the predominant material used in their construction:

5.5.1 *Metal Thickness*—The side wall of steel sheet metal molds shall be manufactured from sheet metal not thinner than can-making quality blackplate and shall have a minimum metal thickness corresponding to that of 48.5-kg [107-lb] blackplate, which is approximately 0.300 mm [0.0118 in.] thick or 30½ gage. The metal for the bottom of the mold shall have a minimum thickness of 0.23 mm [0.009 in.] (Note 6).

5.5.2 *Bottom Design*—The bottom shall be so designed that it will be flush with the bottom of the side wall within a tolerance of 2 mm [1⁄16 in.]. An inside crimp, if used, shall produce an indentation around the circumference of the cylinder no more than 4 mm [⅛ in.] in the vertical or 5 mm [3⁄16 in.] in the radial direction.

5.5.3 *Top Edge*—The top edge of the side wall shall be curled or beaded to strengthen the mold and protect the user from sharp edges. If such bead protrudes to the inside of the mold, the indentation produced in the concrete cylinder shall not exceed 4 mm [⅛ in.] in either a radial or vertical direction.

5.5.4 *Coating*—If the mold is made of material which will rust, corrode, react, or adhere to the freshly mixed or hardened concrete, it must be coated with a protective coating of lacquer or other suitable material.

6. Test Methods for Elongation, Absorption, and Water Leakage

6.1 *Apparatus*—The assembly used for the absorption-elongation test shall follow the principles illustrated in Fig. 1.

6.2 *Specimens*—Molds shall be selected as described in Section 2. Single-use molds shall not be reused nor the same mold retested.

6.3 *Test Procedure for Molds:*

6.3.1 Samples of all types of single-use molds and reusable plastic molds shall be subjected to the dry rodded coarse aggregate test as described in 6.3.2 to evaluate their resistance to damage under use and to the water leakage test described in 6.3.3 and 6.3.4. Paper or other potentially absorptive molds shall additionally be tested for absorptivity and elongation described in 6.3.5. Plastic and sheet metal molds need not be tested for elongation and absorption, but should be tested for water leakage. Dimensional requirements for all molds shall be verified.

6.3.2 Prepare the mold for test by filling with dry crushed stone coarse aggregate meeting the grading requirements of Specification C33 size No. 57, 25.0 to 4.75 mm [1 in. to No. 4] or No. 67, 19.0 to 4.75 mm [¾ in. to No. 4]. Fill and compact the mold by the rodding procedure specified in Practice C192/C192M for compression test specimens using the tamping rod, number of layers and number of strokes per layer specified. It will generally not be possible to obtain the penetration of the tamping rod specified in Practice C192/

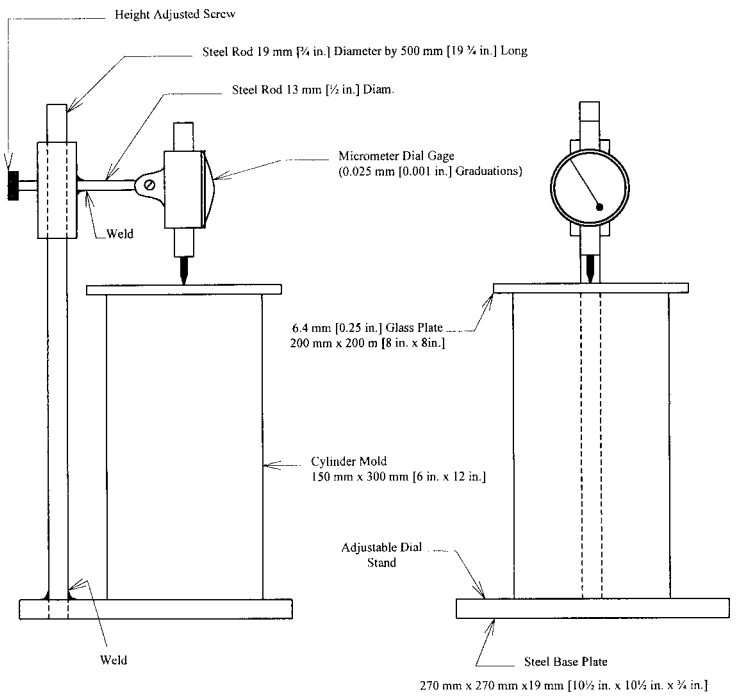

FIG. 1 Apparatus for Absorption-Elongation Test of Paper Molds

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C192M. After rodding the final layer, empty the coarse aggregate, wipe lightly with a dry cloth and examine the mold for physical damage.

6.3.3 After completion of 6.3.2, determine the mass of the mold and record to the nearest 0.004 g/mm [0.1 g/in.] of mold height. Place the mold on a firm, flat surface and fill with water at room temperature to a depth of 90 to 95 % of the mold height. Then place the mold on the dial stand, cover with the glass or metal plate and record the initial length by dial micrometer to the nearest 0.025 mm [0.001 in.].

6.3.4 Allow the mold to stand for 3 h and take a final reading of the micrometer. Examine and record any visible leakage. Empty water from the mold, dry lightly with a towel and record the final mass to the nearest 0.04 g/cm [0.1 g/in.] of mold height.

6.3.5 Calculate the elongation as the difference between the final length and initial length. Calculate the absorption as the difference between the final mass and initial mass of the mold.

6.3.6 Verify all dimensional requirements.

6.4 *Water Leakage Test for Reusable Molds:*

6.4.1 Prepare reusable molds with the sealant to be used, if required. Fill molds with water to a depth of 90 to 95 % of the nominal height. Subject the mold to tapping and jarring which is judged to be typical of what occurs when specimens are molded in accordance with the applicable provisions of Practice C31/C31M or C192/C192M.

6.4.2 One hour after tapping, examine for visible leakage.

7. Sampling and Rejection

7.1 At least three single-use and reusable molds shall be selected at random from each shipment by the purchaser to ensure that the molds are in compliance with this specification.

7.2 Failure of any one of the three molds to comply with this specification shall be basis for rejection of the shipment.

8. Record to be Prepared by the Purchaser

8.1 Where applicable for the type of mold tested, record and retain in accordance with Practice C1077 the following information for each mold tested:

8.1.1 Brand or source of molds,

8.1.2 Shipment or lot from which the mold was taken,

8.1.3 Date sampled and date tested,

8.1.4 Brief general description of the mold including nominal dimensions, type of mold, and materials of which it is made,

8.1.5 Total absorption, g, if specified,

8.1.6 Total expansion, mm [in.], if specified, and

8.1.7 Water leakage reported in terms of compliance, or failure by leakage.

8.2 Where applicable for the type of mold tested, record and retain the following information for samples which do not meet the requirements of the specification:

8.2.1 Average diameter or height, mm [in.],

8.2.2 Maximum and minimum diameters or heights, mm [in.],

8.2.3 Nonconformance with required perpendicularity of rim or base to the axis of the mold,

8.2.4 Apparent reaction between mold materials and concrete or mortar or corrosion of metal in contact with concrete,

8.2.5 Melting point less than 49 °C [120 °F],

8.2.6 Minimum thickness of materials in side walls or bottom, and

8.2.7 Dimension of crimp in bottom, top edge or construction of paper bottom.

9. Keywords

9.1 concrete; molds; test cylinders

SUMMARY OF CHANGES

Committee C09 has identified the location of selected changes to this specification since the last issue, C470/C470M – 08, that may impact the use of this specification. (Approved October 1, 2009)

(*1*) Revised 4.3 to require initial compliance testing of reusable molds before being placed in service.

(*2*) Replaced “report” with “record and retain” in Section 8.

(*3*) Added Practice C1077 to 8.1 and Referenced Documents.

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Designation: C 471M – 01 (Reapproved 2006)$^{\epsilon 1}$

Standard Test Methods for Chemical Analysis of Gypsum and Gypsum Products (Metric)[1]

This standard is issued under the fixed designation C 471M; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

ϵ^1 NOTE—Note 1 and certain footnotes were removed editorially to conform to ASTM Form and Style requirements for sole source of supply January 2007.

1. Scope

1.1 These test methods cover the chemical analysis of gypsum and gypsum products, including gypsum ready-mixed plaster, gypsum wood-fibered plaster and gypsum concrete.

1.2 The test methods appear in the following order:

	Sections
Alternative Procedure for Analysis for Calcium Sulfate by Ammonium Acetate Method	17-22
Alternative Procedure for Analysis for Sodium Chloride by the Coulometric Method	23-29
Complete Procedure	5-16
Determination of Sand in Set Plaster	30-36
Optional Procedure for Analysis for Sodium by Flame Photometry	47-54
Optional Procedure for Analysis for Sodium by the Atomic Absorption Method	40-46
Preparation of Sample	4
Wood-Fiber Content in Wood-Fiber Gypsum Plaster	37-39

1.3 The text of this standard references notes and footnotes that provide explanatory material. These notes and footnotes (excluding those in tables and figures) shall not be considered as requirements of the standard.

1.4 The values stated in SI units are to be regarded as the standard.

1.5 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

2. Referenced Documents

2.1 *ASTM Standards:* [2]

C 11 Terminology Relating to Gypsum and Related Building Materials and Systems
C 22/C 22M Specification for Gypsum
C 28/C 28M Specification for Gypsum Plasters
C 59 Specification for Gypsum Casting Plaster and Gypsum Molding Plaster
C 61 Specification for Gypsum Keene's Cement
C 317/C 317M Specification for Gypsum Concrete
C 842 Specification for Application of Interior Gypsum Plaster
D 1193 Specification for Reagent Water
D 1428 Methods of Test for Sodium and Potassium in Water and Water-Formed Deposits by Flame Photometry[3]
D 2013 Practice for Preparing Coal Samples for Analysis
E 11 Specification for Wire Cloth and Sieves for Testing Purposes

3. Terminology

3.1 *Definitions*—Definitions shall be in accordance with Terminology C 11.

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *sample as received*, *n*—a representative portion of raw gypsum or gypsum product in the state received by the testing laboratory, including aggregates, impurities and water content.

3.2.2 *dried sample*, *n*—a sample devoid of free water.

3.2.3 *riffle*, *n*—a hand feed sample divider device that divides the sample into parts of approximately the same weight. **(D 2013)**

4. Preparation of Sample

4.1 *General Procedures*—Details of sample preparation will vary according to the type of material being tested.

4.1.1 *Sample As Received*—Use a sufficient amount of sample such that, after sieving, not less than 50 g of sample will remain for testing. Weigh the entire sample immediately after opening the container in which the material was received. This will become the weight of the sample as received.

[1] These test methods are under the jurisdiction of ASTM Committee C11 on Gypsum and Related Building Materials and Systems and are the direct responsibility of Subcommittee C11.01 on Specifications and Test Methods for Gypsum Products.

Current edition approved Dec. 1, 2006. Published January 2007. Originally approved in 1961. Last previous edition approved in 2001 as C 471 – 01.

[2] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

[3] Withdrawn.

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4.1.2 *Drying*—Dry the sample in accordance with Section 7. This will be the weight of the dried sample.

4.1.3 *Crushing and Grinding*—Crush and grind the sample by hand with a mortar and pestle or by mechanical crushing and grinding equipment to pass a 250-µm (No. 60) sieve. Take care, particularly with mechanical equipment, not to expose the sample to temperatures of more than 52 °C. Clean the equipment thoroughly between samples. Thoroughly remix the ground sample and store it in an airtight container to avoid contamination.

4.1.4 *Rehydrating*—Thoroughly blend and rehydrate samples which contain calcium sulfate in forms other than $CaSO_4 \cdot 2H_2O$ and natural anhydrite. Place the sample in distilled water and keep it wet for not less than 48 h. Dry the hydrated sample in an oven at 45 ± 3 °C to constant weight and recrush or grind it in accordance with 4.1.3.

4.1.5 *Sample Reduction*—Thoroughly mix and reduce large samples as required by quartering or by the use of a riffle to obtain a specimen of approximately 50 g.

4.2 *Gypsum (C 22/C 22M)*—Gypsum samples will be received in the form of rocks, powder or both. If necessary crush and reduce the entire dried sample in accordance with 4.1.3 and 4.1.5.

4.3 *Gypsum Plaster*, (C 28).

4.3.1 *Gypsum Ready-Mixed Plaster or Gypsum WoodFibered Plaster*—Screen the dried sample through a 150-µm (No. 100) sieve[4] and discard the residue retained on the sieve. Reweigh the remaining sample and calculate the percentage of the dried sample. Reduce the sample in accordance with 4.1.5. Thoroughly blend and rehydrate the specimen in accordance with 4.1.4.

4.3.2 *Gypsum Neat Plaster or Gypsum Gauging Plaster*—Reduce the dried sample in accordance with 4.1.5. Thoroughly blend and rehydrate the specimen in accordance with 4.1.4.

4.4 *Gypsum Casting and Molding Plaster , (C 59)*—Reduce the dried sample in accordance with 4.1.5. Thoroughly blend and rehydrate the specimen in accordance with 4.1.4.

4.5 *Gypsum Keene's Cement, (C 61)*—Reduce the dried sample in accordance with 4.1.5. Blend in no more than 1 % molding plaster or K_2SO_4 and rehydrate the specimen in accordance with 4.1.4.

4.6 *Gypsum Concrete, (C 317)*—Screen the dried sample through a 150-µm (No. 100) sieve[4] and discard the residue retained on the sieve. Reweigh the remaining sample and calculate the percentage of the dried sample. Reduce the sample in accordance with 4.1.5. Thoroughly blend and rehydrate the specimen in accordance with 4.1.4.

4.7 *Gypsum Board*—Cut or break the dried sample into small pieces. Using a mortar and pestle, strike the pieces of the sample to loosen the paper face. Remove the pieces of paper by hand as they are separated from the core of the gypsum board. Carefully scrape any remaining powder from the paper. When all the paper has been removed from the pieces of the sample, reduce the sample in accordance with 4.1.5. Thoroughly blend and rehydrate the specimen in accordance with 4.1.4.

[4] Detailed requirements for this sieve are given in Specification E 11.

COMPLETE PROCEDURE

5. Apparatus

5.1 *Analytical Balance*—Capable of weighing the weighing bottles, lids and samples.

5.2 *Balance*—Capable of weighing not less than 100 g at a precision of 0.001 g.

5.3 *Drying Oven*—A mechanical convection oven set at 45 ± 3 °C.

5.4 *Desiccator*—Capable of being tightly sealed and containing calcium chloride or equivalent desiccant.

5.5 *Calcining Oven or Furnace*—Capable of achieving and maintaining temperatures to not less than 1000 °C.

5.6 *Weighing Bottles*—Borosilicate glass or ceramic containers with tightly sealable lids.

5.7 *Hot Plate*—A controllable hot plate capable of heating casseroles to approximately 120 °C.

5.8 *Porcelain Casseroles*—With a capacity of 50 to 100 mL.

5.9 *Filtering Funnels*.

5.10 *Filter Paper*.

5.11 *Porcelain Crucibles*.

5.12 *Mortar and Pestle*.

5.13 *Mechanical Jaw Crusher*—Capable of crushing gypsum rocks up to 50 mm diameter.

5.14 *Mechanical Grinder*—Burr mill or equivalent capable of grinding the granular output of the jaw crusher specified in 5.13.

6. Reagents

6.1 *Purity of Reagents*—Use reagent grade chemicals in all tests. Unless otherwise indicated, use reagents that conform to the specifications of the Committee on Analytical Reagents of the American Chemical Society, where such specifications are available.[5] If it is necessary to use other grades first ascertain that the reagent is of sufficiently high purity so that its use will not lessen the accuracy of the determination.

6.1.1 *Ammonium Chloride* (NH_4Cl).

6.1.2 *Ammonium Hydroxide (sp gr 0.90)*—Concentrated ammonium hydroxide (NH_4OH).

6.1.3 *Ammonium Nitrate (25 g/L)*—Dissolve 25 g of ammonium nitrate (NH_4NO_3) in water and dilute to 1 L.

6.1.4 *Ammonium Oxalate* ($(NH_4)_2C_2O_4$).

6.1.5 *Barium Chloride (100 g/L)*—Dissolve 100 g of barium chloride ($BaCl_2 \cdot 2H_2O$) in water and dilute to 1 L.

6.1.6 *Calcium Chloride ($CaCl_2$)*—Anhydrous Calcium Chloride with a combined water of not more than 5 %.

6.1.7 *Hydrochloric Acid (sp gr 1.19)*—Concentrated hydrochloric acid (HCl).

6.1.8 *Hydrochloric Acid (1 + 4)*—Mix 1 volume of HCl (sp gr 1.19) with 4 volumes of water.

6.1.9 *Hydrochloric Acid (1 + 5)*—Mix 1 volume of HCl (sp gr 1.19) with 5 volumes of water.

[5] *Reagent Chemicals, American Chemical Society Specifications* , American Chemical Society, Washington, DC. For suggestions on the testing of reagents not listed by the American Chemical Society, see *Analar Standards for Laboratory Chemicals*, BDH Ltd., Poole, Dorset, U.K., and the *United States Pharmacopeia and National Formulary*, U.S. Pharmacopeial Convention, Inc. (USPC), Rockville, MD.

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6.1.10 *Nitric Acid (sp gr 1.42)*—Concentrated nitric acid (HNO_3).

6.1.11 *Potassium Chromate Solution (100 g/L)*—Dissolve 5 g of potassium chromate (K_2CrO_4) in 50 mL of water, mix, add 10 drops of 0.05 N silver nitrate ($AgNO_3$) solution, allow to stand for 5 min, and filter.

6.1.12 *Potassium Permanganate (5.6339 g/L)*—Dissolve 5.6339 g of potassium permanganate ($KMnO_4$) in water and dilute to 1 L.

6.1.13 *Silver Nitrate, Standard Solution (0.05 N)*—Prepare and standardize a 0.05 N silver nitrate ($AgNO_3$) solution.

6.1.14 *Sodium Ammonium Phosphate*—($NaNH_4HPO_4$).

6.1.15 *Sulfuric Acid (sp gr 1.84)*—Concentrated sulfuric acid (H_2SO_4).

6.1.16 *Sulfuric Acid (1 + 6)*—Carefully mix 1 volume of H_2SO_4(sp gr 1.84) with 6 volumes of water.

6.1.17 *Nitric Acid (0.1 N)*—Mix 1.4 mL of HNO_3(sp gr 1.42) with 200 mL of water.

6.1.18 *Phenolphthalein Indicator Solution*— Dissolve 0.25 g of phenolphthalein in 30 mL of methanol and dilute to 50 mL with water.

6.1.19 *Sodium Hydroxide Solution (0.1 N)*—Dissolve 1 g of sodium hydroxide (NaOH) in 250 mL of water.

6.1.20 *Water*—Reagent water shall be in accordance with Specification D 1193, type II. Specification D 1193 gives the following values for type II grade water.

Electrical conductivity, max, μS/cm at 298 K (25-C)	1.0
Electrical resistivity, min, MΩ·cm at 298 K (25-C)	1.0
Total organic carbon (TOC), max, μg/L	50.0
Sodium, max, μg/L	5.0
Chlorides max, μg/L	5.0
Total silica, max, μg/L	5.0

7. Free Water

7.1 *Significance and Use*—The free water analysis determines the amount of free water contained in the sample as opposed to chemically combined water, and prepares the sample for further analysis.

7.2 *Procedure*:

7.2.1 Weigh a sample of the material as received of not less than 50 g to a precision of 0.001 g and spread it out in a thin layer in a suitable vessel. Place in an oven and dry at 45 ± 3 °C for 2 h, then cool in a desiccator and weigh again. The loss of weight corresponds to the free water.

7.2.2 Retain the sample in a sealed container or in the desiccator for further analysis.

7.3 *Calculation and Report*—Calculate and report loss in weight as a percentage of the sample as received or of the dried sample as required.

7.4 *Precision and Bias*—Neither the precision nor the bias for the free water analysis has been determined.

8. Combined Water

8.1 *Significance and Use*—The combined water analysis determines the percent of chemically combined water and is used to calculate the purity of gypsum or the amount of gypsum or gypsum plaster in gypsum products.

8.2 *Interferences*—Some materials, such as organic and hydrated compounds that decompose within the same temperature range as gypsum, will cause high results. When the maximum temperature is exceeded, some carbonates undergo decomposition, which will result in high results.

8.3 *Procedure*:

8.3.1 For each sample, place three weighing bottles with lids in the preheated calcining oven or furnace and heat for 2 h at 215 to 230 °C. Place in the desiccator and allow to cool to room temperature. Weigh the bottles and lids to the nearest 0.0001 g and record the tare weights.

8.3.2 Weigh out three specimens of approximately 1 g each of the sample as prepared in Section 4 and dried in Section 7 to a precision of 0.0001 g in the previously tared weighing bottles and record the total weight with lids.

8.3.3 Place the specimens in the calcining oven with the lids placed loosely on each bottle or crucible for 2 h or until constant weight has been obtained.

8.3.4 Place the lids tightly on the weighing bottles, remove from the oven, and place in the desiccator to cool to room temperature.

8.3.5 Weigh each specimen to a precision of 0.0001 g and record the weights.

8.3.6 Retain the residues for carbon dioxide analysis.

8.4 *Calculation and Report*—Calculate and report the average loss in weight of the three specimens as a percentage of the sample as received or of the dried sample, as required, to the nearest 0.001 g and record the tare weights.

8.5 *Precision and Bias*—Neither the precision nor the bias for the combined water analysis has been determined.

9. Carbon Dioxide

9.1 *Summary of Test Method*—The sample is decomposed with HCl and the liberated CO_2 is passed through a series of scrubbers to remove water and sulfides. The CO_2 is absorbed with Ascarite, a special sodium hydroxide absorbent, and the gain in weight of the absorption tube is determined and calculated as percent CO_2.

9.2 *Significance and Use*—The carbon dioxide analysis is useful in estimating carbonates and organic carbon for chemical balance.

9.3 *Special Reagents*:

9.3.1 *Magnesium Perchlorate Desiccant*—for drying.

9.3.2 *Sodium Hydroxide Absorbent*—a coarse sodium hydroxide coated silica.

9.4 *Special Apparatus*—The apparatus illustrated in Fig. 1 consists of the following:

9.4.1 *Purifying Jar A*, Fleming, containing sulfuric acid.

9.4.2 *Drying Tube B*, U-shaped with side arms and glass-stoppers. Side arms are shaped to hold rubber tubing. Contains Anhydrone on left side and Ascarite on right side.

9.4.3 *Erlenmeyer Flask C*, 250 mL, 24/20 ground-glass joint.

9.4.4 *Separatory Funnel D*, with ground glass stopper and interchangeable hollow ground-glass joint. A delivery tube bent at the end extends into the sample flask approximately 15 mm from the bottom and is used to introduce acid into flask.

9.4.5 *Condenser E*.

9.4.6 *Gas-Washing Bottle F*, 250 mL, with fitted disk containing distilled water to retain most of the acid volatilized from the alkalimeter.

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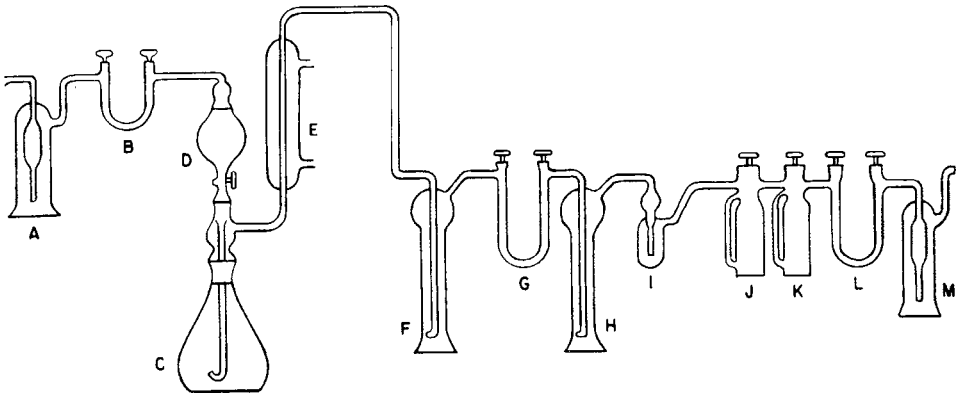

FIG. 1 Apparatus for Carbon Dioxide Analysis

9.4.7 *U-Tube G*, containing mossy zinc to remove the last traces of HCl.

9.4.8 *Gas Washing Bottle H*, 250 mL, with fritted disk, containing concentrated H_2SO_4 and trap *I*, to remove any SO_3 mist that is carried over.

9.4.9 *Absorption Bulb J*, containing Anhydrone to remove last traces of water vapor.

9.4.10 *CO_2 Absorption Bulb*, containing Ascarite filled as follows: On the bottom of the bulb, place a layer of glass wool extending above the bottom outlet and on top of this a layer of Anhydrone approximately 10 mm thick; immediately above this place another layer of glass wool, then add Ascarite to almost fill the bulb. Place a top layer of Anhydrone approximately 10 mm thick on top of the Ascarite and top it off with a covering of glass wool.

9.4.11 *U-Guard Tube L*, filled with Anhydrone in left side and Ascarite in right side.

9.4.12 *Purifying Jar M*, Fleming, containing H_2SO_4.

9.5 *Procedure*:

9.5.1 After drying as described in Section 8 place the residue obtained in the 250 mL Erlenmeyer flask (*C*). Connect the flask to the apparatus as shown in Fig. 1. Purge the system free of carbon dioxide by passing a current of CO_2-free air through the apparatus for 10 to 15 min.

9.5.2 Weigh the absorption bulb to 0.0001 g and attach it to the train. Remove the glass stopper from the separatory funnel, place 50 mL of dilute HCl (1 + 1) in the separatory funnel (*D*) and replace the stopper with the interchangeable hollow ground-glass joint through which passes a tube for admitting purified air. Open the stopcock of the separatory funnel and admit air through the top of the funnel to force the hydrochloric acid into the Erlenmeyer flask (*C*).

9.5.3 Start cold water circulating through the condenser (*E*) and, with CO_2-free air passing at a moderate rate through the absorption train, place a small hot plate or gas burner under the sample flask and boil for approximately 2 min. Remove the hot plate and continue the flow of purified air at approximately three bubbles per second for 10 min to sweep the apparatus free of CO_2. Close the absorption bulb, disconnect it from the train and weigh, opening the stopper momentarily to equalize the pressure. Use a second absorption bulb as counterpoise in all weighings unless a single pan balance is used.

9.6 *Calculation*—Calculate the percent CO_2 to the dried sample as follows:

$$\text{Percent } CO_2 = ((A - B)/C \times 100)(1 - D) \quad (1)$$

where:

A = mass of absorption bulb + CO_2 g,
B = mass of absorption bulb before the run, g,
C = mass of specimen, g, and
D = percent combined water as determined in Section 8 as a decimal.

Calculate the percent CO_2 to the sample as received as follows:

$$\text{Percent } CO_2 = E(1 - F) \quad (2)$$

where:

E = result of Eq 1, and
F = percent free water as determined in Section 7 as a decimal.

9.7 *Precision and Bias*—Neither the precision nor the bias for the carbon dioxide analysis has been determined.

10. Silicon Dioxide and Other Acid Insoluble Matter

10.1 *Summary of Test Method*—The gypsum and other acid soluble components of the sample are dissolved in dilute hydrochloric acid (HCl). The residue is weighed and calculated as silicon dioxide and other acid insoluble matter.

10.2 *Significance and Use*—The silicon dioxide and other acid insoluble matter analysis determines and is used to report the percentage of one of the inert impurities in gypsum and gypsum products.

10.3 *Procedure*—Perform in triplicate.

10.3.1 Weigh approximately 1 g of the specimen prepared in Section 4 to the nearest 0.0001 g.

10.3.2 Place the specimen in a porcelain casserole. Add approximately 50 mL of 1 + 5 hydrochloric acid. Evaporate slowly and carefully to apparent dryness on a hot plate. Take not less than 20 min to do the evaporation. Make a blank determination with one casserole in parallel. Cool to room temperature.

10.3.3 Add enough hydrochloric acid (sp gr 1.19) to wet the solid residue. Add 20 mL of water, boil and filter through filter paper. Wash the filter paper thoroughly using not less than 100 mL of room temperature water to render the precipitate chloride free. The most effective washing technique is to use many small quantities of wash water rather than fill the funnel to the brim two or three times. Test the filtrate for chloride by collecting a small amount and adding a few drops of 0.1

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normal silver nitrate ($AgNO_3$) solution. A white precipitate indicates more washing is needed. Discard this test solution.

10.3.4 Place all the filtrate back in the same casserole. Evaporate to dryness and heat to 120 °C for 1 h and cool. To the cooled casserole add enough HCl (sp gr 1.19) to wet the solid residue. Add 50 mL of water and boil.

10.3.5 Wash the second contents of the casserole through another filter paper. Thoroughly wash the residue in the filter paper until chloride free as in 10.3.3. Retain the filtrate for the iron and aluminum oxide analysis.

10.3.6 Dry sufficient crucibles by placing in a cold muffle furnace during warm up or by placing in a drying oven for 15 to 20 min, then placing in a 900 °C muffle furnace. Cool crucibles to room temperature in a desiccator.

10.3.7 Transfer both filter papers to a tared crucible and char slowly without flaming. Burn off all the carbon and ignite in a muffle furnace at 900 °C for 15 min.

10.3.8 Cool the crucibles in a desiccator and weigh to the nearest 0.0001 g.

10.4 *Calculation and Report*—Calculate the average weight of the three precipitates and report as silicon dioxide (SiO_2) and other insoluble matter to the percentage of sample as received or to the dried sample as required.

10.5 *Precision and Bias*—Neither the precision nor the bias for the silicon dioxide and other acid insoluble matter has been determined.

11. Iron and Aluminum Oxides

11.1 *Significance and Use*—The iron and aluminum oxides ($Fe_2O_3 + Al_2O_3$) analysis is used to determine the quantity of these metal oxides in gypsum or gypsum products.

11.2 *Procedure*—To the filtrate, obtained as described in Section 10, add a few drops of nitric acid (HNO_3), and boil to ensure oxidation of the iron. Add 2 g of ammonium chloride (NH_4Cl) previously dissolved in water. Make alkaline with ammonium hydroxide (NH_4OH). Digest hot for a few minutes until the precipitate coagulates. Filter, wash, ignite the precipitate at 1000 °C for 30 min or to constant weight in a muffle furnace and weigh as $Fe_2O_3 + Al_2O_3$. Save the filtrate for the CaO analysis.

NOTE 1—The addition of a pinch of ashless filter paper pulp will aid in the filtration of the precipitate.

11.3 *Calculation*—Calculate $Fe_2O_3 + Al_2O_3$ to the percentage of sample as received or the dried sample as required. This precipitate may be further treated to separate the two oxides, but this is generally unnecessary.

11.4 *Precision and Bias*—Neither the precision nor the bias for the iron and aluminum oxides analysis has been determined.

12. Calcium Oxide

12.1 *Significance and Use*—The calcium oxide (CaO) analysis is used to determine the amount of CaO and calculate the amount of calcium carbonate ($CaCO_3$) in gypsum and gypsum products.

12.2 *Procedure*:

12.2.1 To the filtrate obtained as described in Section 11 add 5 g of ammonium oxalate ($(NH_4)_2C_2O_4$) dissolved in water. Digest hot for 30 min, making sure that the solution is always alkaline with NH_4OH. Filter, wash, and ignite the precipitate at 1000 °C for 2 h to constant weight in a platinum crucible in a muffle furnace.

12.2.2 *Alternative Method*—To the filtrate obtained as described in Section 11, add 5 g of $(NH_4)_2C_2O_4$ dissolved in water. Digest hot for 30 min, making sure that the solution is always alkaline with NH_4OH. Filter and wash, transfer the precipitate to a beaker, and wash the filter paper with hot H_2SO_4(1 + 6), catching the washing in the same beaker. Heat gently to complete solution, adding more H_2SO_4 if necessary. While still warm, titrate with potassium permanganate ($KMnO_4$) solution (5.6339 g/L) until the pink color persists.

12.3 *Calculation*—The number of milliliters of $KMnO_4$ solution used gives directly the percentage of lime in the dried sample. Calculate the CaO to the percentage of sample as received or the dried sample as required.

12.4 *Precision and Bias*—Neither the precision nor the bias for the calcium oxide analysis has been determined.

13. Magnesium Oxide

13.1 *Significance and Use*—The magnesium oxide (MgO) analysis is used to determine the amount of MgO and calculate the amount of magnesium carbonate $MgCO_3$ in gypsum and gypsum products.

13.2 *Procedure*—To the filtrate obtained as described in 12.2.1 or 12.2.2, add enough water to give a total volume of approximately 600 mL. Cool, and add 10 mL of NH_4OH and 5 g of sodium ammonium phosphate ($NaNH_4HPO_4$) dissolved in water. Stir vigorously until a precipitate begins to form. Let stand overnight. Filter, using a Gooch crucible, and wash with NH_4NO_3 solution. Ignite at 1000°C for 2 h to constant weight in a muffle furnace.

13.3 *Calculation*—Multiply this weight by 0.36207 to find the weight of magnesium oxide (MgO). Calculate the MgO to the percentage of sample as received or to the dried sample as required.

13.4 *Precision and Bias*—Neither the precision nor the bias for the magnesium oxide analysis has been determined.

14. Sulfur Trioxide

14.1 *Summary of Test Method*—In this test method, sulfate is precipitated from an acid solution of the gypsum with barium chloride ($BaCl_2$). The precipitate is filtered and weighed as barium sulfate ($BaSO_4$) and the sulfur trioxide (SO_3) equivalent is calculated.

14.2 *Significance and Use*—The specification for gypsum and some gypsum products specifies the amount of calcium sulfate ($CaSO_4$) required, either in the dihydrate ($CaSO_4 \cdot 2H_2O$) or hemihydrate ($CaSO_4 \cdot ½ H_2O$) form. This procedure assumes that an insignificant amount of sulfate other than calcium sulfate is present. This test method is used to determine compliance to the gypsum and gypsum product specifications. It is also commonly used in quality control work.

14.3 *Interference*—This test method has been developed for natural gypsum and for impurities generally found associated with natural gypsum. Synthetic gypsum will sometimes have an additional number of interfering elements and compounds, and if so, this procedure will not give accurate results. This test

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method has a number of interferences that theoretically affect the results. Co-precipitation and occlusion are problems if the solution is either too acidic or too basic. Calculations using SO_3 analysis are most accurate on samples that are known to be completely hydrated or completely dehydrated.

14.4 *Procedure*:

14.4.1 Having properly selected and prepared the samples as specified in Section 4, weigh a representative specimen of approximately 0.5 g, to the nearest 0.0001 g.

14.4.2 Place the weighed sample into a 400-mL beaker. Add 50 mL of HCl (1 + 5). Boil and disperse with the flattened end of a glass rod while stirring until the sample is completely broken down. Add approximately 100 mL boiling water and continue boiling for 15 min, with this step to be extended as required, so the combined boiling time is not less than 1 h.

14.4.3 Using filter paper, filter into a clean 600-mL flask and rinse the 400-mL beaker thoroughly with hot distilled water. Carefully wash the sides of the 400-mL beaker while wiping the insides with a rubber-tipped glass rod making sure all splatters and insoluble are washed into the filter paper. Dry and burn off the filter paper leaving the residue to be dried and weighed for insoluble matter, if this test method is not otherwise conducted.

14.4.4 Dilute the filtrate to 400 to 500 mL. Add 1 to 2 drops of 0.1 % methyl red indicator. Prepare a 400 to 500-mL sample of 0.05 to 0.1 NHCl. Add 1 to 2 drops of 0.1 % methyl red indicator. Compare the color of this solution to the color of the filtrate. Dilute the filtrate or add HCl (1 + 5) solution as necessary to match the pH of the 0.05 to 0.1 NHCl solution.

14.4.5 Boil the filtrate solution and add 20 mL of near-boiling 10 % barium chloride solution, preferably with the help of a pipette, drop by drop while stirring. The barium chloride solution should be prepared not less than one day before use. Continue boiling the solution for 10 to 15 min and digest hot for 3 h or until the precipitate settles.

14.4.6 Filter and wash with approximately 125 to 150 mL of hot water to render the precipitate chloride free. Test the filtrate for chloride by collecting a small amount and adding a few drops of 0.1 N $AgNO_3$ solution. A white precipitate indicates more washing is needed. Alternately, use filtering crucibles for quick filtering if the particular crucibles to be used are tested prior to use by refiltering the filtrate from the crucibles with filter paper, and no more than 2 mg is collected on the filter paper.

14.4.7 Ignite the precipitate and paper in a tared crucible, and slowly char the paper without inflaming. Burn off all the carbon and ignite in a muffle furnace at 800 to 900 °C or using bright red heat over a Bunsen burner for 15 to 20 min. Dry the filtering crucibles by placing in a cold muffle furnace during warm-up or in a drying oven prior to igniting in a muffle furnace at 800 to 900 °C for 15 to 20 min.

NOTE 2—Thoroughly cleans crucibles before each use and heat in a furnace at 800 to 900 °C and cool in a desiccator before taring.

14.4.8 Cool all crucibles in a desiccator and weigh to the nearest 0.0001 g.

14.5 *Calculation*—Multiply the weight of the precipitate by 0.343 to determine the weight of sulfur trioxide (SO_3). Calculate the SO_3 to the percentage of sample as received or to the dried sample as required.

14.6 *Precision and Bias*—Neither the precision nor the bias for the sulfur trioxide analysis has been determined.

15. Chlorides

15.1 *Significance and Use*—Small amounts of chlorides in gypsum or gypsum products often have a detrimental effect on their use. This procedure is used to measure the amount of chlorides present and report it as sodium chloride.

15.2 *Procedure*:

15.2.1 Weigh approximately 20.0 g of sample as prepared in Section 4 to 0.001 g and transfer to a 400-mL beaker. Add 150 mL of water, stir, and heat to just below the boiling point. Cover with a watch glass and maintain at just below boiling (not less than 80 °C) for 1 h with occasional stirring. Filter with suction on a Buchner funnel fitted with a medium filter paper. Wash the residue with four 20-mL portions of hot water.

15.2.2 Add 2 drops of phenolphthalein indicator solution to the filtrate. If the filtrate fails to turn pink, add 0.1 NNaOH solution dropwise with stirring until a faint pink color develops. Add 0.1 $NHNO_3$ dropwise until the pink color just disappears.

15.2.3 If the chloride content is very low, transfer the entire filtrate quantitatively to a 400-mL beaker and proceed as described in 15.2.4. If larger amounts of chloride are expected, transfer the filtrate quantitatively to a 250-mL volumetric flask, cool to room temperature, and dilute to 250 mL. Take a suitable aliquot, transfer to a 400-mL beaker, and dilute to a volume of 100 to 250 mL.

15.2.4 Place the beaker containing the sample on a white surface, add 0.5 mL (10 drops) of K_2CrO_4 solution and titrate with $AgNO_3$ solution using a micro buret having a 10-mL capacity and graduated in divisions of 0.02 mL. Titrate until a faint but definite orange color is visible.

15.2.5 Perform a blank titration using the same volume of water as the sample volume and the same amount of K_2CrO_4 solution. Titrate to the same color as obtained with the sample.

15.3 *Calculation*—Subtract the volume of $AgNO_3$ solution used for the blank titration from the volume used for the sample to give the net titration. A 1-mL net titration is equivalent to 0.002923 g of sodium chloride (NaCl). Calculate the NaCl as a percentage of the sample as received or the dried sample as required.

15.4 *Precision and Bias*—Neither the precision nor the bias for the chloride analysis has been determined.

16. Report

16.1 Report the results obtained in the analysis as follows:

	Percent
Free water	...
Combined water	...
Carbon dioxide (CO_2)	...
Silicon dioxide (SiO_2) and insoluble matter	...
Iron and aluminum oxides (Fe_2O_3 + Al_2O_3)	...
Lime (CaO)	...
Magnesium oxide (MgO)	...
Sulfur trioxide (SO_3)	
Sodium chloride (NaCl)	...
Total	100.00±

NOTE 3—Since it is frequently advisable to recalculate the results

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obtained in the chemical analysis in order that they may be more enlightening, the following is submitted for consideration:

(*1*) Multiply the percentage of combined water by 4.778 to obtain purity or percentage gypsum. To calculate the percentage of $CaSO_4 \cdot ½ H_2O$ in plasters, multiply the percentage of gypsum by 0.8430.

(*2*) Multiply the percentage of combined water by 2.222 to obtain the amount of SO_3 combined as gypsum.

(*3*) Subtract the result obtained in (*2*) from the total SO_3 found by analysis to obtain the excess SO_3.

(*4*) Multiply the excess SO_3 by 1.700 to obtain the percentage anhydrite, $CaSO_4$.

(*5*) Multiply the percentage of gypsum found in (*1*) by 0.3257 to obtain the percentage of CaO combined as gypsum.

(*6*) Multiply the percentage of anhydrite found in (*4*) by 0.4119 to obtain the percentage of CaO combined as anhydrite.

(*7*) Add (*5*) and (*6*) together. Then subtract this result from the total CaO percentage found by analysis.

(*8*) Multiply the excess CaO percentage by 1.785 to obtain the percentage of calcium carbonate.

(*9*) Multiply the percentage of MgO by 2.091 to obtain the percentage of magnesium carbonate.

NOTE 4—Having made the calculations in Note 3, the results may be reported as follows:

	Percent
Gypsum ($CaSO_4 \cdot 2H_2O$)	...
Anhydrite ($CaSO_4$ natural and manufactured) (Note 3)	...
Silicon dioxide and insoluble (SiO_2 + Ins.)	...
Iron and aluminum oxide (R_2O_3)	...
Calcium carbonate ($CaCO_3$)	...
Magnesium carbonate ($MgCO_3$)	...
Sodium chloride (NaCl)	...
Total	100.00±

NOTE 5—The presence of the different forms of $CaSO_4$ may be determined by a microscopic examination. A paper titled "Gypsum Analysis with the Polarizing Microscope" containing suggested methods can be found in ASTM STP 861.[6]

ALTERNATIVE PROCEDURE FOR ANALYSIS FOR CALCIUM SULFATE BY THE AMMONIUM ACETATE METHOD[7]

17. Significance and Use

17.1 This test method covers the determination of calcium sulfate in gypsum and gypsum products by extraction with ammonium acetate solution.

18. Reagents and Materials

18.1 *Ammonium Acetate Solution*—Dissolve 454 g of ammonium acetate in 2 L of water. Add sufficient NH_4OH to make the solution distinctly ammoniacal, using phenolphthalein as the indicator.

18.2 *Ammonium Hydroxide Wash Solution*— Dilute 100 mL of concentrated ammonium hydroxide (NH_4OH, sp gr 0.90) to 1 L with water.

18.3 *Filter Aid*—Diatomaceous silica, analytical grade.

18.4 *Phenolphthalein Indicator Solution*.

19. Procedure Using Gooch Crucible

19.1 Weigh rapidly approximately 4 g of the well-mixed sample and transfer to a 600-mL beaker. Make all weighings to 0.001 g, except weigh the crucibles and their contents to 0.0001 g.

19.2 Without delay, weigh approximately 1 g of the well-mixed sample in a tared weighing bottle having a ground-glass stopper. Dry the sample and weighing bottle to constant weight at 45 °C. Stopper weighing bottles immediately upon removal from the oven in order to prevent absorption of moisture from the air upon cooling.

19.3 If the percentage by weight of combined water held by the calcium sulfate is required, heat the sample and weighing bottle to constant weight at 220 °C.

19.4 To the contents of the 600-mL beaker (19.1), add 350 mL of the ammonium acetate solution, and stir the mixture thoroughly to loosen all of the solid matter from the bottom of the beaker. Add 0.2000 g of redried diatomaceous silica to the mixture. Heat the beaker and contents to 70 °C on a steam or hot water bath, and maintain at that temperature for 30 min, while stirring frequently. During heating, keep the solvent ammoniacal by additions of NH_4OH and phenolphthalein, if indicated. Meanwhile, heat a supply of the ammonium acetate solution to 70 °C, keeping it also distinctly ammoniacal. Filter the mixture, with suction, through a tared Gooch crucible, stirring frequently during filtration to keep the diatomaceous earth suspended in the liquid. Wash the Gooch crucible containing the residue with five 10-mL portions of the warm acetate solution, draining thoroughly after each washing. Wash in the same manner with eight 10-mL portions of the NH_4OH wash solution. Take care to wash the upper walls of the Gooch crucible. Drain the crucible dry with suction, place in an oven at 70 °C, and dry to constant weight (Note 6). Allow the crucible to cool in a desiccator before weighing.

NOTE 6—Avoid overheating in all oven drying of ammonium acetate residues; that is, place crucibles well away from the heating elements. This is of particular importance for samples high in impurities, as these impurities often have water of hydration that is lost on local overheating.

20. Procedure Using Tared Filter Papers

NOTE 7—This procedure is suggested where several samples are to be analyzed at once. It has been found that gravity filtration on six samples will proceed as rapidly as it is possible to handle the samples.

20.1 Dry a quarter-folded, 110-mm quantitative filter paper overnight at 70 °C in a wideform, glass-stoppered, 30 by 60-mm weighing bottle. After drying, cool the weighing bottle and paper in a desiccator, and weigh.

20.2 Treat the sample exactly as described in 19.1, 19.2, and 19.4 prior to the filtration. Filter the mixture by gravity through a 70-mm glass funnel, stirring frequently during filtration to keep the diatomaceous silica suspended in the liquid. Wash the filter paper and residue with five 10-mL portions of warm acetate solution, draining thoroughly after each washing. Wash in the same manner with eight 10-mL portions of the NH_4OH wash solution. After final draining, replace the paper and residue in the weighing bottle, and dry at 70 °C to constant weight. Cool the weighing bottle, paper, and residue in a

[6] Green, George W., "Gypsum Analysis with the Polarizing Microscope," *The Chemistry and Technology of Gypsum, ASTM STP 861*, ASTM, 1984, pp. 22–47.

[7] This procedure was developed by L. S. Wells and W. F. Clarke, National Bureau of Standards, and modified by B. E. Kester, United States Gypsum Co.

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freshly prepared desiccator before weighing; this is essential, due to the hygroscopic character of paper.

21. Calculation

21.1 Calculate the percentage of loss in weight at 45 °C (free water) as follows:

$$\text{Loss in weight at 45 °C, \%} = [(A - B)/C] \times 100 \quad (3)$$

where:

A = original weight of sample and weighing bottle,
B = weight of sample and weighing bottle dried to constant weight at 45 °C, and
C = original weight of sample.

Calculate the weight of the 4-g sample (19.1), corrected for loss on heating to constant weight at 45 °C.

21.2 Calculate the percentage of combined water as follows:

$$\text{Combined water, \%} = [(B - D)/(B - E)] \times 100 \quad (4)$$

where:

B = weight of sample and weighing bottle dried to constant weight at 45 °C,
D = weight of sample and weighing bottle dried to constant weight at 220 °C, and
E = weight of weighing bottle.

21.3 Calculate the percentage of $CaSO_4 \cdot nH_2O$ on the basis of the sample dried to constant weight at 45 °C as follows:

$$CaSO_4 \cdot nH_2O, \% = [F - (G - H)/F] \times 100 \quad (5)$$

where:

F = weight of sample, corrected for loss on heating to constant weight at 45 °C,
G = weight of dried crucible and contents (19.4) or weight of weighing bottle and contents (20.2), and
H = weight of crucible plus diatomaceous silica used as filter aid (19.4), or weight of weighing bottle, diatomaceous silica used as a filter aid and the weight of filter paper (20.2).

22. Precision and Bias

22.1 Neither the precision nor the bias for the analysis of calcium sulfate by the ammonium acetate method has been determined.

ALTERNATIVE PROCEDURE FOR ANALYSIS FOR SODIUM CHLORIDE BY THE COULOMETRIC METHOD[8]

23. Significance and Use

23.1 This test method covers the determination of sodium chloride in gypsum and gypsum products by the coulometric method.

24. Interferences

24.1 The presence of sulfide, sulfhydryl, or other silver reactive substances will lead to high results. Such interfering substances are removed by alkaline oxidation with hydrogen peroxide.

[8] This procedure was developed by Westroc Industries Limited.

25. Apparatus

25.1 *Chloride Meter*:

25.1.1 The instrument shall be equipped to measure the concentration of dissolved chloride in aqueous solutions by the coulometric method.

25.1.2 The instrument shall be capable of measuring chloride concentrations in the range from 10 to 260 mg/L with a repeatability of ± 1 mg/L.

26. Reagents

26.1 *Acid Buffer Solution*—Dissolve 100 mL of 99.5 % acetic acid ($HC_2H_3O_2$) and 5.5 mL of concentrated nitric acid (sp gr 1.42) in approximately 200 mL of water and dilute to 500 mL.

26.2 *Diluted Standard Solution (100 mg Cl/L)*—Dilute 5.00 mL of stock standard solution to 500 mL.

26.3 *Gelatin Solution*—Add 2.5 g of gelatin and 0.5 g of thymol blue to 250 mL of water and dissolve by stirring continuously while bringing to a boil. With the solution just boiling, continue stirring until all the thymol blue is dissolved. Add 0.5 g of thymol, cool, and dilute the solution to 500 mL.

NOTE 8—The gelatin solution holds the precipitated silver chloride (AgCl) in suspension and also indicates the presence of the acid buffer. The solution will keep for 3 months at room temperature or longer if refrigerated. Warm the refrigerated solution to room temperature before use.

26.4 *Stock Standard Solution (10 g Cl/L)*—Dissolve 8.240 g of dried sodium chloride (NaCl) in water and dilute to 500 mL.

27. Procedure

27.1 Weigh 20.0 g of the well-mixed sample and transfer to a 150-mL beaker.

27.2 Add 50 mL of water, boil, allow the solid material to settle, and filter off the solution. Add an additional 50 mL of water to the solids, boil, and pour the contents of the beaker into the filter. Wash the residue with 100 mL of hot water, adding the washing to the filtrate. Cool and dilute with water to 250 mL.

27.3 Switch on the chloride meter and allow a period of 25 min before use. Set the counter to zero.

27.4 Place a magnetic stirring bar in the test beaker, add 10 mL of diluted standard solution, 3 mL of acid buffer solution, and 5 drops of gelatin solution. Place the test beaker on the platform and lower the electrodes into the solution. Press the "start" button until the pilot light is extinguished. The counter will begin to register after a few seconds. Do not remove the electrodes from the sample until the pilot light comes on. Read the chloride content from the counter. If a reading of 100 ± 1 mg Cl/L is not obtained, refer to the manufacturer's instruction manual. Reset the counter to zero.

27.5 Repeat the procedure used in 27.4, using 10 mL of the sample solution instead of the diluted standard solution. Read the result as milligrams of chlorine per litre. When all tests are completed, lower the electrodes into reagent water.

28. Calculation

28.1 Calculate the amount of NaCl as a percentage of the sample as received or dried sample as follows:

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$$\text{NaCl, \%} = 0.00206 \times A \quad (6)$$

where:
A = chloride meter reading, mg Cl/L.

29. Precision and Bias

29.1 Neither the precision nor the bias for the sodium chloride analysis by the coulometric method has been determined.

DETERMINATION OF SAND IN SET PLASTER

30. Summary of Test Method

30.1 This test method for the determination of the sand content of set gypsum plaster requires for accurate results the following determinations:

30.1.1 Determination of the percentage of insoluble matter in the sand used with the plaster,

30.1.2 Determination of the percentage of insoluble matter in the gypsum neat plaster, and

30.1.3 Determination of the percentage of insoluble matter in the sanded calcined plaster.

NOTE 9—If samples of the original gypsum neat plaster and the sand are not available, an approximation of the insoluble matter may be obtained by the use of this method on plaster and sand from the same sources as those from which the plaster to be analyzed was originally prepared.

31. Significance and Use

31.1 This test method is used for determining the sand content of samples of aggregated plaster taken from job sites to determine compliance with Specification C 842.

32. Reagents

32.1 *Ammonium Acetate (250 g/L)*—Dissolve 250 g of ammonium acetate ($NH_4C_2H_3O_2$) in water and dilute to 1 L.

32.2 *Ammonium Hydroxide (1 + 59)*—Mix 1 volume of concentrated ammonium hydroxide (NH_4OH) (sp gr 0.90) with 59 volumes of water.

33. Sampling

33.1 Where plaster to be tested is part of a two-coat or three-coat plastering operation, take the sample for analysis from that portion of the entire plaster sheet that comprises the single coat being tested. Separate succeeding coats of plaster by use of a stiff putty knife or similar implement. Not less than 500 g shall be taken as a sample, the sample preferably being obtained from different sections of the wall or ceiling under examination.

34. Procedure

34.1 In a clean porcelain mortar, grind the set plaster sample to the size of the largest sand particles present, or smaller, so that approximately 100 % of the sample will pass a 2.36-mm (No. 8) sieve. Fine grinding makes solution of the gypsum faster. Place approximately 200 g of the ground sample in a porcelain casserole or evaporating dish, and calcine on a sand bath. Stir the sample continuously with a thermometer during the heating, and adjust the rate of heating so that 20 to 30 min will be required to raise the temperature of the sample to 160 ± 5 °C. Cool the sample to room temperature in a desiccator.

34.2 After cooling, weigh accurately 20 ± 0.05 g of the calcined sample into a 600-mL beaker. Add 300 to 350 mL of $NH_4C_2H_3O_2$ solution. If acidic to litmus paper, add a few millilitres of NH_4OH (1 + 59) to the stock $NH_4C_2H_3O_2$ solution to render it slightly alkaline prior to the addition to the test sample.

34.3 Warm the suspension to a temperature of 70 ± 5 °C and stir continuously for 20 to 30 min. Filter the warm suspension with the aid of suction through a small Büchner funnel or Gooch crucible in which filter paper has previously been placed. Refilter the first 100 mL of the filtrate. Wash the sand remaining in the beaker onto the filter with an additional 100 mL of warm ammonium acetate solution. Wash the beaker and residue with 200 to 300 mL of water, dry the funnel and sand at 100 °C to constant weight. The weight of the residue is the weight of insoluble matter.

34.4 *Insoluble Matter in Sand*—Determine the weight of insoluble matter in sand as described in 34.1-34.3, except that no grinding of the sample is necessary.

34.5 *Insoluble Matter in Gypsum Neat Plaster*—Determine the weight of insoluble matter in the gypsum neat plaster as described in 34.1-34.3, except that only a 5-g sample is required and no grinding of the sample is necessary.

35. Calculation

35.1 *Insoluble Matter in Plaster*—Multiply by 5 the weight of the insoluble matter obtained as described in 34.3 to obtain the percentage of insoluble matter in sanded plaster.

35.2 *Insoluble Matter in Sand*—Multiply by 5 the weight of the insoluble matter in sand obtained as described in 34.4 to obtain the percentage of insoluble matter in sand.

35.3 *Insoluble Matter in Gypsum Neat Plaster*—Multiply by 20 the weight of the insoluble matter in gypsum neat plaster obtained as described in 34.5 to obtain the percentage of insoluble matter in gypsum neat plaster.

35.4 Calculate the percentage of sand in the sanded plaster as follows:

$$X = [(C - B)/(A - B)] \times 100 \quad (7)$$

where:
X = % of sand in sanded plaster,
A = % of insoluble matter in the sand,
B = % of insoluble matter in the gypsum neat plaster, and
C = % of insoluble matter in the sanded plaster.

35.5 To express the results as a ratio of the parts of sand per part of plaster by weight, use the following equation:

$$\text{Ratio of sand to plaster} = X/(100 - X) \quad (8)$$

NOTE 10—The results obtained by the above procedure indicate the amount of sand originally mixed with the gypsum neat plaster before it had been gaged with water or set.

36. Precision and Bias

36.1 Neither the precision nor the bias for the analysis of sand in set plaster has been determined.

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WOOD-FIBER CONTENT IN WOOD-FIBER GYPSUM PLASTER

37. Significance and Use

37.1 This test method is used to determine the weight of wood fiber in wood-fibered plaster.

38. Procedure

38.1 Place a 100-g sample of wood-fiber plaster, prepared as described in Section 4 on a 600-µm (No. 30) sieve[4] nested over a 150-µm (No. 100) sieve.[4] Wash the plaster on the 600-µm sieve with a stream of cold water, removing the 600-µm sieve when the fiber on it is practically or entirely free of plaster. Next, wash the material on the 150-µm sieve until the bulk of the plaster has been washed through the sieve and the residue is mainly fiber. Transfer the material retained on the 150-µm sieve to a 300-mL, vitreous enamel, lipped pan, adding the charge on the 600-µm sieve if the fiber contains any adhering particles of plaster. Elutriate the material in the pan (purify by washing and straining, effecting as clean a separation of fiber from plaster as is practical), catching the elutriated fibers on a 150-µm sieve. To avoid loss of the fine particles of fiber, make the transfer from the pan to the 150-µm sieve by several stages of washing, stirring the charge, and quickly pouring upon the sieve the fiber flotations, repeating the elutriation procedure several times. Examine the fiber collected on the 150-µm sieve and repeat the elutriation if necessary.

38.2 Dry the sieves (or sieve) and the residue contained thereon overnight in an oven maintained at a temperature of 45 °C. Carefully invert the sieves, or sieve, over a piece of white paper, and transfer the residual material to the paper by brushing the bottom of the inverted sieve. Examine the transferred material visually, noting whether the separation of fibers from plaster has been complete. Then transfer the material to a weighed platinum crucible and dry to constant weight at a temperature of 45 °C. If the previous visual examination of the charge on the white paper showed that the fiber was practically free of particles of plaster, report as the percentage of fiber the weight of the fiber dried at 45 °C, divided by 100. If, on the other hand, the visual examination revealed the presence of an appreciable quantity of plaster associated with the fiber, carefully ignite the contents of the crucible to constant weight. In this case, report as the percentage of fiber the loss on ignition, divided by 100.

39. Precision and Bias

39.1 Neither the precision nor the bias for the analysis of wood-fiber content in wood-fiber gypsum plaster has been determined.

OPTIONAL PROCEDURE FOR ANALYSIS FOR SODIUM BY THE ATOMIC ABSORPTION METHOD

40. Significance and Use

40.1 This test method covers the determination of sodium in gypsum and gypsum products by the atomic absorption method.

41. Interferences

41.1 Sodium is partially ionized in the air-acetylene flame. The effects of ionization will be significantly overcome by the addition of 1 to 2 g/L of another alkali to blanks, standards, and samples. Alternatively, use the air-hydrogen flame, as it produces less ionization and less visible emission than the air-acetylene flame.

42. Apparatus

42.1 *Atomic Absorption Spectrophotometer*:

42.1.1 The instrument shall be equipped to measure the concentration of dissolved sodium in aqueous solutions using either the air-acetylene or air-hydrogen flame.

42.1.2 The instrument shall be capable of measuring sodium concentrations within the optimum analytical range of 0.1 to 0.5 absorbance units while providing a coefficient of variation of approximately 0.5 to 2 %.

43. Reagents

43.1 *Solvent*—Use deionized water to prepare all solutions. If an alkali is to be included for the purpose of suppressing sodium ionization, it is most convenient to add it to the solvent at the start. In this way a constant concentration of alkali in blank, standards, and sample solution is ensured.

43.2 *Stock Standard Solution (1.000 g Na/L)*—Dissolve 2.5418 g of dried sodium chloride (NaCl) in water and dilute to 1 L with water.

43.3 *Dilute Standard Solutions*—Prepare dilute standard solutions bracketing the absorbance range of the dilute sample solution, using the stock standard solution. (Solutions having a concentration less than approximately 0.500 g/L are unstable for periods of more than one day.)

44. Procedure

44.1 Take 18 g of the well-mixed sample and transfer to a 150-mL beaker.

44.2 Add 50 mL of water, boil, allow the solids to settle, and decant the supernatant liquid into a filter. Add an additional 50 mL of water to the solids, boil, and pour the contents of the beaker into the filter. Wash the residue with 100 mL of hot water, adding the washing to the filtrate. Cool the filtrate to room temperature and dilute to 500 mL in a volumetric flask to make the stock sample solution. Take 10 mL of the solution and make up to 500 mL in a second volumetric flask, to make the dilute sample solution.

44.3 Determine the absorbance readings on the dilute standard solutions and the solvent blank at a wavelength of 589.0 to 589.6 nm, following the manufacturer's instruction manual. Subtract the absorbance value for the blank from the absorbance values for the dilute standard solutions and prepare a curve relating sodium concentration in milligrams per litre to absorbance values.

NOTE 11—If the absorbance of the dilute sample solution is known to lie within the linear range, that is, the sodium concentration is below approximately 1 mg/L only one standard and the solvent blank are needed to prepare the curve.

44.4 Determine absorbance readings on the dilute sample solution using the same technique, followed with the dilute

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standard solutions. The concentration of sodium in the dilute sample solution in milligrams per litre is then found by consulting the standard curve.

45. Calculation

45.1 Calculate the amount of NaCl as a percentage of the sample received or the dried sample as required as follows:

$$\text{Sodium calculated as \% NaCl} = A \times 6.3553/S \quad (9)$$

where:

A = concentration of dilute sample solution, mg/L, and
S = weight of sample, g.

46. Precision and Bias

46.1 Neither the precision nor the bias for the analysis of sodium by the atomic absorption method has been determined.

OPTIONAL PROCEDURE FOR ANALYSIS FOR SODIUM BY FLAME PHOTOMETRY

47. Significance and Use

47.1 This test method covers the determination of sodium in gypsum and gypsum products by flame photometry. This test method is based on Methods D 1428.

48. Interferences

48.1 Radiation interferences caused by elements other than that being determined are the greatest contributor to error in flame photometry. Some effects are positive and others negative. Of the elements encountered in this analysis, the greatest effect is that of one alkali metal on another. The foreign-element effects cannot be entirely compensated for without employing calibration standards closely duplicating the composition of the sample. However, the effects are minimized by operating at the lowest practical sodium concentration range or by removal of the interfering elements. For example, aluminum has a depressing effect on alkali-metal emission, which is of serious consequence. Remove aluminum from the extraction liquid prior to flame photometry if its concentration has been found, by preliminary tests, to exceed that of the sodium.

48.2 Self-absorption causes the curve of intensity versus concentration to decrease its slope at higher concentrations, tending to reduce accuracy. Bracketing the unknown by known standard solutions tends to minimize this interference.

49. Apparatus and Materials

49.1 *Flame Photometer*—The instrument shall consist of an atomizer and burner; suitable pressure-regulating devices and gages for fuel and air or oxygen; an optical system, consisting of suitable light-dispensing or filtering devices capable of preventing excessive interference from light of wavelengths other than that being measured; and a photosensitive indicating device.

49.2 *Supply of Fuel and Air or Oxygen*— The supplies of fuel and air or oxygen shall be maintained at pressures somewhat higher than the controlled operating pressure of the instrument.

50. Reagents

50.1 Prepare the following stock solutions from reagents that have been dried to constant weight at 105 °C. Store the stock solutions in polyethylene or equally alkali-metal-free containers.

50.2 *Sodium Chloride Solution (2.5418 g/L)*—Dissolve 2.5418 g of sodium chloride (NaCl) in water and dilute to 1 L with water. This stock standard solution contains 1.000 g/L of sodium ion.

50.3 *Dilute Standard Solutions*—Prepare dilute standard solutions from stock standard solution, bracketing the expected sodium concentration range of the diluted sample extraction liquid. For example, if the expected range of the sample extraction liquid is between 0 and 0.010 g/L, prepare eleven equally spaced standards in tenths of the maximum.

51. Calibration of Instrument

51.1 Select the proper photocell; the blue-sensitive phototube having a range from 320 to 620 nm is required for sodium determination. Open the slit width to approximately one fourth of the maximum opening, set the instrument to the maximum sensitivity range, and balance the meter to obtain electrical equilibrium.

51.2 Feed fuel and air or oxygen to the burner and ignite the emitted mixture. Adjust fuel and air or oxygen pressures and follow the procedures for warm-up time prescribed by the instrument manufacturer. Set the scale-reading dial at approximately 95 % of full scale, introduce a solution containing the maximum amount of sodium in the range to be covered, and allow the emitted light to strike the photocell.

51.3 Select the proper filter, if a filter-type instrument is used. For instruments employing spectral dispersing devices, turn the wavelength dial back and forth slowly and carefully in the vicinity of 589 nm until the galvanometer reaches a maximum deflection. This wavelength setting produces maximum sensitivity. Do not disturb the wavelength dial during the test.

51.4 Continue to atomize the maximum standard of the range to be covered, and set the scale-reading of the dial at exactly full scale (100 or 1000) (Note 12). Adjust the gain so as to balance the galvanometer needle.

NOTE 12—For instruments equipped with a variable slit, carry out the procedure described above with the slit width between fully closed and one fourth open for the preliminary test. In determining the proper slit width for optimum instrument performance, consideration must be given to the fact that the intensity of the emission line is approximately proportional to the slit width, whereas continuous background intensity increases as the square of the slit width. A decrease in slit width results in decreased illumination of the phototube for a given concentration and is compensated for by increasing the gain of the instrument. The most favorable operating conditions are obtained with the smallest slit width that does not result in instability of the galvanometer needle when it is set to give full-scale reading with the maximum standard in the range to be covered. When altering the slit width, determine the background by atomizing a zero standard, and check for sensitivity setting and instrument stability with the maximum standard in the range to be covered. Lower ranges require wider slit widths. Determine and record the optimum slit width for each range and element to be covered. Use these values in all subsequent tests.

51.5 Determine the emission intensity of all standards.

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51.6 Plot emission intensity (scale reading) versus concentration on linear graph paper. For the lower ranges, the curve thus prepared approximates a straight line but sometimes will not intersect zero because of background intensity. At higher ranges, the curves show a decrease in slope with increasing concentration. Record on graphs all data in regard to slit width, fuel pressure, and air or oxygen pressure.

52. Procedure

52.1 Weigh 25 g of the well-mixed sample and transfer to a 150-mL beaker.

52.2 Add 50 mL of water, boil, allow the solid material to settle, and decant the supernatant liquid into a filter. Add an additional 50 mL of water to the solids, boil and pour the contents of the beaker into the filter. Wash the residue with 75 mL of hot water, adding the washing to the filtrate. Cool and dilute with water to 200 mL in a volumetric flask to make the stock sample solution.

52.3 Take 5 mL of the stock sample solution and make up to 100 mL in a volumetric flask to make the dilute sample solution.

NOTE 13—If the concentration of sodium in the sample is found to be greater than the maximum standard, further dilute sample solution with water to bring the concentration within the range. If the concentration of sodium in the sample is less than one tenth of the value of the maximum standard, prepare a new dilute sample solution from the stock sample solution to bring the concentration within the range.

52.4 Turn the instrument on and feed fuel and air or oxygen to the burner. Ignite the gas mixture. For instruments with an adjustment slit, set the width to the value determined as outlined in Note 12.

52.5 Place the scale-reading dial at maximum. Atomize the sample and allow its emitted light to strike the photocell. Set the wavelength to 589 nm as described and adjust the gain to balance the galvanometer. Determine the emission intensity of the sample.

52.6 Refer to the standard curve prepared above and read off the concentration of sodium ion in the dilute sample solution in milligrams per litre.

53. Calculation

53.1 Calculate the amount of NaCl as follows:

$$\text{Sodium, calculated as NaCl, } \% = A \times 0.04067 \quad (10)$$

where:

A = concentration of sodium, mg/L read off the standard curve.

54. Precision and Bias

54.1 Neither the precision nor bias of the analysis for sodium by flame photometry has been determined.

55. Keywords

55.1 ammonium acetate method; atomic absorption; chemical analysis; coulometric method; flame photometry; gypsum; gypsum concrete; gypsum board; gypsum products; plaster; sand in set plaster; wood-fiber plaster

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Standard Test Methods for Physical Testing of Gypsum, Gypsum Plasters and Gypsum Concrete[1]

This standard is issued under the fixed designation C 472; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

This standard has been approved for use by agencies of the Department of Defense.

1. Scope

1.1 These test methods cover the physical testing of gypsum, gypsum plasters, and gypsum concrete.

1.2 The test methods appear in the following sections:

	Sections
Precautions for Physical Tests	4
Reagents and Materials	5
Free Water	6
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Normal Consistency of Gypsum Plaster	8
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Compressive Strength	12
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1.3 The values regarded as the standard are either in inch-pound units or SI (metric). The values stated first shall be regarded as the standard. Values following in parentheses are approximate and are provided for information purposes only.

1.4 The text of this standard references notes and footnotes which provide explanatory material. These notes and footnotes (excluding those in tables and figures) are not requirements of the standard.

1.5 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use*. For a specific precautionary statement, see X1.2.1.

2. Referenced Documents

2.1 *ASTM Standards:*[2]

C 11 Terminology Relating to Gypsum and Related Building Materials and Systems

C 778 Specification for Standard Sand

E 11 Specification for Woven Wire Test Sieve Cloth and Test Sieves

3. Terminology

3.1 *Definitions:*

3.1.1 For useful definitions refer to Terminology C 11.

4. Precautions for Physical Tests

4.1 Gypsum products are greatly affected by small amounts of impurities introduced by careless laboratory manipulation. In order to obtain accurate results, it is absolutely essential to observe the following precautions:

4.1.1 Keep all apparatus thoroughly clean. Remove all traces of set plaster.

NOTE 1—For mixing pastes and mortars, a 500-ml rubber dental bowl is a convenience.

NOTE 2—Use care when drying gypsum, gypsum plasters, or gypsum concrete. Exceeding the specified drying temperatures may calcine the specimens, which will cause inaccurate test results.

5. Reagents and Materials

5.1 *Distilled or Deionized Water*—free of chlorides and sulfates at a temperature of 21 ± 1°C (70 ± 2°F).

5.2 *Standard Sand*— Specification C 778, 20–30 sand.

6. Free Water

6.1 *Significance and Use*—This test method determines the free water contained in gypsum, gypsum plasters, and gypsum concrete samples, and prepares the sample for subsequent testing.

6.2 *Apparatus*:

6.2.1 *Balance*, capable of weighing not less than 500 g at a precision of 0.1 g.

6.2.2 *Drying Oven*, set at 45 ± 3°C.

6.2.3 *Desiccator*, containing calcium chloride or equivalent desiccant.

6.3 *Procedure*:

[1] These test methods are under the jurisdiction of ASTM Committee C11 on Gypsum and Related Building Materials and Systems and are the direct responsibility of Subcommittee C11.01 on Specifications and Test Methods for Gypsum Products.

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[2] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

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6.3.1 Weigh a sample of not less than 500 g of the material as received to the nearest 0.1 g and spread it to a thin layer in a suitable-vessel. Place in an oven (6.2.2) and dry for 2 h; then cool in a desiccator (6.2.3) and weigh again.

6.3.2 Retain the dried sample in an airtight container until used for the fineness test (Section 7).

6.4 *Report*—Report the loss in weight as a percentage of the original weight of the sample as received to a precision of 0.1%.

6.5 *Precision and Bias*—The precision and bias of the free water test method have not been determined.

7. Fineness

7.1 *Significance and Use*—This test method covers a procedure for determining the fineness of gypsum and gypsum plasters and is used to determine compliance with gypsum and gypsum plaster specifications. The degree of correlation between the results of this test method and service performance has not been determined.

7.2 *Apparatus*:

7.2.1 *Sieves*, as required by a particular gypsum or gypsum plaster specification, in accordance with Specification E 11.

7.2.2 *Balance*, capable of weighing not less than 1000 g at a precision of 0.1 g.

7.2.3 *Mechanical Sieving Machine*

7.3 *Procedure*:

7.3.1 Determine fineness by sieving a known weight of the dried sample through sieves of the specified sizes (Note 3 and Note 4). The size of the sample to be used in determining fineness depends upon the particle size of the material. If the material will pass a 6.3-mm (¼-in.) sieve, a 100-g sample will be sufficient; if the largest particles are more than 25 mm (1 in.) in diameter, use not less than a 1000-g sample. With these limitations the size of sample to be used is left to the discretion of the operator. Shake the sample through each sieve with as little abrasion as possible (Note 5). Weigh the amount of material retained on each sieve and calculate the fineness, expressed as a percentage of the weight of the original sample.

7.3.2 If a mechanical sieving machine is used, make a series of tests at one minute intervals, with each type of material and sieve size combination to be used. When not more than 0.5 g passes each sieve in a one minute interval, use that time as the standard sieving time for that test procedure on that machine.

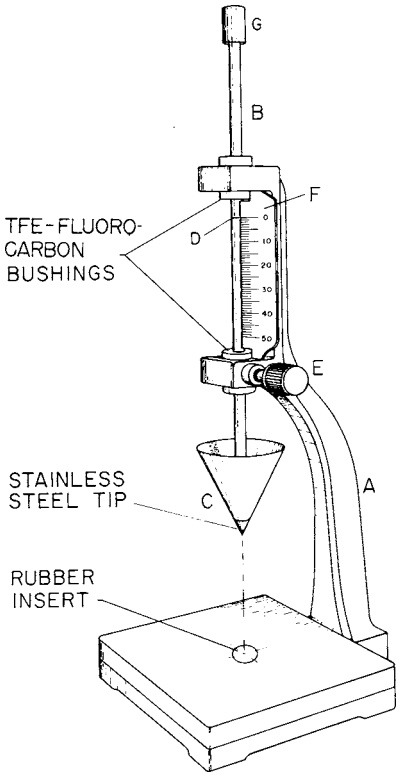
NOTE 3—For suggested method of sieving gypsum through a 45-µm (No. 325) sieve, see Appendix X1.

NOTE 4—The sizes of the sieves to be used are given in the specifications of ASTM covering the particular product in question.

NOTE 5—When sieving by hand through a 150-µm (No. 100) sieve, use a lateral motion, and tap the side of the sieve with the palm of the hand. Continue without brushing until not more than 0.5 g passes through during 1 min of sieving. If the sieve openings become clogged, transfer the retained material temporarily to another vessel, invert the sieve over a sheet of paper on the table and tap it sharply against the table. Then transfer all the retained material back into the sieve and continue sieving.

7.4 *Report*—Report the percent by weight retained on each sieve or passing particular sieves in accordance with the material specification to the nearest full percentage point.

7.5 *Precision and Bias*—The precision and bias of the fineness test method have not been determined.



A—Hinged support bracket
B—Plunger support rod
C—Conical plunger
D—Graduation mark
E—Lock screw
F—Modified scale
G—Weight

FIG. 1 Modified Vicat Apparatus (Conical Plunger Method)

8. Normal Consistency of Gypsum Plaster

8.1 *Significance and Use*—This test method is used to determine the volume of water required for mixing gypsum plaster when performing the setting time and compressive strength tests.

8.2 *Apparatus*:

8.2.1 *Modified Vicat Apparatus*—The modified Vicat apparatus (Fig. 1)[3] shall consist of a bracket, *A*, bearing a movable brass rod, *B*, 6.3 mm in diameter and of suitable length to fit the Vicat Bracket. A conical plunger made of aluminum with an apex angle of 53° 08 min and a height of 45 mm shall be attached to the lower end of the rod. The total weight of the rod and plunger shall be 35 g. A means shall be provided for adding a weight, *G*, to the rod, increasing the total weight to 50 g. The rod shall be capable of being held in any position by a screw, *E*. The rod shall have a mark, *D*, midway between the ends which moves under a scale, *F*, graduated in millimetres, attached to the bracket, *A*.

8.2.2 *Mold*—The conical ring mold shall be made of a noncorroding, nonabsorbent material, and shall have an inside diameter of 60 mm at the base and 70 mm at the top and a height of 40 mm.

[3] This method is described by Kuntze, R. A., "An Improved Method for the Normal Consistency of Gypsum Plasters," *ASTM Bulletin No. 246*, ASTM, May 1960, p. 35.

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8.2.3 *Base Plate*—The base plate for supporting the ring mold shall be of plate glass and about 100 mm square.

8.2.4 *Balance*, capable of weighing not less than 500 g at a precision of 0.1 g.

8.2.5 *Graduated Cylinder*, shall be made to deliver the indicated volume at 20°C (68°F) and shall be subdivided to not less than 1 mL.

8.3 *Procedure*:

8.3.1 Clean the plunger, mold, and base plate of the modified Vicat apparatus. Apply a thin coat of petroleum jelly or other suitable lubricant to the upper surface of the base plate in order to prevent leaks during the test.

8.3.2 Sift a weighed quantity of the sample (200 to 300 g as required to fill the mold) into a known volume of water (See 5.1). If the plaster is unretarded, add to the mixing water 0.2 g of sodium citrate per 100 g of sample. After allowing the sample to soak for 2 min, stir the mixture for 1 min to an even fluidity. Pour this sample into the ring mold, work slightly to remove air bubbles, and then strike off flush with the top of the mold. Wet the plunger of the modified Vicat apparatus and lower it to the surface of the sample at approximately the center of the mold. Read the scale and release the plunger immediately. After the rod has settled, read the scale again. Make three determinations on each mix, care being taken to have the mold completely filled and the plunger clean and wet.

8.3.3 Test gypsum molding plaster and gypsum gauging plaster with different amounts of water until a penetration of 30 ± 2 mm is obtained. Use the rod and plunger for this determination weighing 35 g.

8.3.4 Test all gypsum mixtures containing aggregates with different amounts of water until a penetration of 20 ± 2 mm is obtained. Add weight to the rod and plunger to bring the total weight to 50 g for these determinations.

8.3.5 Mix gypsum neat plaster with standard sand (see 5.2) in the ratio of 200 g of sand to 100 g of plaster before testing for normal consistency.

8.4 *Report*:

Report the normal consistency as the average number of millilitres of water required to be added to 100 g of the dry mixture to the nearest whole millilitre.

8.5 *Precision and Bias*—The precision and bias of the test method for normal consistency of gypsum plaster have not been determined.

9. Normal Consistency of Gypsum Concrete

9.1 *Significance and Use*—This test method is used to determine the volume of water required for mixing gypsum concrete when performing the setting time and compressive strength tests.

9.2 *Apparatus*:

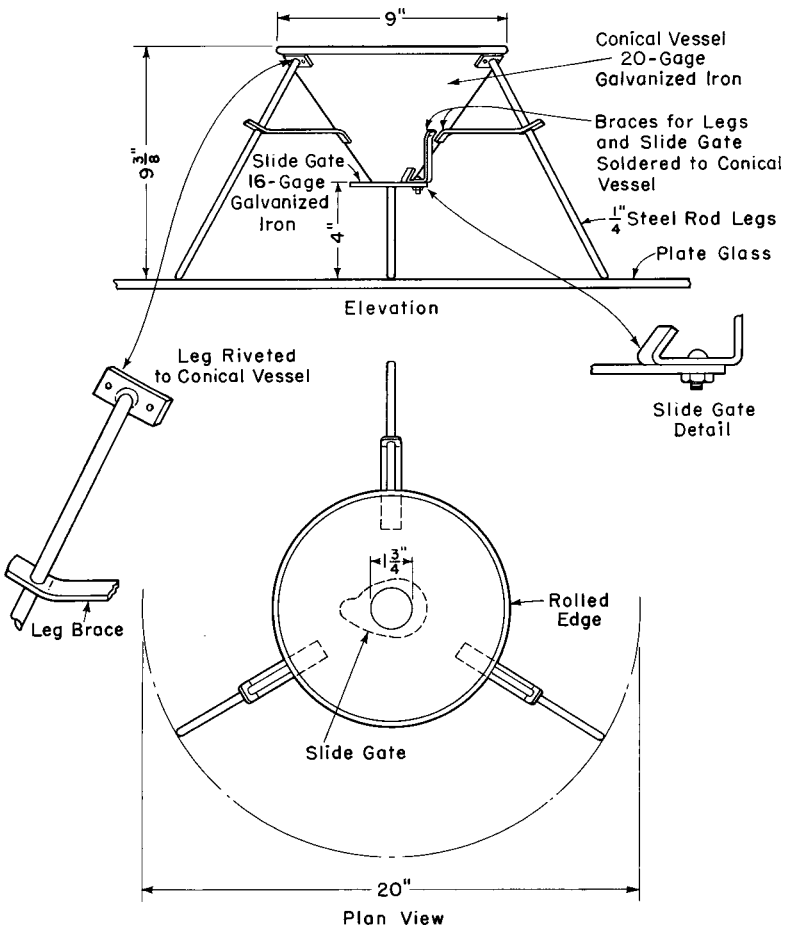

FIG. 2 Consistometer

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9.2.1 *Consistometer (*Fig. 2*)*—The consistometer consists of a conical vessel made of noncorroding, nonabsorbent material, and having an inside diameter of 9 in. (229 mm) at the top and 1¾ in. (44.5 mm) at the bottom, and a height of 5½ in. (139.7 mm). It shall be provided with a sliding gate at the bottom and supported so that the bottom is 4 in. (102 mm) above the base plate. The base plate shall be of plate glass, free of scratches and about 18 in. (457 mm) square.

9.2.2 *Balance*, capable of weighing not less than 2000 g at a precision of 1 g.

9.3 *Procedure*:

9.3.1 Clean and dry the consistometer and the base plate and close the sliding gate.

9.3.2 Sift 2000 g of the sample into a known volume of water (see 5.1) to which 1.0 g of sodium citrate has previously been added. After allowing the sample to soak for 1 min, stir the mixture for 3 min to an even fluidity. Pour the mixture into the consistometer until level with the top. Then rapidly and completely open the sliding gate, allowing the mixture to run out onto the base plate. When the sliding gate is opened, take care to avoid jarring the consistometer.

9.3.3 Measure the resulting patty along its major and minor axes and determine the average diameter.

9.3.4 Test gypsum concrete with different amounts of water until a patty diameter of 380 ± 13 mm (15 ± ½ in.) is obtained.

9.4 *Report*—Report the normal consistency as the number of millilitres of water to the nearest whole millilitre required to be added to 100 g of the gypsum concrete.

9.5 *Precision and Bias*—The precision and bias of the test method for normal consistency of gypsum concrete have not been determined.

10. Setting Time

10.1 *Significance and Use*—This test method is used to determine the setting time of gypsum plaster and gypsum concrete, and is used to determine compliance with gypsum plaster and gypsum concrete specifications. Since variable job conditions influence the setting time, the degree of correlation between this test method and service performance has not been determined.

10.1.1 This test method does not determine the time of complete hydration of gypsum plaster or gypsum concrete. To determine the time of complete hydration see Setting Time, (Temperature Rise Method,) Section 11.

10.2 *Apparatus*:

10.2.1 *Vicat Apparatus*—The Vicat apparatus (Fig. 3) shall consist of a frame, *A*, bearing a movable rod, *B*, weighing 300 g, one end, *C*, the plunger end, being 10 mm in diameter for a distance of not less than 50 mm, the other end having a removable needle, *D*, 1 mm in diameter and 50 mm in length. The rod, *B*, shall be reversible, shall be able to be held in any position by a screw, *E*, and shall have an adjustable indicator, *F*, that moves over a scale (graduated in millimetres) attached to the frame, *A*. The paste shall be held in a rigid conical ring, *G*, resting on a glass plate, *H*, about 100 mm square. The ring shall be made of a noncorroding, nonabsorbent material and shall have an inside diameter of 70 mm at the base and 60 mm at the top, and a height of 40 mm.

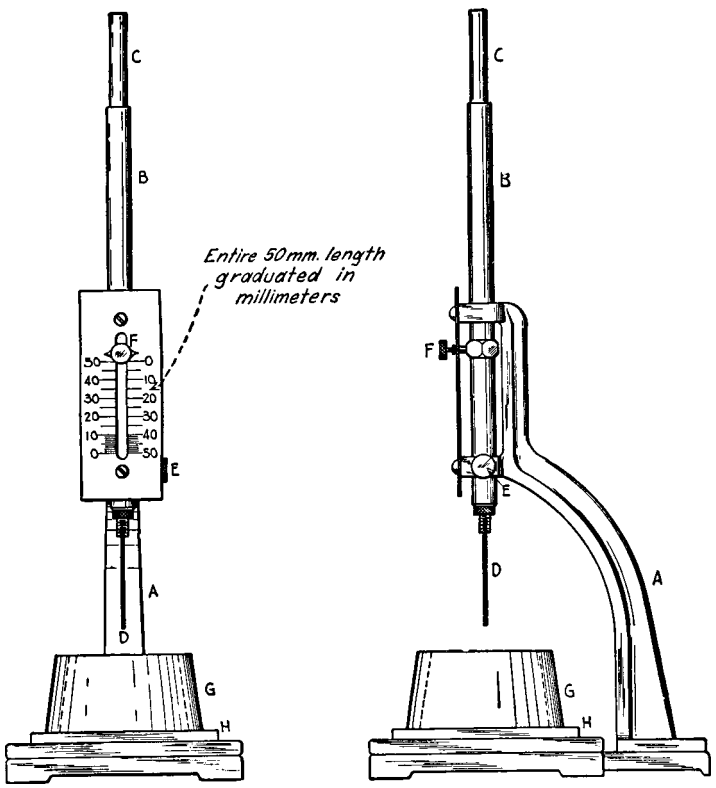

FIG. 3 Vicat Apparatus

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10.2.2 In addition, the Vicat apparatus shall conform to the following requirements:

Weight of plunger	300 ± 0.5 g
Diameter of larger end of plunger	10 ± 0.05 mm
Diameter of needle	1 ± 0.05 mm
Inside diameter of ring at bottom	70 ± 3 mm
Inside diameter of ring at top	60 ± 3 mm
Height of ring	40 ± 1 mm
Graduated scale	The graduated scale, when compared with a standard scale accurate to within 0.1 mm at all points, shall not show a deviation at any point greater than 0.25 mm.

NOTE 6—Automatic setting time apparatus are commercially available and may be used provided they can be shown to give the same results as the specified apparatus and procedure.

10.2.3 *Balance*, capable of weighing not less than 500 g at a precision of 0.1 g.

10.2.4 *Stopwatch or Clock*, for determining setting time.

10.2.5 *Temperature and Humidity Controlled Cabinet*, capable of maintaining a temperature of 21 ± 1°C (70 ± 2°F) and a relative humidity of not less than 85 %.

10.3 *Procedure*:

10.3.1 *Gypsum Concrete and All Gypsum Plasters, Except Gypsum Neat Plaster*—Start the timing of the test approximately at the moment of contact of the dry material with the water (see 5.1). Mix enough paste to fill the conical ring. For the quantity of water and directions for mixing, see Section 8, but do not add retarder. Place the conical ring on the base plate and fill the ring with the paste level with the top of the ring. Position the end of the needle so that it just touches the top surface of the paste and tighten the screw. Release the screw so that the needle falls freely into the paste. After each penetration, wipe the needle clean, and move the base plate and ring slightly so that the needle will not strike the same place twice. Test the sample at intervals according to the table in 10.3.3. Setting time is complete when the needle no longer penetrates to the bottom of the paste. When setting times are expected to be longer than ½ h, store the test specimens in the cabinet described in 10.2.5.

10.3.2 *Gypsum Neat Plaster*—Test gypsum neat plaster for setting time as mixed with three parts by weight of standard sand (see 5.2). Mix dry a 100-g sample of the gypsum neat plaster and 300 g of the sand, and then add sufficient water to produce a normal consistency. For the quantity of water (see 5.1) and mixing instructions, see Section 8, but do not use retarder. Stir for 1 min to an even, lump-free consistency. Place the mortar in the conical ring and test for setting time as described in 10.3.1

10.3.3 *Frequency of Testing*—Test the materials according to the following schedule:

Kind of Material	First Test	Frequency of Subsequent Tests
Molding plaster	15 min	5 min
Keene's cement:		
Standard	15 min	1 h
Quick set	15 min	5 min
Gypsum concrete	15 min	5 min
Ready mixed plaster	1½ h	1 h
Neat plaster	2 h	1 h
Wood-fibered plaster	1½ h	1 h
Bond plaster	1½ h	1 h
Gauging plaster:		
Slow set	40 min	2 h
Quick set	15 min	5 min

10.4 *Report*—Report the setting time as the elapsed time in minutes from the time when the sample was first added to the water to the time when set is complete.

10.5 *Precision and Bias*—The precision and bias for the setting time test method have not been determined.

11. Setting Time (Temperature Rise Method)

11.1 *Significance and Use*:

11.1.1 This test method determines the hydration time by measuring the maximum temperature rise of gypsum plaster or gypsum concrete. The temperature rise is caused by the reaction of calcium sulfate hemihydrate with water to form calcium sulfate dihydrate. It is assumed that the maximum temperature rise coincides with the completion of the reaction. This test method is not used to determine compliance with specifications for gypsum plaster or gypsum concrete unless it is specified in the purchase contract.

11.1.2 The setting time determined by this test method is usually longer than the setting time determined in Section 10.

11.1.3 The degree of correlation between this test method and service performance has not been determined.

11.2 *Apparatus*:

11.2.1 *Potentiometer*—A single- or multiple-channel recording potentiometer or thermistor bridge shall be used to record the temperature change of the sample under test. The chart speed shall be not less than 1 in. (25 mm)/h. Imprints recording the temperature shall not be longer than 1 min apart for each sample.

11.2.2 *Temperature Sensors*—Temperature changes shall be indicated by either thermocouples or thermistors which shall be movable or in a fixed position. Temperature sensing elements shall be of such capacity and sensitivity that, when connected to the recording potentiometer, a temperature change of 0.5°C (1°F) in the sample shall be recorded on the chart.

11.2.3 *Sample Cups*—Cups with a capacity of 175 to 275 mL (6 to 9 oz) shall be used. The cup containing the mixture under test shall be placed inside a matching cup held in an insulated block or beaker, as specified in 11.2.4. The temperature sensor, in this case, shall be positioned 25 to 33 % of the distance up from the bottom and between the inner and outer cup. Alternately, the cup containing the test mixture shall be positioned over a spring-loaded sensor to ensure close contact with the bottom of the cup.

11.2.4 *Insulated Block or Beaker*, with walls and bottom having a thermal resistance of not less than R6 (1.1 ($m^2 \cdot K$)/W) (6 ($h \cdot ft^2 \cdot °F$)/Btu), and a centered cavity into which the sample cup fits snugly.

NOTE 7—An insulating block may be constructed from a block of expanded polystyrene. Carve a cavity in the block so that the sample cup fits snugly, leaving walls and bottom not less than 40 mm (1.5 in.) thick. An insulating beaker may be made by stuffing glass fiber or mineral wool insulation not less than 50.8 mm (2 in.) thick around the sample container and within the walls of a beaker. The insulated block or beaker should have an insulated cover of the same insulating material through which the temperature probe can extend into the test material.

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11.3 *Test Conditions*— Perform tests in a room or cabinet maintained at a temperature of 21 ± 1.1°C (70 ± 2°F). Maintain materials and mixing water used for the test at a temperature of 21 ± 1.1°C (70 ± 2°F).

NOTE 8—If a constant-temperature cabinet is not available, a constant-temperature water bath may be fitted with a cover which will admit the body of the cup holder but not its rim, so that the cup holder is in contact with the water in the bath.

11.4 *Procedure*:

11.4.1 *Gypsum Concrete and All Gypsum Plasters, Except Gypsum Neat Plaster*—Start the timing of the test at the moment of contact of the dry material with the water. Mix approximately 200 g of the sample to make a paste of normal consistency. Place the paste in a clean dry sample cup to about 20 mm (¾ in.) from the top. Place the filled cup in an empty cup in the insulated block or beaker and adjust the sensing element as required in 11.2.3. Cover the cup with a watch glass or plastic film or cover the surface of the paste with mineral oil to a depth of approximately 5 mm (¼ in.).

11.4.2 *Gypsum Neat Plaster*—Prepare the plaster in accordance with 10.3.2 and test in accordance with 11.4.1.

11.5 *Report*—Report the setting time as the elapsed time in minutes from the time when the sample was first added to the water to the time when maximum temperature rise is attained.

11.6 *Precision and Bias*—The precision and bias for the setting time, temperature rise method, have not been determined.

12. Compressive Strength

12.1 *Significance and Use*—This test method is used to determine the compressive strength of gypsum plaster and gypsum concrete and is used to determine compliance with applicable specifications. The correlation between this test method and service performance has not been determined.

12.2 *Apparatus*:

12.2.1 *Specimen Molds*—Molds for making test specimens shall be 2-in. (50.8 mm) split cube molds made of noncorrodible material and shall be sufficiently rigid to prevent spreading during molding. The molds shall have not more than three cube compartments and shall be separable into not more than two parts. When assembled, the parts of the molds shall be held firmly together, and dimensions shall conform to the following requirements: Interior faces shall be plane surfaces with a maximum variation of 0.001 in. (0.03 mm) for new molds and 0.002 in. (0.05 mm) for old molds; distance between opposite faces, and height of the molds, measured separately for each cube compartment, shall be 2 ± 0.005 in. (50.8 ± 0.13 mm) for new molds or 2 ± 0.020 in. (50.8 ± 0.51 mm) for old molds, angle between adjacent interior faces and between interior faces and top and bottom planes of the mold shall be 90 ± 0.5°, measured at points slightly removed from the intersection of the faces.

12.2.2 *Testing Machine*, either the hydraulic or the screw type, with sufficient opening between the upper bearing surface and the lower bearing surface of the machine for the use of verifying apparatus. The load applied to the test specimen shall be indicated with an accuracy of ±1.0 %. The load indicating device shall have a means of indicating maximum load. The upper bearing shall be a spherically seated, hardened metal block firmly attached at the center of the upper head of the machine. The center of the sphere shall lie at the center of the surface of the block in contact with the specimen. The block shall be free to tilt in any direction. A hardened metal bearing block shall be used beneath the specimen to minimize wear of the lower platen of the machine. The lower bearing block shall have concentric circles at ¼-in. intervals centered on the block to facilitate accurate centering of the test specimen. The bearing block surfaces intended for contact with the specimen shall have a Rockwell hardness number not less than 60 HRC. These surfaces shall not depart from plane surfaces by more than 0.0005 in. (0.013 mm) when the blocks are new and 0.001 in. (0.025 mm) after use.

12.2.3 *Drying Oven*, a mechanical convection oven maintained at a temperature of 45 ± 3°C and a relative humidity not more than 50 %.

12.2.4 *Desiccator*, containing magnesium perchlorate or calcium chloride that is capable of being tightly sealed and of such a size as to hold not less than one set of 6 cubes.

12.3 *Test Specimens*:

12.3.1 Mix sufficient sample at normal consistency to produce not less than 1000 mL (34 fluid oz) of mixed mortar and cast into six specimen molds (see 12.2.1). Premix neat gypsum plaster dry with two parts by weight of standard sand (see 5.2). For the quality and quantity of water, see 5.1 and Section 8, but do not add retarder. Place the required amount of water in a clean 2-L (2-qt) mixing bowl.

12.3.2 For all gypsum plasters except gypsum concrete, add the required amount of dried plaster and allow to soak for 2 min. Mix vigorously (about 150 complete circular strokes per minute) for 1 min with a metal spoon, stiff-bladed spatula or mechanical mixer (see Note 9) to produce a mortar of uniform consistency. For gypsum concrete, soak for 1 min, and stir vigorously (about 150 complete circular strokes per minute) with a large spoon or mechanical mixer for 3 min. Setting time of the mortar, as determined by Sections 10-10.5, shall be within the time limits shown in Table 1.

NOTE 9—The Hobart N-50 mixer has been found satisfactory for this purpose.

12.3.3 If setting times as determined in accordance with Section 10 are more than the maximum limits shown in Table 1, discard the cubes and adjust the setting time by adding

TABLE 1 Setting-Time Limits for Mortar

Kind of Material	Setting Time, min	
	min	max
Molding plaster	20	140
Keene's cement:		
Standard	40	120
Quick set	20	40
Gypsum concrete	20	40
Ready-mixed plaster	90	120
Neat plaster (with 2 parts sand)	120	150
Wood-fibered plaster	90	120
Bond plaster	120	150
Gauging plaster:		
Slow set	40	120
Quick set	20	40
Veneer plaster	30	90

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freshly ground gypsum accelerator to the plaster, or add molding plaster to Keene's cement. Do not use more gypsum accelerator or molding plaster than 1 % of the dry weight of plaster or Keene's cement.

12.3.4 Coat the molds with a thin film of mineral oil or other mold release agent and place on an oiled glass or metal plate. Place a layer of mortar about 25 mm (1 in.) in depth in each mold and puddle ten times across the mold between each pair of opposite faces with a 25 mm (1 in.) wide spatula to remove air bubbles. Fill the molds to a point slightly above the tops of the molds, by the same filling and puddling procedure used for the first layer. Also fill the conical mold for the Vicat apparatus described in 10.2.1 and 10.2.2 and determine the setting time (see 10.3). As soon as the mortar or paste has set, cut off the excess to a plane surface flush with the top of the mold, using a stiff broad knife or similar implement.

12.3.5 Place the filled molds in moist air (90 to 100 % relative humidity). Remove the cubes from the molds at any time after they are thoroughly hardened, but retain in the moist air for not less than a total of 16 h. Place the cubes in an oven as specified in 12.2.3. Dry until successive weights are identical to 0.1 g (or differ by no more than 0.1 g). Then place the cubes in a desiccator as described in 12.2.4 for a minimum of 16 h before testing. Test the cubes immediately on removal from the desiccator.

12.4 *Procedure*—As soon as the cube specimens have been dried (12.3), determine their compressive strengths. (If density is to be determined, do so at this time. (See Section 13)). Position the cubes in the testing machine so that the load is applied on surfaces formed by faces of the molds, not on top and bottom. Apply the load continuously and without shock, at a constant rate within the range 15 to 40 psi/s. Do not exceed 40 psi/s ((275 kPa)/s) after 50 % of the maximum load has been reached.

12.5 *Report*—Report the average compressive strength as the compressive strength of the material, in psi (Mpa) rounded to the nearest whole psi (0.1 Mpa) except that if the strengths of one or two of the cubes vary more than 15 % from the average of the six, discard them and report the compressive strength as the average of the remaining specimens. In case the compressive strengths of three or more cubes vary more than 15 % from the average, discard the results and repeat the test.

12.6 *Precision and Bias*—The precision and bias for the compressive strength test method have not been determined.

13. Density

13.1 *Significance and Use*—This test method is used to determine the density of cast gypsum concrete and is used to determine compliance with the specification for gypsum concrete. The correlation between this test method and service performance has not been determined.

13.2 *Apparatus*:

13.2.1 *Balance*, capable of weighing not less than 1500 g to the nearest gram.

13.3 *Procedure*—Determine the density of gypsum concrete by weighing the six cubes to the nearest gram after drying and cooling, as described in 12.3.4, and before determining the compressive strength.

13.4 *Calculation*—Calculate the density by multiplying the total weight of the six cubes by 0.0794.

13.5 *Report*—Report the density in pounds per cubic foot to the nearest 1 lb/ft^3 (10 kg/m^3).

13.6 *Precision and Bias*—The precision and bias for the density test method have not been determined.

14. Keywords

14.1 compressive strength; density; free water; fineness; gypsum; gypsum concrete; gypsum plasters; normal consistency; setting time

APPENDIX

(Nonmandatory Information)

X1. ALCOHOL WASH METHOD OF SIEVING GYPSUM AND GYPSUM PRODUCTS

X1.1 Scope

X1.1.1 This appendix covers a sieve test for fine gypsum and gypsum products using an alcohol wash method.

X1.2 Significance and Use

X1.2.1 It is impractical to sieve dry gypsum through a fine sieve, and water cannot be used as a washing agent without introducing errors due to hydration or solution. This method is used when a purchase order specifies fineness through fine sieves.

X1.3 Apparatus

X1.3.1 Sieves, complying with Specification E 11.

X1.3.2 Mechanical Sieving Machine.

X1.3.3 Vessel, with a diameter not less than 50 mm greater than the sieves, and a depth not less than 75 mm greater than the height of the sieves.

X1.3.4 Balance, capable of reading to a precision of 0.01 g.

X1.4 Reagents

X1.4.1 Isoprophyl alcohol, 99%. The alcohol may be reused after decanting or filtering, provided its strength does not fall below 95%

X1.4.1.1 **Caution—**When using isoprophyl alcohol, keep fire away, provide good ventilation, and avoid excessive inhalation of vapor.

X1.5 Calibration and Standardization

X1.5.1 See 7.3.2 for method of calibrating a mechanical sieving machine.

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X1.6 Procedure

X1.6.1 Place the alcohol in a vessel (X1.3.3) to a depth of 50 mm more than the height of the sieve. Weigh approximately 50 g of the sample to a precision of 0.01 g and place on a 45-μm or coarser sieve up to and including the 150 μm (No. 100).

X1.6.2 Lower the sieve into the alcohol until the specimen is wetted throughout. Lift the sieve out of the alcohol, with a swirling motion, permitting the alcohol to drain through the specimen back into the vessel. Repeat this operation not less than eight times, until the alcohol passes freely through the sieve and the specimen is essentially free from fines. Wash the residue retained on the sieve with about 100 mL of clear alcohol, and then blot the bottom of the sieve with a soft, dry, lint-free cloth. Dry the sieve containing the residue at 45 ± 3°C.

X1.6.3 Shake the sieve on a mechanical shaker for 2 min ± 2 s. If desired, to permit simultaneous determinations of coarser fractions, transfer the residue after drying and before shaking to a series of coarser sieves up to and including the 150 μm nested in sequential order above the 45-μm sieve. Weigh the material retained on each sieve to the nearest 0.01 g.

X1.7 Calculation

X1.7.1 Calculate the percent of the original specimen retained on or through each sieve as follows:

$$\%\ retained = (B/A) \cdot 100$$

$$\%\ through = \frac{A - B}{A} \cdot 100$$

where:

A = Weight of original specimen, and
B = weight of specimen retained on sieve.

X1.8 Report

X1.8.1 Report the percent retained or through each sieve to the nearest 0.1 percent.

X1.9 Precision and Bias

X1.9.1 The precision and bias of the alcohol wash method of sieving gypsum and gypsum products has not been determined.

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Designation: C 473 – 09

Standard Test Methods for Physical Testing of Gypsum Panel Products[1]

This standard is issued under the fixed designation C 473; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope*

1.1 These test methods cover the physical testing of gypsum panel products.

1.2 The test methods appear in the following order:

	Section
Flexural Strength (Method A)	7
Core, End and Edge Hardness (Method A)	8
Nail Pull Resistance (Method A)	9
Flexural Strength (Method B)	11
Core, End and Edge Hardness (Method B)	12
Nail Pull Resistance (Method B)	13
Humidified Deflection	14
End Squareness	15
Nominal Thickness	16
Recessed- or Tapered Edge Depth	17
Width	18
Length	19
Water Resistance of Core-Treated Water-Repellent Gypsum Panel Products	20
Surface Water Resistance of Gypsum Panel Products with Water-Repellent Surfaces	21

1.3 The values stated in inch-pound units are to be regarded as standard. The values given in parentheses are mathematical conversions to SI units that are provided for information only and are not considered standard.

1.4 The text of these test methods references notes and footnotes that provide explanatory material. These notes and footnotes, excluding those in tables and figures, shall not be considered as requirements of these test methods.

1.5 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

2. Referenced Documents

2.1 *ASTM Standards:*[2]

C 11 Terminology Relating to Gypsum and Related Building Materials and Systems

D 3285 Test Method for Water Absorptiveness of Nonbibulous Paper and Paperboard (Cobb Test)

E 4 Practices for Force Verification of Testing Machines

E 177 Practice for Use of the Terms Precision and Bias in ASTM Test Methods

E 691 Practice for Conducting an Interlaboratory Study to Determine the Precision of a Test Method

3. Terminology

3.1 Definitions used in these test methods are in accordance with Terminology C 11.

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *edge*, *n*—the paper-bound edge, or long edge, as manufactured.

3.2.2 *ends*, *n*—the end perpendicular to the paper-bound edge or long edge.

4. Sampling

4.1 For use in these test methods, a sample shall consist of not less than 0.25 % of the number of gypsum panel products in a shipment, but not less than three gypsum panel products. Test specimens shall be taken from the sample lot as indicated in each method.

5. Conditioning

5.1 Condition specimens to constant weight at a temperature of 85 ± 15 °F (29.5 ± 8.5 °C) and relative humidity of 50 ± 2 % (Note 1). Test specimens individually after constant weight is reached and within 10 min upon removal from the conditioning chamber.

NOTE 1—Laboratory test results indicated that conditioning temperatures may range from 70 to 100 °F (21 to 38 °C) without significantly affecting the results. However, relative humidity is critical. This is the reason for testing specimens within 10 min upon removal from the conditioning chamber.

[1] These test methods are under the jurisdiction of ASTM Committee C11 on Gypsum and Related Building Materials and Systems and are the direct responsibility of Subcommittee C11.01 on Specifications and Test Methods for Gypsum Products.

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[2] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

***A Summary of Changes section appears at the end of this standard.**

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Method A—Constant Rate of Loading

INTRODUCTION

The following procedures are applicable to so-called "shot machines" that utilize lead or steel shot that applies a load to the specimen at a constant stress rate or any other device that applies the load at a constant stress rate.

6. Apparatus—Method A

6.1 *Testing Machine*—Apply the test load at a uniform rate of 1 lbf/s (4.45 N/s) ±10 %. Apply the load with a device independent of manual control of the rate of loading during an individual sample test (see Fig. 1). The deformation of the specimen controls the cross head speed.

7. Flexural Strength (Method A)

7.1 *Summary of Test Method*—Flexural properties of gypsum panel products are evaluated by supporting the specimen near the ends and applying a transverse load midway between the supports.

7.2 *Significance and Use*—This test method covers a procedure for evaluating the ability of gypsum panel products to withstand flexural stresses during handling or use of the material. This test method is used to determine compliance with gypsum panel product specifications. The degree of correlation between this test and service performance has not been fully determined.

7.3 *Apparatus*—See Section 6.1.

7.3.1 *Specimen Supports*—All specimen bearing supports and load surfaces shall be true, shall engage the full width of the test specimen, shall be of such strength they will not deform under the test load, and shall be rounded to a radius of 0.125 in. (3.2 mm). The specimen supports shall be spaced 14 ± 0.016 in. (356 ± 0.41 mm) on centers measured at the points of surface contact with the specimen. The supports shall be attached to a plate that shall be rigidly attached to the test apparatus. The supports shall be parallel to each other and perpendicular to the long dimension of the test specimen. The bearing surface of the end supports shall be on the same plane to ensure contact along the entire bearing surfaces. Supports shall be not less than 12 in. (305 mm) in length. When a load is being applied, the loading bar shall be in contact with the full width of the specimen. The load-bearing surface shall be parallel to the bearing surface of the specimen supports. The specimen and supports shall be located so that the vertical axis through the center of the load-bearing surface passes through the specimen at one half of the specimen width and one half of the distance between the supports.

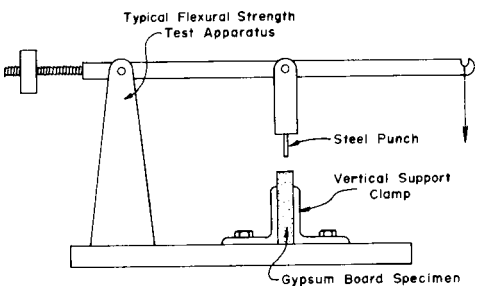

FIG. 1 Apparatus Schematic for Core, End, and Edge Hardness Test

7.4 *Sampling*—Sampling shall be in accordance with Section 4.

7.5 *Test Specimens*:

7.5.1 Cut four specimens, each 12 in. (305 mm) by approximately 16 in. (406 mm) from each gypsum panel product in the sample, two having the 16-in. dimension parallel to the edge and two having the 16-in. dimension perpendicular to the edge. Cut the specimens not less than 4 in. (102 mm) away from the ends and edges of the gypsum panel product except where the product is 24-in. or less in width, where it is impossible to do so.

7.5.2 Condition specimens in accordance with Section 5.

7.6 *Procedure*:

7.6.1 Use the apparatus in 7.3, supporting each specimen centrally on the fixed parallel bearings, 14-in. (356 mm) on centers, and apply the load on a similar bearing midway between the supports. Position perforated gypsum lath so the load is not applied over perforations.

7.6.2 For specimens with the long dimension parallel to the edge, test one specimen from each gypsum panel product face up and the other face down. For specimens with the long dimension perpendicular to the edge, test one specimen from each gypsum panel product face up and the other face down.

7.6.3 For gypsum panel products with surfacing material, the load is determined at the time of transverse failure of the surfacing material and core through the thickness of the specimen. The specimens shall not show a break in the bond between the surfacing and the core before transverse failure of the gypsum panel product. If a single specimen fails, test two additional specimens from the same sample, and, if either one of the two specimen fail, the sample has failed. For gypsum panel products without surfacing material, the load is determined at the time of transverse failure through the thickness of the specimen.

7.7 *Report*—Calculate and report the average breaking load in pound-force or newtons for each test condition, rounded to the nearest 1 lbf (N). The test conditions are: (*1*) parallel, face up; (*2*) parallel, face down; (*3*) perpendicular, face up; and, (*4*) perpendicular, face down.

7.8 *Precision and Bias*—See Section 22 and Tables 1 and 2.

8. Core, End, and Edge Hardness (Method A)

8.1 *Summary of Test Method*—The core, end, and edge hardness of gypsum panel products is evaluated by determining the force required to push a steel punch into the area of test.

8.2 *Significance and Use*—This test method covers a procedure for evaluating the ability of the gypsum panel product core, ends, and edges to resist crushing during handling or use of the material. This test method is used to determine compliance with gypsum panel product specifications. The degree of correlation between these test methods and service performance has not been determined.

8.3 *Apparatus*—See 6.1. Clamp or secure the specimen to the base of the test apparatus shown in Fig. 1 with the face of the specimen perpendicular to the base of the test apparatus and parallel to the movement of the steel punch. Secure the steel punch to the moving head of the test apparatus, positioned so

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TABLE 1 Parallel Flexural Strength, Method B (lbf) 5 Labs / 81 Data Points

Panel	Average[A]	Standard Deviation of the Sample Averages	Repeatability Standard Deviation	Reproducibility Standard Deviation	Repeatability Limit	Reproducibility Limit
	$\bar{\chi}$	$s_{\bar{\chi}}$	s_r	s_R	r	R
A	49.4871	6.3911	11.9766	12.6641	33.5344	35.4593
B	85.2847	5.4871	16.3279	16.3279	45.7180	45.7180
C	35.6045	4.3757	6.3969	7.2970	17.9112	20.4316

[A]The average of the laboratories' calculated averages.

TABLE 2 Perpendicular Flexural Strength, Method B (lbf) 7 Labs / 117 Data Points

Panel	Average[A]	Standard Deviation of the Sample Averages	Repeatability Standard Deviation	Reproducibility Standard Deviation	Repeatability Limit	Reproducibility Limit
	$\bar{\chi}$	$s_{\bar{\chi}}$	s_r	s_R	r	R
A	138.1732	3.8219	6.2402	6.8598	17.4725	19.2075
B	206.7995	7.4186	8.8020	10.9361	24.6457	30.6212
C	80.0015	1.9580	1.5868	2.4356	4.4431	6.8196

[A]The average of the laboratories' calculated averages.

that its center axis is parallel with the line of travel and so that the punch is inserted into the core equidistant from the surfaces of the specimen. Use a steel punch 0.099 ± 0.003 in. (2.515 ± 0.076 mm) in diameter and more than ½ in. (12.7 mm) long with the bearing surface machined to a 90° angle in reference to the punch center line (see Fig. 1 for test setup schematic).

8.4 *Sampling*—Sampling shall be in accordance with Section 4.

8.5 *Test Specimens*:

8.5.1 *Specimens for Core Hardness*—Using a table or band saw, cut one specimen from the center of each gypsum panel product sample approximately 12 by not less than 3 in. (305 by 76 mm), with the 12-in. dimension perpendicular to the edges of the products. The smaller, not less than 3 in., dimension will vary depending on the specific punch length and opening in the testing machines. Place the sample in the tester, with the loading arm in a horizontal position and with the punch resting on the specimen. Saw cuts along the 12-in. dimension shall be smooth and square with the smaller (not less than 3-in.) dimension, as well as with the specimen.

8.5.2 *Specimens for End Hardness*—Cut specimens the same size and method as described in 8.5.1 from one mill-cut end of the gypsum panel product, with the 12-in. (305-mm) dimension perpendicular to the edges and run tests only on the mill-cut end of the specimens.

8.5.3 *Specimens for Edge Hardness*—Cut specimens the same size and method as described in 8.5.1 from the opposite edges of each gypsum panel product, with the 12 in. (305 mm) dimension of the specimens parallel with the edges. For gypsum panel products with surfacing material, cut a ¼ to ½-in. (6 to 13-mm) strip of surfacing material from the edge of the test specimens exposing the core for test. Remove as little of the core as possible when removing the surfacing material. Prepare the first test area 2 ± ½ in. (51 ± 13 mm) from one edge of the specimen, with the next two test areas approximately 4 in. (102 mm) apart.

8.5.4 Condition specimens in accordance with Section 5.

8.6 *Procedure*—Using the apparatus in 8.3, clamp or secure the specimen in a fixed vertical position on its 12 in. (305 mm) dimension edge (see Fig. 1 for test setup schematic. If necessary, modify the flexural strength test equipment to conduct the core, end, and edge hardness test). Place this test surface not less than 1 in. (25 mm) above the grip of the specimen holder. Conduct three tests spaced approximately 4 in. (102 mm) apart on each specimen, with the first test area 2 ± ½ in. (51 ± 13 mm) from one edge of the specimen. Position the steel punch over the test area and apply the load. Report as the core, end, or edge hardness the load required to push the steel punch a distance of ½ in. (13 mm) into the core of the specimen.

8.6.1 *Procedure for Core Hardness*—Test in 3 locations on either of the 12-in. (305-mm) saw cut edges of each specimen.

8.6.2 *Procedure for End Hardness*—Test in 3 locations on the 12-in. (305-mm) mill-cut end of each specimen.

8.6.3 *Procedure for Edge Hardness*—Test in 3 locations along each of the two 12-in. (305-mm) edges. For products with surfacing material, test where the surfacing material has been removed.

8.7 *Report*—Report the core, end, and edge hardness individually as the average load in pounds-force or newtons rounded to the nearest 1 lbf (N). Discard any single test value that varies from the average by more than 15 % and repeat the test on the same sample to obtain a new value.

8.8 *Precision and Bias*—See Section 22 and Tables 3-5.

9. Nail Pull Resistance (Method A)

9.1 *Summary of Test Method*—The ability of gypsum panel products to resist nail pull-through is evaluated by determining the load required to push a standard nail head through the product.

9.2 *Significance and Use*—This test method covers a procedure for evaluating the ability of gypsum panel products to resist nail pull-through by determining the load required to force a standard nail head through the product. This test

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TABLE 3 Core Hardness, Method B (lbf) 10 Labs / 71 Data Points

Panel	Average[A]	Standard Deviation of the Sample Averages	Repeatability Standard Deviation	Reproducibility Standard Deviation	Repeatability Limit	Reproducibility Limit
	$\bar{\chi}$	$s_{\bar{\chi}}$	s_r	s_R	r	R
A	22.4517	3.6610	1.0726	3.7896	3.0032	10.6110
B	24.4100	1.4329	1.2323	1.8218	3.4505	5.1010
C	25.4926	N/A	0.6774	0.6774	1.8968	1.8968

[A]The average of the laboratories' calculated averages.

TABLE 4 End Hardness, Method B (lbf) 10 Labs / 60 Data Points

Panel	Average[A]	Standard Deviation of the Sample Averages	Repeatability Standard Deviation	Reproducibility Standard Deviation	Repeatability Limit	Reproducibility Limit
	$\bar{\chi}$	$s_{\bar{\chi}}$	s_r	s_R	r	R
A	27.2263	N/A	0.6353	0.6353	1.7790	1.7790
B	24.5387	1.8854	1.0977	2.1351	3.0737	5.9784

[A]The average of the laboratories' calculated averages.

TABLE 5 Edge Hardness, Method B (lbf) 10 Labs / 120 Data Points

Panel	Average[A]	Standard Deviation of the Sample Averages	Repeatability Standard Deviation	Reproducibility Standard Deviation	Repeatability Limit	Reproducibility Limit
	$\bar{\chi}$	$s_{\bar{\chi}}$	s_r	s_R	r	R
A	60.3630	N/A	9.3561	9.3561	26.1970	26.1970
B	60.7652	5.5456	7.6803	9.2100	21.5047	25.7880

[A]The average of the laboratories' calculated averages.

method is used to determine compliance with gypsum panel product specifications. The degree of correlation between these test methods and service performance has not been determined.

9.3 *Apparatus*—See 6.1. This apparatus shall be used with either of the specimen support plates in 9.3.1 or 9.3.2.

9.3.1 Fig. 2 shows a schematic of a nail pull resistance apparatus adaptable to a typical flexural strength apparatus commonly used in the gypsum industry. The specimen support plate shall have a 3-in. (76-mm) diameter hole in the center. The support plate shall be not less than 6 by 6 in. (152 by 152 mm). It shall be attached to the apparatus as necessary to maintain the surface of the plate perpendicular to the travel of the test nail. The support plate must also be located so that the vertical axis through the center of the nail shank passes through the center of the hole in the support plate. The test nail shank shall be 0.099 ± 0.003 in. (2.515 ± 0.076 mm) in diameter and the nail head shall be 0.250± 0.005 in. (6.350 ± 0.127 mm) in diameter. The nail shall be attached at the head to the movable cross head of the test apparatus. This attachment shall not exceed the diameter of the nail head and shall be placed directly over the head. It shall also be attached so that the vertical axis through the nail shank is parallel with the travel.

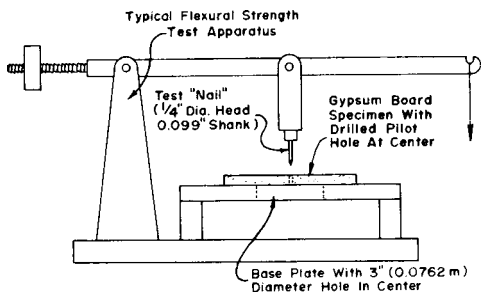

FIG. 2 Apparatus Schematic for Nail-Pull Resistance Test

9.3.2 Fig. 3 shows a schematic of an alternate nail pull resistance apparatus adaptable to a typical flexural strength apparatus commonly used in the gypsum industry. This apparatus mirrors all of the requirements of 9.3.1, except that the nail is not attached at the head to the movable cross head of the test apparatus. The alternate apparatus utilizes a machined plunger with the nail head and shank incorporated as an integral part of the plunger. The plunger fits into a bushing that keeps the nail aligned perpendicular to the test specimen. Manufacture the plunger to slide freely through the bushing without the application of any load.

NOTE 2—Other devices or means of allowing the plunger to move freely (such as collar bearings, etc.) are also acceptable.

9.4 *Sampling*—Sampling shall be in accordance with Section 4.

9.5 *Test Specimens*:

9.5.1 Cut five specimens 6 by 6 in. (152 by 152 mm) from a strip cut across the width of each 48-in. (1220-mm) gypsum panel product starting not less than 4 in. (102 mm) in from the edge. Cut a total of five specimens from more than one full width strip from gypsum panel products less than 38 in. (965 mm) wide. Do not cut the specimen closer than 3 in. (76 mm) from the product edges.

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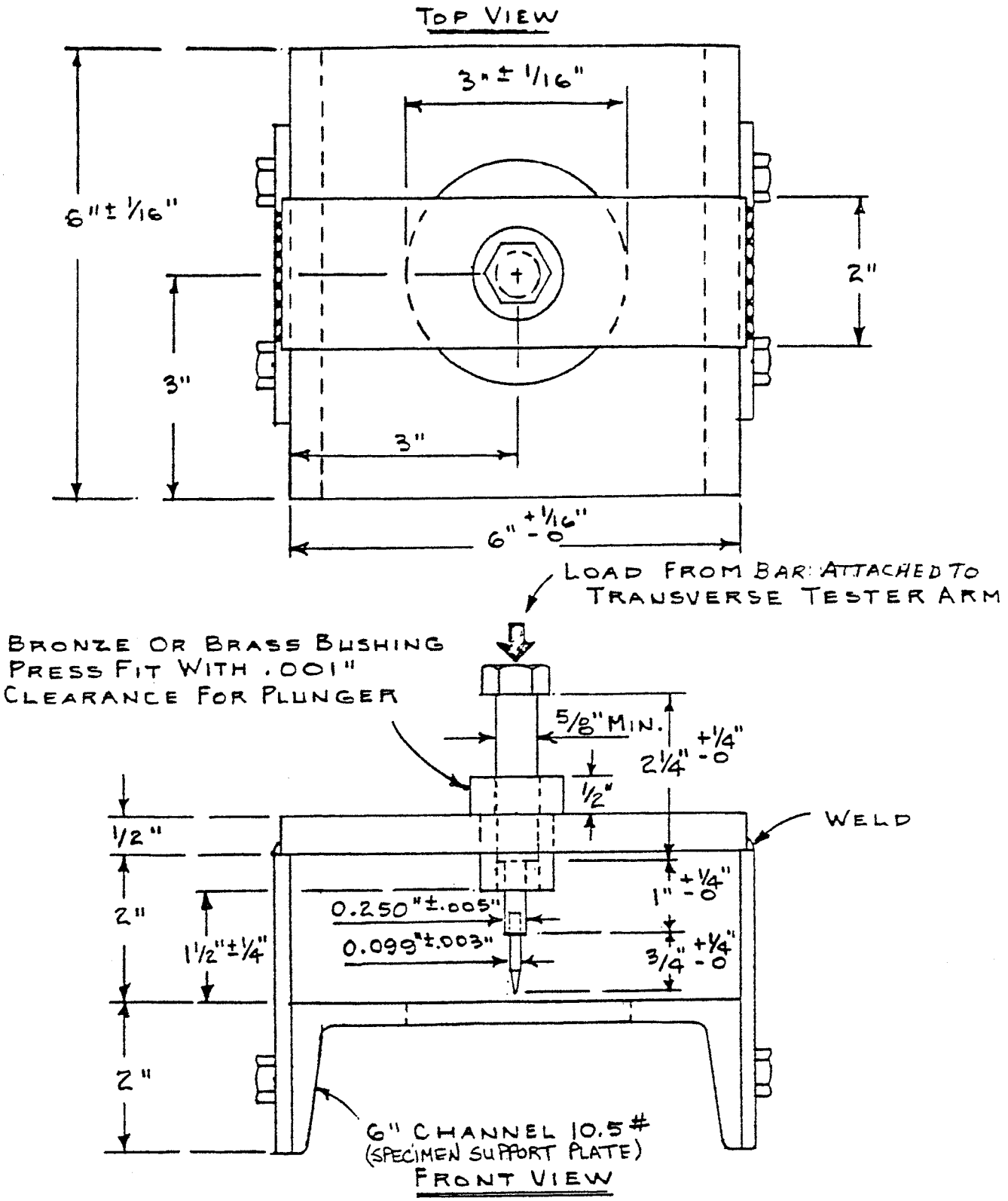

FIG. 3 Typical Nail Pull Specimen Support Plate

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9.5.2 Drill a 7⁄64-in. (2.778-mm) diameter pilot hole through the thickness of the gypsum panel product in the center of each test specimen and perpendicular to the surface.

9.5.3 Condition specimens in accordance with Section 5.

9.6 *Procedure*—Using the apparatus in 9.3, center the specimen face up on the base plate and manually lower the test nail, inserting the nail shank in the pilot hole, until the nail head is flush with the surface of the specimen. Apply the load until the maximum load is achieved. Normally, this will occur as the nail head breaks through the gypsum panel product surface.

9.7 *Report*—Calculate the average maximum load in pounds-force or newtons, rounded to the nearest 1 lbf (N). Discard any single test that varies from the average by more than 15 %. If more than 15 % of the test values are discarded, repeat the test.

9.8 *Precision and Bias*—See Section 22 and Table 6.

Method B—Constant Rate of Cross Head Speed

INTRODUCTION

The following procedures are applicable to so-called universal test machines. These instruments often use electronic load cells and data acquisition equipment to gather information about the specimen being tested. The instruments generally in use move the cross head at a constant speed, as opposed to having the deformation on the specimen control cross head speed, which would be a true constant rate of strain instrument.

10. Apparatus

10.1 *Testing Machine*, of any type that is of sufficient capacity and that is capable of providing a rate of loading at a strain rate of 1.0 in./min ± 5 s (25 mm/min ± 5 s). The load platform of the test equipment shall be of sufficient size to accept the specimen holder and load applying apparatus. The testing machine shall be power operated and shall apply the load continuously and without shock.

10.2 The test apparatus shall be verified according to Practices E 4, the three sections titled "Basis of Verification," "Corrections," and "Time Interval Between Verifications."

10.3 *Load-Indicating Equipment*, capable of reading to 1-lbf (4.45-N) increments, shall be provided for the test apparatus. A means shall be provided to indicate the maximum load attained during the test.

11. Flexural Strength (Method B)

11.1 *Summary of Test Method*—Flexural properties of gypsum panel products are evaluated by supporting the specimen near the ends and applying a transverse load midway between the supports.

11.2 *Significance and Use*—This test method covers a procedure for evaluating the ability of gypsum panel products to withstand flexural stresses during handling or use of the material. This test method is used to determine compliance with gypsum panel product specifications. The degree of correlation between this test and service performance has not been fully determined.

11.3 *Apparatus*—See Section 10.

11.3.1 *Specimen Supports*—All bearing supports and load surfaces shall be true, shall engage the full width of the test specimen, shall be of such strength they will not deform under the test load, and shall be rounded to a radius of 0.125 in. (3.2 mm). The specimen supports shall be spaced 14 ± 0.016 in. (356 ± 0.41 mm) on centers measured at the points of surface contact with the specimen. The supports shall be attached to a plate that shall be rigidly attached to the test apparatus. Test specimen supports shall be parallel to each other and perpendicular to the long dimension of the test specimen. The bearing surface of the end supports shall be on the same plane to ensure contact along the entire bearing surfaces. Supports shall be not less than 12 in. (305 mm) in length. When a load is being applied, the loading bar shall be in contact with the full width of the specimen. The load-bearing surface shall be parallel to the bearing surface of the specimen supports. The specimen and specimen supports shall be located so that the vertical axis through the center of the load-bearing surface passes through the specimen at one half of the specimen width and one half of the distance between the supports (see Fig. 4).

11.4 *Sampling*—Sampling shall be in accordance with Section 4.

11.5 *Test Specimen*:

11.5.1 Cut four specimens, each 12 in. (305 mm) by approximately 16 in. (406 mm) from each gypsum panel product in the sample, two having the 16-in. dimension parallel to the edge and two having the 16-in. dimension perpendicular to the edge. Cut the specimens not less than 4 in. (102 mm) away from the ends and edges of the gypsum panel product except where the product is 24-in. or less in width, where it is impossible to do so.

11.5.2 Condition specimens in accordance with Section 5.

11.6 *Procedure*:

11.6.1 Use the apparatus in 11.3, supporting each specimen centrally on the fixed parallel supports, 14-in. (356-mm) on centers, and apply the load on a similar bearing midway between the supports. Position perforated gypsum lath so the load is not applied over perforations.

11.6.2 For specimens with the long dimension parallel to the edge, test one specimen from each gypsum panel product face

TABLE 6 Nail Pull Resistance, Method B (lbf) 10 Labs / 180 Data Points

Panel	Average[A]	Standard Deviation of the Sample Averages	Repeatability Standard Deviation	Reproducibility Standard Deviation	Repeatability Limit	Reproducibility Limit
	$\bar{\chi}$	$s_{\bar{\chi}}$	s_r	s_R	r	R
A	76.7023	3.9561	2.8870	4.7536	8.0837	13.3100
B	87.5646	4.1139	2.6243	4.7606	7.3479	13.3296
C	59.3105	5.1849	2.6658	5.7275	7.4642	16.0371

[A]The average of the laboratories' calculated averages.

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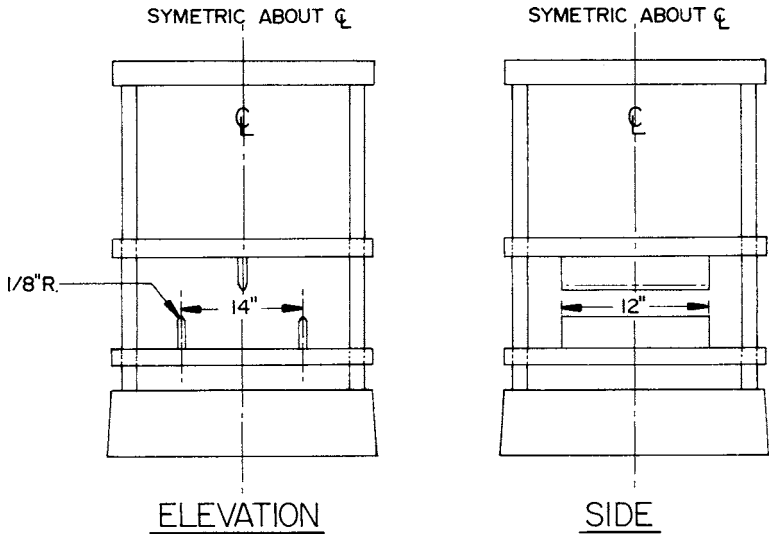

FIG. 4 Testing Machine

up and the other face down. For specimens with the long dimension perpendicular to the edge, test one specimen from each gypsum panel product face up and the other face down.

11.6.3 For gypsum panel products with surfacing material, the load is determined at the time of transverse failure of the surfacing material and core through the thickness of the specimen. The specimens shall not show a break in the bond between the surfacing and the core before transverse failure of the gypsum panel product. If a single specimen fails, test two additional specimens from the same sample, and, if either one of the two specimens fail, the sample has failed. For gypsum panel products without surfacing material, the load is determined at the time of transverse failure through the thickness of the specimen.

11.7 *Report*—Calculate and report the average breaking load in pounds-force or newtons for each test condition, rounded to the nearest 1 lbf (N). The test conditions are: (*1*) parallel, face up; (*2*) parallel, face down; (*3*) perpendicular, face up; and, (*4*) perpendicular, face down.

11.8 *Precision and Bias*:

11.8.1 *Precision*—The 95 % repeatability limit of the Parallel, Face Up (Method B) test is the test result ±4.796 lbf [21.33 N]. The 95 % reproducibility limit of the Parallel, Face Up (Method B) test is the test result ±8.992 lbf [40.00 N].

11.8.2 *Precision*—The 95 % repeatability limit of the Parallel, Face Down (Method B) test is the test result ±5.087 lbf [22.63 N]. The 95 % reproducibility limit of the Parallel, Face Down (Method B) test is the test result ±7.370 lbf [32.78 N].

11.8.3 *Precision*—The 95 % repeatability limit of the Across, Face Up (Method B) test is the test result ±10.290 lbf [45.77 N]. The 95 % reproducibility limit of the Across, Face Up (Method B) test is the test result ±13.368 lbf [59.46 N].

11.8.4 *Precision*—The 95 % repeatability limit of the Across, Face Down (Method B) test is the test result ±11.704 lbf [52.06 N]. The 95 % reproducibility limit of the Across, Face Down (Method B) test is the test result ±19.429 lbf [86.42 N].

11.8.5 *Bias*—No information can be presented on the bias of the procedure in these test methods for measuring the Flexural Strength (Method B) because there is no material having an accepted reference value.

12. Core, End, and Edge Hardness (Method B)

12.1 *Summary of Test Method*—The core, end, and edge hardness of gypsum panel products is evaluated by determining the force required to push a steel punch into the area of test.

12.2 *Significance and Use*—This test method covers a procedure for evaluating the ability of the gypsum panel product core, ends, and edges to resist crushing during handling or use of the material. This test method is used to determine compliance with gypsum panel product specifications. The degree of correlation between this test method and service performance has not been fully determined.

12.3 *Apparatus*—See Section 10.

12.3.1 A means of securing the specimen to the base of the test apparatus shall be provided. The face of the specimen shall be perpendicular to the base of the test apparatus and parallel to the movement of the steel punch. The steel punch shall be secured to the moving head of the test apparatus. It shall be positioned so that its center axis is parallel with the line of travel. It also shall be positioned so that the punch is inserted into the core equidistant from the surfaces of the specimen. The steel punch shall be 0.099 ± 0.003 in. (2.515 ± 0.076 mm) in diameter and more than ½ in. (12.7 mm) long with the bearing surface machined to a 90° angle in reference to the punch center line (see Fig. 5 and Fig. 6).

12.4 *Sampling*—Sampling shall be in accordance with Section 4.

12.5 *Test Specimens*:

12.5.1 *Specimens for Core Hardness*—Using a table or band saw, cut a specimen not less than 12 by 3 in. (305 by 76 mm) from the center of each gypsum panel product. The 12-in. (305-mm) dimension shall be perpendicular to the edges of the gypsum panel product. Cuts along the 12 in. (305 mm) dimension shall be smooth and perpendicular to the face of the specimen.

12.5.2 *Specimens for End Hardness*—Cut a specimen not less than 12 by 3 in. (305 by 76 mm) from one mill-cut end of

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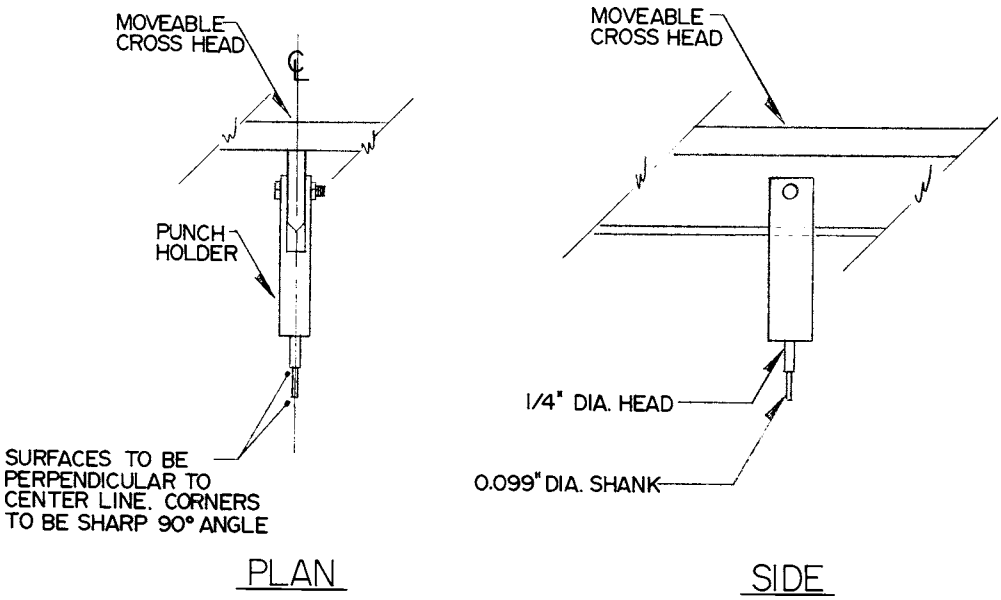

FIG. 5 Test Setup—Punch for Hardness and Nail Pull Resistance

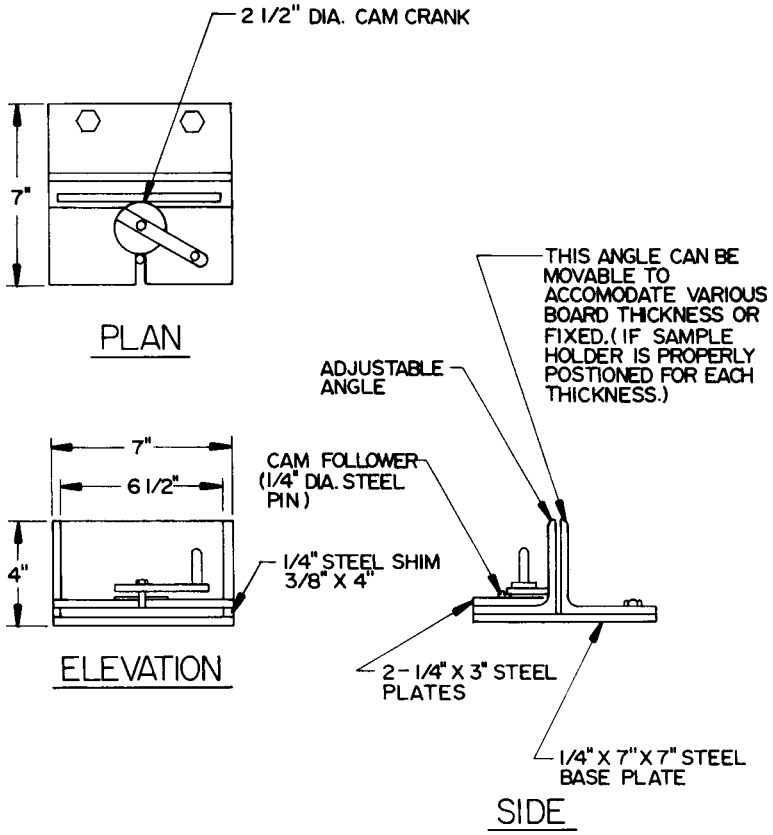

FIG. 6 Test Setup—Sample Holder for Hardness Test

each gypsum panel product. Cut the 12-in. (305-mm) dimension perpendicular to the edges of the gypsum panel product.

12.5.3 *Specimens for Edge Hardness*—Cut a specimen not less than 12 by 3 in. (305 by 76 mm) from each edge of each gypsum panel product. Cut the 12-in. (305-mm) dimension parallel to the edge of the gypsum panel product. For gypsum panel products with surfacing material, cut a ¼ to ½-in. (6 to 13-mm) strip of surfacing material from the edge of the test specimens exposing the core for test. Remove as little of the core as possible when removing the surfacing material. Prepare the first test area 2 ± ½ in. (51 ± 13 mm) from one edge of the specimen, with the next two test areas spaced approximately 4 in. (102 mm) apart.

12.5.4 Condition specimens in accordance with Section 5.

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12.6 *Procedure*—Using the apparatus in 12.3, clamp or secure the specimen in a fixed vertical position on its 12 in. (305 mm) dimension edge. If necessary, modify the flexural strength test equipment to conduct the core, end, and edge hardness test. Place this test surface not less than 1 in. (25 mm) above the grip of the specimen holder. After the specimen is in place, zero the load indicator. Conduct three tests spaced approximately 4 in. (102 mm) apart on each specimen, with the first test area 2 ± ½ in. (51 ± 13 mm) from one edge of the specimen. Position the steel punch over the test area and apply the load. Report as the core, end, or edge hardness the load required to push the steel punch a distance of ½ in. (13 mm) into the core of the specimen.

12.6.1 *Procedure for Core Hardness*—Test in 3 locations on either of the 12-in. (305-mm) saw cut edges of each specimen.

12.6.2 *Procedure for End Hardness*—Test in 3 locations on the 12-in. (305-mm) mill-cut end of each specimen.

12.6.3 *Procedure for Edge Hardness*—Test in 3 locations along each of the two 12-in. (305-mm) edges. For products with surfacing material, test where the surfacing material has been removed.

12.7 *Report*—Report the core, end, and edge hardness individually as the average load in pounds-force or newtons rounded to the nearest 1 lbf (N). Discard any single test value that varies from the average by more than 15 % and repeat the test on the same sample to obtain a new value.

12.8 *Precision and Bias*:

12.8.1 *Precision*—The 95 % repeatability limit of the End Hardness (Method B) test is the test result ±8.103 lbf [36.04 N]. The 95 % reproducibility limit of the End Hardness (Method B) test is the test result ±9.725 lbf [43.56 N].

12.8.2 *Precision*—The 95 % repeatability limit of the Core Hardness (Method B) test is the test result ±4.231 lbf [18.82 N]. The 95 % reproducibility limit of the Core Hardness (Method B) test is the test result ±9.668 lbf [43.01 N].

12.8.3 *Precision*—The 95 % repeatability limit of the Edge Hardness (Method B) test is the test result ±7.730 lbf [34.38 N]. The 95 % reproducibility limit of the Edge Hardness (Method B) test is the test result ±23.031 lbf [102.45 N].

12.8.4 *Bias*—No information can be presented on the bias of the procedure in these test methods for measuring the End, Core, and Edge Hardness because there is no material having an accepted reference value.

13. Nail Pull Resistance (Method B)

13.1 *Summary of Test Method*—The ability of gypsum panel products to resist nail pull-through is evaluated by determining the load required to push a standard nail head through the product.

13.2 *Significance and Use*—This test method covers a procedure for evaluating the ability of gypsum panel products to resist nail pull-through by determining the load required to force a standard nail head through the product. This test method is used to determine compliance with gypsum panel product specifications. The degree of correlation between these test methods and service performance has not been determined.

13.3 *Apparatus*—See Section 10. The apparatus shall be used with either of the specimen support plates in 13.3.1 or 13.3.2.

13.3.1 *Specimen Support Plate*, shall be true and have a 3-in. (76-mm) diameter hole in the center. The support plate shall be not less than 6 by 6 in. (152 by 152 mm). It shall be attached to the apparatus as necessary to maintain the surface of the plate perpendicular to the travel of the test nail. The support plate must also be located so that the vertical axis through the center of the nail shank passes through the center of the hole in the support plate. The test nail shank shall be 0.099 ± 0.003 in. (2.515 ± 0.076 mm) in diameter and the nail head shall be 0.250 ± 0.005 in. (6.350 ± 0.127 mm) in diameter. The nail shall be attached at the head to the movable cross head of the test apparatus. This attachment shall not exceed the diameter of the nail head and shall be placed directly over the head. It shall also be attached so that the vertical axis through the nail shank is parallel with the travel. See Figs. 5 and 7 for examples of the test setup configuration.

13.3.2 Fig. 3 shows a schematic of an alternate nail pull resistance apparatus adaptable to a typical flexural strength apparatus commonly used in the gypsum industry. This apparatus mirrors all of the requirements of 13.3.1, except that the nail is not attached at the head to the movable cross head of the test apparatus. The alternate apparatus utilizes a machined plunger with the nail head and shank incorporated as an integral part of the plunger. The plunger fits into a bushing that keeps the nail aligned perpendicular to the test specimen. Manufacture the plunger to slide freely through the bushing without the application of any load.

NOTE 3—Other devices or means of allowing the plunger to move freely (such as collar bearings, etc.) are also acceptable.

13.4 *Sampling*—Sampling shall be in accordance with Section 4.

13.5 *Test Specimens*:

13.5.1 Cut five specimens 6 by 6 in. (152 by 152 mm) from a strip cut across the width of each 48-in. (1220-mm) gypsum panel product starting not less than 4 in. (102 mm) in from the edge. Cut a total of five specimens from more than one full width strip from gypsum panel products less than 38 in. (965 mm) wide. Do not cut the specimen closer than 3 in. (76 mm) from the product edges.

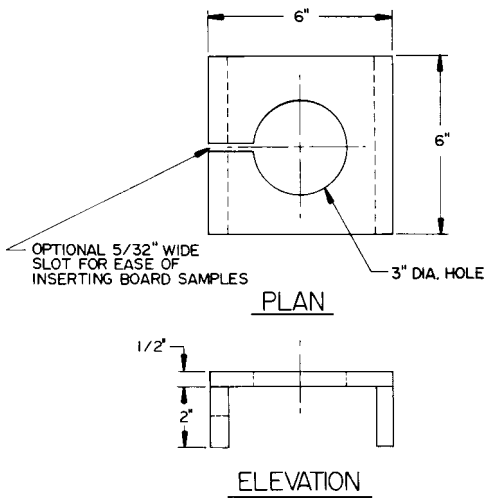

FIG. 7 Test Setup—Sample Holder for Nail Pull Resistance

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13.5.2 Drill a 7⁄64-in. (2.778-mm) diameter pilot hole through the thickness of the gypsum panel product in the center of each test specimen and perpendicular to the surface.

13.5.3 Condition specimens in accordance with Section 5.

13.6 *Procedure*—Using the apparatus in 13.3, place the specimen on the specimen support plate so that the drilled hole is aligned with the nail shank tip. After the specimen is in place, zero the load indicator. Insert the nail shank into the specimen hole and apply the load until the maximum load is achieved. Normally, this will occur as the nail head breaks through the gypsum panel product surface and is followed by a very significant decrease in load.

13.7 *Report*—Calculate the average maximum load in pounds-force or newtons, rounded to the nearest 1 lbf (N). Discard any single test that varies from the average by more than 15 %. If more than 15 % of the test values are discarded, repeat the test.

13.8 *Precision and Bias*:

13.8.1 *Precision*—The 95 % repeatability limit of the Nail Pull (Method B) test is the test result ±5.610 lbf [24.95 N]. The 95 % reproducibility limit of the Nail Pull (Method B) test is the test result ±8.961 lbf [39.86 N].

13.8.2 *Bias*—No information can be presented on the bias of the procedure in these test methods for measuring Nail Pull because there is no material having an accepted reference value.

14. Humidified Deflection

14.1 *Summary of Test Method*—The humidified deflection of gypsum panel products is evaluated by supporting a specimen that has been cut with the long dimension perpendicular to the machine direction, supported horizontally, and subjected to high humidity for 48 h.

14.2 *Significance and Use*—This test method covers a procedure for evaluating the deflection of gypsum panel products when horizontally suspended and subjected to high humidity. This test method is used to determine compliance with gypsum panel product specifications. Since job factors other than high humidity influence the deflection of gypsum panel products, the degree of correlation between this test method and service performance has not been determined.

14.3 *Apparatus*—A humidity cabinet of sufficient size to accommodate test specimens 12 by 24 in. (305 by 610 mm) capable of maintaining an atmosphere of 90 ± 3 °F (32 ± 1.7 °C) and 90 ± 3 % relative humidity for 48 h.

14.4 *Sampling*—Sampling shall be in accordance with Section 4.

14.5 *Test Specimens*:

14.5.1 Cut two specimens 12 by 24 in. (305 by 610 mm) from each gypsum panel product in the sample so the 12-in. dimension is parallel to the edges. Cut specimens not less than 12-in. away from the ends and edges of gypsum panel products 48 in. (1220 mm) or more in width. Cut specimens from the center of gypsum panel products that are narrower than 48 in. (1220 mm) as noted in Fig. 8.

14.5.2 Condition specimens in accordance with Section 5.

14.6 *Procedure*—Suspend each specimen face down on parallel and level bearing edges, having ⅛-in. (3.2-mm) radii, 12 in. (305 mm) long, and 23 in. (584 mm) apart in the humidity cabinet in an atmosphere of 90 ± 3 °F (32 ± 1.7 °C) and 90 ± 3 % relative humidity for 48 h. Measure the humidified deflection of each specimen, while suspended on the bearing edges, as the distance between a straightedge placed on the top end edges of the gypsum panel product and the upper surface of the product at its center. Take measurements to the nearest 1⁄16 in. (1.6 mm).

14.7 *Report*—Report the humidified deflection as the average of the specimens to the nearest ⅛ in. (3 mm).

14.8 *Precision and Bias*—See Section 22 and Table 7.

15. End Squareness

15.1 *Summary of Test Method*—The end squareness of gypsum panel products is evaluated by drawing a line perpendicular to the edge of a full width specimen to its opposite edge and measuring the length of the side of the triangle formed.

15.2 *Significance and Use*—This test method covers a procedure for determining the end squareness of gypsum panel products. This test method is used to determine compliance with gypsum panel product specifications. The degree of correlation between this test method and service performance has not been determined.

15.3 *Apparatus*—A T-shaped or L-shaped square for drawing or testing right angles. The long edge of the square shall be not less than 48 in.

15.4 *Sampling*—Sampling shall be in accordance with Section 4.

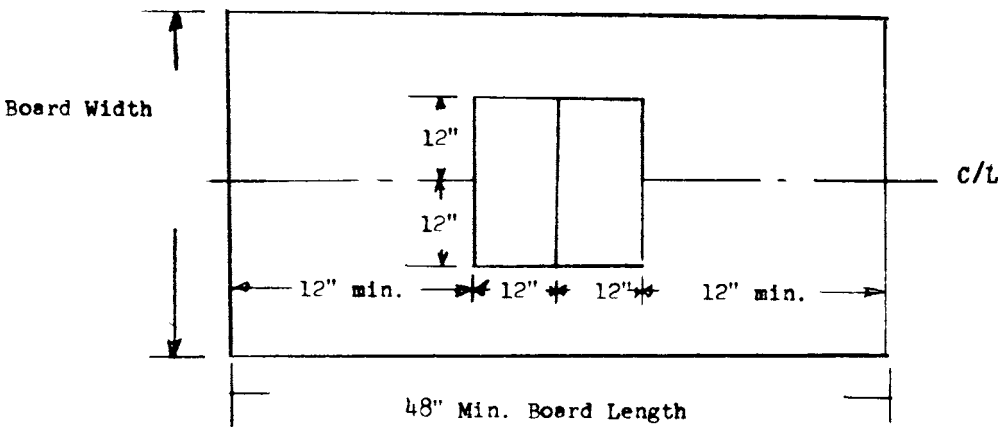

FIG. 8 Sample Selection Detail for Humidified Deflection Test

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TABLE 7 Humidified Deflection (in.) 10 Labs / 176 Data Points

Panel	Average[A]	Standard Deviation of the Sample Averages	Repeatability Standard Deviation	Reproducibility Standard Deviation	Repeatability Limit	Reproducibility Limit
	$\bar{\chi}$	$s_{\bar{\chi}}$	s_r	s_R	r	R
A	0.1566	0.0826	0.0397	0.0902	0.1112	0.2525
B	0.1143	0.0487	0.0644	0.0763	0.1802	0.2137
C	0.5952	0.3575	0.0829	0.3655	0.2323	1.0233

[A]The average of the laboratories' calculated averages.

15.5 *Test Specimens*—Use full-size gypsum panel products with undamaged ends for test specimens.

15.6 *Procedure*—Place one edge of the square flush against the edge of the gypsum panel product with the apex of the square at one corner of the product. Determine the distance *b*, to the nearest 1⁄16 in. (1.6 mm) at the specified distance *a*. Distance is measured from the apex of the square (see Fig. 9).

15.7 *Report*—Report the average of distance *b* to the nearest 1⁄8 in. (3.2 mm).

15.8 *Precision and Bias*—The precision and bias of this test method has not been determined.

16. Thickness

16.1 *Summary of Test Method*—The thickness of gypsum panel products is evaluated by measuring the thickness of the specimen with a micrometer.

16.2 *Significance and Use*—This test method covers a procedure for determining the average thickness of gypsum panel products, and is used to determine compliance with gypsum panel product specifications. The degree of correlation between this test method and service performance has not been determined.

16.3 *Apparatus*—A micrometer gage for determining the thickness measurement to 0.001 in. (0.025 mm). The micrometer shall be a 1-in. (25.4-mm) hand micrometer with 1⁄4-in. (6.35-mm) diameter anvils graduated to 0.01 in. (0.25 mm).

16.4 *Sampling*—Sampling shall be in accordance with Section 4.

16.5 *Test Specimens*:

16.5.1 Use full-size gypsum panel products for test specimens.

16.5.2 Mark the product to be tested, score on both sides, and break at 12 in. (305 mm) from each end, discarding the two ends prior to testing. Retain the remaining part of each gypsum panel product as a test specimen.

16.6 *Procedure*—Mark measurement points at approximately equal points across the width at each end of the gypsum panel product excluding the tapered, beveled, or recessed edges if applicable. Engage the micrometer firmly, but do not indent the surfacing material of the gypsum panel product. Measure the thickness of the gypsum panel product with the micrometer not less than 1⁄2 in. (13 mm) from cut ends. Take a minimum of not less than seven readings at each end of the 54-in. (1370-mm) wide gypsum panel product, six readings at each end of the 48-in. (1220-mm) wide gypsum panel product, five readings at each end of the 32-in. (813-mm) wide gypsum panel product, four readings at each end of the 24-in. (610-mm) wide gypsum panel product, or three readings at each end of the 16-in. (406-mm) wide gypsum panel product.

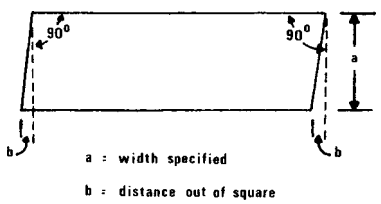

FIG. 9 End Squareness Determination

16.7 *Report*—Calculate the thickness of each specimen as the sum of the individual readings taken on each gypsum panel product specimen then divided by the quantity of individual readings made on each specimen. Calculate and report the sample thickness as the average measured thickness of all the specimens in the sample to the nearest 0.001 in. (0.1 mm).

16.8 *Precision and Bias*—The precision and bias of this test method has not been determined.

17. Recessed- or Tapered-Edge Depth

17.1 *Summary of Test Method*—The recessed- or tapered-edge depth of gypsum panel products is evaluated by comparing the thickness near the edge of the specimen to the thickness in the field of the specimen.

17.2 *Significance and Use*—This test method provides a procedure for determining the depth of the recess or taper on the edge of gypsum panel products board and is used to determine compliance with gypsum panel product specifications. The degree of correlation between this test method and service performance has not been determined.

17.3 *Apparatus*—Use the micrometer gage described in 16.3. Engage the micrometer firmly but do not indent the surfacing material. Take all readings to the nearest 0.001 in. (0.025 mm) of specimen thickness.

17.4 *Sampling*—Sampling shall be in accordance with Section 4.

17.5 *Specimens*:

17.5.1 Use the same specimens prepared in 16.5, or prepare another set of specimens as indicated in 16.5.

17.6 *Procedure*:

17.6.1 At one corner, determine the thickness 6 in. (152 mm) from the cut end and 3⁄8 in. (9.5 mm) from the edge.

17.6.2 Subtract the specimen as determined in 17.6.1 from the average specimen thickness as determined in Section 16.

17.6.3 Repeat the procedure in 17.6.1 and 17.6.2 on the remaining three corners of this specimen and on the remaining two specimens of the sample.

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17.6.4 Determine the average recessed or tapered-edge depth from all the individual recessed or tapered-edge depths, as in 17.5.

17.6.5 Determine the variation of any individual recessed or tapered-edge depth from the average as determined in 17.6.4 using the subtraction method.

17.6.6 Reject or discard any individual recessed- or tapered-edge depth calculation, as in 17.6.2, if the variation from average, as in 17.6.5, exceeds 0.050 in. (1.27 mm). To constitute a valid test do not discard more than three individual calculations.

17.7 *Report*—Report the average recessed- or tapered-edge depth as in 17.6.4 after any adjustments for exclusions of data as in 17.6.5 or 17.6.6 to the nearest 0.001 in. (0.025 mm).

17.8 *Precision and Bias*—The precision and bias of this test method has not been determined.

18. Width

18.1 *Summary of Test Method*—The width of gypsum panel products is evaluated by measuring the edge-to-edge dimension of a full size specimen.

18.2 *Significance and Use*—This test method provides a procedure for determining the width of gypsum panel products and is used to determine compliance with gypsum panel products specifications. The degree of correlation between this test method and service performance has not been determined.

18.3 *Apparatus*—Any accurate measuring device capable of measuring the width of the gypsum panel product to the nearest 1⁄32 in. (1 mm).

18.4 *Sampling*—Sampling shall be in accordance with Section 4.

18.5 *Test Specimens*—Use full-size gypsum panel products for test specimens.

18.6 *Procedure*:

18.6.1 Measure the width of an individual gypsum panel product by placing the measuring device perpendicular to the edges of the gypsum panel product when measurements are taken. The width of the specimen is the distance between extremities of the edges, so in cases where the edge or edges are beveled (slope in or out) with the face or back of the specimen, or are round, determine the overall distance. One exception is tongue and groove edge specimens, the width of which is the distance between the rip of the tongue and the bottom of the groove.

18.6.2 The width of an individual gypsum panel product is the maximum of two readings taken not less than 48 in. (1220 mm) apart and about 6 in. (152 mm) away from both ends of the specimen. Cut off 6 in. (152 mm) from both ends before taking measurements at ends of tongue and groove-edge specimens.

18.7 *Report*—Report the width as the average width of not less than three specimens to the nearest 1⁄32 in. (1 mm).

18.8 *Precision and Bias*—The precision and bias of this test method has not been determined.

19. Length

19.1 *Summary of Test Method*—The length of gypsum panel products is evaluated by measuring the end-to-end dimension of a full size specimen.

19.2 *Significance and Use*—This test method provides a procedure for determining the length gypsum panel products and is used to determine compliance with gypsum panel products specifications. The degree of correlation between this test method and service performance has not been determined.

19.3 *Apparatus*—Any accurate measuring device capable of measuring the length of the gypsum panel product to the nearest 1⁄16 in. (2 mm).

19.4 *Sampling*—Sampling shall be in accordance with Section 4.

19.5 *Test Specimens*—Use full-size gypsum panel products for test specimens.

19.6 *Procedure*:

19.6.1 Measure the length of an individual gypsum panel product by placing the measuring device parallel with the edges when measurements are taken. The length of the specimen is the distance between extremities of the ends, so in cases where the ends are beveled, determine the overall distance.

19.6.2 The length of a specimen is the maximum of two readings taken about 3 in. (76 mm) away from both edges of the specimen.

19.7 *Report*—Report the length as the average length of not less than three specimens to the nearest 1⁄8 in. (3 mm).

19.8 *Precision and Bias*—The precision and bias of this test method has not been determined.

20. Water Resistance of Core-Treated Water-Repellent Gypsum Panel Products

20.1 *Summary of Test Method*—The water resistance of core-treated water-repellent gypsum panel products is evaluated by immersing the specimen in water for the specified period of time.

20.2 *Significance and Use*—This test method provides a procedure for evaluating the ability of core-treated gypsum panel products to resist water penetration. This test method is used to determine compliance with gypsum panel product specifications. The degree of correlation between this test method and service performance has not been determined.

20.3 *Apparatus*:

20.3.1 *Water Bath*, not less than 16 by 16 by 3 in. (406 by 406 by 75 mm) capable of maintaining the water at a constant temperature of 70 ± 1 °F (21 ± 0.5 °C).

20.3.2 *Glass Rods*, 0.25 in. (6 mm) in diameter, or other supports capable of keeping the specimens off the bottom of the water bath.

20.4 *Sampling*—Sampling shall be in accordance with Section 4.

20.5 *Test Specimens*:

20.5.1 Prepare a 12 by 12-in. (305 by 305-mm) test specimen cut from the center of the gypsum panel product being tested by scoring and breaking. Cut specimens approximately centered between both edges and not less than 6 in. (152 mm) from either end. Do not treat the edges of the specimen nor damage any surfacing material.

20.5.2 Condition the specimens in accordance with Section 5, except at a temperature of 70 ± 5 °F (21 ± 2 °C), and then weigh to within 0.5 g.

20.6 *Procedure*:

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20.6.1 Position the specimen so that it rests flatwise on glass rods or other supports in the water bath with a head of 1 in. (25 mm) of water over the top of the specimen. If the specimen floats, place sufficient weight on the specimen to keep it in contact with the supports under the 1-in. (25-mm) head of water.

20.6.2 After 2 h have elapsed, remove the specimen from the bath, wipe excess water from the surfaces and edges of the specimen and weigh immediately to within 0.5 g.

20.7 *Report*—Calculate the gain in weight for each specimen as a percentage of the original weight as determined in 20.5.2 to the nearest 1 % and report the average percentage as the water absorption of the gypsum panel product.

20.8 *Precision and Bias*—See Section 22 and Table 8.

21. Surface Water Resistance of Gypsum Panel Products with Water-Repellent Surfaces

21.1 *Summary of Test Method*—The surface water resistance of gypsum panel products with water-repellent surfaces is evaluated by damming a specified area on the treated surface, filling that area with water, and allowing it to remain undisturbed for the specified time period.

21.2 *Significance and Use*—This test method provides a procedure for evaluating the ability of water-repellent surfacing of gypsum panel products to resist water penetration. This test method is used to determine compliance with gypsum panel product specifications. The degree of correlation between this test method and service performance has not been determined.

21.3 *Apparatus*—A Cobb Tester conditioned to a temperature of 70 ± 1 °F (21 ± 0.5 °C).

NOTE 4—For a description of the test apparatus see Test Method D 3285. The studs that anchor the metal crossbar may need to be lengthened to accommodate gypsum panel products.

21.4 *Sampling*—Sampling shall be in accordance with Section 4.

21.5 *Test Specimens*:

21.5.1 Cut three specimens 5 in. (127 mm) square from the field of each sample piece of gypsum panel product.

21.5.2 Condition the specimens in accordance with Section 5, except at a temperature of 70 ± 5 °F (21 ± 2 °C), to constant weight within 0.1 % and then weigh to within 0.05 g.

21.6 *Procedure*:

21.6.1 Place the conditioned test specimens in the Cobb Tester with the side to be exposed to water facing up. Fill the Cobb ring with tap water adjusted to a temperature of 70 ± 1 °F (21 ± 0.5 °C), resulting in a 1 in. (25.4 mm) head of water above the test area of the specimen.

21.6.2 After 2 h have elapsed, pour the water out of the Cobb ring and remove the specimen from the Cobb Tester. Immediately remove excess water from the specimen by blotting and weigh to the nearest 0.05 g.

21.7 *Report*—Calculate average difference between the dry and wet weights of the test specimens to the nearest 0.1 g and report this as the surface water absorption of the gypsum panel product.

21.8 *Precision and Bias*—See Section 22 and Table 9.

22. Precision and Bias

22.1 The precision of these test methods is based on an interlaboratory study of Test Methods C 473-07 conducted in 2007. Ten laboratories tested five different gypsum panel products. Every "test result" represents an individual determination. Participants were asked to submit six replicate test results for each parameter/material combination (twelve replicates for Edge Hardness). Practice E 691 was followed for the design and analysis of the data.

22.1.1 *Repeatability limit (r)*—Two test results obtained within one laboratory shall be judged not equivalent if they differ by more than the "*r*" value for that material; "*r*" is the interval representing the critical difference between two test results for the same material, obtained by the same operator using the same equipment on the same day in the same laboratory.

22.1.1.1 Repeatability limits are listed in Tables 1-9.

22.1.2 *Reproducibility limit (R)*—Two test results shall be judged not equivalent if they differ by more than the "*R*" value for that material; "*R*" is the interval representing the critical difference between two test results for the same material, obtained by different operators using different equipment in different laboratories.

22.1.2.1 Reproducibility limits are listed in Tables 1-9.

22.1.3 The above terms (repeatability limit and reproducibility limit) are used as specified in Practice E 177.

22.1.4 Any judgment in accordance with statements 22.1.1 and 22.1.2 would normally have an approximate 95 % probability of being correct, however not all of the precision statistics obtained in this ILS may be treated as definitive mathematical quantities, applicable to all circumstances and uses. The limited number of replicates tested and laboratories reporting results for some analyses guarantees that there will be times when differences greater than predicted by these ILS results will arise, sometimes with considerably greater or smaller frequency than the 95 % probability limit would imply. The repeatability limits and the reproducibility limits for those analyses should be considered as general guides, and the

TABLE 8 Water Resistance - Core (% Gain) 9 Labs / 107 Data Points

Panel	Average[A]	Standard Deviation of the Sample Averages	Repeatability Standard Deviation	Reproducibility Standard Deviation	Repeatability Limit	Reproducibility Limit
	$\bar{\chi}$	$s_{\bar{\chi}}$	s_r	s_R	r	R
D	5.4983	1.1189	0.4424	1.1896	1.2386	3.3308
E	3.9818	0.9004	0.1920	0.9173	0.5375	2.5685

[A]The average of the laboratories' calculated averages.

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TABLE 9 Water Resistance - Surface (gm) 9 Labs / 107 Data Points

Panel	Average[A]	Standard Deviation of the Sample Averages	Repeatability Standard Deviation	Reproducibility Standard Deviation	Repeatability Limit	Reproducibility Limit
	$\bar{\chi}$	$s_{\bar{\chi}}$	s_r	s_R	r	R
D	1.2929	0.0759	0.1161	0.1303	0.3250	0.3649
E	1.3040	0.0703	0.0660	0.0926	0.1847	0.2592

[A]The average of the laboratories' calculated averages.

associated probability of 95 % as only a rough indicator of what can be expected.

22.2 *Bias*—At the time of the study, there was no accepted reference material suitable for determining the bias for this test method, therefore no statement on bias is being made.

22.3 The precision statement was determined through statistical examination of 1019 test results, from ten laboratories, on five materials. These five materials were described as the following:

Panel A: ½ " regular gypsum wallboard
Panel B: ⅝ " type X gypsum wallboard
Panel C: ¼ " regular gypsum wallboard
Panel D: gypsum sheathing
Panel E: water-resistant gypsum backing board

To judge the equivalency of two test results, it is recommended to choose the material closest in characteristics to the test material.

23. Keywords

23.1 absorption testing; core hardness testing; dimension measurements; edge hardness testing; end hardness testing; flexural strength; gypsum panel products; humidified sag; nail pull testing

APPENDIXES

(Nonmandatory Information)

X1. INTRODUCTION

X1.1 ASTM specifications for gypsum panel products do not contain a specification for weight. The procedure, however, is referenced in other industry standards, and is therefore retained as an appendix item.

X2. WEIGHT

X2.1 *Test Specimens*—A sample shall consist of not less than three full size pieces of the gypsum panel product.

X2.2 *Procedure*—Measure the length and width of each specimen in accordance with Sections 17 and 18. Weight the specimens on a suitable scale and record the weight to the nearest ¼ lb (0.1 kg).

X2.3 *Calculation*—Calculate the weight in accordance with the following equation and table:

$$W = \frac{(K \times P)}{(L \times B)}$$

Where:	Meaning of Symbol	Inch-Pound Units	SI Units
W =	weight of specimen	lb/1000 ft^2	kg/100 m^2
L =	length of specimen	in.	mm
B =	width of specimen	in.	mm
P =	weight of specimen	lb	kg
K =	constant	1.44×10^5 in.^{2}/1000 ft^2	1×10^8 mm^2/ 100 m^2

X2.4 *Report*—Report the weight as the average calculated weight, in lb/1000 ft^2(kg/100 m^2) of the three gypsum specimens.

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X3. COMPRESSIVE STRENGTH

X3.1 *Introduction*—The following procedure is intended to evaluate the compressive strength of the core of the gypsum panel products.

X3.2 *Summary of Test Method*—The core strength of gypsum panel products is evaluated by crushing the sample.

X3.3 *Significance and Use*—This test method covers a procedure for evaluating the compressive strength of the gypsum panel product. The degree of correlation between this test and service performance has not been fully determined.

X3.4 *Apparatus*—See Section 10.

Testing Machine, as described for test Method B—Constant Rate of Cross Head Speed with the rate of loading at a strain rate of ⅛ in./min. ± 5 s (4 mm/min. ± 5 s).

X3.4.1 *Specimen Supports*—All bearing supports and load surfaces shall be true, shall engage the full width of the test specimen, shall be of such strength they will not deform under the test load and shall be flat. The minimum diameter of the supporting and load plates shall be 3.0 in. (75 mm). The loading and supporting plates shall be 90° to the direction of loading and parallel to each other.

X3.5 *Sampling*—Sampling shall be in accordance with Section 4.

X3.6 *Test Specimen*

X3.6.1 Cut nine specimens, each approximately 2.4-in. (61-mm) in diameter with a 0.25-in. (6.4-mm) center hole. (A 2.5-in. (63-mm) outside diameter hole saw may be used to cut sample.) Three specimens are taken from each side and the center of the gypsum panel product. Cut the specimens not less than 12 in. (300 mm) away from the ends and edges of the gypsum panel product except where the product is 24 in. (600 mm) or less in width, where it is impossible to do so.

X3.6.2 Measure and record the actual diameter of each specimen to the nearest 0.01 in. (0.1 mm). Calculate and record the area of each specimen using the measured diameter and subtracting the area of the center hole.

X3.6.3 Condition specimens at 113 °F ± 5 °F (45 °C ± 3 °C) in a ventilated oven until constant weight.

X3.7 *Procedure*

X3.7.1 Weigh each specimen and record its mass to 0.1 g.

NOTE X3.1—It is very important to perform the test on dry specimens. Only one specimen should be removed from the drying oven at a time. Testing should immediately follow weighing.

X3.7.2 Use the apparatus in X3.4, supporting each specimen centered on the supporting plate.

X3.7.3 Bring the loading plate in contact with the specimen (a faster rate of loading may be used but do not exceed 2.5 lb (10 N) initial load).

X3.7.4 Begin test at specified load rate.

X3.7.5 Failure load is the maximum load at the end of the elastic portion of the loading. (In Fig. X3.1, this would be at the sharp change in slope as shown by the X in Area 1 for one of the specimens.)

X3.7.6 Test can be terminated at any time after the maximum elastic load is obtained. (In Fig. X3.1, anywhere in Area 2).

X3.7.7 Remove the specimen. Clean the test surfaces.

X3.7.8 Repeat for next specimen.

X3.8 *Report*—Record the weight of each specimen and the compressive strength in psi (MPa) (total load/specimen area) for each specimen. Calculate and report the average weight and average compressive strength for each side and the center and the overall average.

X3.9 *Precision and Bias*—The precision and bias for this test method has not been determined.

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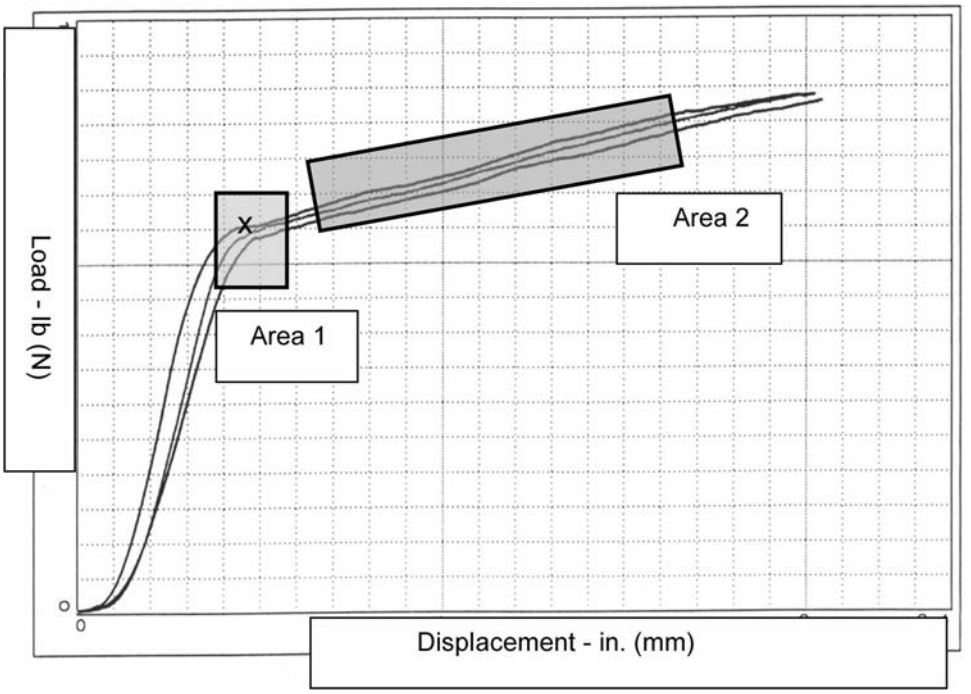

FIG. X3.1 Example Compression Test—Results for 3 Specimens Are Shown

SUMMARY OF CHANGES

Committee C11 has identified the location of selected changes to these test methods since the last issue, C 473 – 07, that may impact the use of these test methods. (Approved September 1, 2009)

(*1*) Added new Section 22 and Tables 1-9.

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Designation: C 474 – 05

Standard Test Methods for Joint Treatment Materials for Gypsum Board Construction[1]

This standard is issued under the fixed designation C 474; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope*

1.1 These test methods cover the physical testing of joint compound, paper joint tape, glass-mesh joint tape, and an assembly of joint compound and paper joint tape.

1.1.1 Joint treatment materials are specified in Specification C 475/C 475M.

1.1.2 The joint treatment material described in this standard are for use with gypsum board installed in accordance with Specification C 840.

1.2 The test methods appear in the following order:

	Section
Joint Compound Tests:	
Viscosity	5
Shrinkage	6
Check Cracking	7
Putrefaction	8
Joint Tape Tests:	
Tensile Strength	9
Width	10
Thickness	11
Paper Joint Tape Tests	
Dimensional Stability	12
Assemblages of Paper Joint Tape and Joint Compound:	
Bond of Paper Joint Tape to Joint Compound	15
Cracking of Joint Compound at Tape Edges	14
Glass-Mesh Joint Tape Test	
Skewness	13

1.3 The values stated in inch-pound units are to be regarded as the standard. The SI (metric) values given in brackets are approximate and are provided for information purposes only.

1.4 The text of this standard references notes and footnotes that provide explanatory material. These notes and footnotes (excluding those in tables and figures) shall not be considered as requirements of the standard.

1.5 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

2. Referenced Documents

2.1 *ASTM Standards:* [2]

C 11 Terminology Relating to Gypsum and Related Building Materials and Systems

C 472 Test Methods for Physical Testing of Gypsum, Gypsum Plasters, and Gypsum Concrete

C 475/C 475M Specification for Joint Compound and Joint Tape for Finishing Gypsum Board

C 840 Specification for Application and Finishing of Gypsum Board

C 1396/C 1396M Specification for Gypsum Board

D 685 Practice for Conditioning Paper and Paper Products for Testing

D 828 Test Method for Tensile Properties of Paper and Paperboard Using Constant-Rate-of-Elongation Apparatus

D 3882 Test Method for Bow and Skew in Woven and Knitted Fabrics

E 100 Specification for ASTM Hydrometers

2.2 *TAPPI Standard:*

T 411 Thickness (Caliper) of Paper, Paperboard, and Combined Board[3]

3. Terminology

3.1 *Definitions*—For definitions of terms relating to gypsum, see Terminology C 11.

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *bond*, *n—in joint systems*, the quality of adhesion between the paper joint tape and joint compound.

3.2.1.1 *Discussion*—A 0 % bond means that no paper fiber is adhering to the joint compound. A 100 % bond means that there is cohesive failure of the paper joint tape.

3.2.2 *check cracking*, *n—in joint systems*, short, narrow cracks randomly oriented in the surface of the dried joint compound.

3.2.3 *joint compound, powder*, *n*—A drying-type or setting-type cementitious material to be mixed with water.

[1] These test methods are under the jurisdiction of ASTM Committee C11 on Gypsum and Related Building Materials and Systems and are the direct responsibility of Subcommittee C11.02 on Specifications and Test Methods for Accessories and Related Products.

Current edition approved Jan. 1, 2005. Published February 2005. Originally approved in 1961. Last previous edition approved in 2002 as C 474 – 02.

[2] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

[3] Available from Technical Association of the Pulp and Paper Industry, Technology Park, P.O. Box 105113, Atlanta, GA 30348.

***A Summary of Changes section appears at the end of this standard.**

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3.2.4 *joint compound, ready-mix*, *n*—A drying-type cementitious material that is factory mixed in ready-to-use form.

4. Specimen Preparation

4.1 *Joint Compound, Powder*:

4.1.1 Mix 300 g of joint compound, powder, with approximately 150 to 160 mL of water.

4.1.2 Allow the specimen to stand for 30 min (Note 1), remix and adjust the temperature to 77 ± 2 °F [25 ± 1 °C] by placing the container holding the specimen in warm or cool water.

NOTE 1—Allow setting type compounds to stand for one half of their setting times, as determined by Test Methods C 472 but not more than 30 min, prior to remixing.

4.1.3 Measure the viscosity in accordance with Section 5.

4.1.4 If the measured viscosity is not between 480 and 520 Brabender units, repeat 4.1.1-4.1.3 through with an increase or decrease in water as necessary.

4.1.5 Record the volume of water used to adjust the viscosity to 500 ± 20 Brabender units (see Note 2).

NOTE 2—Making note of the volumes of water, in millilitres per 100 g of material, used to adjust the viscosity, will facilitate specimen preparation in other tests.

4.2 *Joint Compound, Ready-Mix*:

4.2.1 Remix joint compound, ready-mix, to reincorporate any separated ingredients. Adjust the temperature to 77 ± 2 °F [25 ± 1 °C] by placing the container holding the specimen in warm or cool water.

4.2.2 Measure the viscosity in accordance with Section 5.

4.2.3 If the viscosity is more than 520 Brabender units, add water to achieve a viscosity of 500 ± 20 Brabender units (see Note 2).

4.2.3.1 If the original sample viscosity is less than 480 Brabender units, test as received.

JOINT COMPOUND

5. Joint Compound Viscosity

5.1 *Significance and Use*:

5.1.1 This test method provides a procedure for measuring joint compound viscosity.

5.2 *Sampling*:

5.2.1 Sampling shall be in accordance with Specification C 475/C 475M.

5.3 *Specimen Preparation*:

5.3.1 Prepare specimens in accordance with Section 4.

5.4 *Apparatus*:

5.4.1 *Viscosity Specimen Container*, metal or plastic with an open top having an inside diameter of 2½ to 3 in. [65 to 75 mm] and a height of 2½ to 3 in. [65 to 75 mm].

5.4.2 *Viscometer*[4], adjusted to operate at 78 ± 1 r/min, and with a 250 cm-g sensitivity cartridge.

5.4.3 *Viscometer Pin*, having dimensions as follows:

	in. [mm]
Shaft diameter	0.187 ± 0.015 [4.75 ± 0.38]
Pin diameter	0.094 ± 0.015 [2.39 ± 0.38]
Immersion depth (from bottom of spindle)	1.625 ± 0.015 [41.3 ± 0.38]
Length of pin projecting from shaft	0.750 ± 0.015 [19.1 ± 0.38]
Upper pin from bottom of shaft	0.313 ± 0.015 [7.95 ± 0.38]
Lower pin from bottom of shaft	0.125 ± 0.015 [3.28 ± 0.38]

5.5 *Procedure*:

5.5.1 Fill the viscosity container with the mixed specimen until level with the top of the container.

5.5.1.1 Remove all air bubbles by puddling the sample container with a spatula and sharply rapping the bottom of the container on a hard flat surface.

5.5.2 Lock the filled container in the center of the viscometer spindle platform. Raise the platform until the level of the specimen reaches the mark on the viscometer pin and lock the platform in place.

5.5.3 Start the viscometer. Read the viscosity after the pen starts to trace a straight line (usually within 1 min). If the tracing remains inconsistent, estimate the average viscosity reading.

5.6 *Report*:

5.6.1 Report the viscosity of the joint compound specimen in Brabender units.

5.7 *Precision and Bias*:

5.7.1 Precision and bias of this test method have not been determined.

6. Shrinkage

6.1 *Significance and Use*:

6.1.1 This test is used to measure the amount of shrinkage in joint compound. The degree of correlation between this test and service performance has not been determined.

6.2 *Sampling*:

6.2.1 Sampling shall be in accordance with Specification C 475/C 475M.

6.3 *Specimen Preparation*:

6.3.1 Specimen preparation shall be in accordance with Section 4.

6.4 *Apparatus*:

6.4.1 *Plastic or Rubber Film*, approximately 5 by 5 in. [130 by 130 mm]. Any thin, flexible film that peels clean from a partially dried patty may be used.[5]

6.4.2 *Balance*, having a sensitivity of 10 mg (Fig. 1 and Fig. 2).

6.4.3 *Beaker, Ring Stand, and Wire Cradle* (see Fig. 1).

6.4.4 *Forced Air Drying Oven*, capable of being maintained at 90 to 120 °F [32 to 49 °C].

6.4.5 *Spatula*, having a blade approximately 4 in. by ½ in. [100 by 13 mm].

6.4.6 *Steel-Reinforced Broad Knife*, a 5 to 8 in. [130 by 200 mm] drywall broad knife reinforced by a steel bar, 1 in. [25 mm] wide by ⅛ in. [3 mm] thick, by the knife width, attached to the back of the knife blade ¼ in. [6 mm] from the edge.

6.4.7 *Hydrometer*, having a range of 0.7 to 0.8 sp gr, in accordance with Specification E 100.

[4] The sole source of supply of the apparatus known to the committee at this time is the Brabender "Visco-Corder" Model VC-3, manufactured by C.W. Brabender Instruments Inc., South Hackensack, NJ. If you are aware of alternative suppliers, please provide this information to ASTM International Headquarters. Your comments will receive careful consideration at a meeting of the responsible technical committee [1], which you may attend.

[5] Rubber dental dam dusted with talc, polyethylene, or PTFE films have been found satisfactory for this use.

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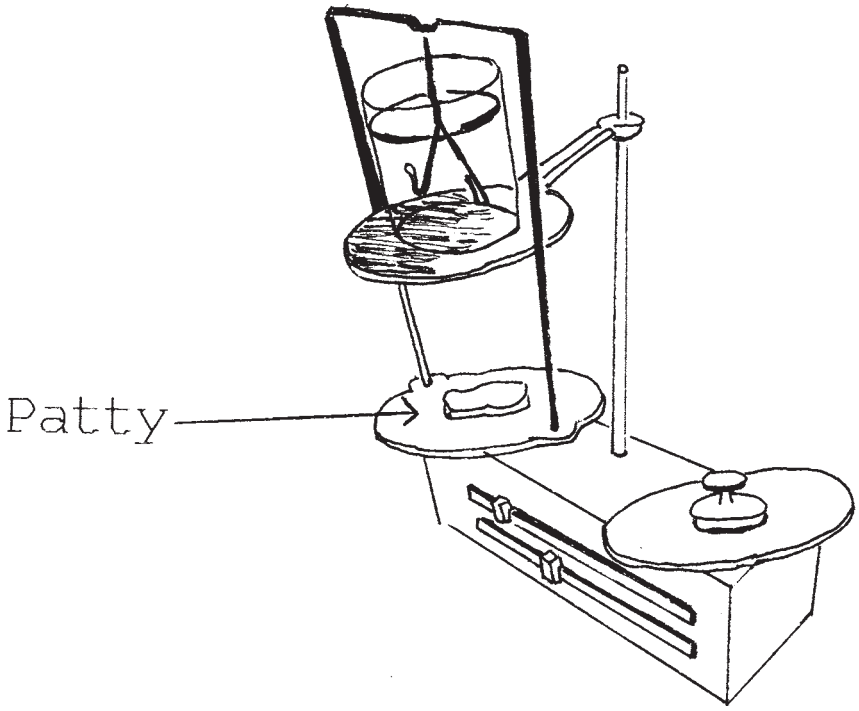

FIG. 1 Wire Cradle in Kerosine

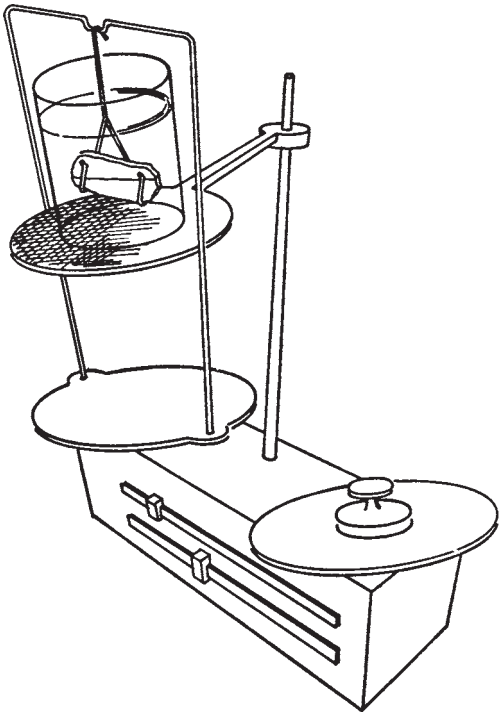

FIG. 2 Patty Immersed in Kerosine

6.4.8 *Volumetric Container*, a container which has a volume between 25 and 300 cm^3.

6.5 *Reagents and Materials*:

6.5.1 *Displacement Fluids*.

6.5.1.1 *Mineral Spirits*, odorless.

6.5.1.2 *Kerosine*.

6.6 *Preparation of Apparatus*:

6.6.1 *Support Plates*—Cover three plastic or glass plates with plastic or rubber film.

6.6.2 Obtain and record the tare weight of each assembly.

6.7 *Calibration*:

6.7.1 *Volumetric Container*—Determine the container volume in cubic centimetres and its tare weight in grams.

6.7.2 *Mineral Spirits, Kerosine*—Using the hydrometer, determine the specific gravity and record the result as *M*.

6.8 *Determination of Wet Volume*:

6.8.1 Prepare a specimen to determine the wet specific gravity by weighing the specimen in the volumetric container.

6.8.1.1 Adjust the temperature to 77 ± 2 °F [25 ± 1 °C] by placing the container holding the specimen in warm or cool water.

6.8.1.2 Puddle the specimen with the spatula to remove entrapped air bubbles.

6.8.1.3 Fill the container completely and strike off the surface flush with the top using the steel-reinforced broad knife.

6.8.1.4 Weigh the filled container to the nearest 0.01 g. Record the weight of the filled container.

6.9 *Preparation of Specimen to Determine Dry Volume*:

6.9.1 Place approximately 30 g of specimen onto each prepared support plate.

6.9.1.1 Spread the specimen into an elongated patty 3⁄16 to ¼ in. [5.0 to 6.5 mm] thick with a spatula.

6.9.1.2 Remove any specimen remaining on the spatula and add to the patty.

NOTE 3—The patty may be scored across its narrowest width to facilitate breaking the patty after it is dry.

6.9.1.3 Weigh and record the total weight of each patty, film and plate.

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6.9.1.4 When testing setting type joint compounds, place the patties in the drying oven one h after the setting time has been reached as determined by Test Methods C 472.

6.9.1.5 When testing drying type joint compounds, place the patties in the drying oven immediately after weighing.

6.9.2 Dry patties at a temperature between 100° and 120 °F [32 to 49 °C] for 16 to 24 h.

6.9.3 Strip off the plastic or rubber film, and continue to dry until constant weight is reached.

6.10 *Determination of Dry Volume*:

6.10.1 Immerse each patty in a beaker of the displacement fluid, such that they do not touch the sides of the beaker, until constant weight is reached.

NOTE 4—Each patty may be broken into two or three pieces to fit in the beaker without touching the sides.

6.10.2 Remove each patty from the displacement fluid. Using a cloth moistened in the same fluid, lightly blot off the excess fluid from the surface of the patty.

6.10.3 With the wire cradle suspended in the beaker of displacement fluid, weigh each patty in air on the pan of the balance (Fig. 1), and record as its air weight.

6.10.4 Next, weigh each patty in the wire cradle, making sure that the patty is completely immersed in the liquid and that it does not touch the sides of the beaker (Fig. 2). Record these weights as the immersed weight.

6.11 *Calculation of Shrinkage*:

6.11.1 Determine the net weight of the compound in the volumetric container by subtracting the weight obtained in 6.8.1.4 from the weight obtained in 6.7.1.

6.11.2 Divide the net weight obtained in 6.11.1 by the volume of the container obtained in 6.7.1. Record the result as *G*, grams per millilitre.

$$G = \frac{\text{Total weight} - \text{Container tare weight}}{\text{Volume of Container}} \quad (1)$$

6.11.3 Determine the net weight of each specimen by subtracting the tare weight of its support plate weight and its weight obtained in 6.9.1.3.

6.11.4 Divide the net weight obtained in 6.11.3 by *G*. Record as *V*, volume of patty.

$$V = \frac{\text{Dry weight} - \text{Support plate tare weight}}{G} \quad (2)$$

6.11.5 Subtract the immersed patty weight obtained in 6.10.4 from the air patty weight obtained in 6.10.3. Record as *D*, the weight difference.

6.11.6 Calculate the percent shrinkage as follows:

$$\% \text{ Shrinkage} = D(X/V), \quad (3)$$

where:

D = the difference in air and immersed weight,
X = 100/displacement fluids specific gravity, and
V = weight of wet patty/specific gravity of the compound.

6.12 *Report*:

6.12.1 Take the average of the three patties tested. If there is a difference between the percent shrinkage of the three patties of more than 1.5 %, completely retest an additional three specimens and take the average of the six.

6.13 *Precision and Bias*:

6.13.1 Precision and bias of this test method have not been determined.

7. Check Cracking of Joint Compound

7.1 *Significance and Use*

7.1.1 This test method is used to measure the degree and type of field and edge cracking of joint compound. The degree of correlation between this test and service performance has not been determined.

7.2 *Sampling*:

7.2.1 Sampling shall be in accordance with Specification C 475/C 475M.

7.3 *Specimen Preparation*:

7.3.1 Prepare specimens in accordance with Section 4, except use a quantity of 100 g.

7.4 *Apparatus*:

7.4.1 *Rod*, metal or glass, ⅛ in. [3.2 mm] in diameter by 7 in. [180 mm] in length.

7.4.2 *Steel-Reinforced Broad Knife*, as defined in 6.4.6.

7.4.3 *Gypsum Wallboard*, Specification C 1396/C 1396M.

7.4.3.1 To determine compliance to Specification C 475/C 475M, Specification C 1396/C 1396M gypsum wallboard shall be used.[6]

7.4.4 *Electric Fan*, capable of forcing a continuous current of air at a velocity of 350 to 450 ft/min [1.8 to 2.3 m/s] at a distance of approximately 3 ft [1 m].

7.5 *Procedure*:

7.5.1 Place the rod on a piece of gypsum wallboard and place some of the specimen next to the rod.

7.5.2 Form a 3½ to 4 in. [90 to 100 mm] wide wedge of the specimen with the steel-reinforced broad knife, with the rod on one side and the wallboard on the other side to guide the knife.

7.5.2.1 Hold the broad knife at an angle less than 45° with respect to the plane of the wallboard. Draw the broad knife over the specimen two or more times to leave the surface smooth.

7.5.3 Remove the rod and adjust the wedge to a 5 in. [130 mm] length.

7.5.4 Immediately place the wedge-shaped specimen in front of the fan blowing over the surface of the wedge for 8 to 16 h. The current of air shall be maintained at 70 to 85 °F [21 to 29 °C] and 45 to 55 % relative humidity.

7.6 *Report*:

7.6.1 Report the type and amount of cracking in both the thick half and the thin half of the wedge.

7.7 *Precision and Bias*:

7.7.1 Precision and bias of this test method have not been determined.

8. Putrefaction

8.1 *Significance and Use*:

[6] Other substrates may be used to evaluate the effect that they have on the performance of the joint compound and assemblies of joint compound and joint tape.

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8.1.1 This test method is used to evaluate the tendency of the joint compound to putrefy. The degree of correlation between this test and service performance has not been determined.

8.2 *Sampling*:

8.2.1 Sampling shall be in accordance with Specification C 475/C 475M.

8.3 *Apparatus*:

8.3.1 *Humidity Cabinet*, a chamber capable of maintaining 85 to 95 °F [29 to 35 °C] and 85 to 95 % relative humidity.

8.3.2 *Glass Container*, capable of being sterilized in an autoclave, having a minimum volume of 250 mL.[7]

8.3.3 *Cover*, made of glass or aluminum foil large enough to cover the glass container and capable of being sterilized in an autoclave.

8.3.4 *Autoclave*, capable of maintaining 260 °F [130 °C] at 21 psi [145 kPa] steam pressure for not less than 15 min.

8.4 *Preparation of Apparatus*:

8.4.1 Sterilize the glass container and cover in an autoclave at 21 psi [145 kPa] and 260 °F [130 °C] for 15 min or more.

8.5 *Procedure*:

8.5.1 *Joint Compound, Powder*—Mix 50 g of joint compound with water, as determined in 4.1 in the glass container. Allow it to soak 30 min and then remix. Place the cover over the glass container and place in the humidity cabinet.

8.5.2 *Joint Compound, Ready-mix*—Select an unopened container that has not exceeded the producer's specified shelf life.

8.5.2.1 Open the container. If the material in the container has separated, mix thoroughly.

8.5.2.2 Remove 100 g of joint compound, ready-mix, from the container.

8.5.2.3 Put the specimen in the glass container and cap with the cover.

8.5.2.4 Place in the humidity cabinet.

8.6 *Interpretation of Results*:

8.6.1 Observe daily for putrefaction.

8.7 *Report*:

8.7.1 Report the number of days required to produce putrefaction.

8.8 *Precision and Bias*:

8.8.1 Precision and bias of this test method have not been determined.

JOINT TAPE

9. Tensile Strength

9.1 *Significance and Use*:

9.1.1 This test method is used to evaluate the cross-directional strength of joint tape used to reinforce the joints created by gypsum wallboard construction. The degree of correlation between this test and service performance has not been determined.

9.2 *Sampling*:

9.2.1 Sampling shall be in accordance with Specification C 475/C 475M.

9.2.2 A sample for the purpose of testing shall consist of not less than 12 ft [3.6 m] of tape from each roll.

9.2.3 Take ten specimens in the cross direction at not less than 1 ft (300 mm) intervals. Cut each specimen to 1 in. [25 mm] by roll width.

9.3 *Apparatus*:

9.3.1 The apparatus shall be in accordance with Test Method D 828 except that the distance of the jaw spacing shall be reduced to ½ ± 1/64 in. [12.7 ± 0.4 mm]; the rate of elongation shall be 0.66 in./min ± 5 s [17 mm/min ± 5 s].

9.4 *Procedure*:

9.4.1 Condition the specimens for a minimum of 24 h at 72 ± 4 °F [22 ± 2 °C] and 50 ± 2 % relative humidity.

9.4.2 Test in accordance with Test Method D 828 with equipment as set forth in 9.3.

9.5 *Interpretation of Results*:

9.5.1 Accept or reject results of the individual test specimens in accordance with Test Method D 828.

9.5.2 If any results are rejected, test additional specimens so that there are at least ten test results for the evaluation of any unit of tape.

9.6 *Report*:

9.6.1 Report test results as pounds-force per inch (Newtons per millimetre) of width of specimen.

9.7 *Precision and Bias*:

9.7.1 Precision and bias statements as listed in Test Method D 828 are suitable for use with this product.

10. Width

10.1 *Significance and Use*:

10.1.1 This test method is used to determine the average variation in width of the joint tape. The degree of correlation between this test and service performance has not been determined.

10.2 *Sampling*:

10.2.1 Sampling shall be in accordance with Specification C 475/C 475M.

10.3 *Specimen Preparation*:

10.3.1 Cut a specimen of joint tape not less than 12 ft [3.5 m] long from the roll to be tested.

10.4 *Apparatus*:

10.4.1 *Steel Rule, Caliper Rule*, or other measuring device capable of resolving 1/32 in. A metric device must be capable of resolving 1.0 mm.

10.5 *Procedure*:

10.5.1 Measure the width of the specimen in ten places, at least 1 ft [300 mm] apart, to the nearest 1/32 in. [1.0 mm]. Record each measurement.

10.6 *Calculation of Results*:

10.6.1 Determine the maximum and minimum widths. Calculate the average width.

10.6.2 Determine the difference between the maximum and minimum width by subtraction.

10.7 *Report*:

10.7.1 Report the average width, and the difference between the maximum and minimum width.

10.8 *Precision and Bias*:

[7] Deep Petri dishes and 250 mL beakers have been found suitable for this purpose.

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10.8.1 Precision and bias of this test method have not been determined.

11. Thickness

11.1 *Significance and Use*:

11.1.1 This test method is used to determine the average thickness of joint tape. The degree of correlation between this test and service performance has not been determined.

11.2 *Sampling*:

11.2.1 Sampling shall be in accordance with Specification C 475/C 475M.

11.3 *Specimen Preparation*:

11.3.1 Cut a specimen of tape not less than 12 ft [3.5 m] long from the roll to be tested.

11.3.2 Condition the specimen for a minimum of 24 h as described in Practice D 685.

11.4 *Apparatus*:

11.4.1 *Paper Micrometer* having circular faces of 0.25 to 0.33 in.^{2} [160 to 215 mm^2] in area. Faces shall be under steady pressure of 7 to 9 psi [50 to 60 kPa].

NOTE 5—For details see TAPPI T 411, except waive Section 7.

11.5 *Procedure*:

11.5.1 Measure the thickness of the specimen in 10 places, between the edges, at least 1 ft [300 mm] apart. Skived areas on the tape edges shall not be included in the area measured for thickness.

NOTE 6—Skiving is not present on all tapes.

11.5.2 Record the thickness to the nearest 0.001 in. [0.01 mm].

11.6 *Report*:

11.6.1 Report the average thickness.

11.7 *Precision and Bias*:

11.7.1 Precision as reported in the TAPPI Standard T 411 states that the within-laboratory repeatability is 1.25 % and the laboratory reproducibility is 5.50 %.

PAPER JOINT TAPE

12. Dimensional Stability

12.1 *Significance and Use*:

12.1.1 This test method is used to determine the lengthwise and crosswise expansion characteristics of the paper joint tape used to reinforce the joints created in gypsum wallboard construction. The degree of correlation between this test and service performance has not been determined.

12.2 *Sampling*:

12.2.1 Sampling shall be in accordance with Specification C 475/C 475M.

12.3 *Specimen Preparation*:

12.3.1 Cut not less than three specimens of tape 10 to 16 in. [250 to 400 mm] long from the roll to be tested.

12.3.2 Condition the specimens for a minimum of 16 h at 72 ± 4 °F [22 ± 2 °C] and 50 ± 2 % relative humidity.

12.4 *Apparatus*:

12.4.1 *Steel Rule, Caliper Rule, Cathetometer* or other measuring device capable of resolving 0.005 in. over a minimum span of 10 in. A metric rule must be capable of resolving 0.10 mm over a minimum span of 250 mm.

12.4.2 *Sharp Knife, 4 to 5× Magnifying Glass, Pencil*.

12.4.3 *Glass Container* at least 2½ in. [65 mm] deep and 6 in. [150 mm] in diameter.

12.5 *Reagents and Materials*:

12.5.1 *Water*, distilled or deionized.

12.6 *Procedure*:

12.6.1 Place the conditioned specimens on a flat surface.

12.6.1.1 At about ½ in. [10 mm] from each end of the paper tape, cut two ½ in. [10 mm] long reference marks for the length-wise measurement crosswise of the tape with a sharp knife.

12.6.1.2 Place the rule on the tape so that one edge is centered lengthwise.

12.6.2 Move the rule so that starting mark (A) coincides with the reference mark at one end of the tape. Record the value at A. Take the reading at the other reference mark. Read to the nearest 0.005 in. [0.10 mm]. (See Fig. 3).

NOTE 7—Measuring from the 1 in. [25 mm] mark and subtracting this value may be a useful method to obtain an accurate measurement. Reading the rule with a magnifying glass of 4 to 5× is recommended.

12.6.3 Place the rule across the width of the tape.

12.6.3.1 Align the starting mark (B) of the rule with one edge of the tape. Record the value at B.

12.6.3.2 Take the reading at the opposite edge of the tape. Mark the location of this crosswise measurement by drawing a 1½ in. [40 mm] long pencil mark across the tape without marring the edges of the tape. (See Fig. 4.)

12.6.4 Roll up the tape and submerge it in the container full of water at 72 ± 4 °F [22 ± 2 °C].

12.6.5 After 30 min, remove the tape from the water and roll it out on the flat surface. Repeat the lengthwise and crosswise measurements.

12.7 *Calculation of Results*:

12.7.1 Subtract A from the reading obtained in 12.6.2 and record as the dry length of the tape at this point.

12.7.2 Subtract B from the reading obtained in 12.6.3.2 and record as the dry width of the tape at this point.

12.7.3 Determine the amount of expansion by subtracting the original measurement from the final measurement. Divide the expansion in inches (millimetres) by the original reading and multiply by 100 to obtain the percentage expansion.

$$\% \text{ Expansion} = \frac{(\text{Wet Measurement} - \text{Dry Measurement})}{\text{Dry Measurement}} \times 100 \quad (4)$$

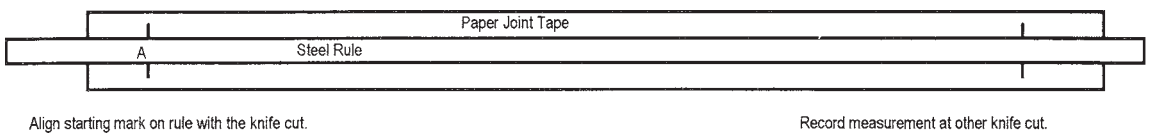

FIG. 3 Arrangement for Length Expansion Measurement

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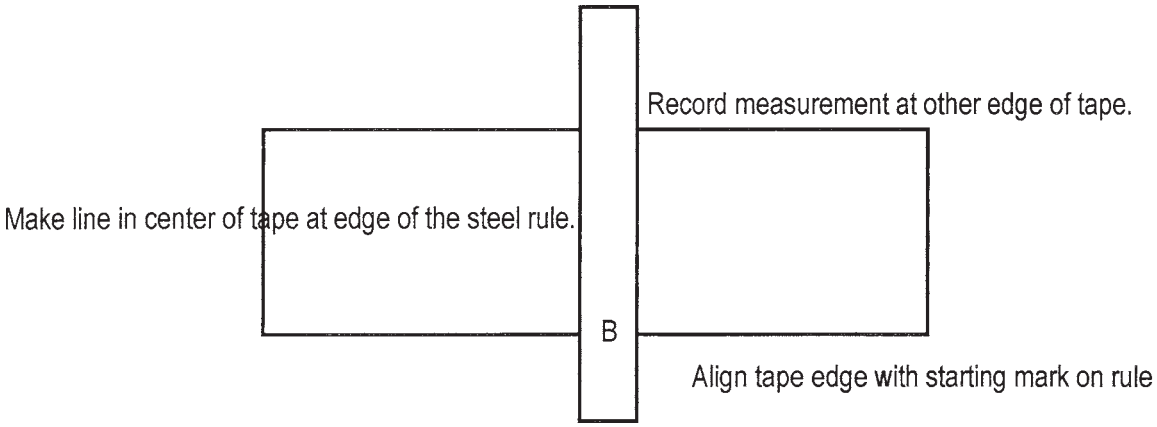

FIG. 4 Arrangement for Width Expansion Measurement

12.8 *Report*:

12.8.1 Report test results as percent expansion in the lengthwise and crosswise directions.

12.9 *Precision and Bias*:

12.9.1 Precision and bias of this test method have not been determined.

GLASS-MESH JOINT TAPE

13. Skewness

13.1 The skewness of the warp and fill yarns shall be tested in accordance with Test Method D 3882.

ASSEMBLAGES OF JOINT TAPE AND JOINT COMPOUND

14. Cracking of Joint Compound at Tape Edges

14.1 *Significance and Use*:

14.1.1 This test method is used to determine the adhesion of the joint compound to the edges of the joint tape. The degree of correlation between this test and service performance has not been determined.

14.2 *Sampling*:

14.2.1 Sampling shall be in accordance with Specification C 475/C 475M.

14.3 *Specimen Preparation*:

14.3.1 Select specimens of joint tape in accordance with 9.2.2.

14.3.2 Cut specimens of joint tape into not less than 12 in. [300 mm] specimens.

14.3.3 Prepare specimens of joint compound in accordance with Section 4, except use a quantity of 200 g.

14.4 *Apparatus*:

14.4.1 *Feeler Gage Strips*, two required for each test, each 12-in. [300 mm] long, ½ in. [13 mm] wide, 0.040 in. [1 mm] thick.

14.4.2 *Steel-Reinforced Broad Knife*, see 15.4.2.

14.4.3 *Gypsum Wallboard*, Specification C 1396/C 1396M (See 7.4.3.1), approximately 6 by 12 in. [150 by 300 mm].

14.4.4 *Electric Fan*, in accordance with 7.4.4.

14.5 *Procedure*:

14.5.1 Place the two feeler gage strips on the face of the wallboard about 4 in. [100 mm] apart.

14.5.2 Fill the space between the feeler gage strips with joint compound specimen and level to the thickness of the feeler gage strips.

14.5.3 After leveling to the correct thickness, center a specimen of joint tape between the feeler gage strips.

14.5.3.1 Using the steel-reinforced broad knife at about a 45° angle, press the tape specimen firmly into contact with the joint compound.

14.5.3.2 Use a final flat stroke of the knife to smooth the joint compound on both sides of the tape. Do not press so hard that the joint compound will be squeezed out from under the tape, but hard enough so that the tape is in full contact with the joint compound.

14.5.4 Remove the feeler gage strips.

14.5.5 Place this assembly in front of the electric fan blowing a current of air over the surface of the assembly. Maintain a current of air at 100 ± 5 °F [38 ± 2 °C] and 25 ± 5 % relative humidity.

14.5.5.1 Alternatively, in very dry air (under 20 % relative humidity) at temperatures between 75 and 90 °F [24 to 32 °C] just allow the electric fan to blow a current of air over the surface.

14.5.6 After 1 h, examine the assembly for cracks along the edges of the tape with a magnifying glass of 4 to 5×.

14.6 *Calculation of Results*:

14.6.1 Measure the total length of any cracking at the edge of the joint tape and joint compound.

14.6.2 Divide the total length of cracked edges by the total length of the edges exposed and multiply 100 to obtain percent of cracked edge.

14.7 *Report*:

14.7.1 Report the percentage of cracking along the edges of the tape.

14.8 *Precision and Bias*:

14.8.1 Precision and bias of this test method have not been determined.

15. Bond of Paper Joint Tape to Joint Compound

15.1 *Significance and Use*:

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15.1.1 This test method is used to determine the bonding properties of the paper joint tape. The degree of correlation between this test and service performance has not been determined.

15.2 *Sampling*:

15.2.1 Sampling shall be in accordance with Specification C 475/C 475M.

15.3 *Specimen Preparation*:

15.3.1 Select specimens of paper joint tape in accordance with 9.2.2.

15.3.2 Cut specimens of paper joint tape into at least 12 in. [300 mm] specimens for use in test.

15.3.3 Prepare specimens of joint compound in accordance with Section 4, except use a quantity of 200 g.

15.4 *Apparatus*:

15.4.1 *Feeler Gage Strips* (two required for each test), each 12 in. [300 mm] long, ½ in. [14 mm] wide, 0.025 in. [0.64 mm] thick with a small hole drilled in one end.

15.4.2 *Steel-Reinforced Broad Knife*, in accordance with 6.4.6.

15.4.3 *Gypsum Wallboard*, Specification C 1396/C 1396M (See 7.4.3.1), two pieces, 6 by 14 in. [150 by 350 mm] with the 14-in. [350-mm] length in the machine direction of the paper.

15.4.4 *Overlay Transparency Grid*—A transparent photo copy of 10 by 10 divisions/in. graph paper. An area 2 by 5 in. [50 by 125 mm] enclosing 1000 square divisions is outlined.

15.5 *Procedure*:

15.5.1 Place two feeler gage strips parallel to each other about 4 in. [100 mm] apart and fasten to the face of the gypsum wallboard with a thumb tack through the hole in the end.

15.5.2 Using the steel reinforced broad knife, apply an amount of joint compound sufficient to cover the area between the feeler gage strips. Spread the specimen evenly between the feeler gage strips leaving the specimen slightly thicker than the strips.

15.5.3 Center a 12-in. [300-mm] length of the paper tape in the specimen. Press one end of the tape into the specimen and hold it in place.

15.5.4 Embed the tape by applying two or three pressure strokes with the steel-reinforced broad knife. Wipe away from the end being held so the excess joint compound is squeezed out.

NOTE 8—The thickness of the joint compound plus the tape is about 0.025 in. [0.64 mm].

15.5.4.1 Carefully remove the feeler gages before drying.

15.5.5 Allow the test assembly to dry to constant weight in an atmosphere of 75 ± 5 °F [24 ± 2 °C] and 50 ± 5 % relative humidity.

15.5.6 When the test assembly is dry, use a sharp knife to make a cut across and perpendicular to the tape 3½ in. [90 mm] from one end. Make a second cut 5 in. [140 mm] from and parallel to the first cut. Make two diagonal cuts across the tape connecting the opposite corners of the 5-in. [140 mm] section. With the tip of the knife, peel back the tabs formed by the "X" cuts and pull up sharply.

15.5.6.1 Make a second test by repeating 15.5.6 below the first test.

15.5.7 Using a sharp pencil, lightly outline the areas where fiber remains attached to the compound. Align the overlay transparency grid so that the grid outline matches the 2 by 5-in. [50 by 125-mm] sides of the tape bond area.

15.6 *Calculation of Results*:

15.6.1 Using the overlay transparency grid, count the number of squares that are more than half bare of fiber separated from the tape and outlined by pencil.

15.6.2 Subtract this number from 1000 and divide by 10 to determine the percent bond. Record the average of the two tests.

15.7 *Report*:

15.7.1 Report the average percent bond failure.

15.8 *Precision and Bias*:

15.8.1 Precision and bias of this test method have not been determined.

16. Keywords

16.1 bond of tape; cracking; glass-mesh joint tape; joint compound; joint tape; joint treatment; paper joint tape; putrefaction; shrinkage; tensile strength; topping compound; viscosity

APPENDIX

(Nonmandatory Information)

X1. TEST METHOD FOR EVALUATING TENSILE PROPERTIES OF GYPSUM PANEL JOINTS

X1.1 *Introduction:*

X1.1.1 ASTM standards do not include a method to determine the strength of a joint between pieces of panel products. After significant investigation, the following procedure is proposed to evaluate reinforced gypsum panel product joints. This method is intended for use with any joint compound or tape intended for use as a joint reinforcement in construction of gypsum panel product systems in accordance with Specification C 840. Forward any comments relating to the suitability of this procedure to Technical Committee C11 for review.

X1.2 *Significance and Use:*

X1.2.1 This procedure is used to determine the tensile strength of the joint created by an assemblage of joint

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compound and joint tape. The degree of correlation between this test and service performance has not been determined.

X1.3 *Sampling:*

X1.3.1 Sampling shall be in accordance with Specification C 475/C 475M, except the number of specimens prepared shall be as shown.

X1.3.2 *Number of Specimens Required*

The number of specimens required for 5 % accuracy with 95 % confidence on the mean, assuming the set in question is a population, is calculated as follows:

$$n = (tv/A)^2 \quad \text{(X1.1)}$$

where:

n = number of samples required
t = student t distribution for 95 % confidence. t_∞= 1.645 for n>30
σ = population standard deviation
μ = population mean
v = coefficient of variation = % standard deviation = σ/μ*100
A = value of the allowable variation (that is, A = 0.05 for 5 % variation)

Without proper historical data for A, set n at 18 samples until such data is achieved.

X1.4 *Apparatus:*

X1.4.1 *Materials Required To Create the Standard Substrate*:

X1.4.1.1 High-density polyethylene plastic ½ in. [12.7 mm] thick,

X1.4.1.2 Jigsaw or table saw with blade suitable for cutting plastic,

X1.4.1.3 Router table with straight edging bit,

X1.4.1.4 Orbital sander with 60-grit sandpaper,

X1.4.1.5 Drill press with ½ in. [12.7 mm] drill bit,

X1.4.1.6 Six ¼ in. by 16 in. by 20 in. [6 mm by 400 mm by 500 mm] aluminum trays, and

X1.4.1.7 Ruler and fine-tip permanent ink marker.

X1.4.2 *Materials Required for Preparation of the Reinforced Joint*:

X1.4.2.1 Joint tape roll (of required tape or style),

X1.4.2.2 Two 20 in. by 1 in. by 0.030 in. [500 mm by 25 mm by 0.76 mm] thick stainless steel spacers,

X1.4.2.3 Two 20 in. by 1 in. by 0.045 in. [500 mm by 25 mm by 1.14 mm] thick stainless steel spacers,

X1.4.2.4 Two 20 in. by 1 in. by 0.055 in. [500 mm by 25 mm by 1.40 mm] thick stainless steel spacers,

X1.4.2.5 Six in. [150 mm] finishing trowel,

X1.4.2.6 Two 4 in. [100 mm] putty knife,

X1.4.2.7 Ruler,

X1.4.2.8 Fine-tip permanent ink marker,

X1.4.2.9 Joint compound, ready-mix or powder prepared in accordance with Test Methods C 474,

X1.4.2.10 One in. [25 mm] masking tape,

X1.4.2.11 Razor knife,

X1.4.2.12 Sanding block with 320-grit sandpaper,

X1.4.2.13 High-purity air-drying conductive silver paint, and

X1.4.2.14 Test circuit: 9 V battery, light-emitting diode, 27 KΩ resistor, wires, and breadboard.

X1.4.3 *Tensile Test Machine*:

X1.4.3.1 A tensiometer, universal test machine, or other suitable device capable of being operated at test speeds of 0.04 in. per min [1.0 mm per min] and 0.4 in. per min [10.0 mm per min].

X1.4.3.2 *Load Cell*—Installed in the load train of the test machine. It shall have a capacity such that the crack and peak values fall within 20 % to 80 % of its stated capacity.

X1.4.3.3 *Specimen Tensile Jaws/Grips*—Installed in the tensiometer. They shall be as illustrated in Fig. X1.1 and Fig. X1.2, or a similar device capable of isolating the joint face along the center line of the apparatus.

NOTE X1.1—Alternately, if the special "eccentric" grips are not available, conventional grips that open greater than 1 in. [25 mm] can be used, provided that ½ in. [13 mm] spacers are used to isolate the joint face along the center line.

X1.4.3.4 *Data Acquisition*—The load-versus-extension data shall be acquired by mechanical or electronic means. The data may be captured electronically by data acquisition equipment or mechanically with a chart recorder, either X-Y or strip chart styles. If using a mechanical method, ensure that the plotting parameters (that is, load range and proportion) are such that the maximum load falls between 30 % and 90 % of the chart paper range.

X1.4.4 Eighteen 6 in. [150 mm] wide prepared joints.

X1.5 *Preparation of the Substrate:*

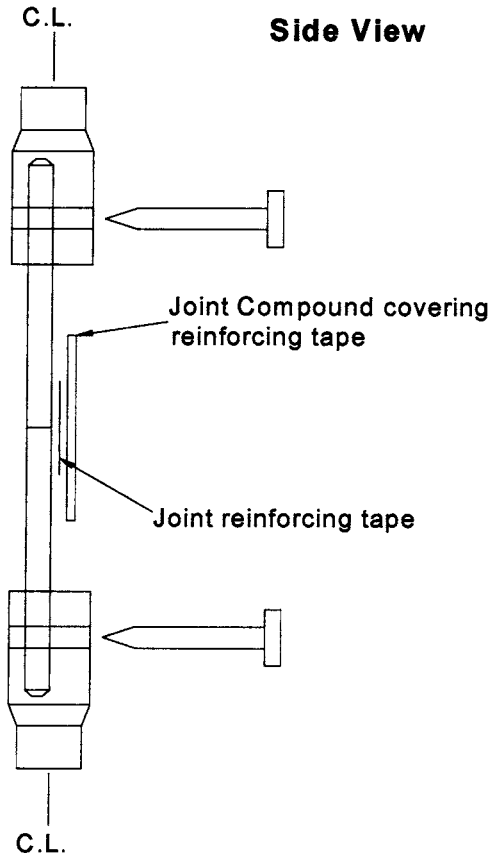

FIG. X1.1 Side View of Test Specimen and Tensile Jaw/Grips

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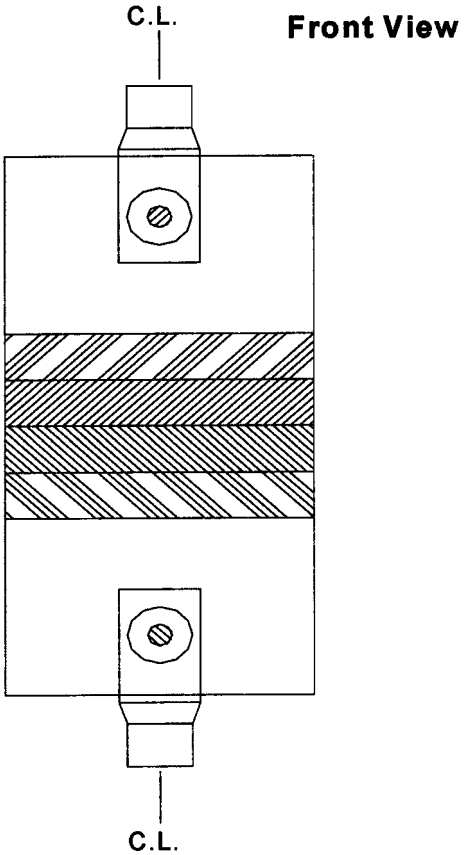

FIG. X1.2 Front View of Test Specimen and Tensile Jaw/Grips

X1.5.1 Sand one surface of high-density polyethylene plastic sheets with the orbital sander loaded with 60-grit sandpaper. Use average pressure and a circular motion to abrade the surface so that the shiny look of the unsanded plastic is completely gone.

X1.5.2 Cut plastic sheets into 6 ¼ in. by 6 ¼ in. [160 mm by 160 mm] pieces. Thirty-six pieces are required for one joint set of 18 samples.

X1.5.3 Set router guide to 6 ⅛ in. [155 mm] and pass each sample through, smoothing one edge of each piece. Send each piece through again, only smoothing the edge perpendicular to the one done previously.

X1.5.4 Set router guide to 6 in. [150 mm] and repeat previous step, but smooth the two remaining unfinished edges.

X1.5.5 Resand the surface of each finished piece to get rid of irregularities caused by cutting and smoothing.

X1.5.6 On each piece, drill a ½ in. [12.7 mm] hole 5 in. [125 mm] from the bottom edge, and 3 in. [75 mm] from either side edge. Also, place an index mark using a fine marker on either side of each piece, 2 in. [50 mm] from the sanded edge. See Fig. X1.3.

X1.6 *Preparation of the Joint Set:*

X1.6.1 Match up the substrate pieces by twos, with sanded faces down. Push one piece to the other and tape the joint tightly using masking tape. Repeat this with remaining 17 pairs.

X1.6.2 Trim excess tape and set three taped pairs on each aluminum tray, with sanded faces up. Maneuver the samples to ensure the joints are aligned. Place a stirp of masking tape across either side of the samples (parallel to the joint), covering the drill holes and securing one sample to another.

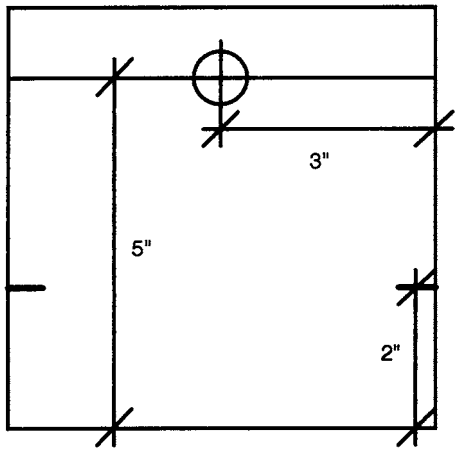

FIG. X1.3 Placement of Drill Hole in Plastic Substrate

X1.6.3 *Applying Glass Mesh Tape and First Coat*:

X1.6.3.1 Apply glass mesh tape centered on joint across the three samples on each tray, and press onto the substrate firmly, ensuring a flat, even adhesion. Trim excess tape.

X1.6.3.2 Set the 0.030 in. [0.76 mm] spacers on the 2 in. [50 mm] marks on either side of the joint. Apply compound to the joint, working it through the tape. Apply more compound, using the guides to estimate when enough compound has been used.

X1.6.3.3 Lightly wet one edge of the trowel. Set the trowel at a 45° angle to the surface of the samples, and smooth along the spacers in two even strokes. Remove any excess compound on the trowel and do one more pass with the trowel set at a 90° angle to the surface of the samples, to finish.

X1.6.3.4 Remove the spacers and any excess compound on the samples. Let samples dry overnight.

X1.6.3.5 Repeat steps for the remaining trays.

X1.6.4 *Applying Paper Tape and First Coat*:

X1.6.4.1 Set the 0.055 in. [1.4 mm] spacers on the 2 in. [100 mm] marks on either side of the joint. Apply general purpose compound to the joint, using the guides to estimate when enough compound has been used.

X1.6.4.2 Lightly wet one edge of the trowel. Set the trowel on a 45° angle to the surface of the samples, and smooth along the spacers in two even strokes. Remove any excess compound on the trowel and make one more pass with the trowel set at a 90° angle to the surface of the samples.

X1.6.4.3 Cut a length of selected paper tape slightly longer than the samples on the tray, and gently place the paper tape centered on the joint.

X1.6.4.4 Change spacers to the 0.030 in. [0.76 mm] spacers. Apply a small amount of compound to the working edge of the trowel and work the tape into the compound with the trowel at 45° as in X1.6.4.2, but use no water. This step ensures that the tape is at a level of 0.030 in. above the substrate.

X1.6.4.5 Repeat steps for the remaining trays.

X1.6.5 *Applying Second Coat*:

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X1.6.5.1 Second coat is to be applied on the day following the application of the first coat (that is, allow a 24-h cure for the first coat).

X1.6.5.2 Set the 0.045 in. [1.14 mm] spacers on either side of the joint. Apply compound to the joint, using the guides to estimate when enough compound has been used.

X1.6.5.3 Lightly wet one edge of the trowel. Set the trowel at a 45° angle to the surface of the samples, and smooth along the spacers in two even strokes. Remove any excess compound on the trowel and do one more pass with the trowel set at a 90° angle to the surface of the samples.

X1.6.6 *Applying Conductive Paint*:

X1.6.6.1 Lightly sand the joint surface with a 320-grit sanding block to smooth out any superficial irregularities.

X1.6.6.2 Apply conductive paint no sooner than one day after the application of the second coat (that is, allow a minimum 24-h cure for the second coat) and no later than 24 h before tensile testing.

X1.6.6.3 Using a razor knife, score the compound between the samples to separate them from one another. Also, trim any excess compound from the ends of each sample to ensure a 6 in. [150 mm] joint length.

X1.6.6.4 Shake the bottle of silver conductive paint to ensure uniform consistency. Draw a trace in conductive paint over the test area as shown in Fig. X1.4. Extend the trace at least 0.4 in. [10 mm] from the centerline, and have a spacing of 0.4 in. [10 mm]. The thickness of the trace should not exceed 0.08 in. [2 mm]. At each end of the trace, paint an excess amount as a "pad" for attaching the circuit.

X1.6.7 *Test Circuit*:

X1.6.7.1 Connect the battery, LED, and resistor in series, leaving two long wires to attach to the test trace "pads" (see Fig. X1.5). The resistor is included to save battery life, and the resistance may be reduced if a brighter light is desired.

X1.6.8 *Curing Time*:

X1.6.8.1 Cure prepared samples for six days following the application of the second coat in a room or cabinet at a temperature of 70 ± 3.5 °F [21 ± 2 °C] and relative humidity of 50 ± 2 %. The total time from sample preparation and curing to testing is seven days.

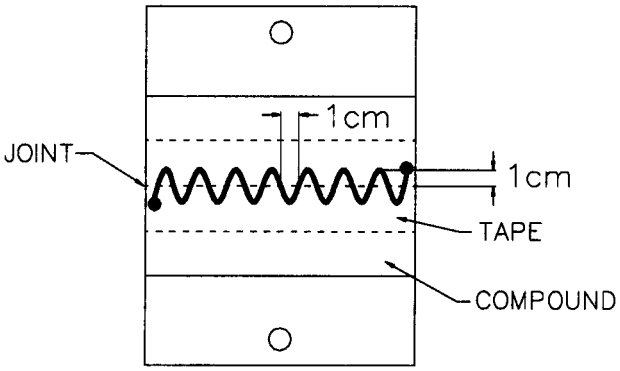

FIG. X1.4 Conductive Paint Trace

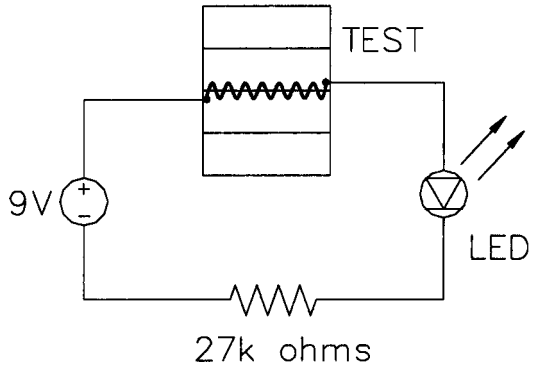

FIG. X1.5 Test Circuit Schematic

X1.7 *Tensile Testing:*

X1.7.1 Use extreme care while handling the samples, as cracking at the joint may occur, rendering the sample invalid.

X1.7.2 Use the tensiometer with a load cell having limits such that the crack and peak values fall within 20 % to 80 % of its capacity. Use plotting parameters (that is, load range and proportion) to ensure that the maximum load falls between 30 % and 90 % of the chart paper range. Set the speed of testing to 0.04 in. per min [1.0 mm per min] until first visible crack, then 0.4 in. per min [10 mm per min] until joint failure occurs.

X1.7.3 Load a sample by placing the pins in the loading apparatus through the drilled holes in the sample. Connect the trace into the circuit by taping the free wires to each end of the conductive paint line. This completes the circuit, illuminating the LED. Place a 10 lbf [50 N] preload on the sample by jogging the crosshead up slightly.

X1.7.4 Start the machine at 0.04 in. per min [1 mm per min] and note first crack at circuit failure when the LED deactivates. Increase the speed to 0.4 in. per min [10 mm per min] until failure of the joint occurs. Repeat these steps until all samples have been tested.

X1.8 *Report:*

X1.8.1 In all reports, a description of the preparation, conditioning, and testing conditions is necessary.

X1.8.2 Set up all data in a tabular format. Include the following information in the table, along with the corresponding standard deviation values:

X1.8.2.1 Force at first cracking (at circuit failure) in pounds-force (Newtons),

X1.8.2.2 Extension at first cracking (at circuit failure) in inches (millimeters),

X1.8.2.3 Force at peak load in pounds-force (Newtons), and

X1.8.2.4 Extension at peak load in inches (millimeters).

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SUMMARY OF CHANGES

Committee C11 has identified the location of selected changes to this test method since the last issue, C 474 – 02, that may impact the use of this test method. (Approved January 1, 2005)

(*1*) Section 15, which contained test methods specifically applicable to glass-mesh tape, has been moved and renumbered as Section 13. No content was changed.

(*2*) The title of the sections applicable to assemblages of tape has been renamed to ASSEMBLAGES OF JOINT TAPE AND JOINT COMPOUND to indicate that there are some test methods applicable to paper and glass-mesh joint tapes.

(*3*) Section 14, which contained a test method to evaluate Cracking of Joint Compound at Tape Edges, has been moved so that it immediately follows the heading referenced in item change (*2*). Instructions that contain the word "paper" as a modifier for joint tape were changed to have the word "paper" removed to indicate that the method is applicable to paper and glass-mesh joint tape.

(*4*) The information formerly in Section 13 has been moved to Section 15. The word "paper" in the section title indicates that it is applicable only to paper joint tape.

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Designation: C 475/C 475M – 02 (Reapproved 2007)

Standard Specification for Joint Compound and Joint Tape for Finishing Gypsum Board [1]

This standard is issued under the fixed designation C 475/C 475M; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

This standard has been approved for use by agencies of the Department of Defense.

1. Scope

1.1 This specification covers all-purpose, taping and finishing joint compounds, paper joint tape and glass-mesh joint tape.

1.1.1 The joint materials used in this standard are designed to be used with gypsum board installed in accordance with Specification C 840.

1.2 This specification also covers the minimum requirements for an assembly of taping and all-purpose compound and joint tape.

1.3 The text of this specification references notes and footnotes that provide explanatory material. These notes and footnotes (excluding those in tables and figures) shall not be considered as requirements of the specification.

1.4 The values stated in either inch-pound or SI (metric) units are to be regarded separately as standard. Within the text, the SI units are shown in parentheses. The values stated in each system shall be used independent of the other. Values from the two systems shall not be combined.

2. Referenced Documents

2.1 *ASTM Standards:* [2]

C 11 Terminology Relating to Gypsum and Related Building Materials and Systems

C 474 Test Methods for Joint Treatment Materials for Gypsum Board Construction

C 840 Specification for Application and Finishing of Gypsum Board

D 123 Terminology Relating to Textiles

D 3382 Test Methods for Measurement of Energy and Integrated Charge Transfer Due to Partial Discharges (Corona) Using Bridge Techniques

F 1615 Specification for Cautionary Labeling for Five-Gallon Open-Head Plastic Containers

3. Terminology

3.1 *Definitions*—Definitions shall be in accordance with Terminology C 11.

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *glass-mesh joint-tape*, *n*—a strip of multidirectional glass yarn material designed to reinforce the joint between two gypsum boards.

3.2.2 *joint tape*, *n*—a strip of material used to conceal and reinforce the joint between two gypsum boards.

3.2.3 *joint tape, self-adhering*, *n*—a joint tape manufactured to adhere directly to the substrate.

3.2.3.1 *Discussion*—Tapes having this quality do not require mechanical or embedment means of attachment to the substrate.

3.2.4 *paper joint tape*, *n*—a strip of paper reinforcing material designed to be embedded in the joint compound and to reinforce the joint between two gypsum boards.

3.2.5 *skewness*, *n*—as defined in Terminology D 123.

4. Physical Properties

4.1 *General*—The physical properties shall be determined in accordance with Test Methods C 474, except as noted.

4.2 *Joint Compounds*.

4.2.1 *Check Cracking*—No cracks in the thinner half of the wedge and no deep fissure cracks in the thicker half of the wedge.

4.2.2 *Putrefaction*—No putrefaction in less than 4 days.

4.2.3 *Shrinkage*—Not more than 35 % by volume.

4.3 *Joint Tape*—The following tests are required of all joint tape:

4.3.1 *Width*—Shall be not less than 1⅞ in. (48 mm) nor more than 2¼ in. (60 mm). The width of an individual roll shall vary not more than ±1⁄32 in. (1 mm).

4.3.2 *Thickness*—Shall be not more than 0.012 in. (0.30 mm).

4.3.3 *Tensile Strength*—Shall be not less than 30 lbf/in. (5.25 N/mm) in the cross direction.

[1] This specification is under the jurisdiction of ASTM Committee C11 on Gypsum and Related Building Materials and Systems and is the direct responsibility of Subcommittee C11.02 on Specifications and Test Methods for Accessories and Related Products.

Current edition approved June 1, 2007. Published October 2007. Originally approved in 1961. Last previous edition approved in 2002 as C 475 – 02.

[2] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

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4.4 The following tests are required of paper joint tape:

4.4.1 *Dimensional Stability*—Shall expand not more than 0.4 % lengthwise and not more than 2.5 % crosswise.

4.4.2 *Assembly of Taping or All-Purpose Compound and Joint Tape*:

4.4.2.1 *Bond* between the joint tape and the joint compound shall be not less than 90 %.

4.4.2.2 *Edge Cracking* shall be not more than 10 % along the edges of the tape specimen.

4.5 The following test is required of glass-mesh joint tape:

4.5.1 *Skewness*, when tested in accordance with Test Method D 3882, shall be not more than 8.75 %.

5. Sampling

5.1 *Sampling of Joint Compound*—At least 1 %, but not less than one package or container shall be sampled and shall be so selected as to be representative of the shipment. The material so obtained shall be thoroughly blended and divided. Provide not less than one 6-lb (2.75-kg) sample for the test.

5.2 *Sampling of Joint Tape*—At least one roll for every ten cases or a fraction thereof, but not more than ten rolls per shipment shall constitute a sample.

6. Inspection

6.1 Inspection of the joint compound and joint tape shall be agreed upon between the purchaser and the supplier as part of the purchase agreement.

7. Rejection

7.1 Rejection of joint compound and joint tape that fails to conform to requirements of this specification shall be reported to the producer or supplier promptly and in writing. The notice of rejection shall contain a statement documenting how the joint compound or joint tape has failed to conform to the requirements of this specification.

8. Certification

8.1 When specified in the purchase agreement, a producer's or supplier's report shall be furnished at the time of shipment certifying that the product is in compliance with this specification.

9. Packaging and Package Marking

9.1 Joint compound and joint tape shall be marked on each item or package with the name, brand or trademark of the manufacturer or seller, size, and volume or net weight of contents.

9.2 Joint compound packaged in 3-½ through 6-½ gal (U.S. liquid) (13 through 25 L) open-head pails shall be labeled in accordance with Specification F 1615.

10. Keywords

10.1 all-purpose compound; bond; check cracking; dimensional stability; edge cracking; finishing compound; glass-mesh joint tape; joint compound; joint tape; paper joint tape; putrefaction; shrinkage; taping compound; tensile strength; topping compound

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Designation: C490/C490M – 09

Standard Practice for Use of Apparatus for the Determination of Length Change of Hardened Cement Paste, Mortar, and Concrete[1]

This standard is issued under the fixed designation C490/C490M; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope*

1.1 This practice covers the requirements for the apparatus and equipment used to prepare specimens for the determination of length change in hardened cement paste, mortar, and concrete, the apparatus and equipment used for the determination of these length changes, and the procedures for its use.

1.2 Methods for the preparation and curing of test specimens, conditions of testing and curing, and detailed procedures for calculating and reporting test results are contained in applicable test methods.

1.3 The values stated in either SI units or inch-pound units are to be regarded separately as standard. The values stated in each system may not be exact equivalents; therefore, each system shall be used independently of the other. Combining values from the two systems may result in non-conformance with the standard.

2. Referenced Documents

2.1 *ASTM Standards:*[2]

C511 Specification for Mixing Rooms, Moist Cabinets, Moist Rooms, and Water Storage Tanks Used in the Testing of Hydraulic Cements and Concretes

C1005 Specification for Reference Masses and Devices for Determining Mass and Volume for Use in the Physical Testing of Hydraulic Cements

3. Terminology

3.1 *length change*—an increase or decrease in the linear dimension of a test specimen, measured along the longitudinal axis, due to causes other than applied load.

4. Significance and Use

4.1 This practice is intended to provide standard requirements for apparatus common to many test methods used in connection with cement and concrete and standardized procedures for its use. The detailed requirements as to materials, mixtures, specimens, conditioning of specimens, number of specimens, ages at which measurements are to be made, interpretation of results, and precision and bias are left to be dealt with in specific test methods.

5. Apparatus

5.1 *Reference Masses and Devices for Determining Mass and Volume*, shall conform to the requirements of Specification C1005.

5.2 *Molds*, shall have either one or two compartments and shall be constructed as shown in Fig. 1 or Fig. 2. Molds for test specimens used in determining the length change of cement pastes and mortars shall provide for 25 by 25 by 285-mm prisms having a 250-mm gauge length, or for 1 by 1 by 11¼ –in. prisms having a 10–in. gauge length. Molds for test specimens used in the length change of concretes shall provide for prisms of the desired cross section having a 10-in. or 250-mm gauge length. In some routine tests, 25 by 25 by 160-mm specimens with a gauge length of 125 mm, or 1 by 1 by 6¼ –in. specimens with a gauge length of 5-in. are permitted, but in case of dispute, results obtained with specimens of 250-mm [10-in.] gauge length shall govern.

5.2.1 The gauge length shall be considered as the nominal length between the innermost ends of the gauge studs. The parts of the molds shall be tight fitting and firmly held together when assembled, and their surfaces shall be smooth and free of pits. The molds shall be made of steel or other hard metal not readily attacked by the cement paste, mortar, or concrete. The sides of the molds shall be sufficiently rigid to prevent spreading or warping. For the molds shown in Fig. 1, the tolerance on dimension A is ±0.7 mm. For the molds shown in Fig. 2, the tolerance on dimension A is ±0.03 in.

5.2.2 Each end plate of the mold shall be equipped to hold properly in place, during the setting period, one of the gauge studs shown in Fig. 1 or Fig. 2. The gauge studs shall be of American Iron and Steel Institute (AISI)[3] Type 316 stainless steel or other corrosion-resistant metal of similar hardness.

[1] This practice is under the jurisdiction of ASTM Committee C01 on Cement and is the direct responsibility of Subcommittee C01.95 on Coordination of Standards.

Current edition approved Dec. 1, 2009. Published January 2010. Originally approved in 1962. Last previous edition approved in 2008 as C490 – 08. DOI: 10.1520/C0490_C0490M-09.

[2] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

[3] Details on this material are available from American Iron and Steel Institute (AISI), 1140 Connecticut Ave., NW, Suite 705, Washington, DC 20036, http://www.steel.org.

***A Summary of Changes section appears at the end of this standard.**

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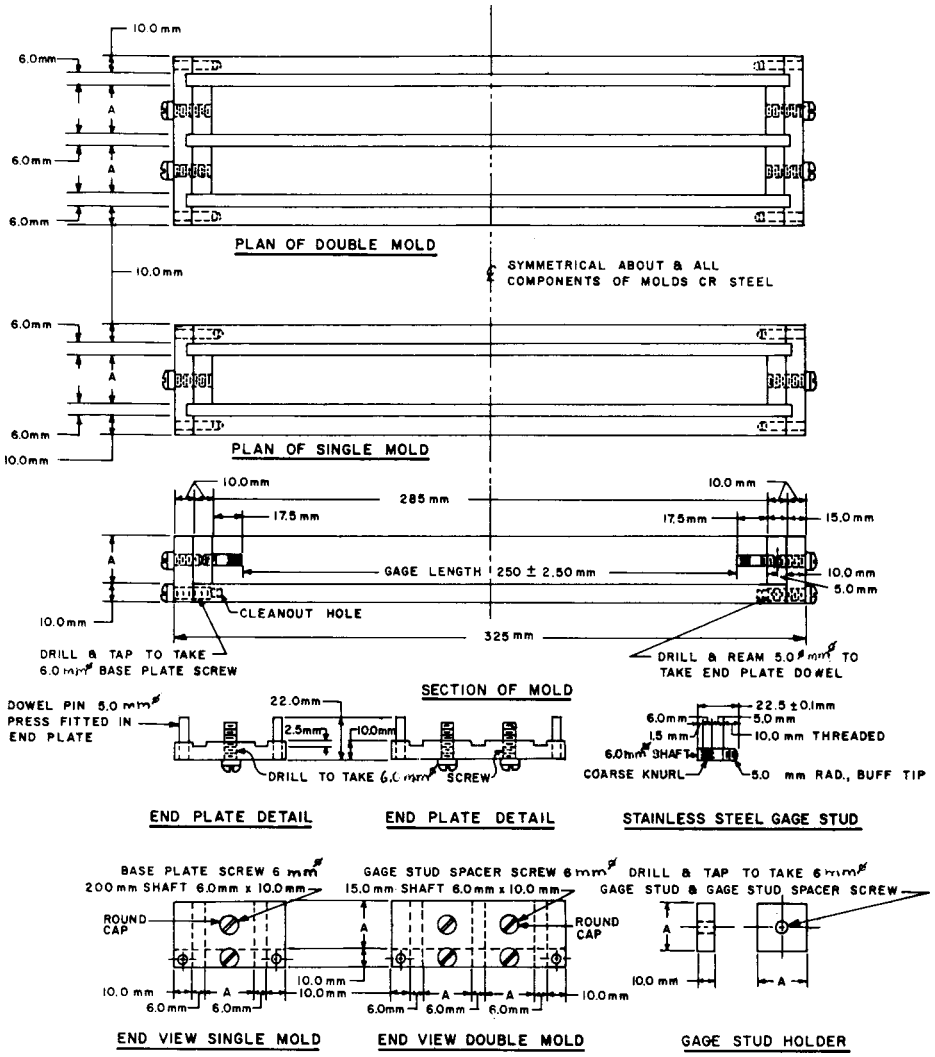

NOTE—Dimension A to be specified by the purchaser.

FIG. 1 Molds (SI Units)

Gauge studs of Invar or similar metal shall be used when specimens are tested at widely different temperatures. To prevent restraint of the gauge studs before demolding of the specimen, the device for holding the gauge studs in position shall be so arranged that, if necessary, it can be partially or completely released after the compaction of the paste or mortar into place in the mold. The gauge studs shall be set so that their principal axes coincide with the principal axis of the test specimen. For the molds shown in Fig. 1, gauge studs shall extend into the specimen 17.5 ± 0.5 mm and the distance between the inner ends of the gauge studs shall be 250.0 ± 2.5 mm and 250 mm shall be considered the gauge length for calculating length change. For the molds shown in Fig. 2, gauge studs shall extend into the specimen 0.625 ± 0.025 in. and the distance between the inner ends of the gauge studs shall be 10.00 ± 0.10 in. and 10 in. shall be considered the gauge length for calculating length change.

5.3 *Length Comparator*, for determining length change of specimens, shall be designed to accommodate the size of specimen employed and to provide or permit a positive means of contact with the gauge studs and the convenient and rapid obtaining of comparator readings (Note 1).

5.3.1 The comparator for determining length changes of specimens produced in the molds shown in Fig. 1 shall provide a dial micrometer or other measuring device graduated to read in 0.002-mm units or less, accurate within 0.002 mm in any 0.020-mm range, and within 0.004 mm in any 0.200-mm range, and sufficient range (at least 8.0 mm) in the measuring device to allow for small variations in the actual length of various specimens. The terminals of the comparator shall be plane, polished and heat-treated. They shall be fitted with collars held in place with set screws. The collars shall extend 1.5 ± 0.1 mm beyond the plane face of the terminal. The collars shall allow free rotation of the gauge stud tips that fit inside the collars and have an inside diameter no more than 0.5 mm larger than the average diameter of that portion of the gauge stud tips that fit into the collars.

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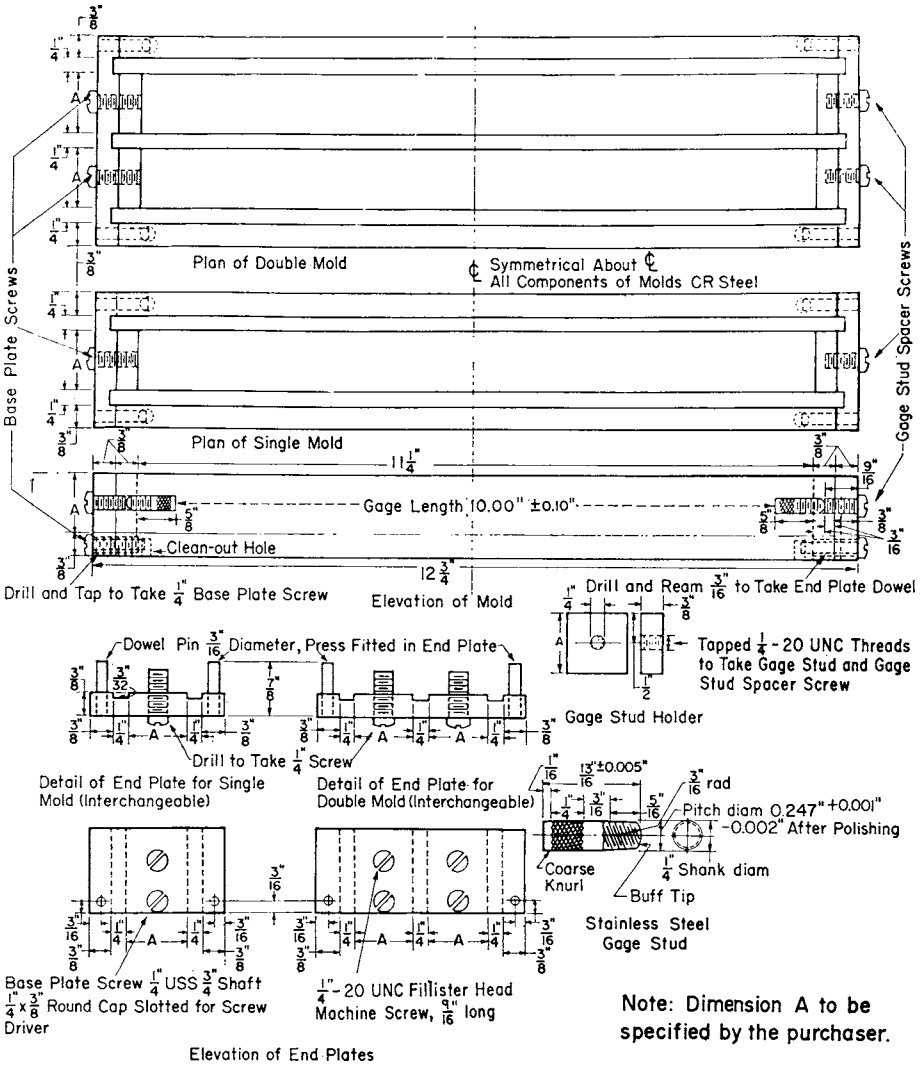

FIG. 2 Molds (Inch-Pound Units)

NOTE 1—One type of instrument that has been found satisfactory for use with small prisms is shown in Fig. 3. A horizontal comparator should be used with prisms with a cross section greater than 9 in.^{2} or 58 cm^2.

5.3.2 The comparator for determining length changes of specimens produced in the molds shown in Fig. 2 shall provide a dial micrometer or other measuring device graduated to read in 0.0001-in. units, accurate within 0.0001 in. in any 0.0010-in. range, and within 0.0002 in. in any 0.0100-in. range, and sufficient range (at least 0.3 in.) in the measuring device to allow for small variations in the actual length of various specimens. The terminals of the comparator shall be plane, polished and heat-treated. They shall be fitted with collars held in place with set screws. The collars shall extend 0.062 ± 0.003 in. beyond the plane face of the terminal. The collars shall allow free rotation of the gauge stud tips that fit inside the collars and have an inside diameter no more than 0.02 in. larger than the average diameter of that portion of the gauge stud tips that fit into the collars.

5.3.3 The design shall provide a means for checking the measuring device against a reference bar at regular intervals.

5.4 *Reference Bar*, shall have an overall length of 295 ± 3.0 mm or 170 ± 3.0 mm [11⅝ ± ⅛ in. or 6 ⅝ ± ⅛ in.], whichever is appropriate for the specimen in use. The bar shall be of a steel alloy having a coefficient of thermal expansion not greater than two millionths per degree Celsius. Each end of the reference bar shall be fitted with heat treated, hardened, and polished tips machined to the same shape as the contact end of the gauge studs used in test specimens. That portion of the bar that extends into the comparator's collar shall have a diameter of 6 ± 0.25 mm [0.250 ± 0.010 in.], and the length of that portion shall extend beyond the depth of the collar. Except for the tips, which are attached after heat treatment, no part of the reference bar shall be heat treated. The central 100 mm [4 in.] of the length of the reference bar shall be covered by a rubber tube with a wall at least 3 mm [⅛ in.] thick to minimize the effect of temperature change during handling. The reference bar shall be provided near one end with a positioning mark.

NOTE 2—Alloys such as invar lose their low coefficient of thermal expansion properties when heat treated.

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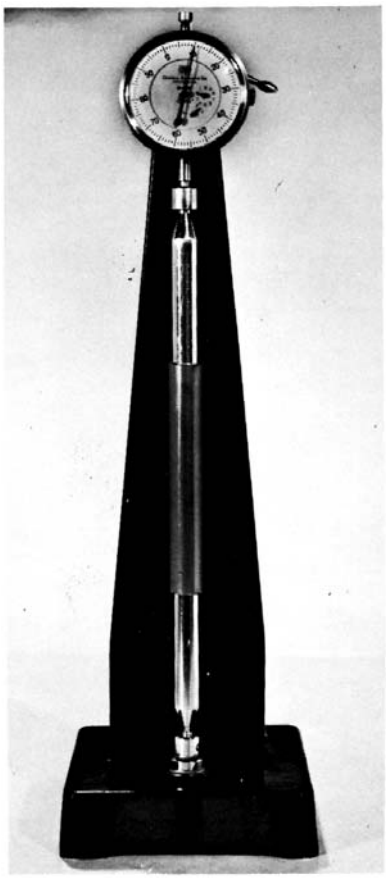

FIG. 3 Type of Suitable Apparatus for Measurement of Length Changes

5.5 Check and document the bar mold dimensions, gauge stud projection into the mold interior, length comparator, and length measuring device for conformance to the design and dimensional requirements of this specification at least every 2½ years.

6. Procedure

6.1 *Preparation of Molds*—Prior to the molding of specimens, the outside joints of the mold and the contact lines of the mold and base plate shall be sealed to prevent loss of mixing water from a freshly molded specimen. Thinly cover the interior surfaces of the mold with mineral oil. After this operation, set the gauge studs, taking care to keep them clean, and free of oil, grease, and foreign matter.

6.2 *Use of Reference Bar*—Place the reference bar in the instrument in the same position each time a comparator reading is taken. Check the dial gauge setting of the measuring device by use of the reference bar at least at the beginning and end of the readings made within a half day when the apparatus is kept in a room maintained at constant temperature. Check it more often when kept in a room where the temperature is not constant.

NOTE 3—The equation given in the section on calculation of length change contemplates that a comparator reading for the reference bar will be recorded each time the reference bar is used and a difference calculated for each test specimen reading. Alternatively, the dial gauge setting can be reset, if necessary, to its original setting with the reference bar in place each time the reference bar is read. Doing so simplifies the calculation of length change by canceling the comparator reading of the reference bar from the values of L_x and L_i. If this procedure is used, care should be taken to ensure that the dial set screw is tightened adequately each time the dial is reset.

6.3 *Obtaining Comparator Readings*—Rotate specimens slowly in the measuring instrument while the comparator reading is being taken. Record the minimum reading of the dial if the rotation causes a change in the dial reading. Place specimens in the instrument with the same end up each time a comparator reading is taken.

6.3.1 *Obtaining Comparator Readings of Specimens Stored Moist*—Clean the hole in the base of the comparator into which the gauge stud on the lower end of the bar fits (this hole tends to collect water and sand and should be cleaned after every reading). Read and record the comparator indication of the length of the reference bar. Take one bar out of immersion, blot the pins, put the bar in the comparator, read, and record the indication. Return the bar to immersion and clean the hole in the base of the comparator. Take out the second bar and treat it in a like manner. Return the second bar to immersion, record the reading, and clean the hole in the base of the comparator. Continue the procedure until all bars have been read, returned to immersion, and the readings recorded, cleaning the hole in the bottom of the comparator each time. After reading the last bar, clean the hole in the comparator base and read and record the reference-bar indication. Blot only around the pins (Note 4).

NOTE 4—The purpose of the minimal blotting of the pins and no blotting of the bars is to avoid drying and shrinkage of the bars. It has been observed that if the pins are blotted, and the bar placed in the comparator and the dial read, and the bar is then wiped gently with a dry cloth, the bar will shrink measurably. Therefore, drying should be minimized.

7. Calculation of Length Change

7.1 Calculate the length change at any age as follows:

$$L = \frac{(L_x - L_i)}{G} \times 100$$

where:

L = change in length at x age, %,
L_x = comparator reading of specimen at x age minus comparator reading of reference bar at x age; in millimetres when using Fig. 1 apparatus, in inches when using Fig. 2 apparatus,
L_i = initial comparator reading of specimen minus comparator reading of reference bar at that same time; in millimetres when using Fig. 1 apparatus, in inches when using Fig. 2 apparatus, and
G = nominal gauge length, 250 mm when using Fig. 1 apparatus, 10 in. when using Fig. 2 apparatus.

7.2 Calculate length change values for each specimen to the nearest 0.001 % and report averages to the nearest 0.01 %.

8. Temperature, Humidity, and Time

8.1 *Molding Room*—The temperature of the molding room and dry materials shall be maintained between 23.0 ± 4 °C. The relative humidity shall be not less than 50 %. The temperature of the mixing water shall be 23.0 ± 2.0 °C.

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8.2 *Moist Storage Facility*—The temperature and humidity of the air in the moist storage facility shall conform to the requirements of Specification C511.

8.3 *Time*—Comparator readings shall be taken at specified time intervals or ages. All intervals and ages shall be met within ±2 %.

9. Keywords

9.1 cement paste; comparator; concrete; length change apparatus; molds; mortar

SUMMARY OF CHANGES

Committee C01 has identified the location of selected changes to this practice since the last issue, C490 – 08, that may impact the use of this practice. (Approved December 1, 2009)

(*1*) Moved part of 5.3.3 into new 5.4 and renumbered subsequent paragraphs.

Committee C01 has identified the location of selected changes to this practice since the last issue, C490 – 07, that may impact the use of this practice. (Approved June 1, 2008)

(*1*) Editorially changed the designation to dual editorially to agree with the units statement in the Scope.

(*2*) Revised 5.3.1 and 5.3.2.

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Designation: C494/C494M – 10

Standard Specification for Chemical Admixtures for Concrete[1]

This standard is issued under the fixed designation C494/C494M; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

This standard has been approved for use by agencies of the Department of Defense.

1. Scope*

1.1 This specification covers materials for use as chemical admixtures to be added to hydraulic-cement concrete mixtures in the field for the purpose or purposes indicated for the eight types as follows:

1.1.1 *Type A*—Water-reducing admixtures,

1.1.2 *Type B*—Retarding admixtures,

1.1.3 *Type C*—Accelerating admixtures,

1.1.4 *Type D*—Water-reducing and retarding admixtures,

1.1.5 *Type E*—Water-reducing and accelerating admixtures,

1.1.6 *Type F*—Water-reducing, high range admixtures,

1.1.7 *Type G*—Water-reducing, high range, and retarding admixtures, and

1.1.8 *Type S*—Specific performance admixtures.

1.2 This specification stipulates tests of an admixture with suitable concreting materials as described in 11.1-11.3 or with cement, pozzolan, aggregates, and an air-entraining admixture proposed for specific work (11.4). Unless specified otherwise by the purchaser, the tests shall be made using concreting materials as described in 11.1-11.3.

NOTE 1—It is recommended that, whenever practicable, tests be made using the cement, pozzolan, aggregates, air-entraining admixture, and the mixture proportions, batching sequence, and other physical conditions proposed for the specific work (11.4) because the specific effects produced by chemical admixtures may vary with the properties and proportions of the other ingredients of the concrete. For instance, Types F and G admixtures may exhibit much higher water reduction in concrete mixtures having higher cement factors than that listed in 12.1.1.

Mixtures having a high range water reduction generally display a higher rate of slump loss. When high-range admixtures are used to impart increased workability (6 to 8-in. slump [150 to 200–mm]), the effect may be of limited duration, reverting to the original slump in 30 to 60 min depending on factors normally affecting rate of slump loss. The use of chemical admixtures to produce high-slump (flowing) concrete is covered by Specification C1017/C1017M.

NOTE 2—The purchaser should ensure that the admixture supplied for use in the work is equivalent in composition to the admixture subjected to test under this specification (see Section 6, Uniformity and Equivalence).

NOTE 3—Admixtures that contain relatively large amounts of chloride may accelerate corrosion of prestressing steel. Compliance with the requirements of this specification does not constitute assurance of acceptability of the admixture for use in prestressed concrete.

1.3 This specification provides for three levels of testing.

1.3.1 *Level 1*—During the initial approval stage, proof of compliance with the performance requirements defined in Table 1 demonstrates that the admixture meets the requirements of this specification. Admixtures (except for Types B, C, E, and S) shall qualify for provisional compliance when the physical requirements and any of the alternative compressive strength requirements in Table 1 are met. If subsequent test results at 6 months or one year fail to meet the standard requirement of 100 % of reference strength, the compliance of the admixture to this standard is withdrawn and all users of the admixture shall be notified immediately. Uniformity and equivalence tests of Section 6 shall be carried out to provide results against which later comparisons can be made (See Note 4).

NOTE 4—Allowing for provisional compliance while retaining longer term compressive strength requirements promotes more rapid qualification of new materials, but also provides assurance that new admixture technologies will not exhibit unexpected longer term performance. The alternative compressive strength requirements in Table 1 are based on statistical analysis of 103 Specification C494/C494M evaluation tests. The alternative requirements correspond to a 99 % probability of passing subsequent test age requirements.[2]

1.3.2 *Level 2*—Limited retesting is described in 5.2, 5.2.1 and 5.2.2. Proof of compliance with the requirements of Table 1 demonstrates continued conformity of the admixture with the requirements of the specification.

1.3.3 *Level 3*—For acceptance of a lot or for measuring uniformity within or between lots, when specified by the purchaser, the uniformity and equivalence tests of Section 6 shall be used.

1.4 The values stated in either SI units or inch-pound units are to be regarded separately as standard. The values stated in each system may not be exact equivalents; therefore, each system shall be used independently of the other. Combining values from the two systems may result in non-conformance with the standard.

[1] This specification is under the jurisdiction of ASTM Committee C09 on Concrete and Concrete Aggregates and is the direct responsibility of Subcommittee C09.23 on Chemical Admixtures.

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[2] Supporting data have been filed at ASTM International Headquarters and may be obtained by requesting Research Report RR:C09-1030.

***A Summary of Changes section appears at the end of this standard.**

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1.5 The text of this standard references notes and footnotes which provide explanatory material. These notes and footnotes (excluding those in tables and figures) shall not be considered as requirements of the standard.

1.6 The following precautionary caveat pertains only to the test method sections, Sections 11-18 of this Specification: *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

2. Referenced Documents

2.1 *ASTM Standards:*[3]

C33 Specification for Concrete Aggregates
C39/C39M Test Method for Compressive Strength of Cylindrical Concrete Specimens
C78 Test Method for Flexural Strength of Concrete (Using Simple Beam with Third-Point Loading)
C136 Test Method for Sieve Analysis of Fine and Coarse Aggregates
C138/C138M Test Method for Density (Unit Weight), Yield, and Air Content (Gravimetric) of Concrete
C143/C143M Test Method for Slump of Hydraulic-Cement Concrete
C150 Specification for Portland Cement
C157/C157M Test Method for Length Change of Hardened Hydraulic-Cement Mortar and Concrete
C183 Practice for Sampling and the Amount of Testing of Hydraulic Cement
C192/C192M Practice for Making and Curing Concrete Test Specimens in the Laboratory
C231 Test Method for Air Content of Freshly Mixed Concrete by the Pressure Method
C260 Specification for Air-Entraining Admixtures for Concrete
C403/C403M Test Method for Time of Setting of Concrete Mixtures by Penetration Resistance
C666/C666M Test Method for Resistance of Concrete to Rapid Freezing and Thawing
C1017/C1017M Specification for Chemical Admixtures for Use in Producing Flowing Concrete
D75 Practice for Sampling Aggregates
D1193 Specification for Reagent Water
E100 Specification for ASTM Hydrometers
Manual of Aggregate and Concrete Testing

2.2 *American Concrete Institute Standard:*

ACI 211.1–91 Standard Practice for Selecting Proportions for Normal, Heavyweight, and Mass Concrete[4]

3. Terminology

3.1 *Definitions:*

3.1.1 *accelerating admixture*—an admixture that accelerates the setting and early strength development of concrete.

3.1.2 *retarding admixture*—an admixture that retards the setting of concrete.

3.1.3 *water-reducing admixture*—an admixture that reduces the quantity of mixing water required to produce concrete of a given consistency.

3.1.4 *water-reducing admixture, high range*—an admixture that reduces the quantity of mixing water required to produce concrete of a given consistency by 12 % or greater.

3.1.5 *water-reducing and accelerating admixture*— an admixture that reduces the quantity of mixing water required to produce concrete of a given consistency and accelerates the setting and early strength development of concrete.

3.1.6 *water-reducing and retarding admixture*— an admixture that reduces the quantity of mixing water required to produce concrete of a given consistency and retards the setting of concrete.

3.1.7 *water-reducing, high range, and retarding admixture*—an admixture that reduces the quantity of mixing water required to produce concrete of a given consistency by 12 % or greater and retards the setting of concrete.

3.1.8 *specific performance admixture*—an admixture that provides a desired performance characteristic(s) other than reducing water content, or changing the time of setting of concrete, or both, without any adverse effects on fresh, hardened and durability properties of concrete as specified herein, excluding admixtures that are used primarily in the manufacture of dry-cast concrete products (See Note 5).

NOTE 5—Other specific performance characteristics include, but are not limited to, shrinkage reduction, mitigation of alkali-silica reaction, and viscosity modification. Admixtures used for the purposes of reducing water content or changing the time of setting of concrete are classified within the Type A through Type G grouping. Plasticizing, water-repellent, and efflorescence-controlling admixtures are examples of admixtures that are used in the manufacture of dry-cast concrete products.

4. Ordering Information

4.1 The purchaser shall specify the type of chemical admixture desired, and in the case of a Type S admixture the specific performance characteristic(s) required.

5. General Requirements

5.1 For initial compliance with this specification, test concrete in which each type of admixture shown in 1.1 is used shall conform to the respective requirements prescribed in Table 1.

5.2 The purchaser is allowed to require a limited retesting to confirm current compliance of the admixture to specification requirements. The limited retesting will cover physical properties and performance of the admixture.

5.2.1 The physical properties retesting shall consist of uniformity and equivalence tests for infrared analysis, residue by oven drying and specific gravity.

5.2.2 The performance property retesting shall consist of water content of fresh concrete, setting time and compressive strength at 3, 7 and 28 days. Purchasers having special requirements are allowed to require additional tests currently in this standard.

[3] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

[4] Available from American Concrete Institute (ACI), P.O. Box 9094, Farmington Hills, MI 48333-9094, http://www.aci-int.org.

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5.3 At the request of the purchaser, the manufacturer shall state in writing that the admixture supplied for use in the work is identical in all essential respects, including concentration, to the admixture tested under this specification.

5.4 At the request of the purchaser, when the admixture is to be used in prestressed concrete, the manufacturer shall state in writing the chloride content of the admixture and whether or not chloride has been added during its manufacture.

5.5 At the request of the purchaser, the manufacturer shall provide data to substantiate the specific performance characteristic(s) stated by the manufacturer for a Type S admixture.

5.6 Tests for uniformity and equivalence, as indicated in Section 6, shall be made on the initial sample and the results retained for reference and comparison with the results of tests of samples taken from elsewhere within the lot or subsequent lots of admixture supplied for use in the work.

6. Uniformity and Equivalence

6.1 When specified by the purchaser, the uniformity of a lot, or the equivalence of different lots from the same source shall be established by the use of the following requirements:

6.1.1 *Infrared Analysis*—The absorption spectra of the initial sample and the test sample, obtained as specified in 18.1, shall be essentially similar.

6.1.2 *Residue by Oven Drying (Liquid Admixtures)*—When dried as specified in 18.2, the oven-dried residues of the initial sample and of subsequent samples shall be within ± 12 % of the mid-point of the manufacturer's stated range, but not exceeding the manufacturer's stated limits (See Note 6).

NOTE 6—As an example, for an admixture produced with a residue range from 27 to 35 %, the manufacturer would provide maximum acceptable limits of 27.3 to 34.7 %, representing ± 12 % of the mid-point of the limits, where the mid-point is 31.0 %.

6.1.3 *Residue by Oven Drying (Nonliquid Admixtures)*—When dried as specified in 18.3, the oven-dried residues of the initial sample and of the subsequent samples shall be within a range of variation not greater than ± 4 percentage points.

6.1.4 *Specific Gravity (Liquid Admixtures)*—When tested as specified in 18.4, the specific gravity of subsequent test samples shall not differ from the specific gravity of the initial sample by more than 10 % of the difference between the specific gravity of the initial sample and that of reagent water at the same temperature. If 10 % of the difference between the specific gravity of the initial sample and water is less than 0.01, use the value 0.01 as the maximum allowable difference. Reagent water conforming to Specification D1193, Types III or IV, and prepared by distillation ion exchange, reverse osmosis, electrodialysis, or a combination of these procedures is adequate.

6.2 When the nature of the admixture or the analytical capability of the purchaser make some or all of these procedures unsuitable, other requirements for uniformity and equivalence from lot to lot or within a lot shall be established by agreement between the purchaser and the manufacturer.

7. Packaging and Marking

7.1 When the admixture is delivered in packages or containers, the proprietary name of the admixture, the type under this specification, and the net weight or volume shall be plainly marked thereon. Similar information shall be provided in the shipping advices accompanying packaged or bulk shipments of admixtures.

8. Storage

8.1 The admixture shall be stored in such a manner as to permit easy access for proper inspection and identification of each shipment, and in a suitable weathertight building that will protect the admixture from dampness and freezing.

9. Sampling and Inspection

9.1 Every facility shall be provided the purchaser for careful sampling and inspection, either at the point of manufacture or at the site of the work, as specified by the purchaser.

9.2 Samples shall be either "grab" or "composite" samples, as specified or required by this specification. A grab sample is one obtained in a single operation. A composite sample is one obtained by combining three or more grab samples.

9.3 For the purposes of this specification, it is recognized that samples will be taken for two reasons:

9.3.1 *Quality Tests*—A sample taken for the purpose of evaluating the quality of a source or lot of admixture will be required to meet all the applicable requirements of this specification. Samples used to determine conformance with the requirements of this specification shall be composites of grab samples taken from sufficient locations to ensure that the composite sample will be representative of the lot.

9.3.2 *Uniformity and Equivalence Tests*— When specified by the purchaser, a sample taken for the purpose of evaluating the uniformity of a single lot, or equivalence of different lots from one source shall be tested as provided in Section 6. Such samples shall be composite samples from individual lots when different lots from the same source are being compared. When the uniformity of a single lot is being determined, grab samples shall be used.

9.4 *Liquid Admixtures*—Liquid admixtures shall be agitated thoroughly immediately prior to sampling. Grab samples taken for quality or uniformity tests shall represent a unit shipment or a single production lot. Each grab sample shall have a volume of at least 1 pt [0.5 L]. A minimum of three grab samples shall be taken. Composite samples shall be prepared by thoroughly mixing the grab samples selected and the resultant mixture sampled to provide at least 1 gal [4 L] for quality tests. Grab samples shall be taken from different locations well distributed throughout the quantity to be represented.

9.4.1 Admixtures in bulk storage tanks shall be sampled equally from the upper, intermediate, and lower levels by means of drain cocks in the sides of the tanks or a weighted sampling bottle fitted with a stopper that can be removed after the bottle is lowered to the desired depth.

9.4.2 Samples shall be packaged in impermeable, airtight containers which are resistant to attack by the admixture.

9.5 *Nonliquid Admixtures*—Grab samples taken for quality or uniformity tests shall represent not more than 2 tons [2 Mg] of admixture and shall weigh at least 2 lb [have a mass of at least 1 kg]. A minimum of four grab samples shall be taken. Composite samples shall be prepared by thoroughly mixing the grab samples selected and the resultant mixture sampled to

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TABLE 1 Physical Requirements[A]

	Type A, Water Reducing	Type B, Retarding	Type C, Acceler-ating	Type D, Water Reducing and Retarding	Type E, Water Reducing and Accelerating	Type F, Water Reducing, High Range	Type G, Water Reducing, High Range and Retarding	Type S Specific Performance
Water content, max, % of control	95	...	...	95	95	88	88	...
Time of setting, allowable deviation from control, h:min:								
Initial: at least	...	1:00 later	1:00 earlier	1:00 later	1:00 earlier	...	1:00 later	
not more than	1:00 earlier nor 1:30 later	3:30 later	3:30 earlier	3:30 later	3:30 earlier	1:00 earlier nor 1:30 later	3:30 later	1:00 earlier nor 1:30 later
Final: at least	...	...	1:00 earlier	...	1:00 earlier	...	...	
not more than	1:00 earlier nor 1:30 later	3:30 later	...	3:30 later	...	1:00 earlier nor 1:30 later	3:30 later	1:00 earlier nor 1:30 later
Compressive strength, min, % of control:[B]								
1 day	...	...	...	...	...	140	125	...
3 days	110	90	125	110	125	125	125	90
7 days	110	90	100	110	110	115	115	90
28 days	110 (120)[C]	90	100	110 (120)[C]	110	110 (120)[C]	110 (120)[C]	90
90 days	(117)[C]	n/a	n/a	(117)[C]	n/a	(117)[C]	(117)[C]	n/a
6 months	100 (113)[C]	90	90	100 (113)[C]	100	100 (113)[C]	100 (113)[C]	90
1 year	100	90	90	100	100	100	100	90
Flexural strength, min, % control:[B]								
3 days	100	90	110	100	110	110	110	90
7 days	100	90	100	100	100	100	100	90
28 days	100	90	90	100	100	100	100	90
Length change, max shrinkage (alternative requirements):[D]								
Percent of control	135	135	135	135	135	135	135	135
Increase over control	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010
Relative durability factor, min[E]	80	80	80	80	80	80	80	80

[A] The values in the table include allowance for normal variation in test results. The object of the 90 % compressive strength requirement for a Type B amd Type S admixture is to require a level of performance comparable to that of the reference concrete.

[B] The compressive and flexural strength of the concrete containing the admixture under test at any test age shall be not less than 90 % of that attained at any previous test age. The objective of this limit is to require that the compressive or flexural strength of the concrete containing the admixture under test shall not decrease with age.

[C] Alternative requirement. If the physical requirements are met and any of the measured relative strengths are greater than the requirement in parentheses, the admixture shall be considered provisionally qualified until the 1-year strength test results are obtained.

[D] Alternative requirements, see 17.1.4, % of control limit applies when length change of control is 0.030 % or greater; increase over control limit applies when length change of control is less than 0.030 %.

[E] This requirement is applicable only when the admixture is to be used in air-entrained concrete which may be exposed to freezing and thawing while wet.

provide at least 5 lb [2.5 kg] for the composite sample. Grab samples shall be taken from different locations well distributed throughout the quantity to be represented.

9.5.1 Samples of packaged admixtures shall be obtained by means of a tube sampler as described in Practice C183.

9.5.2 Samples shall be packaged in moisture-proof, airtight containers.

9.6 Samples shall be thoroughly mixed before testing to ensure uniformity. When recommended by the manufacturer, the entire sample of a nonliquid admixture shall be dissolved in water prior to testing.

10. Rejection

10.1 For initial compliance testing, the purchaser is allowed to reject the admixture if it fails to meet any of the applicable requirements for this specification.

10.2 For limited retesting, the purchaser is allowed to reject the admixture if it fails to meet any of the requirements of the Uniformity and Equivalence Section and of the applicable parts of Table 1.

10.3 An admixture stored at the point of manufacture, for more than 6 months prior to shipment, or an admixture in local storage in the hands of a vendor for more than 6 months, after completion of tests, shall be retested before use when requested by the purchaser and is allowed to be rejected if it fails to conform to any of the applicable requirements of this specification.

10.4 Packages or containers varying more than 5 % from the specified weight or volume are allowed to be rejected. If the average weight or volume of 50 packages taken at random is less than that specified, the entire shipment is allowed to be rejected.

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10.5 When the admixture is to be used in non-air-entrained concrete, it shall be rejected when the purchaser desires if the test concrete containing it has an air content greater than 3.5 %; when the admixture is to be used in air-entrained concrete, it can be rejected if the test concrete containing it has an air content greater than 7.0 %.

TEST METHODS

NOTE 7—These tests are based on arbitrary stipulations which make possible highly standardized testing in the laboratory and are not intended to simulate actual job conditions.

11. Materials

TESTS NOT FOR A SPECIFIC USE

11.1 *Cement*—The cement used in any series of tests shall be either the cement proposed for a specific use in accordance with 11.4, a Type I or Type II cement conforming to Specification C150, or a blend of two or more cements, in equal parts. Each cement of the blend shall conform to the requirements of either Type I or Type II, Specification C150. If when using a cement other than that proposed for specific work, the air content of the concrete made without admixture, tested as prescribed in 14.3, is more than 3.5 %, select a different cement, or blend, so that the air content of the concrete will be 3.5 % or less.

11.2 *Aggregates*—Except when tests are made in accordance with 11.4 using the aggregates proposed for a specific use, the fine and coarse aggregates used in any series of tests shall come from single lots of well-graded, sound materials that conform to the requirements of Specification C33, except that the grading of the aggregates shall conform to the following requirements:

11.2.1 *Fine Aggregate Grading*:

Sieve	Weight Percent Passing
No. 4 [4.75-mm]	100
No. 16 [1.18-mm]	65 to 75
No. 50 [300 µm]	12 to 20
No. 100 [150 µm]	2 to 5

11.2.2 *Coarse Aggregate Grading*— The coarse aggregate shall meet the requirements for size number 57 of Specification C33. Take care in loading and delivery to avoid segregation.

11.2.3 The coarse aggregate used for each set of reference concrete and comparable test admixture-treated concrete shall be essentially the same. Therefore, a set of test concrete consists of one reference concrete and as many test admixture-containing concretes as are intended to be compared to that one reference. Thus, coarse aggregate for one set shall consist of enough material for one reference concrete, the test admixture-containing concrete to be compared with that reference and the sample for grading analysis testing.

11.2.3.1 Prepare coarse aggregate for a set, comprising a sample large enough for concrete trials, as follows: Fill tared containers, one each for a sample, a batch of reference concrete and one or more test concretes to the required mass from the aggregate stockpile. Accomplish this by starting with a scoopful into the first container and repeat this procedure until all containers have their required mass. Repeat the process for each of the three or more sets needed. One or more spare sets may be needed. See the Appendix of Practice D75, Sampling from Stockpiles, and the Manual of Aggregate and Concrete TestingManual of Aggregate and Concrete Testing for guidance for conditions and procedures.

11.2.4 Test coarse aggregate samples representing each set by Method C136 requirements for the sieves shown below. Discard any set for which the sample does not comply with size 57. Average test results for samples which comply with size 57 for each sieve size. Discard any set for which the sample deviates from this average by more than the amount shown in column 3. Continue the process of preparation, testing and averaging until sufficient sets of aggregate within tolerance are obtained.

Sieve	Specification C33, No. 57 Percent Passing	Maximum variation from average/passing
1½ in. [37.5-mm]	100	0.0
1.00 in. [25.0-mm]	95 to 100	1.0
½ in. [12.5-mm]	25 to 60	4.0
No. 4 [4.75-mm]	0 to 10	4.0
No. 8 [2.36-mm]	0 to 5	1.0

NOTE 8—All of the results required for demonstrating compliance under this specification are dependent on the uniformity of the aggregate samples prepared and used. Careful, skilled and well-supervised work is essential.

11.3 *Air-Entraining Admixture*—Except when tests are made in accordance with 11.4 using the air-entraining admixture proposed for specific work, the air-entraining admixture used in the concrete mixtures specified in Section 12 shall be a material such that when used to entrain the specified amount of air in the concrete mixture will give concrete of satisfactory resistance to freezing and thawing. The material to be so used will be designated by the person or agency for whom the testing is to be performed. If no material is designated, "neutralized Vinsol resin[5]" shall be used. Accomplish neutralization by treating 100 parts of Vinsol resin with 9 to 15 parts of NaOH by mass. In an aqueous solution, the ratio of water to the resinate shall not exceed 12 to 1 by mass.

TESTS FOR SPECIFIC USES

11.4 *Materials for Tests*—The effects of a chemical admixture on the time of setting and water requirement of concrete are known to vary with the time of its addition during the batching and mixing sequence. To test a chemical admixture for use in specific work, the cement, pozzolan, aggregates, and air-entraining admixture used shall be representative of those proposed for use in the work. Add the chemical admixture in the same manner and at the same time during the batching and mixing sequence as it will be added on the job. Proportion the concrete mixtures to have the cement content specified for use in the work. If the maximum size of coarse aggregate is greater than 1 in. [25.0 mm], screen the concrete over a 1-in. [25.0-mm] sieve prior to fabricating the test specimens.

11.4.1 *Other Use Conditions*—Other conditions are known to affect the overall suitability of the concrete mixture for

[5] The sole source of supply of Vinsol resin known to the committee at this time is Hercules Inc., Wilmington, DE. If you are aware of alternative suppliers, please provide this information to ASTM International Headquarters. Your comments will receive careful consideration at a meeting of the responsible technical committee [1], which you may attend.

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specific intended uses. These include the temperature of the materials or the surroundings, the humidity, the length of time between mixing and placing, the amount of mixing activity and other factors. These physical conditions may be incorporated into the tests with intention for indicating the potential interactions. These tests would be only for guidance. After incorporation of such test conditions it would not be suitable to expect compliance with this specification requirement.

11.5 *Preparation and Batching*—Prepare all material and make all weighings as prescribed in Practice C192/C192M.

12. Proportioning of Concrete Mixtures

12.1 *Proportions*—Except when tests are being made for specific uses, all concrete shall be proportioned using ACI 211.1–91 to conform to the requirements described in 12.1.1-12.1.4. After evaluation of the trial mixtures, aggregate proportions shall be adjusted as needed to obtain workable, cohesive mixtures with the correct yield to obtain the required contents. Unless otherwise specified, the admixture shall be added with the first increment of mixing water that is added to the mixer.

12.1.1 The cement content shall be 517 ± 5 lb/yd ^{3}[307 ± 3 kg/m^3].

12.1.2 For the first trial mixture, refer to the table on volume of coarse aggregate per unit volume of concrete in ACI 211.1–91 for guidance on the amount of coarse aggregate to use, given the nominal maximum size of the aggregate and the fineness modulus of the fine aggregate being used (see Note 9

NOTE 9—Values in the referenced table of ACI 211.1–91 are intended to ensure workable mixtures with the least favorable combinations of aggregate likely to be used. It is suggested, therefore, that for a closer approximation of the proportions required for this test, the values selected from this table be increased by about 7 for the first trial mixture.

12.1.3 For the non-air-entrained mixtures, the air content used in calculating the proportions shall be 1.5, as shown in Table number 5.3.3 of ACI 211.1–91. For the air-entrained mixtures, the air content used for this purpose shall be 5.5.

12.1.4 Adjust the water content to obtain a slump of 3½ ± ½ in. [90 ± 15 mm]. The workability of the concrete mixture shall be suitable for consolidation by hand rodding and the concrete mixture shall have the minimum water content possible. Achieve these conditions by final adjustments in the proportion of fine aggregate to total aggregate or in the amount of total aggregate, or both, while maintaining the yield and slump in the required ranges.

12.2 *Conditions*—Prepare concrete mixtures both with and without the admixture under test. Refer herein to the concrete mixture without the chemical admixture as the reference or control concrete mixture. Except in the case of a Type S admixture, add the admixture in the manner recommended by the manufacturer and in the amount necessary to comply with the applicable requirements of the specifications for water reduction or time of setting, or both. When desired by the person or agency for whom the tests are being performed, the admixture is allowed to be added in an amount such as to produce a specific time of setting of the concrete mixture within the limits of the applicable provisions of this specification. A Type S admixture shall be tested at a dosage within the range recommended by the manufacturer for field use.

12.2.1 *Non-Air-Entrained Concrete*—When the admixture is to be tested for use only in non-air-entrained concrete, the air content of both the mixture containing the admixture under test and the reference concrete mixture shall be 3.5 % or less, and the difference between the air contents of the two mixtures shall not exceed 1.0. If necessary, the air-entraining admixture shall be added to the reference concrete mixture. Tests for resistance to freezing and thawing shall not be made.

12.2.2 *Air-Entrained Concrete*—When the admixture is to be tested for use only in air-entrained concrete, the air-entraining admixture shall be added to the reference concrete mixture and, if necessary, to the concrete mixture containing the admixture under test in sufficient amounts to produce air contents in the range 3.5 to 7.0 %, except that for tests for resistance to freezing and thawing, the range shall be 6.0 ± 1.0 %. In both cases the difference between the air content of the reference concrete and that of the concrete containing the admixture under test shall not exceed 0.5.

13. Mixing

13.1 Machine mix the concrete as prescribed in Practice C192/C192M.

14. Tests and Properties of Freshly Mixed Concrete

14.1 Samples of freshly mixed concrete from at least three separate batches for each condition of concrete shall be tested in accordance with the methods described in 14.2-14.5.

14.2 *Slump*—Test Method C143/C143M.

14.3 *Air Content*—Test Method C231.

14.4 *Time of Setting*—Test Method C403/C403M, except that the temperature of each of the ingredients of the concrete mixtures, just prior to mixing, and the temperature at which the time-of-setting specimens are stored during the test period shall be 73 ± 3 °F [23.0 ± 2.0 °C].

14.5 *Water Content*:

14.5.1 Report the water-cement ratio of the concrete, computed to the nearest 0.001, as follows: Determine the net water content of the batch as the weight of water in the batch in excess of that present as absorbed water in the aggregates. Calculate the actual volume of concrete in the batch by determining the density of concrete in the batch as prescribed in Test Method C138/C138M. Determine the water-cement ratio by dividing the net weight of water by the weight of cement in the batch.

14.5.2 Calculate the relative water content of the concrete containing the admixture under test as a percentage of the water content of the reference concrete as follows: Divide the average water content of all batches of concrete containing the admixture under test by the average water content of all batches of the reference concrete and multiply the quotient by 100.

15. Preparation of Test Specimens

15.1 Make specimens for tests of hardened concrete, representing each test and age of test and each condition of concrete being compared, from at least three separate batches, and the

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minimum number of specimens shall be as prescribed in Table 2. On a given day make at least one specimen for each test and age of test from each condition of concrete, except make at least two specimens for the freezing and thawing test from each condition of concrete. If desired, the preparation of all specimens can be completed in one, two, or three days of mixing, provided the test concrete and its reference are made on the same day.

15.2 *Manifestly Faulty Specimens*—Visually examine each group of specimens representing a given test or a given age of test, including tests of freshly mixed concrete, before or during the test, or both, whichever is appropriate. Discard any specimen found to be manifestly faulty by such examination without testing. Visually examine all specimens representing a given test at a given age after testing, and should any specimen be found to be manifestly faulty the test results thereof shall be disregarded. Should more than one specimen representing a given test at a given age be found manifestly faulty either before or after testing, the entire test shall be disregarded and repeated. The test result reported shall be the average of the individual test results of the specimens tested or, in the event that one specimen or one result has been discarded, it shall be the average of the test results of the remaining specimens.

16. Test Specimens of Hardened Concrete

16.1 *Number of Specimens*—Six or more test specimens for the freezing and thawing test and three or more test specimens for each other type of test and age of test specified in Table 2 shall be made for each condition of concrete to be compared.

16.2 *Types of Specimens*—Specimens made from concrete with and without the chemical admixture under test shall be prepared in accordance with the following:

16.2.1 *Compressive Strength*—Make and cure test specimens in accordance with Practice C192/C192M.

16.2.2 *Flexural Strength*—Make and cure test specimens in accordance with Practice C192/C192M.

TABLE 2 Types and Minimum Number of Specimens and Tests

	Number of Types of Specimens[A]	Number of Test Ages	Number of Conditions of Concrete[B]	Number of Specimens, min
Water content	...	1	2	[C]
Slump	1	1	2	C
Air content	1	1	2	C
Time of setting	1	[D]	2	6
Compressive strength				
Types B, C, and E	1	5	2	30
Types A, D, and S	1	6	2	36
Types F and G	1	7	2	42
Flexural strength	1	3	2	18
Freezing and thawing	1	1	2	12
Length change	1	1	2	6
Water reducing, high range	...	6	...	36
Water reducing, high —range and retarding	...	6	...	36

[A] See Section 14 and 16.2.
[B] See 12.2.
[C] Determined on each batch of concrete mixed.
[D] See 14.4.

16.2.3 *Resistance to Freezing and Thawing*— Test specimens shall consist of prisms made and cured in accordance with the applicable requirements of Practice C192/C192M. Test specimen dimensions shall be as required by Test Method C666/C666M. Make one set of specimens from the concrete mixture containing the chemical admixture under test and from the reference concrete mixture, the air content of each mixture being as specified in 12.2.2.

16.2.4 *Length Change*—Make and cure test specimens in accordance with Test Method C157/C157M. The moist-curing period, including the period in the molds, shall be 14 days.

17. Tests on Hardened Concrete

17.1 Test specimens of hardened concrete (see Table 1) in accordance with the following methods :

17.1.1 *Compressive Strength*—Test Method C39/C39M. Test specimens at ages of 1 (Types F and G only), 3, 7, and 28 days, 6 months, and 1 year. Test specimens at 90 days if compliance to the alternative requirement for provisional compliance is desired. Calculate the compressive strength of the concrete containing the admixture under test as a percentage of the compressive strength of the reference concrete as follows:

17.1.1.1 Divide the average compressive strength of the specimens made from the concrete containing the admixture under test at a given age of test by the average compressive strength of the specimens made from the reference concrete at the same age of test and multiply the quotient by 100.

17.1.1.2 When tests are conducted with materials representative of those proposed for a specific use in accordance with 11.4, and if the results of the tests are required in a period of time that will not permit curing of specimens to ages of 6 months and 1 year, the tests at those ages are permitted to be waived.

17.1.2 *Flexural Strength*—Test Method C78. Test specimens at ages 3, 7, and 28 days. Calculate the flexural strength of the concrete containing the admixture under test as a percentage of the flexural strength of the reference concrete as follows:

17.1.2.1 Divide the average flexural strength of the specimens made from the concrete containing the admixture under test at a given age of test by the average flexural strength of the specimens made from the reference concrete at the same age of test, and multiply the quotient by 100.

17.1.3 *Resistance to Freezing and Thawing*— Comparison tests of the concrete containing the admixture under test with the reference concrete mixture shall be made concurrently using Procedure A of Test Method C666/C666M. Place specimens under test at the age of 14 days. Calculate the relative durability factors as shown in Specification C260.

17.1.4 *Length Change*—Test specimens shall consist of molded prisms made and tested in accordance with Test Method C157/C157M except that the moist curing period, including the period in the molds, shall be 14 days. Then store the specimens in air under conditions specified in the section on Air Storage of Test Method C157/C157M for a period of 14 days, at which time determine the length change of the specimen. Consider the drying shrinkage to be the length

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change during the drying period, based on an initial measurement at the time of removal of the specimen from the mold, and express it as percent to the nearest 0.001 % based on the specimen gage length. If the length change of the reference concrete after 14 days of drying is 0.030 % or greater, the length change on drying of concrete containing the admixture under test, expressed as percent of the length change of the reference concrete, shall not exceed the maximum specified in Table 1. If the length change of the reference concrete after 14 days of drying is less than 0.030 %, the length change on drying of concrete containing the admixture under test shall be not more than 0.010 percentage units greater than that of the reference concrete.

NOTE 10—Because the specific effects produced by chemical admixtures may vary with the properties of the other ingredients of the concrete, results of length change tests using aggregates of such a nature that the length change on drying is low may not accurately indicate relative performance to be expected with other aggregates having properties such as to produce concrete of high length change on drying.

18. Uniformity and Equivalence Tests

18.1 *Infrared Analysis*—This test procedure is intended to compare qualitatively the composition of different samples and results should not be interpreted quantitatively. Sections 18.1.1, 18.1.2, and 18.1.3 give a general procedure for the infrared analysis of admixtures (see Note 11).

18.1.1 *Liquid Admixtures*—Determine the dissolved solids concentration by 18.2 and dilute an aliquot of the liquid admixture sample with distilled water to yield a dissolved solids concentration of about 0.015 g/mL, for example, a 5-mL aliquot diluted to 200 mL. Pipet 5 mL of above solution and add it to a petri dish with 2.5 g of potassium bromide of a grade suitable for use in infrared analysis and 5 mL of distilled water. Stir and mix to dissolve. Place in a drying oven (18.2.1.1) and dry for 17 ± ¼ h at 105 ± 3 °C. Cool and transfer the dried residue to a mortar and grind to a fine powder. Work quickly to avoid moisture pick-up. Weigh 0.1 g of the powder and 0.4 g of potassium bromide of a grade suitable for use in infrared analysis. Mix in an electric amalgamator for 30 s using stainless steel capsule and balls. Proceed in accordance with 18.1.3.

18.1.2 *Non-liquid Admixtures*—Grind 10 g to a fine powder with mortar and pestle. Transfer the sample to a petri dish, place in a drying oven (18.2.1.1) and dry for 17 ± ¼ h at 105 ± 3 °C. Weigh approximately 0.005 g of the dry powder and 0.995 g of potassium bromide of a grade suitable for use in infrared analysis. Mix in an electric amalgamator for 30 s using stainless steel capsule and balls. Proceed in accordance with 18.1.3.

18.1.3 To prepare a disk for infrared analysis, weigh 0.300 g of the mixture prepared in 18.1.1 or 18.1.2 and transfer into a suitable die. If an evacuable die is used, apply vacuum for 2 min prior to pressing. Continue vacuum and press at a suitable force for 3 min, producing a disk about 1 mm thick. Remove the disk from the die, insert into the infrared spectrophotometer and obtain infrared absorption spectra.

NOTE 11—It is important that the same procedures be used on all samples to be compared with each other and preferably that they be conducted by the same analyst. Major changes in infrared spectra may result from (*a*) water content differences due to drying variations, (*b*) water picked up by hygroscopic materials, (*c*) reaction between the potassium bromide and some other compound present, and (*d*) differences in time between formation of the disk and its use. Also, the threshold for detection of individual components by infrared absorption varies widely, depending upon the identity and concentration of accompanying substances. For example, significant amounts of saccharides may be present in a lignosulfonate admixture without their presence being indicated by this method.

18.2 *Residue by Oven Drying* (Liquid Admixtures):

18.2.1 Place 25 to 30 g of standard Ottawa sand (20 to 30 mesh) in a wide-mouth, low-form (about 60 mm inside diameter and 30 mm in height) glass weighing bottle provided with a ground-glass stopper. Place the weighing bottle and stopper, with stopper removed, in a drying oven (18.2.1.1) and dry for 17 ± ¼ h at 105 ± 3 °C (Note 10). Insert the stopper in the weighing bottle, transfer to a desiccator, cool to room temperature, and weigh to the nearest 0.001 g. Remove the stopper and, using a pipet, evenly distribute 4 ml of the liquid admixture over the sand. Immediately insert the stopper to avoid loss by evaporation and weigh to the nearest 0.001 g. Remove the stopper and place both the bottle and stopper in a drying oven (18.2.1.1). Dry for 17 ± ¼ h at 105 ± 3 °C. At the end of the drying period, stopper the weighing bottle, transfer to a desiccator, cool to room temperature, and weigh to the nearest 0.001 g.

18.2.1.1 *Drying Oven*—The drying oven shall be either a forced circulation type or one with provision for free access of air. There shall be precise control of temperature and time of drying so that the degree of volatilization of the material other than water from sample to sample will not vary.

18.2.2 *Calculation*:

18.2.2.1 Record the following masses:

m_1 = mass of stoppered bottle with sand and sample,
m_2 = mass of stoppered bottle with sand,
m_3 = $m_1 - m_2$ = mass of sample,
m_4 = mass of stoppered bottle with sand and dried residue, and
m_5 = $m_4 - m_2$ = mass of dried residue.

18.2.2.2 Calculate the residue by using the following equation:

$$\text{Residue by oven drying (percent by mass)} = (m_5 \times 100)/m_3 \quad (1)$$

NOTE 12—For laboratories conducting this test as a routine operation, previously dried sand and weighing bottles can be maintained in desiccators so that they are immediately available for use when a sample is to be tested.

18.2.3 *Precision Statement*—The maximum multilaboratory coefficient of variation for residue by oven drying (liquid admixtures) has been found to be 1.25 %. Therefore, results of tests by two different laboratories on identical samples of an admixture are not expected to differ from each other by more than 3.5 % of their average (Note 13). The maximum single-operator coefficient of variation has been found to be 0.6 %. Therefore, results of two properly conducted tests by the same operator on the same material are not expected to differ by more than 1.7 %.

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NOTE 13—The precision statements are based on the maximum variation of tests made in 18 laboratories on sets of three duplicate samples of two different admixtures.

NOTE 14—Testing Type C and E admixtures, which commonly contain calcium salts, for oven-dried residue using the oven-dry method can yield inconsistent values. This is because these salts can retain bound water of hydration in an unpredictable manner upon drying. Purchasers and users of these types of chemical admixtures should preferably use the specific gravity test to determine uniformity and equivalence.

18.3 *Residue by Oven Drying* (Nonliquid Admixtures):

18.3.1 Place about 3 g of the nonliquid admixture into a dried and tared glass-stoppered weighing bottle (similar to the one described in 18.2.1). Stopper and determine the mass of the bottle and contents to the nearest 0.001 g. Remove the stopper and immediately place both bottle and stopper in a drying oven (18.2.1.1). Dry for 17 ± ¼ h at 105 ± 3 °C. At the end of the drying period, stopper the weighing bottle, transfer to the desiccator, cool to room temperature, and weigh to the nearest 0.001 g.

18.3.2 *Calculation*:

18.3.2.1 Record the following masses:

m_1 = mass of tared stoppered weighing bottle and sample before drying,
m_2 = mass of empty, stoppered weighing bottle,
m_3 = mass of sample = $(m_1 - m_2)$,
m_4 = mass of tared stoppered weighing bottle and sample after drying, and
m_5 = mass of oven-dried residue = $m_4 - m_2$.

18.3.2.2 Calculate the oven-dried residue by using the following equation:

$$\text{Residue by oven drying (mass percent)} = [m \times 100]/m_3 \quad (2)$$

18.3.3 *Precision Statement*—The maximum multilaboratory coefficient of variation for residue by oven-drying (non-liquid admixture) has been found to be 1.40 %. Therefore, results of tests by two different laboratories on identical samples of an admixture are not expected to differ from each other by more than 4.0 % of their average. The maximum single-operator coefficient of variation for residue by oven drying (non-liquid admixture) has been found to be 0.48 %. Therefore, results of two properly conducted tests by the same operator on the same material are not expected to differ by more than 1.4 % of their average. Note 13 also applies to 18.3.3.

18.4 *Specific Gravity* (Liquid Admixtures):

18.4.1 Determine the specific gravity at 25 ± 1 °C of a liquid admixture using hydrometers complying with Specification E100. Hydrometers No. 112H through 117H will cover the range for most determinations. A250-mL graduated cylinder, and a water bath capable of maintaining 25 ± 1 °C will also be required.

18.4.2 Place a sample in the 250-mL graduated cylinder and put in the hydrometer in such a manner that it floats free and does not touch the side of the cylinder. Place the cylinder with sample and hydrometer in the constant-temperature bath until the temperature of the cylinder, hydrometer, and sample is uniform at 25 ± 1 °C. If all are at proper temperature prior to insertion of the hydrometer, approximately 10 min should be allowed for equilibrium. If the sample shows evidence of foaming, hydrometer reading should be continued until constant readings are obtained. Read the hydrometer at the base of the meniscus to the nearest 0.005.

18.4.2.1 If foaming is encountered during transfer of the admixture to the cylinder, sufficient time shall be allowed for the foam to dissipate or rise to the surface, where it shall be removed before inserting the hydrometer. Crusting of the admixture on the hydrometer stem due to evaporation during temperature adjustment shall be avoided.

18.4.3 *Precision Statement*—The maximum multilaboratory coefficient of variation for specific gravity (liquid admixtures) has been found to be 0.316 %. Therefore, results of two different laboratories on identical samples of an admixture are not expected to differ from each other by more than 0.9 % of their average (Note 13). The maximum single-operator coefficient of variation has been found to be 0.09 %. Therefore, results of two properly conducted tests by the same operator on the same material are not expected to differ by more than 0.275 %.

19. Report

19.1 Report the following:

19.1.1 Results of the tests specified in Sections 6, 14, and 17, and the relevant specification requirements with which they are compared,

19.1.2 Brand name, manufacturer's name, and lot number, character of the material, and quantity represented by the sample of the admixture under test,

19.1.3 Brand name, manufacturer's name, and other pertinent data on the material used as the air-entraining admixture,

19.1.4 Brand name, manufacturer's name, type, and test data on the portland cement or cements used,

19.1.5 Description of, and test data on the fine and coarse aggregates used,

19.1.6 Detailed data on the concrete mixtures used, including amounts and proportions of admixtures used, actual cement factors, water-cement ratios, unit water contents, ratios of fine to total aggregate, slump, and air content, and

19.1.7 In the event that, in accordance with the provisions of 17.1.1.2, some of the tests have been waived, the circumstances under which such action was taken shall be stated.

19.1.8 For a Type S admixture and when required by the purchaser, a report on the performance characteristics of the admixture in accordance with 5.5.

20. Keywords

20.1 accelerating; chemical admixtures; concrete; physical requirements; retarding; specific performance; testing; water reducing

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SUMMARY OF CHANGES

Committee C09 has identified the location of selected changes to this specification since the last issue, C494/C494M–08a, that may impact the use of this specification. (Approved February 1, 2010)

(*1*) Added new Note 14.

Committee C09 has identified the location of selected changes to this specification since the last issue, C494/C494M – 08, that may impact the use of this specification. (Approved September 1, 2008)

(*1*) Added Type S admixture to Scope in new paragraph 1.1.8.

(*2*) Added new paragraph 3.1.8, definition of Type S admixture.

(*3*) Added new Note 5 and renumbered subsequent notes.

(*4*) Revised paragraph 4.1, ordering information.

(*5*) Added new paragraph 5.5 regarding provision of data, at the request of the purchaser, to substantiate specific performance claim(s) for a Type S admixture, and renumbered subsequent paragraphs.

(*6*) Revised 12.2 to include a test dosage for a Type S admixture.

(*7*) Added new paragraph 19.1.8 to require the attachment of a report on the specific performance characteristic offered by a Type S admixture to the Specification C494/C494M test report.

(*8*) Addition of specific performance to keywords.

(*9*) Added physical requirements for Type S admixture in Table 1.

(*10*) Revised Table 2 to include Type S admixture.

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Designation: C 495 – 07

Standard Test Method for Compressive Strength of Lightweight Insulating Concrete[1]

This standard is issued under the fixed designation C 495; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

This standard has been approved for use by agencies of the Department of Defense.

1. Scope*

1.1 This test method covers the preparation of specimens and the determination of the compressive strength of lightweight insulating concrete having an oven-dry density not exceeding 50 lb/ft^3 (800 kg/m^3) as determined by the procedures described herein. This test method covers the preparation and testing of molded 3 by 6-in. (75 by 150-mm) cylinders.

1.2 The values stated in inch-pound units are to be regarded as the standard.

1.3 *This standard does not purport to address all of the safety problems, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

2. Referenced Documents

2.1 *ASTM Standards:* [2]

C 39/C 39M Test Method for Compressive Strength of Cylindrical Concrete Specimens

C 88 Test Method for Soundness of Aggregates by Use of Sodium Sulfate or Magnesium Sulfate

C 109/C 109M Test Method for Compressive Strength of Hydraulic Cement Mortars(Using 2-in. or [50-mm] Cube Specimens)

C 172 Practice for Sampling Freshly Mixed Concrete

C 617 Practice for Capping Cylindrical Concrete Specimens

C 670 Practice for Preparing Precision and Bias Statements for Test Methods for Construction Materials

3. Significance and Use

3.1 This test method provides standardized requirements for sampling, molding, curing, and testing lightweight insulating concretes for the purpose of determining compliance with compressive strength and density specifications.

4. Apparatus

4.1 *Testing Machine*—Use a testing machine as prescribed in Test Method C 39/C 39M.

4.2 *Scales and Weights*—Use scales and weights in weighing specimens that conform to those specified in the Apparatus Section of Test Method C 109/C 109M.

4.3 *Drying Oven*—Use an oven as specified in Test Method C 88.

4.4 *Molds*—Use molds made of nonabsorbent materials or of materials treated to reduce absorption, that are watertight, and not subject to distortion of more than 1/16 in. (1.6 mm) in any dimension during molding and early curing of specimens. Coat all mold surfaces that will be in contact with concrete except single use plastic molds with wax or mineral oil, prior to use. Use molds having a diameter of 3 ± 1/16 in. (75 ± 1.6 mm) and a length of 6 ± 1/8 in. (150± 3 mm).

5. Sampling

5.1 Sample fresh lightweight insulating concrete in accordance with applicable provisions of Practice C 172, with the following exceptions:

5.1.1 *Sampling from Pump Equipment*—Fill a bucket of approximately 10-qt (9-dm^3) capacity by passing through the discharge stream of the concrete pump hose being used to place the concrete, at the point of placement of the concrete. Exercise care to ensure that the sample is representative of the pour, avoiding the beginning or ending of the discharge from the equipment. Prepare the test specimens as described in Section

[1] This test method is under the jurisdiction of ASTM Committee C09 on Concrete and Concrete Aggregates and is the direct responsibility of Subcommittee C09.21 on Lightweight Aggregates and Concrete.

Current edition approved July 15, 2007. Published August 2007. Originally approved in 1962. Last previous edition approved in 1999 as C 495 – 99a.

[2] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

***A Summary of Changes section appears at the end of this standard.**

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6, by filling them with a scoop of lightweight insulating concrete dipped from the bucket.

5.1.2 *Remixing Sample*—Do not remix the sample.

6. Test Specimens

6.1 *Size and Shape*—Use cylindrical test specimens 3 ± 1⁄16 in. (75 ± 1.6 mm) in diameter and 6 ± 1⁄8 in. (150 ± 3 mm) in length, with the base of each specimen perpendicular to the longitudinal axis within the limits prescribed in 6.8.

6.2 *Number*—Obtain at least four test specimens for compressive strength tests from each sample of lightweight insulating concrete.

6.3 *Molding*—In molding the specimens, place the concrete in two approximately equal layers. Tap the sides of the mold lightly with a rubber mallet after placing each layer until the surface of the layer has subsided approximately to a plane. Over fill the mold when placing the second layer. Do not rod the concrete.

6.4 *Finishing Surface*—Strike off the specimens immediately after filling the molds. Cover them in such a manner as to prevent evaporation without marring the surface (Note 1). If desired, cover the filled mold with a glass or metal plate to obtain a surface that will be suitable for testing without capping and with a minimum of grinding.

NOTE 1—It is desirable to place the filled mold in a moist room if one is available. If this is done, protect the surface from dripping water.

6.5 *Removal from Molds*—Do not remove specimens from molds until danger of damage to the specimens is past. In any event, remove specimens from the molds within 7 days after molding.

6.6 *Curing*—For the first 24 h after molding, maintain the specimens at a temperature of 70 ± 10 °F (21.1 ± 5.5 °C). After 24± 2 h, store the specimens in a moist condition (Note 2) at a temperature of 73.4 ± 3 °F (23.0 ± 1.7 °C) (Note 3). Do not expose specimens to a stream of running water nor store in water, unless a saturated lime (calcium hydroxide) solution is used. After 7 days, store the specimens at a temperature of 70 ± 10 °F and a relative humidity of 50 ± 30 % for 18 days. Twenty-five days after molding, dry the specimens in an oven at 140 ± 5 °F (60 ± 2.8 °C) for 3 days (Note 4). Cool specimens to room temperature and test for compressive strength at an age of 28 days.

NOTE 2—A moist condition is that in which free water is maintained on the surfaces of the specimens at all times.

NOTE 3—The temperature within damp sand and under wet burlap or similar materials will always be lower than the temperature in the surrounding atmosphere if evaporation takes place.

NOTE 4—Caution must be observed in loading the oven so that the moisture content of the specimen at time of test does not exceed 5 % of the oven-dry density determined in accordance with 9.1.

6.7 *Preparation for Testing*—Check the surfaces of the specimen that will be in contact with the bearing surfaces of the testing machine within 0.02 in. (0.5 mm). If the bearing surfaces depart from a plane more than 0.02 in. (0.5 mm), grind them to conform to this tolerance or cap in accordance with Practice C 617. Cap surfaces to be plane within 0.002 in. (0.05 mm). Check the planeness of the bearing surface of the specimen by means of a straightedge and feeler gage, making a minimum of three measurements on different diameters of the specimen. Make sure the surface of the specimen in contact with the lower bearing block of the testing machine does not depart from perpendicularity with the longitudinal axis of the cylinder by more than 1° (approximately equivalent to 0.1 in. in 6 in. (2.5 mm in 150 mm)) or the combined departure of the two bearing surfaces from perpendicularity by more than 3°.

6.8 *Measurement of Specimen*—Determine the diameter of the specimens to the nearest 0.01 in. (0.3 mm) by averaging two diameters measured at right angles to each other at about midheight of the specimen. Use these dimensions in computing the cross-sectional areas. Determine the height of the specimen to the nearest 0.01 in.

7. Procedure

7.1 *Placing of Specimen*—Wipe clean the bearing faces of the upper and lower bearing blocks of the compression test machine and of the test specimen and place the test specimen on the lower bearing block. Carefully align the axis of the specimen with the center of thrust of the spherically seated block. As the spherically seated block is brought to bear on the specimen, gently rotate its movable portion by hand so that uniform seating is obtained.

7.2 *Rate of Loading*—Continuously apply the load without shock at a constant rate such that the maximum load will be reached in 65 ± 15 s. Record the maximum load sustained by the specimen. Note the type of failure and the appearance of the concrete.

8. Calculation

8.1 Calculate the unit compressive strength of the concrete by dividing the maximum load by the average cross-sectional area and record to the nearest 10 psi (69 kPa).

9. Oven-Dry Density

9.1 When the oven-dry unit density is desired, mold two companion specimens for this purpose at the same time as the compressive strength specimens. Cure the companion specimens the same as the compressive strength specimens, except dry the companion specimens at the age of 28 days in an oven at 230 ± 18 °F (110 ± 10 °C) and weigh at 24-h intervals until the loss in weight does not exceed 1 % in a 24-h period. Determine the mass and dimensions of the oven-dry specimens and calculate the density from the average data obtained.

10. Report

10.1 For each specimen tested report the following information where applicable:

10.1.1 Identification number,

10.1.2 Dimensions of test specimen, in inches (millimetres),

10.1.3 The cross-sectional area in square inches (square centimetres),

10.1.4 Type of cap,

10.1.5 Maximum load, in pounds-force (or kilonewtons),

10.1.6 Unit compressive strength in pounds-force per square inch (or kilopascals),

10.1.7 Type of fracture and appearance of the concrete following determination of compressive strength,

10.1.8 Defects in either specimen or caps,

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10.1.9 Age of specimen, in days,

10.1.10 Calculated oven-dry density, if determined,

10.1.11 Average ambient temperature and average relative humidity at which specimens were stored during the 18-day curing period, and

10.1.12 Summation of tests of specimens from same sample with average of test results. This summation shall be shown on the report of the last specimen tested and should be referenced in reports of other specimens.

11. Precision and Bias

11.1 *Precision*:

11.1.1 The single operator standard deviation for a test result (where a test result is, as defined in this test method, the average of four separate compressive strength measurements) has been found to be 21 psi (Note 5). Therefore, results of two properly conducted tests (each consisting of the average of four individual measurements) by the same operator on concrete samples from the same batch should not differ by more than 59 psi (Note 5). The range (difference between highest and lowest) of the four individual measurements used in calculating the average should not exceed 155 psi (Note 6).

11.1.2 The multilaboratory standard deviation for a test result has been found to be 29 psi (Note 5). Therefore, results of two properly conducted tests (each consisting of the average of four individual measurements) by two different laboratories on concrete samples from the same batch should not differ by more than 83 psi (Note 5).

NOTE 5—These numbers represent, respectively, the (1s) and (d2s) limits as described in Practice C 670.

NOTE 6—Calculated as described in 3.4.3 of Practice C 670.

11.2 *Bias*—The bias of this test method cannot be determined because compressive strength can only be defined in terms of this test method.

12. Keywords

12.1 compressive strength; density; lightweight insulating concrete; oven-dry density

SUMMARY OF CHANGES

Committee C09 has identified the location of selected changes to this test method since the last issue, C 495 – 99a, that may impact the use of this test method. (Approved July 15, 2007)

(*1*) Replaced “weight” with “density” in 1.1, Note 4, the title of Section 9, 9.1, and Section 12.

(*2*) Replaced “weight” with “mass” in 9.1, and corrected the citation in Note 4 from 8.1 to 9.1.

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Designation: C 496/C 496M – 04$^{\epsilon 1}$

Standard Test Method for Splitting Tensile Strength of Cylindrical Concrete Specimens[1]

This standard is issued under the fixed designation C 496/C 496M; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

This standard has been approved for use by agencies of the Department of Defense.

ε[1] NOTE—Footnote 3 was reinserted editorially to correct a typo in December 2006.

1. Scope*

1.1 This test method covers the determination of the splitting tensile strength of cylindrical concrete specimens, such as molded cylinders and drilled cores.

1.2 The values stated in either inch-pound or SI units are to be regarded separately as standard. The SI units are shown in brackets. The values stated in each system may not be exact equivalents; therefore, each system shall be used independently of the other. Combining values from the two systems may result in nonconformance with the standard.

1.3 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

1.4 The text of this standard references notes that provide explanatory material. These notes shall not be considered as requirements of the standard.

2. Referenced Documents

2.1 *ASTM Standards:* [2]

C 31/C 31M Practice for Making and Curing Concrete Test Specimens in the Field

C 39/C 39M Test Method for Compressive Strength of Cylindrical Concrete Specimens

C 42/C 42M Test Method for Obtaining and Testing Drilled Cores and Sawed Beams of Concrete

C 192/C 192M Practice for Making and Curing Concrete Test Specimens in the Laboratory

C 670 Practice for Preparing Precision and Bias Statements for Test Methods for Construction Materials

3. Summary of Test Method

3.1 This test method consists of applying a diametral compressive force along the length of a cylindrical concrete specimen at a rate that is within a prescribed range until failure occurs. This loading induces tensile stresses on the plane containing the applied load and relatively high compressive stresses in the area immediately around the applied load. Tensile failure occurs rather than compressive failure because the areas of load application are in a state of triaxial compression, thereby allowing them to withstand much higher compressive stresses than would be indicated by a uniaxial compressive strength test result.

3.2 Thin, plywood bearing strips are used to distribute the load applied along the length of the cylinder.

3.3 The maximum load sustained by the specimen is divided by appropriate geometrical factors to obtain the splitting tensile strength.

4. Significance and Use

4.1 Splitting tensile strength is generally greater than direct tensile strength and lower than flexural strength (modulus of rupture).

4.2 Splitting tensile strength is used in the design of structural lightweight concrete members to evaluate the shear resistance provided by concrete and to determine the development length of reinforcement.

5. Apparatus

5.1 *Testing Machine*—The testing machine shall conform to the requirements of Test Method C 39/C 39M and be of a type with sufficient capacity that will provide the rate of loading prescribed in 7.5.

5.2 *Supplementary Bearing Bar or Plate*—If the diameter or the largest dimension of the upper bearing face or the lower bearing block is less than the length of the cylinder to be tested, a supplementary bearing bar or plate of machined steel shall be used. The surfaces of the bar or plate shall be machined to within ± 0.001 in. [0.025 mm] of planeness, as measured on any line of contact of the bearing area. It shall have a width of at least 2 in. [50 mm], and a thickness not less than the distance

[1] This test method is under the jurisdiction of ASTM Committee C09 on Concrete and Concrete Aggregates and is the direct responsibility of Subcommittee C09.61 on Testing for Strength.

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[2] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

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from the edge of the spherical or rectangular bearing block to the end of the cylinder. The bar or plate shall be used in such manner that the load will be applied over the entire length of the specimen.

5.3 *Bearing Strips*—Two bearing strips of nominal ⅛ in. [3.2 mm] thick plywood, free of imperfections, approximately 1 in. [25 mm] wide, and of a length equal to, or slightly longer than, that of the specimen shall be provided for each specimen. The bearing strips shall be placed between the specimen and both the upper and lower bearing blocks of the testing machine or between the specimen and supplemental bars or plates, when used (see 5.2). Bearing strips shall not be reused.

6. Test Specimens

6.1 The test specimens shall conform to the size, molding, and curing requirements set forth in either Practice C 31/C 31M (field specimens) or Practice C 192/C 192M (laboratory specimens). Drilled cores shall conform to the size and moisture-conditioning requirements set forth in Test Method C 42/C 42M. Moist-cured specimens, during the period between their removal from the curing environment and testing, shall be kept moist by a wet burlap or blanket covering, and shall be tested in a moist condition as soon as practicable.

6.2 The following curing procedure shall be used for evaluations of light-weight concrete: specimens tested at 28 days shall be in an air-dry condition after 7 days moist curing followed by 21 days drying at 73.5 ± 3.5°F [23.0 ± 2.0°C] and 50 ± 5 % relative humidity.

7. Procedure

7.1 *Marking*—Draw diametral lines on each end of the specimen using a suitable device that will ensure that they are in the same axial plane (see Fig. 1, Fig. 2 and Note 1), or as an alternative, use the aligning jig shown in Fig. 3 (Note 2).

NOTE 1—Figs. 1 and 2 show a suitable device for drawing diametral lines on each end of a 6 in. by 12 in. [150 mm by 300 mm] cylinder in the same axial plane. The device consists of three parts as follows:

(1) A length of 4-in. [100-mm] steel channel, the flanges of which have been machined flat,

(2) A section, part a, that is grooved to fit smoothly over the flanges of the channel and that includes cap screws for positioning the vertical member of the assembly, and

(3) A vertical bar, part b, for guiding a pencil or marker,

The assembly (part a and part b) is not fastened to the channel and is positioned at either end of the cylinder without disturbing the position of the specimen when marking the diametral lines.

NOTE 2—Fig. 4 is a detailed drawing of the aligning jig shown in Fig. 3 for achieving the same purpose as marking the diametral lines. The device consists of:

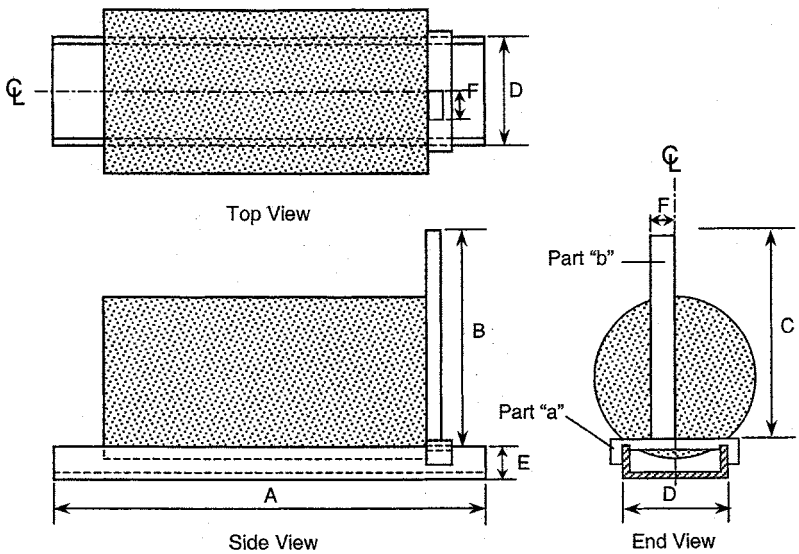
(1) A base for holding the lower bearing strip and cylinder,

(2) A supplementary bearing bar conforming to the requirements in Section 5 as to critical dimensions and planeness, and

(3) Two uprights to serve for positioning the test cylinder, bearing strips, and supplementary bearing bar.

7.2 *Measurements*—Determine the diameter of the test specimen to the nearest 0.01 in. [0.25 mm] by averaging three diameters measured near the ends and the middle of the specimen and lying in the plane containing the lines marked on the two ends. Determine the length of the specimen to the nearest 0.1 in. [2 mm] by averaging at least two length measurements taken in the plane containing the lines marked on the two ends.

7.3 *Positioning Using Marked Diametral Lines*—Center one of the plywood strips along the center of the lower bearing block. Place the specimen on the plywood strip and align so that the lines marked on the ends of the specimen are vertical and centered over the plywood strip. Place a second plywood strip lengthwise on the cylinder, centered on the lines marked on the ends of the cylinder. Position the assembly to ensure the following conditions:



A	B	C	D	E	F
16 in	8 ¼ in.	8 in.	4 in.	1 ¼ in.	1 in.
400 mm	205 mm	200 mm	100 mm	32 mm	25 mm

FIG. 1 General Views of a Suitable Apparatus for Marking End Diameters Used for Alignment of Specimen in Testing Machine

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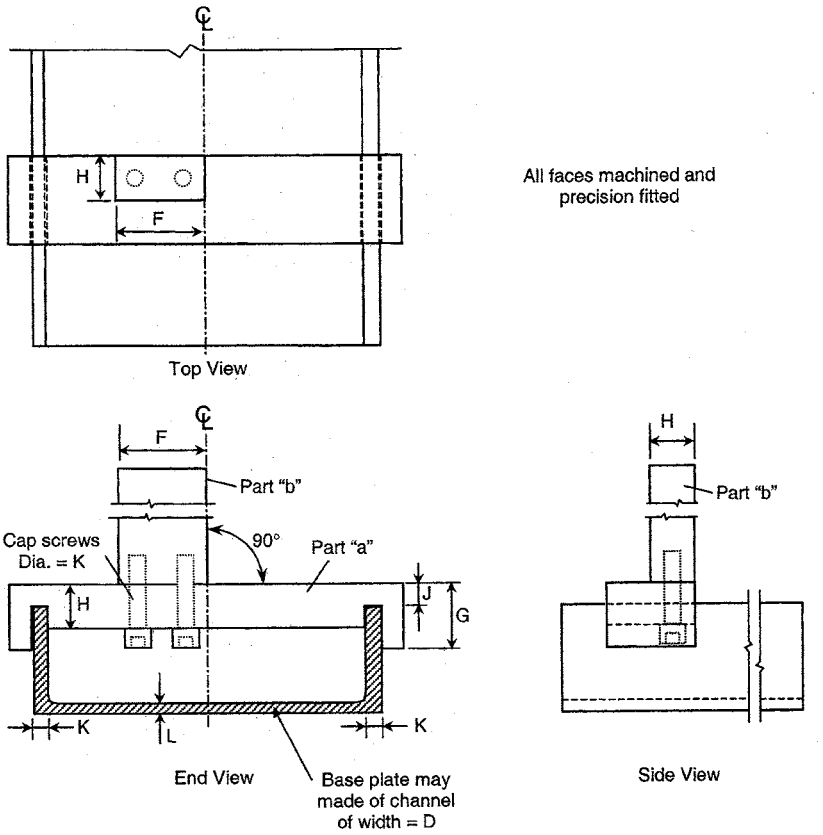

D	F	G	H	J	K	L
4 in.	1 in.	¾ in.	½ in.	¼ in.	3/16 in.	1/8 in.
100 mm	25 mm	20 mm	13 mm	6 mm	4.8 mm	3.2 mm

FIG. 2 Detailed Plans for a Suitable Apparatus for Marking End Diameters Used for Aligning the Specimen

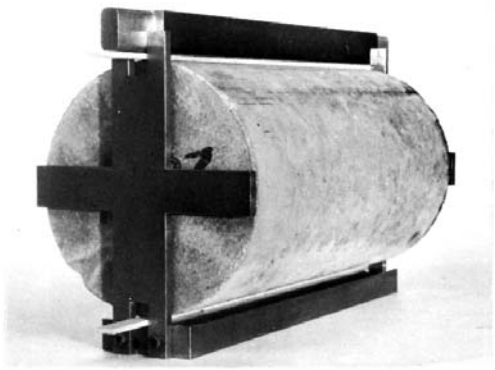

FIG. 3 Jig for Aligning Concrete Cylinder and Bearing Strips

7.3.1 The projection of the plane of the two lines marked on the ends of the specimen intersects the center of the upper bearing plate, and

7.3.2 The supplementary bearing bar or plate, when used, and the center of the specimen are directly beneath the center of thrust of the spherical bearing block (see Fig. 5).

7.4 *Positioning by Use of Aligning Jig*—Position the bearing strips, test cylinder, and supplementary bearing bar by means of the aligning jig as illustrated in Fig. 3 and center the jig so that the supplementary bearing bar and the center of the specimen are directly beneath the center of thrust of the spherical bearing block.

7.5 *Rate of Loading*—Apply the load continuously and without shock, at a constant rate within the range 100 to 200 psi/min [0.7 to 1.4 MPa/min] splitting tensile stress until failure of the specimen (Note 3). Record the maximum applied load indicated by the testing machine at failure. Note the type of failure and the appearance of the concrete.

NOTE 3—The relationship between splitting tensile stress and applied load is shown in Section 8. The required loading range in splitting tensile stress corresponds to applied total load in the range of 11 300 to 22 600 lbf [50 to 100 kN]/min for 6 by 12-in. [150 by 300-mm] cylinders.

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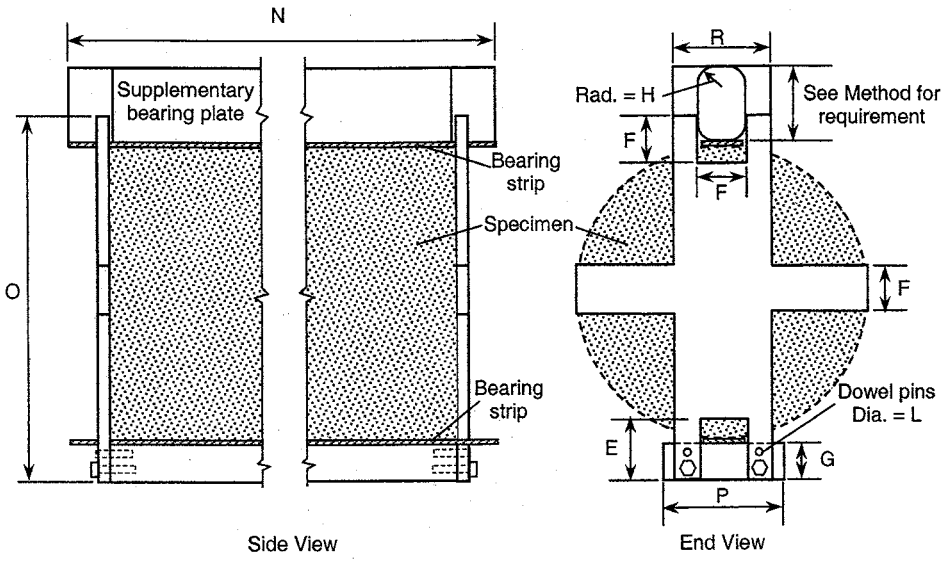

N	O	P	R	E	F	G	H	L
15 in.	7 ½ in.	2 ½ in.	2 in.	1 ¼ in.	1 in.	¾ in.	½ in.	1/8 in.
375 mm	190 mm	65 mm	50 mm	32 mm	25 mm	20 mm	13 mm	3 mm

FIG. 4 Detailed Plans for a Suitable Aligning Jig for 6 by 12 in. [150 by 300 mm] Specimen

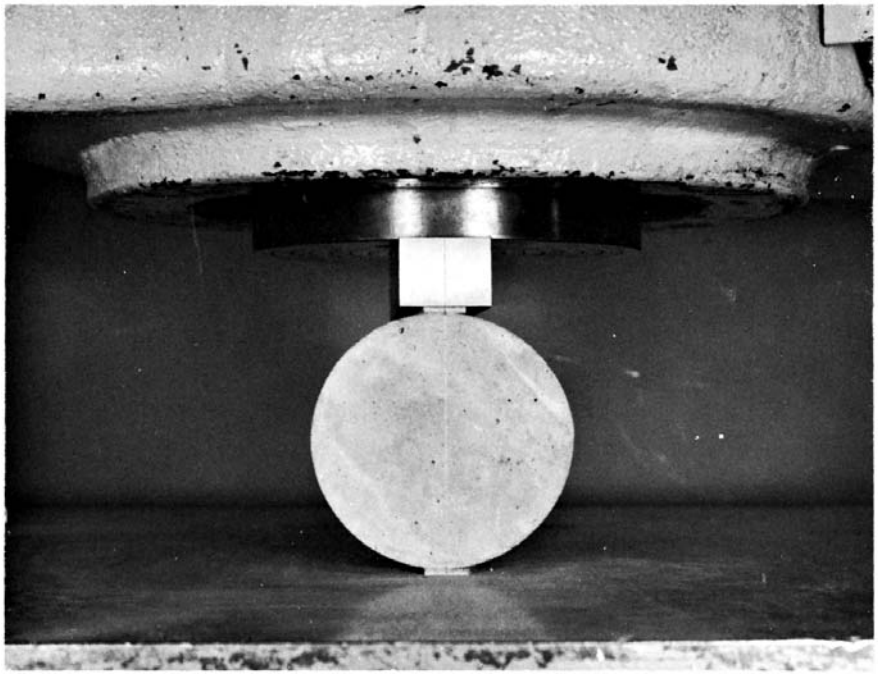

FIG. 5 Specimen Positioned in a Testing Machine for Determination of Splitting Tensile Strength

8. Calculation

8.1 Calculate the splitting tensile strength of the specimen as follows:

$$T = 2P/\pi ld \quad (1)$$

where:

T = splitting tensile strength, psi [MPa],
P = maximum applied load indicated by the testing machine, lbf [N],
l = length, in. [mm], and
d = diameter, in. [mm].

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9. Report

9.1 Report the following information:
9.1.1 Identification number,
9.1.2 Diameter and length, in. [mm],
9.1.3 Maximum load, lbf [N],
9.1.4 Splitting tensile strength calculated to the nearest 5 psi [0.05 MPa],
9.1.5 Estimated proportion of coarse aggregate fractured during test,
9.1.6 Age of specimen,
9.1.7 Curing history,
9.1.8 Defects in specimen,
9.1.9 Type of fracture, and
9.1.10 Type of specimen.

10. Precision and Bias

10.1 *Precision*—An interlaboratory study of this test method has not been performed. Available research data,[3] however, suggests that the within batch coefficient of variation is 5 % (see Note 4) for 6 × 12-in. [150 × 300-mm] cylindrical specimens with an average splitting tensile strength of 405 psi [2.8 MPa]. Results of two properly conducted tests on the same material, therefore, should not differ by more than 14 % (see Note 4) of their average for splitting tensile strengths of about 400 psi [2.8 MPa].

NOTE 4—These numbers represent, respectively, the (1s %) and (d2s %) limits as defined in Practice C 670.

10.2 *Bias*—The test method has no bias because the splitting tensile strength can be defined only in terms of this test method.

11. Keywords

11.1 cylindrical concrete specimens; splitting tension; tensile strength

[3] Wright, P. J. F., "Comments on an Indirect Tensile Test on Concrete Cylinders," Magazine of Concrete Research, Vol 7, No. 20, July 1955, pp. 87–95.

SUMMARY OF CHANGES

Committee C09 has identified the location of selected changes to this test method since the last issue, C 496 – 96, that may impact the use of this test method. (Approved February 1, 2004)

(*1*) Revised 1.2.
(*2*) Added 1.4.
(*3*) Revised 5.1, 6.1, Section 2, and Note 1 to correct references.
(*4*) Revised 5.2, 6.2, 7.2, 7.5, 10.1, and Note 4 by metrication rules.
(*5*) Revised Section 4.
(*6*) Revised 3.2 and 5.3.
(*7*) Revised Note 2.
(*8*) Figs. 1, 2, and 4 were revised and redrawn.

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Designation: C 496/C 496M – 04$^{\epsilon 1}$

Standard Test Method for Splitting Tensile Strength of Cylindrical Concrete Specimens[1]

This standard is issued under the fixed designation C 496/C 496M; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

This standard has been approved for use by agencies of the Department of Defense.

ε[1] NOTE—Footnote 3 was reinserted editorially to correct a typo in December 2006.

1. Scope*

1.1 This test method covers the determination of the splitting tensile strength of cylindrical concrete specimens, such as molded cylinders and drilled cores.

1.2 The values stated in either inch-pound or SI units are to be regarded separately as standard. The SI units are shown in brackets. The values stated in each system may not be exact equivalents; therefore, each system shall be used independently of the other. Combining values from the two systems may result in nonconformance with the standard.

1.3 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

1.4 The text of this standard references notes that provide explanatory material. These notes shall not be considered as requirements of the standard.

2. Referenced Documents

2.1 *ASTM Standards:* [2]

C 31/C 31M Practice for Making and Curing Concrete Test Specimens in the Field

C 39/C 39M Test Method for Compressive Strength of Cylindrical Concrete Specimens

C 42/C 42M Test Method for Obtaining and Testing Drilled Cores and Sawed Beams of Concrete

C 192/C 192M Practice for Making and Curing Concrete Test Specimens in the Laboratory

C 670 Practice for Preparing Precision and Bias Statements for Test Methods for Construction Materials

3. Summary of Test Method

3.1 This test method consists of applying a diametral compressive force along the length of a cylindrical concrete specimen at a rate that is within a prescribed range until failure occurs. This loading induces tensile stresses on the plane containing the applied load and relatively high compressive stresses in the area immediately around the applied load. Tensile failure occurs rather than compressive failure because the areas of load application are in a state of triaxial compression, thereby allowing them to withstand much higher compressive stresses than would be indicated by a uniaxial compressive strength test result.

3.2 Thin, plywood bearing strips are used to distribute the load applied along the length of the cylinder.

3.3 The maximum load sustained by the specimen is divided by appropriate geometrical factors to obtain the splitting tensile strength.

4. Significance and Use

4.1 Splitting tensile strength is generally greater than direct tensile strength and lower than flexural strength (modulus of rupture).

4.2 Splitting tensile strength is used in the design of structural lightweight concrete members to evaluate the shear resistance provided by concrete and to determine the development length of reinforcement.

5. Apparatus

5.1 *Testing Machine*—The testing machine shall conform to the requirements of Test Method C 39/C 39M and be of a type with sufficient capacity that will provide the rate of loading prescribed in 7.5.

5.2 *Supplementary Bearing Bar or Plate*—If the diameter or the largest dimension of the upper bearing face or the lower bearing block is less than the length of the cylinder to be tested, a supplementary bearing bar or plate of machined steel shall be used. The surfaces of the bar or plate shall be machined to within ± 0.001 in. [0.025 mm] of planeness, as measured on any line of contact of the bearing area. It shall have a width of at least 2 in. [50 mm], and a thickness not less than the distance

[1] This test method is under the jurisdiction of ASTM Committee C09 on Concrete and Concrete Aggregates and is the direct responsibility of Subcommittee C09.61 on Testing for Strength.

Current edition approved Feb. 1, 2004. Published March 2004. Originally approved in 1962. Last previous edition approved in 1996 as C 496 – 96.

[2] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

***A Summary of Changes section appears at the end of this standard.**

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from the edge of the spherical or rectangular bearing block to the end of the cylinder. The bar or plate shall be used in such manner that the load will be applied over the entire length of the specimen.

5.3 *Bearing Strips*—Two bearing strips of nominal ⅛ in. [3.2 mm] thick plywood, free of imperfections, approximately 1 in. [25 mm] wide, and of a length equal to, or slightly longer than, that of the specimen shall be provided for each specimen. The bearing strips shall be placed between the specimen and both the upper and lower bearing blocks of the testing machine or between the specimen and supplemental bars or plates, when used (see 5.2). Bearing strips shall not be reused.

6. Test Specimens

6.1 The test specimens shall conform to the size, molding, and curing requirements set forth in either Practice C 31/C 31M (field specimens) or Practice C 192/C 192M (laboratory specimens). Drilled cores shall conform to the size and moisture-conditioning requirements set forth in Test Method C 42/C 42M. Moist-cured specimens, during the period between their removal from the curing environment and testing, shall be kept moist by a wet burlap or blanket covering, and shall be tested in a moist condition as soon as practicable.

6.2 The following curing procedure shall be used for evaluations of light-weight concrete: specimens tested at 28 days shall be in an air-dry condition after 7 days moist curing followed by 21 days drying at 73.5 ± 3.5°F [23.0 ± 2.0°C] and 50 ± 5 % relative humidity.

7. Procedure

7.1 *Marking*—Draw diametral lines on each end of the specimen using a suitable device that will ensure that they are in the same axial plane (see Fig. 1, Fig. 2 and Note 1), or as an alternative, use the aligning jig shown in Fig. 3 (Note 2).

NOTE 1—Figs. 1 and 2 show a suitable device for drawing diametral lines on each end of a 6 in. by 12 in. [150 mm by 300 mm] cylinder in the same axial plane. The device consists of three parts as follows:

(1) A length of 4-in. [100-mm] steel channel, the flanges of which have been machined flat,

(2) A section, part a, that is grooved to fit smoothly over the flanges of the channel and that includes cap screws for positioning the vertical member of the assembly, and

(3) A vertical bar, part b, for guiding a pencil or marker,

The assembly (part a and part b) is not fastened to the channel and is positioned at either end of the cylinder without disturbing the position of the specimen when marking the diametral lines.

NOTE 2—Fig. 4 is a detailed drawing of the aligning jig shown in Fig. 3 for achieving the same purpose as marking the diametral lines. The device consists of:

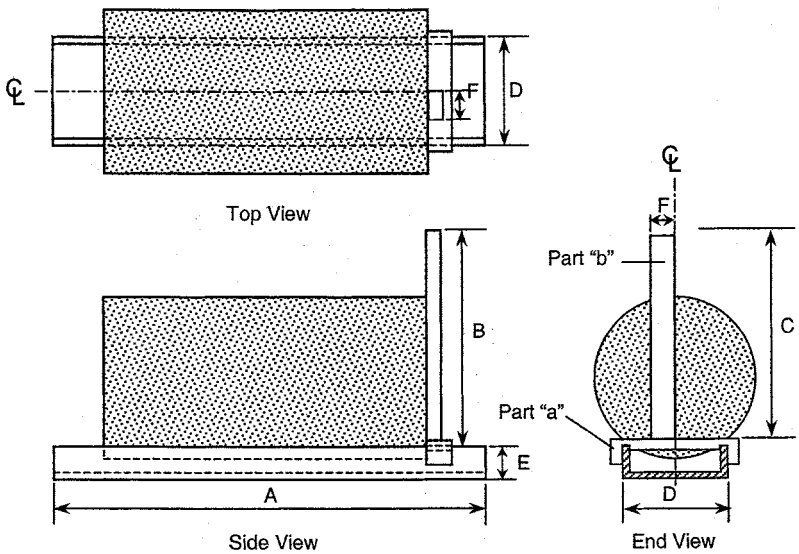
(1) A base for holding the lower bearing strip and cylinder,

(2) A supplementary bearing bar conforming to the requirements in Section 5 as to critical dimensions and planeness, and

(3) Two uprights to serve for positioning the test cylinder, bearing strips, and supplementary bearing bar.

7.2 *Measurements*—Determine the diameter of the test specimen to the nearest 0.01 in. [0.25 mm] by averaging three diameters measured near the ends and the middle of the specimen and lying in the plane containing the lines marked on the two ends. Determine the length of the specimen to the nearest 0.1 in. [2 mm] by averaging at least two length measurements taken in the plane containing the lines marked on the two ends.

7.3 *Positioning Using Marked Diametral Lines*—Center one of the plywood strips along the center of the lower bearing block. Place the specimen on the plywood strip and align so that the lines marked on the ends of the specimen are vertical and centered over the plywood strip. Place a second plywood strip lengthwise on the cylinder, centered on the lines marked on the ends of the cylinder. Position the assembly to ensure the following conditions:



A	B	C	D	E	F
16 in	8 ¼ in.	8 in.	4 in.	1 ¼ in.	1 in.
400 mm	205 mm	200 mm	100 mm	32 mm	25 mm

FIG. 1 General Views of a Suitable Apparatus for Marking End Diameters Used for Alignment of Specimen in Testing Machine

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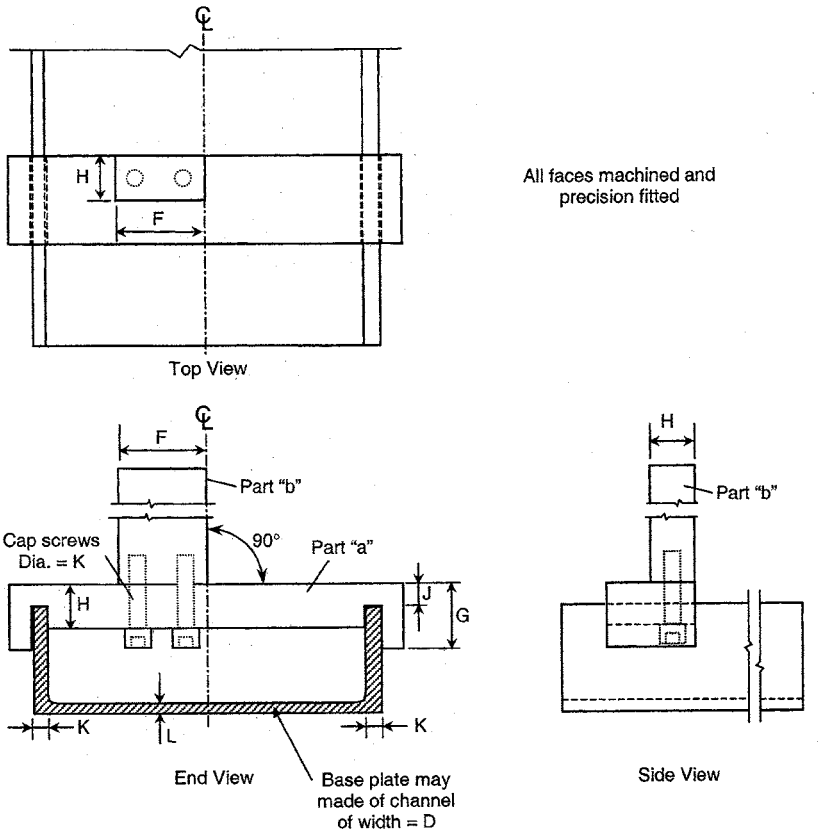

D	F	G	H	J	K	L
4 in.	1 in.	¾ in.	½ in.	¼ in.	3/16 in.	1/8 in.
100 mm	25 mm	20 mm	13 mm	6 mm	4.8 mm	3.2 mm

FIG. 2 Detailed Plans for a Suitable Apparatus for Marking End Diameters Used for Aligning the Specimen

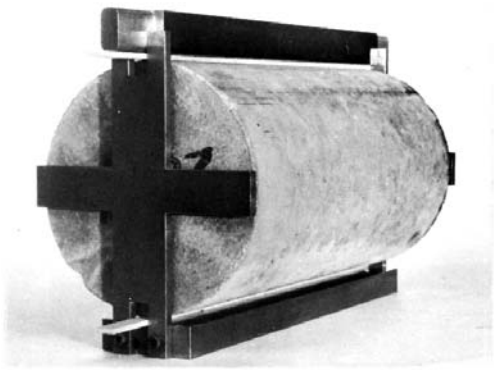

FIG. 3 Jig for Aligning Concrete Cylinder and Bearing Strips

7.3.1 The projection of the plane of the two lines marked on the ends of the specimen intersects the center of the upper bearing plate, and

7.3.2 The supplementary bearing bar or plate, when used, and the center of the specimen are directly beneath the center of thrust of the spherical bearing block (see Fig. 5).

7.4 *Positioning by Use of Aligning Jig*—Position the bearing strips, test cylinder, and supplementary bearing bar by means of the aligning jig as illustrated in Fig. 3 and center the jig so that the supplementary bearing bar and the center of the specimen are directly beneath the center of thrust of the spherical bearing block.

7.5 *Rate of Loading*—Apply the load continuously and without shock, at a constant rate within the range 100 to 200 psi/min [0.7 to 1.4 MPa/min] splitting tensile stress until failure of the specimen (Note 3). Record the maximum applied load indicated by the testing machine at failure. Note the type of failure and the appearance of the concrete.

NOTE 3—The relationship between splitting tensile stress and applied load is shown in Section 8. The required loading range in splitting tensile stress corresponds to applied total load in the range of 11 300 to 22 600 lbf [50 to 100 kN]/min for 6 by 12-in. [150 by 300-mm] cylinders.

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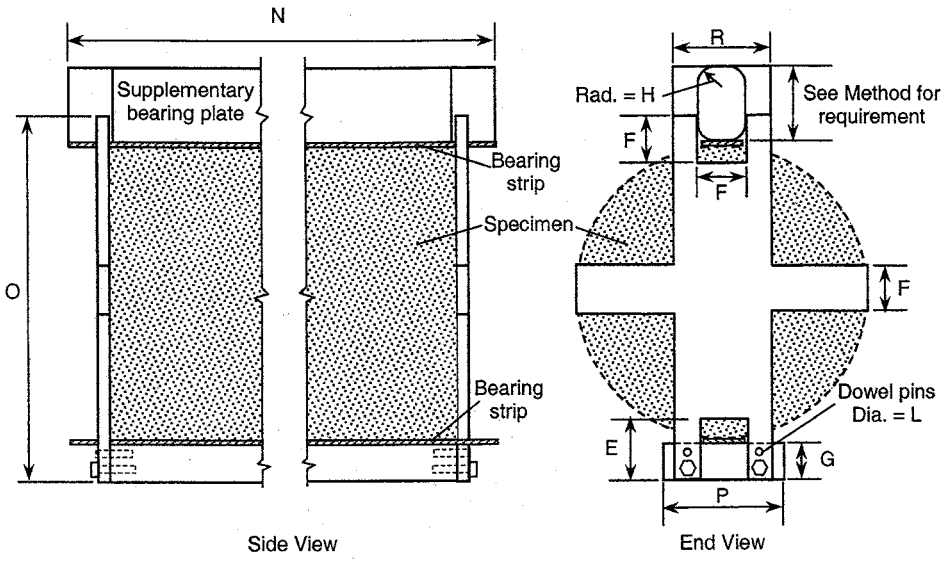

N	O	P	R	E	F	G	H	L
15 in.	7 ½ in.	2 ½ in.	2 in.	1 ¼ in.	1 in.	¾ in.	½ in.	1/8 in.
375 mm	190 mm	65 mm	50 mm	32 mm	25 mm	20 mm	13 mm	3 mm

FIG. 4 Detailed Plans for a Suitable Aligning Jig for 6 by 12 in. [150 by 300 mm] Specimen

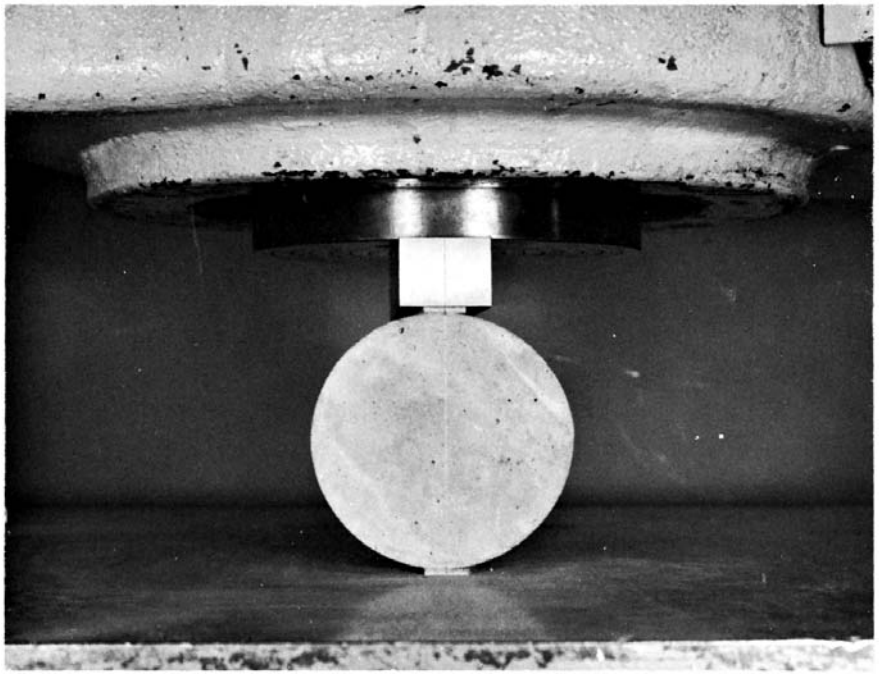

FIG. 5 Specimen Positioned in a Testing Machine for Determination of Splitting Tensile Strength

8. Calculation

8.1 Calculate the splitting tensile strength of the specimen as follows:

$$T = 2P/\pi ld \quad (1)$$

where:

T = splitting tensile strength, psi [MPa],
P = maximum applied load indicated by the testing machine, lbf [N],
l = length, in. [mm], and
d = diameter, in. [mm].

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9. Report

9.1 Report the following information:
9.1.1 Identification number,
9.1.2 Diameter and length, in. [mm],
9.1.3 Maximum load, lbf [N],
9.1.4 Splitting tensile strength calculated to the nearest 5 psi [0.05 MPa],
9.1.5 Estimated proportion of coarse aggregate fractured during test,
9.1.6 Age of specimen,
9.1.7 Curing history,
9.1.8 Defects in specimen,
9.1.9 Type of fracture, and
9.1.10 Type of specimen.

10. Precision and Bias

10.1 *Precision*—An interlaboratory study of this test method has not been performed. Available research data,[3] however, suggests that the within batch coefficient of variation is 5 % (see Note 4) for 6 × 12-in. [150 × 300-mm] cylindrical specimens with an average splitting tensile strength of 405 psi [2.8 MPa]. Results of two properly conducted tests on the same material, therefore, should not differ by more than 14 % (see Note 4) of their average for splitting tensile strengths of about 400 psi [2.8 MPa].

NOTE 4—These numbers represent, respectively, the (1s %) and (d2s %) limits as defined in Practice C 670.

10.2 *Bias*—The test method has no bias because the splitting tensile strength can be defined only in terms of this test method.

11. Keywords

11.1 cylindrical concrete specimens; splitting tension; tensile strength

[3] Wright, P. J. F., "Comments on an Indirect Tensile Test on Concrete Cylinders," Magazine of Concrete Research, Vol 7, No. 20, July 1955, pp. 87–95.

SUMMARY OF CHANGES

Committee C09 has identified the location of selected changes to this test method since the last issue, C 496 – 96, that may impact the use of this test method. (Approved February 1, 2004)

(*1*) Revised 1.2.
(*2*) Added 1.4.
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(*5*) Revised Section 4.
(*6*) Revised 3.2 and 5.3.
(*7*) Revised Note 2.
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Designation: C 511 – 09

Standard Specification for Mixing Rooms, Moist Cabinets, Moist Rooms, and Water Storage Tanks Used in the Testing of Hydraulic Cements and Concretes[1]

This standard is issued under the fixed designation C 511; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope*

1.1 This specification includes requirements for mixing rooms where paste and mortar specimens are prepared; and for moist cabinets, moist rooms, and water storage tanks where paste, mortar, and concrete specimens are stored.

1.2 The values stated in SI units are to be regarded as standard. No other units of measurement are included in this standard. Values in SI units shall be obtained by measurement in SI units or by appropriate conversion, using the Rules for Conversion and rounding given in Standard IEEE/ASTM SI 10, of measurements made in other units.

1.3 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

2. Referenced Documents

2.1 *ASTM Standards:*[2]

C 51 Terminology Relating to Lime and Limestone (as used by the Industry)

E 77 Test Method for Inspection and Verification of Thermometers

IEEE/ASTM SI 10 Standard for Use of the International System of Units (SI): The Modern Metric System

3. Terminology

3.1 *Definitions:*

3.1.1 *mixing room*, *n*—a room with controlled temperature and relative humidity where cement paste and mortar specimens are prepared.

3.1.2 *moist cabinet*, *n*—a compartmented storage facility of moderate dimensions with controlled temperature and relative humidity.

3.1.3 *moist room*, *n*—a "walk-in" storage facility with controlled temperature and relative humidity, commonly called a fog room when the prescribed relative humidity is achieved by the atomization of water.

4. Requirements for Cement Mixing Rooms

4.1 The temperature of the air in the vicinity of the mixing slab, molds, and base plates shall be maintained at 23.0 ± 4.0 ° C and at a relative humidity of not less than 50 %.

4.2 The temperature of the mixing water used to prepare cement paste and mortar specimens shall be 23.0 ± 2.0 °C.

5. Temperature Measuring Devices

5.1 *Reference Temperature Measuring Device*—used to verify the temperature recorder, must be accurate and readable to 0.5 ºC. A copy of the certificate or report which verifies the accuracy shall be available in the laboratory.

NOTE 1—The ice-point method described in Test Method E 77 may be used to ensure that no damage to the reference thermometer has occurred during shipping.

5.2 *Temperature Recorder*—shall record temperatures every 15 min or less and shall be accurate and readable to 1 º C. The data from the recorder shall be evaluated at a minimum of once each week. A record of this evaluation documenting the date checked, a confirmation that the data is within the required temperature range, and the name of the individual performing this evaluation shall be maintained in the laboratory. (Note 2)

NOTE 2—This requirement may be satisfied by an initialed and dated temperature recorder chart. Brief changes in the temperature due to door openings should be ignored.

5.2.1 The temperature recorder shall be verified at least every six months or whenever there is a question of accuracy.

5.2.1.1 For moist cabinets and rooms, position the reference temperature measuring device in a readable position in air as near as practical to the temperature recorder probe. Keep the door closed for at least 5 min prior to taking readings. Record the temperature readings of both the temperature recorder and

[1] This specification is under the jurisdiction of ASTM Committee C01 on Cement and is the direct responsibility of Subcommittee C01.95 on Coordination of Standards.

Current edition approved June 1, 2009. Published July 2009. Originally approved in 1968. Last previous edition approved in 2006 as C 511 – 06.

[2] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

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the reference temperature measuring device. When taking these readings, the reference temperature measuring device shall remain in the moist cabinet or room and read immediately upon opening the door.

5.2.1.2 For water storage tanks, position the reference temperature measuring device in a readable position in water as near as practical to the temperature recorder probe. Without removing the reference temperature measuring device from the water, record the temperature readings of both the temperature recorder and the reference temperature measuring device after the temperatures have stabilized.

5.2.1.3 Verify the accuracy of the temperature recorder by comparing the reading of the temperature recorder with that of the reference temperature measuring device during the normal operation of the moist cabinet, moist room or water storage tanks. If the difference between the temperature readings is greater than 1 ºC, the temperature recorder shall be adjusted to within 0.5 ºC of the reference temperature measuring device.

6. Requirements for Moist Cabinets and Moist Rooms

6.1 *General*—Except during those times when specimens are being placed into or removed from storage, maintain the atmosphere in a moist cabinet or moist room at a temperature of 23.0 ± 2.0 °C and a relative humidity of not less than 95 %. Maintain atmospheric conditions within a moist cabinet or moist room such that test specimens in storage are saturated with moisture to the degree needed to ensure that the exposed surfaces of all specimens in storage both look moist and feel moist (See Note 5). Equip all moist cabinets and moist rooms with a temperature recorder. The use of humidity recording devices is optional. Keep shelves on which fresh specimens are placed level.

6.1.1 The air temperature inside the moist cabinet or moist room shall be controlled with provisions made for heating or cooling, or both, as may be necessary. This shall be accomplished in one of two ways:

6.1.1.1 Thermostatically control the air temperature within the moist cabinet or moist room when surrounding space is not conditioned. In this case the sensing element for the controls shall be located inside the moist cabinet or moist room.

6.1.1.2 Thermostatically control the space surrounding the moist cabinet or moist room and manually control the temperature within the moist cabinet or moist room.

6.1.2 In either of the preceding cases, the laboratory shall demonstrate the ability of the controls to maintain the required temperature in the moist cabinet or moist room over an extended period of time. Data from the temperature recorder that indicates that the temperatures are within the temperature limits specified in 6.1 shall be required as evidence of this ability.

6.2 *Moist Cabinets*—A moist cabinet shall be constructed of durable materials and the doors shall be tight-fitting. The specified relative humidity shall be maintained by the use of one or more fog sprays, water sprays, or curtains of water on the inner walls that are so directed that the discharge will collect in a pool at or near the bottom of the moist storage section.

6.3 *Moist Rooms*:

6.3.1 *General*—The walls of a moist room shall be constructed of durable materials, and all openings shall be provided with tight-fitting doors or windows (Note 3). The specified relative humidity may be maintained in any convenient and suitable manner (Note 4).

NOTE 3—Well insulated walls will substantially help maintain necessary conditions.

NOTE 4—A fog spray found suitable for this purpose is shown in Fig. 1.

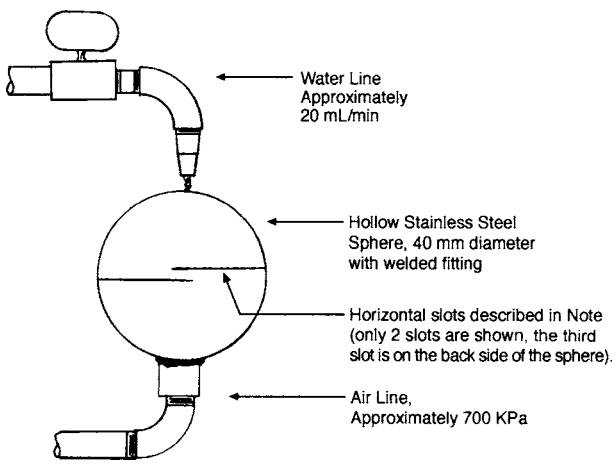
6.3.2 *Moist Rooms Used in Cement Testing*—Durable shelving that is properly shielded to prevent droplets of water from falling on the surfaces of freshly molded specimens shall be available within each moist room.

6.3.3 *Moist Rooms Used in Concrete Testing*—Maintain atmospheric conditions within each moist room such that test specimens in storage both look moist and feel moist (See Note 5). Do not expose specimens to dripping or running water.

NOTE 5—Maintenance of adequate water spray(s) and adequate spray distribution in the moist room will result in stored specimens looking and feeling moist and will maintain the required humidity. Inadequate numbers of spray nozzles, partially obstructed spray nozzles, or disturbances in the moist air system such as open doors, air-conditioning or heating drafts, or overly crowded shelf space may result in relative dry spots. Specimen surface texture and age can influence the surface appearance and should be considered when specimens in localized areas do not look and feel moist.

7. Requirements for Water Storage Tanks

7.1 *General*—Tanks shall be constructed of non-corroding materials. Provision for automatic control of water temperature at 23.0 ± 2.0 °C shall be made where a tank is located in a room not having temperature controlled within that range and in any other instance where difficulty in maintaining temperatures within the specified range is encountered. With the exception of water storage tanks located in a moist room or moist cabinet, all water storage tanks shall be equipped with a



NOTE 1—Cut three horizontal air slots around circumference of hollow sphere using a 0.20 mm thick diamond lapidary saw covering 120° to 150° each and spaced approximately 5 mm apart. Air passing through these slots strikes the water (which is flowing over the outer surface of the sphere) to produce a spray.

FIG. 1 Example of a Fog Spray for Maintaining Relative Humidity in Moist Rooms (Full Scale)

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temperature recorder with its sensing element in the storage water. For the purpose of temperature recording, a group of water storage tanks may be considered one tank if the following three conditions are met: (*1*) all the tanks are interconnected with tubing that allows the water to flow between the tanks, (*2*) some means of circulation is provided between tanks, and (*3*) temperature variation between the tanks must not exceed 1.0 °C when checked and recorded weekly. The water in a storage tank shall be saturated with calcium hydroxide to prevent leaching of calcium hydroxide from the specimens (Note 6). Water not saturated with calcium hydroxide (high-calcium hydrated lime) may affect test results due to leaching of lime from the test specimens and shall not be used in storage tanks. To maintain saturation with calcium hydroxide, excess calcium hydroxide shall be present. For the purposes of lime saturation to prevent leaching, lime means high-calcium hydrated lime, not calcium carbonate (limestone)—see Terminology C 51. The water in the storage tank shall be thoroughly stirred at intervals not to exceed one month to help replace calcium ions that have depleted. Tanks shall be cleaned and refilled with water containing 3 g/L of calcium hydroxide at intervals not to exceed 24 months (Note 7).

NOTE 6—pH is not a reliable indicator of lime saturation in storage tank water since severe reductions in dissolved calcium ions can occur before pH values are significantly reduced.

NOTE 7—The 3 g/L level is intended to provide a quantity of calcium hydroxide approximately two times that required for initial saturation.

7.2 Do not use continuously running fresh water or demineralized water in storage tanks because it may effect test results due to excessive leaching. A closed system, circulating the saturated lime water between or among storage tanks, may be used.

8. Keywords

8.1 cement paste; concrete; mixing room; moist cabinets; moist rooms; mortar; water storage tanks

SUMMARY OF CHANGES

Committee C01 has identified the location of selected changes to this specification since the last issue, C 511 – 06, that may impact the use of this specification. (Approved June 1, 2009)

(*1*) Revised 6.1.
(*2*) Deleted old 6.1.1 and renumbered subsequent sections
(*3*) Revised 6.3.3.
(*4*) Added new Note 5 and renumbered subsequent notes.

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Designation: C 512 – 02

Standard Test Method for Creep of Concrete in Compression[1]

This standard is issued under the fixed designation C 512; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope

1.1 This test method covers the determination of the creep of molded concrete cylinders subjected to sustained longitudinal compressive load. This test method is limited to concrete in which the maximum aggregate size does not exceed 2 in. (50 mm).

1.2 The values stated in inch-pound units are to be regarded as the standard.

1.3 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

2. Referenced Documents

2.1 *ASTM Standards:*

C 39/C 39M Test Method for Compressive Strength of Cylindrical Concrete Specimens[2]

C 192/C 192M Practice for Making and Curing Concrete Test Specimens in the Laboratory[2]

C 470/C 470M Specification for Molds for Forming Concrete Test Cylinders Vertically[2]

C 617 Practice for Capping Cylindrical Concrete Specimens[2]

C 670 Practice for Preparing Precision and Bias Statements for Test Methods for Construction Materials[2]

3. Significance and Use

3.1 This test method measures the load-induced time-dependent compressive strain at selected ages for concrete under an arbitrary set of controlled environmental conditions.

3.2 This test method can be used to compare creep potentials of different concretes. A procedure is available, using the developed equation (or graphical plot), for calculating stress from strain data within massive non-reinforced concrete structures. For most specific design applications, the test conditions set forth herein must be modified to more closely simulate the anticipated curing, thermal, exposure, and loading age conditions for the prototype structure. Current theories and effects of material and environmental parameters are presented in ACI SP-9, Symposium on Creep of Concrete.[3]

3.3 In the absence of a satisfactory hypothesis governing creep phenomena, a number of assumptions have been developed that have been generally substantiated by test and experience.

3.3.1 Creep is proportional to stress from 0 to 40 % of concrete compressive strength.

3.3.2 Creep has been conclusively shown to be directly proportional to paste content throughout the range of paste contents normally used in concrete. Thus, the creep characteristics of concrete mixtures containing aggregate of maximum size greater than 2 in. (50 mm) may be determined from the creep characteristics of the minus 2-in. (minus 50-mm) fraction obtained by wet-sieving. Multiply the value of the characteristic by the ratio of the cement paste content (proportion by volume) in the full concrete mixture to the paste content of the sieved sample.

3.4 The use of the logarithmic expression (Section 8) does not imply that the creep strain-time relationship is necessarily an exact logarithmic function; however, for the period of one year, the expression approximates normal creep behavior with sufficient accuracy to make possible the calculation of parameters that are useful for the purpose of comparing concretes.

3.5 There are no data that would support the extrapolation of the results of this test to tension or torsion.

4. Apparatus

4.1 *Molds*—Molds shall be cylindrical conforming to the provisions of Practice C 192/C 192M, or to the provisions of Specification C 470/C 470M. If required, provisions shall be made for attaching gage studs and inserts, and for affixing integral bearing plates to the ends of the specimen as it is cast.

4.1.1 Horizontal molds shall conform to the requirements of the section on horizontal molds for creep test cylinders of Practice C 192/C 192M. A horizontal mold that has proven satisfactory is shown in Fig. 1.

4.2 *Loading Frame*, capable of applying and maintaining the required load on the specimen, despite any change in the dimension of the specimen. In its simplest form the loading

[1] This test method is under the jurisdiction of ASTM Committee C09 on Concrete and Concrete Aggregates and is the direct responsibility of Subcommittee C09.61 on Testing for Strength.

Current edition approved Aug. 10, 2002. Published October 2002. Originally published as C 512 – 63 T. Last previous edition C 512 – 87 (1994).

[2] *Annual Book of ASTM Standards*, Vol 04.02.

[3] Available from the American Concrete Institute, P. O. Box 19150, Detroit, MI 48219.

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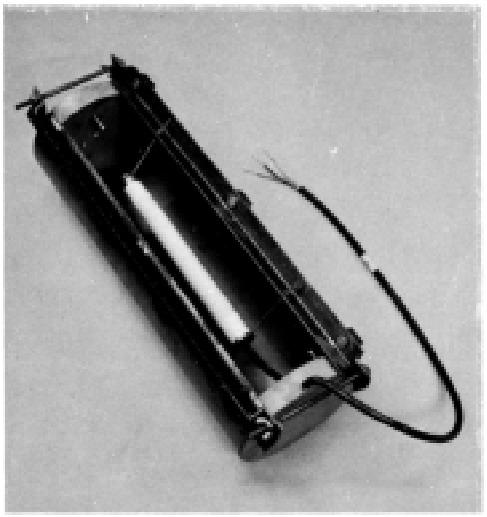

FIG. 1 Horizontal Mold for Creep Specimens

frame consists of header plates bearing on the ends of the loaded specimens, a load-maintaining element that is either a spring or a hydraulic capsule or ram, and threaded rods to take the reaction of the loaded system. Bearing surfaces of the header plates shall not depart from a plane by more than 0.001 in. (0.025 mm). In any loading frame, it is not prohibited to stack several specimens for simultaneous loading. The length between header plates shall not exceed 70 in. (1780 mm). When a hydraulic load-maintaining element is used, several frames may be loaded simultaneously through a central hydraulic pressure-regulating unit consisting of an accumulator, a regulator, indicating gages, and a source of high pressure, such as a cylinder of nitrogen or a high-pressure pump. Springs such as railroad car springs may be used to maintain the load in frames similar to those described above; the initial compression shall be applied by means of a portable jack or testing machine. When springs are used, care should be taken to provide a spherical head or ball joint, and end plates rigid enough to ensure uniform loading of the cylinders. Fig. 2 shows an acceptable spring-loaded frame. Means shall be provided for measuring the load to the nearest 2 % of total

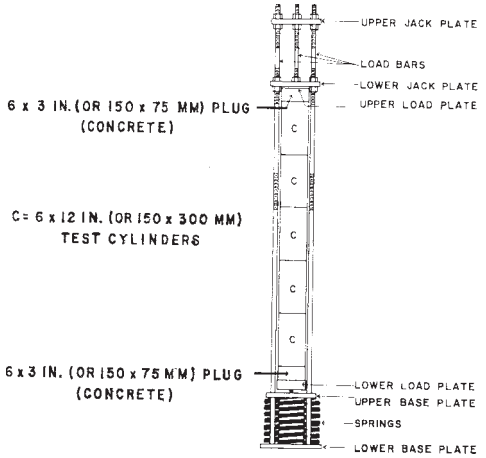

FIG. 2 Spring-Loaded Creep Frame

applied load. It is not prohibited to use a permanently installed hydraulic pressure gage or a hydraulic jack and a load cell inserted in the frame when the load is applied or adjusted.

4.3 *Strain-Measuring Device*—Suitable apparatus shall be provided for the measurement of longitudinal strain in the specimen to the nearest 10 millionths. It is not prohibited for the apparatus to be embedded, attached, or portable. If a portable apparatus is used, gage points shall be attached to the specimen in a positive manner. Attached gages relying on friction contact are not permissible. If an embedded device is used, it shall be situated so that its strain movement occurs along the longitudinal axis of the cylinder. If external devices are used, strains shall be measured on not less than two gage lines spaced uniformly around the periphery of the specimen. The gages may be instrumented so that the average strain on all gage lines can be read directly. The effective gage length shall be at least three times the maximum size of aggregate in the concrete. The strain-measuring device shall be capable of measuring strains for at least 1 year without change in calibration.

NOTE 1—Systems in which the varying strains are compared with a constant-length standard bar are considered most reliable, but unbonded electrical strain gages are satisfactory.

5. Test Specimens

5.1 *Specimen Size*—The diameter of each specimen shall be 6 ± 1/16 in. (or 150 ± 1.6 mm), and the length shall be at least 11½ in. (292 mm). When the ends of the specimen are in contact with steel bearing plates, the specimen length shall be at least equal to the gage length of the strain-measuring apparatus plus the diameter of the specimen. When the ends of the specimen are in contact with other concrete specimens similar to the test specimen, the specimen length shall be at least equal to the gage length of the strain-measuring apparatus plus 1½ in. (38 mm). Between the test specimen and the steel bearing plate at each end of a stack, a supplementary noninstrumented cylinder whose diameter is equal to that of the test cylinders and whose length is at least half its diameter shall be installed.

5.2 *Fabricating Specimens*—The maximum size of aggregate shall not exceed 2 in. (50-mm) (Section 3). Vertically cast cylinders shall be fabricated in accordance with the provisions of Practice C 192/C 192M. The ends of each cylinder shall meet the planeness requirements described in the scope of Practice C 617 (Note 2). Horizontally cast specimens shall be consolidated by the method appropriate to the consistency of the concrete as indicated in the methods of consolidation section of Practice C 192/C 192M. Care must be taken to ensure that the rod or vibrator does not strike the strain meter. When vibration is used, the concrete shall be placed in one layer and the vibrating element shall not exceed 1¼ in. (32 mm) in diameter. When rodding is used, the concrete shall be placed in two approximately equal layers and each layer shall be rodded 25 times evenly along each side of the strain meter. After consolidation, the concrete shall be struck off with trowel or float, then trowelled the minimum amount to form the concrete in the opening concentrically with the rest of the specimen. It is not prohibited to use a template curved in the radius of the specimen as a strikeoff to shape and finish the

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concrete more precisely in the opening. When cylinders are to be stacked, lapping of ends is strongly recommended.

NOTE 2—Requirements for planeness may be met by capping, lapping, or, at the time of casting, fitting the ends with bearing plates normal to the axis of the cylinder.

5.3 *Number of Specimens*—No fewer than six specimens (Note 3) shall be made from a given batch of concrete for each test condition; two shall be tested for compressive strength, two shall be loaded and observed for total deformation, and two shall remain unloaded for use as controls to indicate deformations due to causes other than load. Each strength and control specimen shall undergo the same curing and storage treatment as the loaded specimen.

NOTE 3—It is recommended that specimens be tested in triplicate although duplicate specimens are acceptable.

6. Curing and Storage of Specimens

6.1 *Standard Curing*—Before removal from the molds, specimens shall be stored at 73.4 ± 3.0°F (23.0 ± 1.7°C) and covered to prevent evaporation. The specimens shall be removed from the molds not less than 20 nor more than 48 h after molding and stored in a moist condition at a temperature of 73.4 ± 3.0°F until the age of 7 days. A moist condition is that in which free water is maintained on the surfaces of the specimens at all times. Specimens shall not be exposed to a stream of running water nor be stored in water. After the completion of moist curing the specimens shall be stored at a temperature of 73.4 ± 2.0°F (23.0 ± 1.1°C) and at a relative humidity of 50 ± 4 % until completion of the test.

6.2 *Basic Creep Curing*—If it is desired to prevent the gain or loss of water during the storage and test period, specimens shall at the time of fabrication or stripping be enclosed and sealed in moistureproof jackets (for example, copper or butyl rubber) to prevent loss of moisture by evaporation and shall remain sealed throughout the period of storage and testing.

6.3 *Variable Curing Temperature Regimen*—When it is desired to introduce the effect of temperature on the elastic and inelastic properties of a concrete (as, for example, the adiabatic temperature conditions existing in massive concrete or temperature conditions to which concrete is subjected during accelerated curing), temperatures within the specimen storage facility shall be controlled to correspond to the desired temperature history. The user shall be responsible for establishing the time-temperature history to be followed and the permissible range of deviation therefrom.

6.4 *Other Curing Conditions*—Other test ages and ambient storage conditions may be substituted when information is required for specific applications. The storage conditions shall be carefully detailed in the report.

7. Procedure

7.1 *Age at Loading*—When the purpose of the test is to compare the creep potential of different concretes, initially load the specimens at an age of 28 days. When the complete creep behavior of a given concrete is desired, prepare the specimens for initial loading in the following ages: 2, 7, 28, and 90 days, and 1 year. If information is desired for other ages of loading, include the age in the report.

7.2 *Loading Details*—Immediately before loading the creep specimens, determine the compressive strength of the strength specimens in accordance with Test Method C 39/C 39M. At the time unsealed creep specimens are placed in the loading frame, cover the ends of the control cylinders to prevent loss of moisture (Note 4). Load the specimens at an intensity of not more than 40 % of the compressive strength at the age of loading. Take strain readings immediately before and after loading, 2 to 6 h later, then daily for 1 week, weekly until the end of 1 month, and monthly until the end of 1 year. Before taking each strain reading, measure the load. If the load varies more than 2 % from the correct value, it must be adjusted (Note 5). Take strain readings on the control specimens on the same schedule as the loaded specimens.

NOTE 4—In placing creep specimens in the frame, take care in aligning the specimens to avoid eccentric loading. When cylinders are stacked and external gages are used, it may be helpful to apply a small preload such that the resultant stress does not exceed 200 psi (1380 kPa) and note the strain variation around each specimen, after which the load may be removed and the specimens realigned for greater strain uniformity.

NOTE 5—Where springs are used to maintain the load, the adjustment can be accomplished by applying the correct load and tightening the nuts on the threaded reaction rods.

8. Calculation

8.1 Calculate the total load-induced strain per pound per square inch (or kilopascal) at any time as the difference between the average strain values of the loaded and control specimens divided by the average stress. To determine creep strain per pound-force per square inch (or kilopascal) for any age, subtract from the total load-induced strain per pound-force per square inch (or kilopascal) at that age the strain per pound-force per square inch (or kilopascal) immediately after loading. If desired, plot total strain per pound-force per square inch (or kilopascal) on semilog coordinate paper, on which the logarithmic axis represents time, to determine the constants $1/E$ and F (K) for the following equation:

$$\epsilon = (1/E) + F(K)\ln(t + 1) \quad (1)$$

where:

ϵ = total strain psi (or kPa),
E = instantaneous elastic modulus, psi (or kPa),
$F(K)$ = creep rate, calculated as the slope of a straight line representing the creep curve on the semilog plot, and
t = time after loading, days.

The quantity $1/E$ is the initial elastic strain per pound per square inch (or kilopascal) and is determined from the strain readings taken immediately before and after loading the specimen. If loading was not accomplished expeditiously, some creep may have occurred before the after-loading strain was observed, in which event extrapolation to zero time by the method of least squares may be used to determine this quantity.

9. Report

9.1 Report the following information:

9.1.1 Cement content, water-cement ratio, maximum aggregate size, slump, and air content,

9.1.2 Type and source of cement, aggregate, admixture, and mixing water (if other than fresh water is used),

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9.1.3 Position of cylinder when cast,
9.1.4 Storage conditions prior to and subsequent to loading,
9.1.5 Age at time of loading,
9.1.6 Compressive strength at age of loading,
9.1.7 Type of strain measuring device,
9.1.8 Magnitude of any preload,
9.1.9 Intensity of applied load,
9.1.10 Initial elastic strain,
9.1.11 Creep strain per pound per square inch (or kilopascal) at designated ages up to 1 year, and
9.1.12 Creep rate, *F* (*K*), if determined.

10. Precision and Bias

10.1 *Precision*—The single-operator single-batch coefficient of variation has been found to be 4.0 %[4], and the single-operator-multi-batch coefficient of variation has been found to be 9.0 % [4], over the range of creep strains from 250 to 2000 millionths. The results of two properly conducted tests by the same operator on the same material should not differ by more than 6 %[5] of their average. The results of two properly conducted tests by the same operator on material cast from different batches should not differ by more than 13 %[5] of their average.

10.2 *Bias*—This test method has no bias because the values determined can only be defined in terms of the test method.

11. Keywords

11.1 compression; concrete; creep; creep strain; elastic strain

[4] These numbers represent the (1s %) limit as described in Practice C 670.
[5] These numbers represent the (d2s %) limit as described in Practice C 670.

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Designation: C 514 – 04 (Reapproved 2009)ε1

Standard Specification for Nails for the Application of Gypsum Board[1]

This standard is issued under the fixed designation C 514; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

This standard has been approved for use by agencies of the Department of Defense.

ε[1] NOTE—The units statement in 1.3 was revised editorially in May 2009.

1. Scope

1.1 This specification covers requirements for steel wire nails suitable for use in the application of gypsum board.

1.2 Details of construction for a specific assembly to achieve the required fire resistance shall be obtained from reports of fire-resistance tests, engineering evaluations, or listings from recognized fire testing laboratories.

1.3 The values stated in inch-pound units are to be regarded as standard. The values given in parentheses are mathematical conversions to SI units that are provided for information only and are not considered standard.

1.4 The following precautionary caveat pertains only to the test method portion, Sections 7 and 8, of this specification: *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

2. Referenced Documents

2.1 *ASTM Standards:*[2]

E 4 Practices for Force Verification of Testing Machines

3. Materials

3.1 *Steel Wire*, used in the manufacture of nails, shall be of hard-drawn low or medium-low-carbon steel, entirely suitable for the purpose intended. Before fabrication it shall be sufficiently ductile to withstand cold-bending, without fracture, through 180° over a radius not greater than the diameter of the wire (see Section 8).

4. Physical Properties

4.1 *Ductility*—The nail shall be sufficiently ductile to withstand cold bending without fracture when tested according to Section 8.

4.2 *Withdrawal Resistance*—The average withdrawal resistance, both immediate and delayed, shall be at least equal to that provided by 12.5 gage (0.099 ± 0.003 in.) (2.515 ± 0.08 mm) bright, smooth shank, nails with a medium diamond point, when tested according to 8.2.

5. Dimensions and Permissible Variations

5.1 *Heads*—Shall be not less than 0.2375 in. (6.0 mm) and not more than 0.3875 in. (9.8 mm) in diameter, shall be not more than 1/64 in. (0.4 mm) thick at the peripheral edge, shall be uniformly tapered to a small fillet around the shank, shall be either flat or concave, and shall be free from protrusions and sharp, irregular edges.

5.2 *Shanks*—Diameter shall not vary more than ± 0.003 in. (0.08 mm) for shank diameters 0.076 in. (1.93 mm) or larger.

5.3 *Points*—The nails shall have medium to long diamond or needle points.

5.4 *Clearance*—Where a deformation process produces other than a smooth shank nail, a clearance area (round and smooth), measured from the top of the head to the deformed section, shall be provided equal to the nominal thickness of the gypsum board for which the nails are specified.

6. Workmanship, Finish, and Appearance

6.1 The nails shall be bright, or chemically treated, or coated with rust inhibiting material provided that such chemical treatment or rust inhibitor does not adversely affect the performance of the nail as specified in Section 4. The nails

[1] This specification is under the jurisdiction of ASTM Committee C11 on Gypsum and Related Building Materials and Systems and is the direct responsibility of Subcommittee C11.02 on Specifications and Test Methods for Accessories and Related Products.

Current edition approved May 1, 2009. Published September 2009. Originally approved in 1963. Last previous edition approved in 2004 as C 514 – 04.

[2] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

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shall also be compatible with the joint compound and decoration. Nails shall be neatly formed and free from injurious defects or deformations.

7. Number of Tests

7.1 At least five nails from each lot of 100 individual containers shall be examined to determine conformance to the requirements of this specification.

8. Test Methods

8.1 *Bend Test*:

8.1.1 *Significance and Use*—This test method is performed to determine the ductility of a nail, and used to determine compliance with this specification.

8.1.2 *Procedure*—Hold the test nail in a vise and bend by means of a clamp or similar device attached to the free end of the nail through 90° over a radius not greater than the diameter of the nail.

8.1.3 *Precision and Bias*—Neither the precision nor the bias of the nail bend test have been determined.

8.2 *Withdrawal Resistance*

8.2.1 *Significance and Use*—This test method determines the resistance to withdrawal from a wood block of the test nail compared to a standard nail. It is used to determine compliance with this specification.

8.2.2 *Apparatus*:

8.2.2.1 *Testing machine*—The testing machine shall be of any type that is of sufficient capacity and that is capable of applying a tensile load at the strain rate prescribed in 8.2.3.2. The load platform shall be of sufficient size to accept the block of wood described in 8.2.2.5. The testing machine shall be power operated and shall apply the load continuously and without shock.

8.2.2.2 The test apparatus shall be verified according to Practices E 4, Sections 16 through 18.

8.2.2.3 *Load Indicating Equipment*, capable of reading to 1 lbf (4.45 N) increments shall be provided for the test apparatus. A means shall be provided to indicate the maximum load attained during the test.

8.2.2.4 A means of securing the blocks of wood to the platform or lower cross head shall be provided so that the nails are aligned with the direction of pull. A device shall be attached to the upper cross head to grasp the nail head securely and hold it during the test for the purpose of pulling the nail from the block of wood.

8.2.2.5 *Wood Nailing Blocks*—Nominal 2 by 6 in. (38 by 140 mm) Douglas Fir, construction grade, containing at least 16 %, but not more than 19 %, free moisture as determined by a suitable moisture meter. Required wood blocks for a test series shall be cut from a single piece of lumber creating blocks free of knots.

8.2.3 *Procedure*:

8.2.3.1 Alternately use twenty of the standard 12.5 gage nails and twenty of the nails being tested and hammer drive to a depth of ⅞ in. (22.2 mm) into the longitudinal center line of one edge and one side face of the wood blocks. Space nails 3 in. (76 mm) apart. Determine the comparative performance as follows:

8.2.3.2 *Immediate*—Withdraw alternate samples of each type of nail from each face, ten of each nail, at the rate of 0.06 in. (1.5 mm)/min.

8.2.3.3 *Delayed*—Condition the lumber, into which the nails are driven, at 50 ± 2 % relative humidity and 70 ± 5 °F (21.1 ± 3 °C) to constant weight, after which withdraw the remaining nails.

8.2.4 *Precision and Bias*—Neither the precision nor the bias have been determined for the nail withdrawal test method.

9. Certification

9.1 When specified in the purchase order a producer's or supplier's certification shall be furnished to the purchaser that the material is in compliance with this specification.

10. Packaging and Package Marking

10.1 Unless otherwise specified, nails shall be packaged in substantial commercial containers of the type, size, and kind commonly used for the purpose, so constructed as to preserve the contents in good condition and to ensure acceptance and safe delivery by common or other carriers, at the lowest rate, to the point of delivery. In addition, the containers shall be so made that the contents can be partially removed without destroying the container's ability to serve as a receptacle for the remainder of the contents.

10.2 Unless otherwise specified, individual packages and shipping containers shall be marked with the type and length of nail and the name of the manufacturer or distributor. Individual packages shall also be marked with the name of the manufacturer or distributor and the net mass.

11. Keywords

11.1 gypsum board; nail; points; shanks; wire heads

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Designation: C 535 – 09

Standard Test Method for Resistance to Degradation of Large-Size Coarse Aggregate by Abrasion and Impact in the Los Angeles Machine[1]

This standard is issued under the fixed designation C 535; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

This standard has been approved for use by agencies of the Department of Defense.

1. Scope*

1.1 This test method covers testing sizes of coarse aggregate larger than 19 mm (¾ in.) for resistance to degradation using the Los Angeles testing machine (Note 1).

NOTE 1—A procedure for testing coarse aggregate smaller than 37.5 mm (1½ in.) is covered in Test Method C 131.

1.2 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

1.3 The values stated in SI units are to be regarded as the standard. The inch-pound values given in parentheses are for information only.

2. Referenced Documents

2.1 *ASTM Standards:*[2]

C 125 Terminology Relating to Concrete and Concrete Aggregates

C 131 Test Method for Resistance to Degradation of Small-Size Coarse Aggregate by Abrasion and Impact in the Los Angeles Machine

C 136 Test Method for Sieve Analysis of Fine and Coarse Aggregates

C 702 Practice for Reducing Samples of Aggregate to Testing Size

D 75 Practice for Sampling Aggregates

E 11 Specification for Woven Wire Test Sieve Cloth and Test Sieves

3. Terminology

3.1 For definitions of terms used in this test method, refer to Terminology C 125.

4. Summary of Test Method

4.1 This test is a measure of degradation of mineral aggregates of standard gradings resulting from a combination of actions including abrasion or attrition, impact, and grinding in a rotating steel drum containing 12 steel spheres. As the drum rotates, a shelf plate picks up the sample and the steel spheres, carrying them around until they are dropped to the opposite side of the drum, creating an impact-crushing effect. The contents then roll within the drum with an abrading and grinding action until the shelf plate picks up the sample and the steel spheres, and the cycle is repeated. After the prescribed number of revolutions, the contents are removed from the drum and the aggregate portion is sieved to measure the degradation as percent loss.

5. Significance and Use

5.1 The test has been widely used as an indicator of the relative quality or competence of various sources of aggregate having similar mineral compositions. The results do not automatically permit valid comparisons to be made between sources distinctly different in origin, composition, or structure. Assign specification limits with extreme care in consideration of available aggregate types and their performance history in specific end uses.

6. Apparatus

6.1 *The Los Angeles Machine* shall conform to the requirements of Test Method C 131.

6.1.1 The operation and maintenance of the machine shall be as prescribed in Test Method C 131.

[1] This test method is under the jurisdiction of ASTM Committee C09 on Concrete and Concrete Aggregates and is the direct responsibility of Subcommittee C09.20 on Normal Weight Aggregates.

Current edition approved July 1, 2009. Published August 2009. Originally approved in 1964. Last previous edition approved in 2003 as C 535 – 03$^{\varepsilon 1}$.

[2] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

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6.2 *Sieves*, conforming to Specification E 11.

6.3 *Balance*—A balance or scale accurate within 0.1 % of test load over the range required for this test

6.4 *Charge*—The charge (Note 2) shall consist of 12 steel spheres averaging approximately 47 mm (1 27/32 in.) in diameter, each having a mass between 390 and 445 g, and having a total mass of 5000 ± 25 g.

NOTE 2—Steel ball bearings 46.0 mm (1 13/16 in.) and 47.6 mm (1 7/8 in.) in diameter, having a mass approximately 400 and 440 g each, respectively, are readily available. Steel spheres 46.8 mm (1 27/32 in.) in diameter having a mass approximately 420 g may also be obtainable. The charge may consist of a mixture of these sizes conforming to the total mass tolerance of 6.4.

7. Sampling

7.1 Obtain the field sample in accordance with Practice D 75 and reduce to an adequate sample size in accordance with Practice C 702.

8. Test Sample Preparation

8.1 Wash the reduced sample and oven dry at 110 ± 5°C (230 ± 9°F) to substantially constant mass, separate into individual size fractions, and recombine to the grading of Table 1 most nearly corresponding to the range of sizes in the aggregate as furnished for the work. Record the mass of the sample prior to test to the nearest 1 g.

9. Procedure

9.1 Place the test sample and charge in the Los Angeles testing machine and rotate the machine at 30 to 33 r/min for 1000 revolutions (Note 3). After the prescribed number of revolutions, discharge the material from the machine and make a preliminary separation of the sample on a sieve coarser than the 1.70-mm (No. 12) sieve. Sieve the finer portion on a 1.70-mm sieve in a manner conforming to Test Method C 136. Wash the material coarser than the 1.70-mm sieve and oven dry at 110 ± 5°C (230 ± 9°F) to substantially constant mass, and determine the mass to the nearest 1 g .

9.1.1 If the aggregate is essentially free of adherent coatings and dust, the requirement for washing after the test is optional. However, in the case of referee testing, the washing procedure shall be performed. Elimination of washing after test will seldom reduce the measured loss by more than about 0.2 % of the original sample mass.

NOTE 3—Valuable information concerning the uniformity of the sample under test may be obtained by determining the loss after 200 revolutions. This loss should be determined by dry sieving the material on the 1.70-mm (No. 12) sieve without washing. The ratio of the loss after 200 revolutions to the loss after 1000 revolutions should not greatly exceed 0.20 for material of uniform hardness. When this determination is made, take care to avoid losing any part of the sample; return the entire sample, including the dust of fracture, to the testing machine for the final 800 revolutions required to complete the test.

10. Calculation

10.1 Calculate the loss (the difference between the original mass and the final mass of the test sample) as a percentage of the original mass of the test sample (Note 4).

NOTE 4—The percent loss determined by this method has no known consistent relationship to the percent loss for the same material when tested by Test Method C 131.

11. Report

11.1 Report the following information:

11.2 Identification of the aggregate as to source, type, and nominal size, and

11.3 Grading designation from Table 1 used for the test, and

11.4 Loss by abrasion and impact of the sample expressed to the nearest 1 % by mass.

12. Precision

12.1 *Repeatability*—Based on four replicate tests by a single operator on one aggregate at a single laboratory using the same equipment, the average degradation (abrasion) loss, with a No. 1 grading was found to be 38.8 % and the standard deviation was 1.8 %

12.2 *Bias*—No statement is being made about the bias of this Test Method since there is no accepted reference material suitable for determining the bias of this procedure.

13. Keywords

13.1 abrasion; aggregate (coarse; large size); degradation; impact; Los Angeles machine

TABLE 1 Gradings of Test Samples

Sieve Size, mm (in.) (Square Openings)		Mass of Indicated Sizes, g		
Passing	Retained on	Grading		
		1	2	3
75 (3)	63 (2½)	2 500 ± 50	...	...
63 (2½)	50 (2)	2 500 ± 50	...	...
50 (2)	37.5 (1½)	5 000 ± 50	5 000 ± 50	...
37.5 (1½)	25.0 (1)	...	5 000 ± 25	5 000 ± 25
25.0 (1)	19.0 (¾)	...	...	5 000 ± 25
	Total	10 000 ± 100	10 000 ± 75	10 000 ± 50

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APPENDIX

(Nonmandatory Information)

X1. MAINTENANCE OF SHELF

X1.1 The shelf of the Los Angeles machine is subject to severe surface wear and impact. With use, the working surface of the shelf is peened by the balls and tends to develop a ridge of metal parallel to and about 32 mm (1¼ in.) from the junction of the shelf and the inner surface of the cylinder. If the shelf is made from a section of rolled angle, not only may this ridge develop but the shelf itself may be bent longitudinally or transversely from its proper position.

X1.2 The shelf should be inspected periodically to determine that it is not bent either lengthwise or from its normal radial position with respect to the cylinder. If either condition is found, the shelf should be repaired or replaced before further tests are made. The influence on the test result of the ridge developed by peening of the working face of the shelf is not known. However, for uniform test conditions, it is recommended that the ridge be ground off if its height exceeds 0.1 in. (2 mm).

SUMMARY OF CHANGES

Committee C09 has identified the location of selected changes to this test method since the last issue, C 535 – 03$^{\varepsilon 1}$, that may impact the use of this test method. (Approved July 1, 2009)

(*1*) Revised 12.1.

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Designation: C 563 – 07

Standard Test Method for Approximation of Optimum SO_3 in Hydraulic Cement Using Compressive Strength[1]

This standard is issued under the fixed designation C 563; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope*

1.1 This test method describes the determination of approximate optimum SO_3 for maximum compressive strength at 24 h, 3 days, or 7 days by measuring the change in strength produced in hydraulic cement mortar as a result of substituting calcium sulfate for a portion of the cement.

1.2 This test method refers to the sulfur trioxide (SO_3) content of the cement only. Slag cements and occasionally other hydraulic cements can contain sulfide or other forms of sulfur. The determination of SO_3 content by rapid methods may include these other forms, and may therefore produce a significant error. If a significant error occurs, analyze the cement for SO_3 content using the reference test method of Test Methods C 114 for sulfur trioxide.

1.3 Values stated as SI units are to be regarded as standard.

1.4 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

2. Referenced Documents

2.1 *ASTM Standards:* [2]

C 109/C 109M Test Method for Compressive Strength of Hydraulic Cement Mortars(Using 2-in. or [50-mm] Cube Specimens)

C 114 Test Methods for Chemical Analysis of Hydraulic Cement

C 150 Specification for Portland Cement

C 204 Test Methods for Fineness of Hydraulic Cement by Air-Permeability Apparatus

C 305 Practice for Mechanical Mixing of Hydraulic Cement Pastes and Mortars of Plastic Consistency

C 471M Test Methods for Chemical Analysis of Gypsum and Gypsum Products [Metric]

C 511 Specification for Mixing Rooms, Moist Cabinets, Moist Rooms, and Water Storage Tanks Used in the Testing of Hydraulic Cements and Concretes

C 595 Specification for Blended Hydraulic Cements

C 778 Specification for Standard Sand

C 1157 Performance Specification for Hydraulic Cement

C 1437 Test Method for Flow of Hydraulic Cement Mortar

3. Significance and Use

3.1 The purpose of this test method is to estimate the SO_3 content for a hydraulic cement that gives maximum compressive strength in mortar made and cured at 23 °C. The value obtained is used to establish an appropriate level of sulfate in the manufacture of cements specified in Specifications C 150, C 595 and C 1157. In Specifications C 150 and C 595 it is used to justify exceeding the prescriptive limits for SO_3.

3.2 The SO_3 content of a cement giving maximum compressive strength is different at different ages of mortar; typically this SO_3 content is higher at 3 days than the 24-h, and often higher for 7 days than that for 3 days. A manufacturer can choose the age of 24-h, 3 days or 7 days for specimens at which to determine optimum SO_3 content.

3.3 This test method indicates optimum SO_3 content for cement in mortar made and cured at a standard temperature of 23.0 ± 2.0 °C (73.5 ± 3.5 °F). The optimum SO_3 increases with increasing temperature and may increase when water-reducing admixtures are used.

3.4 It should not be assumed that the optimum SO_3 estimated in this test method is the same SO_3 content for optimum performance of a concrete prepared from the cement.

3.5 The test method is applicable to cements specified in Specifications C 150, C 595, and C 1157.

4. Apparatus

4.1 Use the apparatus as specified in Test Method C 109/C 109M.

5. Materials

5.1 *Calcium Sulfate*—Use calcium sulfate for addition to the cement that is either a high-grade natural gypsum having an SO_3 content of at least 46 %, or the calcium sulfate from the source used for the intended plant production. Grind the

[1] This test method is under the jurisdiction of ASTM Committee C01 on Cement and is the direct responsibility of Subcommittee C01.28 on Sulfate Content

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[2] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

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calcium sulfate to 100 % passing the 75-μm (No. 200) sieve, and at least 800 m^2/kg Blaine fineness (Test Method C 204). If the SO_3 content of the calcium sulfate is unknown, analyze it in accordance with Test Methods C 471M.

5.2 *Blended Standard Sand*—Use graded sand conforming to Specification C 778.

6. Test Specimens

6.1 Make six specimens from each batch of mortar. Make two rounds of three mixtures of mortar as described in 6.3. Make both rounds during the same day if possible. Make only complete rounds on any given day.

6.2 *Preparing Specimen Molds*—Prepare molds in accordance with the section on Preparation of Specimen Molds of Test Method C 109/C 109M.

6.3 *Proportioning, Consistency, and Mixing of Mortar*—Proportion the dry material for the standard mortar as one part of cement to 2.75 parts graded sand by mass. Mix the following quantities of dry materials at one time for a 6-cube batch:

Mixture No. 1—	500 g cement
	1375.0 g graded sand
Mixture No. 2—	494.6 g cement
	5.3 g calcium sulfate
	1375.0 g graded sand
Mixture No. 3—	489.2 g cement
	10.6 g calcium sulfate
	1375.0 g graded sand

6.3.1 Use an amount of mixing water to produce a flow of 110 ± 5 using 25 drops of the table as determined in the section on Procedures in Test Method C 1437 for all types of cement.

6.3.2 Mix mechanically in accordance with the section on Procedure for Mixing Mortars of Practice C 305, except as follows:

6.3.2.1 Add the calcium sulfate to the water; then start the mixer and mix at slow speed (140 ± 5 rpm) for 15 s; then stop the mixer and add the cement to the water; then start the mixer and mix at slow speed (140 ± 5 rpm) for 30 s.

6.4 *Molding of Test Specimens*—Mold specimens in accordance with the Procedure Section of Test Method C 109/C 109M.

6.5 *Storage of Test Specimens*—Immediately upon completion of molding, place the test specimens in the moist closet or moist room. Keep all test specimens, immediately after molding, in the molds on the base plates in the moist closet or moist room for 20 to 24 h with their upper surfaces exposed to the moist air but protected from dripping water. If the specimens are removed from the molds before 24 h, keep them on the shelves of the moist closet or moist room until they are 24-h old and then immerse the specimens, except those for the 24-h test, in saturated lime water in storage tanks constructed of noncorroding materials until the age chosen for the test. Keep the storage water clean by changing as required.

7. Temperature and Humidity

7.1 The temperature and humidity of the moist cabinet or moist room shall be as specified in Specification C 511.

7.2 The temperature and humidity of the mixing room shall be as specified in Test Method C 109/C 109M.

8. Procedure

8.1 Test the specimens at the age of 24 ± ¼ h, 3 days ± 1 h, or 7 days ± 3 h, from the time the cement and water made contact during mixing, immediately after removal from storage in accordance with Test Method C 109/C 109M. If more than one specimen at a time is removed from storage, keep these specimens covered with a damp cloth until time of testing. Note and observe precautions regarding testing and retesting given in the applicable sections of Test Method C 109/C 109M.

9. Calculation

9.1 Calculate and record the strength of specimens as described in the section on Calculation in Test Method C 109/C 109M.

9.1.1 Calculate the indicated optimum SO_3 content as follows:

$$G = [a/(a - b)]\, c + d + c/2$$

where:

G = optimum percent SO_3,
a = average strength both rounds of Mixture No. 2 minus Mixture No. 1,
b = average strength both rounds of Mixture No. 3 minus Mixture No. 2,
c = (percent SO_3 in calcium sulfate)/100, and
d = percent SO_3 in test cement.

10. Retest

10.1 Regard the results obtained as suspect and repeat the test under any of the following conditions:

10.1.1 If a and b both are positive and the ratio a/b is less than 2.00,

10.1.2 If a and b both are negative and the ratio a/b is greater than 0.500, or

10.1.3 If a is negative and b is positive.

11. Report

11.1 If repeat tests confirm that the ratio of a/b departs from the limiting values as stated above, report the SO_3 content of the cement as "above optimum" or "below optimum" as the data may indicate, but without stating the numerical value of optimum SO_3.

11.2 If the test data indicate that the cement is "below optimum" but do not permit a computation of the percentage of SO_3 required for optimum, an additional series of tests involving greater substitutions of gypsum for part of the cement should yield results that will permit an acceptable calculation of the percentage of SO_3 required for optimum. If the test data indicate that the cement is "above optimum" but do not permit a computation of the percentage of SO_3 required for optimum, in order to establish the required percentage of SO_3 for optimum, it is necessary to make tests of a new sample of similar cement but having an original SO_3 content lower than that of the original cement.

11.3 Report the age of the test specimens.

12. Precision and Bias

12.1 *Precision*—The coefficient of variation for this test method, using 6 cubes per batch, is very similar to that for Test

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Method C 109/C 109M compression cubes tested at later ages. Refer to Test Method C 109/C 109M for suitable values.

12.2 *Bias*—Since there is no accepted reference material suitable for determining optimum SO_3, bias has not been determined.

13. Keywords

13.1 blended hydraulic cement; calcium sulfate; cement; compressive strength; gypsum; hydraulic cement; optimum sulfate content (of cement); portland cement; strength (of cement); sulfate content (of cement)

APPENDIX

(Nonmandatory Information)

X1. DISCUSSION OF THE TERM "OPTIMUM"

X1.1 The scope statement notes that this test method determines the optimum SO_3 content in cements in mortar at a particular temperature and age. Usually, but not always, the SO_3 content that produces the highest 24-h strength at 23 °C also produces approximately the lowest expansion in water and the lowest contraction in air at that temperature.

X1.2 The "optimum" determined by this test is approximate. The "optimum" SO_3 content will vary with changes in mortar proportions; between cement paste, mortars and concrete; will vary with the source of SO_3; with the age of test; with the use of chemical admixtures; and with the use of supplementary cementitious materials. Thus, the term "optimum SO_3" refers to an approximate value.

X1.3 The age for determining the optimum is typically chosen by the manufacturer based on experience with local concrete materials.

X1.4 For convenience, the method uses the compressive strength of specimens at three different SO_3 contents for the cement. If the strength results are plotted against SO_3 content, the three points are assumed to give a curve in the shape of a parabola, and the calculation used assumes this shape. If more points are used with smaller SO_3 content increments, the shape of the curve is seen to be that of a "sawtooth," with a decreasing slope up to the apex at maximum strength, followed by a precipitous fall in strength immediately after the apex. The apex represents the actual optimum SO_3 content, and is typically higher than that calculated using three points. Therefore, this affords a small "cushion" when targeting the calculated optimum SO_3 (determined using three points) during manufacture to allow for variation in the process.

SUMMARY OF CHANGES

Committee C01 has identified the location of selected changes to this test method since the last issue, C 563 – 04, which may impact the use of this test method. (Approved April 1, 2007)

(*1*) Changed the titled to add the word "Approximate" and remove "24-h."

(*2*) Added 3- and 7-day testing options.

(*3*) Added an appendix to provide a home for explanatory information, and moved appropriate text into the appendix.

(*4*) Changed 6.5 to match Test Method C 109/C 109M provisions for storage, and made the corresponding change to Section 8.

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Designation: C 566 – 97 (Reapproved 2004)

Standard Test Method for Total Evaporable Moisture Content of Aggregate by Drying[1]

This standard is issued under the fixed designation C 566; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

This standard has been approved for use by agencies of the Department of Defense.

1. Scope

1.1 This test method covers the determination of the percentage of evaporable moisture in a sample of aggregate by drying both surface moisture and moisture in the pores of the aggregate. Some aggregate may contain water that is chemically combined with the minerals in the aggregate. Such water is not evaporable and is not included in the percentage determined by this test method.

1.2 The values stated in SI units are to be regarded as the standard. The values stated in parentheses are provided for information only.

1.3 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.* For specific precautionary statements, see 5.3.1, 7.2.1, and 7.3.1.

2. Referenced Documents

2.1 *ASTM Standards:* [2]

C 29/C 29M Test Method for Bulk Density (Unit Weight) and Voids in Aggregate

C 125 Terminology Relating to Concrete and Concrete Aggregates

C 127 Test Method for Density, Relative Density (Specific Gravity), and Absorption of Coarse Aggregate

C 128 Test Method for Density, Relative Density (Specific Gravity), and Absorption of Fine Aggregate

C 670 Practice for Preparing Precision and Bias Statements for Test Methods for Construction Materials

D 75 Practice for Sampling Aggregates

E 11 Specification for Wire Cloth and Sieves for Testing Purposes

2.2 *Other Document:*

National Research Council Report SHRP-P-619[3]

3. Terminology

3.1 *Definitions:*

3.1.1 For definitions of terms used in this test method, refer to Terminology C 125.

4. Significance and Use

4.1 This test method is sufficiently accurate for usual purposes, such as adjusting batch quantities of ingredients for concrete. It will generally measure the moisture in the test sample more reliably than the sample can be made to represent the aggregate supply. In cases where the aggregate itself is altered by heat, or where more refined measurement is required, the test should be conducted using a ventilated, controlled temperature oven.

4.2 Large particles of coarse aggregate, especially those larger than 50 mm (2 in.), will require greater time for the moisture to travel from the interior of the particle to the surface. The user of this test method should determine by trial if rapid drying methods provide sufficient accuracy for the intended use when drying large size particles.

5. Apparatus

5.1 *Balance*—A balance or scale accurate, readable, and sensitive to within 0.1 % of the test load at any point within the range of use. Within any interval equal to 10 % of the capacity of the balance or scale used to determine mass, the load indication shall be accurate within 0.1 % of the difference in masses.

5.2 *Source of Heat*—A ventilated oven capable of maintaining the temperature surrounding the sample at 110 ± 5°C (230 ± 9°F). Where close control of the temperature is not required (see 4.1), other suitable sources of heat may be used, such as an electric or gas hot plate, electric heat lamps, or a ventilated microwave oven.

5.3 *Sample Container*—A container not affected by the heat, of sufficient volume to contain the sample without danger of spilling, and of such shape that the depth of sample will not exceed one fifth of the least lateral dimension.

[1] This test method is under the jurisdiction of ASTM Committee C09 on Concrete and Concrete Aggregates and is the direct responsibility of Subcommittee C09.20 on Normal Weight Aggregates.

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[2] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

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5.3.1 **Precaution**—When a microwave oven is used, the container shall be nonmetallic.

NOTE 1—Except for testing large samples, an ordinary frying pan is suitable for use with a hot plate, or any shallow flat-bottomed metal pan is suitable with heat lamps or oven. Note the precaution in 5.3.1.

5.4 *Stirrer*—A metal spoon or spatula of convenient size.

6. Sampling

6.1 Sample in accordance with Practice D 75, except for the sample size.

6.2 Secure a sample of the aggregate representative of the moisture content in the supply being tested and having a mass not less than the amount listed in Table 1. Protect the sample against loss of moisture prior to determining the mass.

7. Procedure

7.1 Determine the mass of the sample to the nearest 0.1 %.

7.2 Dry the sample thoroughly in the sample container by means of the selected source of heat, exercising care to avoid loss of any particles. Very rapid heating may cause some particles to explode, resulting in loss of particles. Use a controlled temperature oven when excessive heat may alter the character of the aggregate, or where more precise measurement is required. If a source of heat other than the controlled temperature oven is used, stir the sample during drying to accelerate the operation and avoid localized overheating. When using a microwave oven, stirring of the sample is optional.

7.2.1 **Caution—**When using a microwave oven, occasionally minerals are present in aggregates that may cause the material to overheat and explode. If this occurs it can damage the microwave oven.

7.3 When a hot plate is used, drying can be expedited by the following procedure. Add sufficient anhydrous denatured alcohol to cover the moist sample. Stir and allow suspended material to settle. Decant as much of the alcohol as possible without losing any of the sample. Ignite the remaining alcohol and allow it to burn off during drying over the hot plate.

7.3.1 **Warning**—Exercise care to control the ignition operation to prevent injury or damage from the burning alcohol.

7.4 The sample is thoroughly dry when further heating causes, or would cause, less than 0.1 % additional loss in mass.

TABLE 1 Sample Size for Aggregate

Nominal Maximum Size of Aggregate, mm (in.)[A]	Mass of Normal Weight Aggregate Sample, min, kg[B]
4.75 (0.187) (No. 4)	0.5
9.5 (⅜)	1.5
12.5 (½)	2
19.0 (¾)	3
25.0 (1)	4
37.5 (1½)	6
50 (2)	8
63 (2½)	10
75 (3)	13
90 (3½)	16
100 (4)	25
150 (6)	50

[A] Based on sieves meeting Specification E 11.

[B] Determine the minimum sample mass for lightweight aggregate by multiplying the value listed by the dry-loose unit mass of the aggregate in kg/m^3(determined using Test Method C 29/C 29M) and dividing by 1600.

7.5 Determine the mass of the dried sample to the nearest 0.1 % after it has cooled sufficiently not to damage the balance.

8. Calculation

8.1 Calculate total evaporable moisture content as follows:

$$p = 100\,(W - D)/D \quad (1)$$

where:

p = total evaporable moisture content of sample, percent,
W = mass of original sample, g, and
D = mass of dried sample, g.

8.2 Surface moisture content is equal to the difference between the total evaporable moisture content and the absorption, with all values based on the mass of a dry sample. Absorption may be determined in accordance with Test Method C 127 or Test Method C 128.

9. Precision and Bias

9.1 *Precision*:

9.1.1 The within-laboratory single operator standard deviation for moisture content of aggregates has been found to be 0.28 % (Note 2). Therefore, results of two properly conducted tests by the same operator in the same laboratory on the same type of aggregate sample should not differ by more than 0.79 % (Note 2) from each other.

9.1.2 The between-laboratory standard deviation for moisture content of aggregates has been found to be 0.28 % (Note 2). Therefore, results of properly conducted tests from two laboratories on the same aggregate sample should not differ by more than 0.79 % (Note 2) from each other.

9.1.3 Test data used to derive the above precision indices were obtained from samples dried to a constant mass in a drying oven maintained at 110 ± 5°C. When other drying procedures are used, the precision of the results may be significantly different than that indicated above.

NOTE 2—These numbers represent, respectively, the 1s and 2s limits as described in Practice C 670.

9.2 *Bias*:

9.2.1 When experimental results are compared with known values from accurately compounded specimens, the following has been derived.

9.2.1.1 The bias of moisture tests on one aggregate material has been found to have a mean of +0.06 %. The bias of individual test values from the same aggregate material has been found with 95 % confidence to lie between −0.07 % and +0.20 %.

9.2.1.2 The bias of moisture tests on a second aggregate material has been found to have a mean of < +0.01 %. The bias of individual test values from the same aggregate material has been found with 95 % confidence to lie between −0.14 % and +0.14 %.

9.2.1.3 The bias of moisture tests overall on both aggregate materials has been found to have a mean of +0.03 %. The bias of individual test values overall from both aggregate materials has been found with 95 % confidence to lie between −0.12 % and +0.18 %.

9.2.2 Test data used to derive the above bias statements were obtained from samples dried to a constant mass in a

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drying oven maintained at 110 ± 5°C. When other drying procedures are used, the bias of the results may be significantly different than that indicated above.

NOTE 3—These precision and bias statements were derived from aggregate moisture data provided by 17 laboratories participating in the SHRP Soil Moisture Proficiency Sample Program which is fully described in the National Research Council Report SHRP-P-619. The samples tested which relate to these statements were well-graded mixtures of fine and coarse aggregate with moisture contents ranging from air dry to saturated surface dry.

10. Keywords

10.1 aggregate; drying; moisture content

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Designation: C 567 – 05a

Standard Test Method for Determining Density of Structural Lightweight Concrete[1]

This standard is issued under the fixed designation C 567; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

This standard has been approved for use by agencies of the Department of Defense.

1. Scope

1.1 This test method provides procedures to determine the oven-dry and equilibrium densities of structural lightweight concrete.

1.2 The values stated in SI units are to be regarded as the standard. The values given in parentheses are for information only.

1.3 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

2. Referenced Documents

2.1 *ASTM Standards:* [2]

C 31/C 31M Practice for Making and Curing Concrete Test Specimens in the Field

C 88 Test Method for Soundness of Aggregates by Use of Sodium Sulfate or Magnesium Sulfate

C 125 Terminology Relating to Concrete and Concrete Aggregates

C 138/C 138M Test Method for Density (Unit Weight), Yield, and Air Content (Gravimetric) of Concrete

C 172 Practice for Sampling Freshly Mixed Concrete

C 192/C 192M Practice for Making and Curing Concrete Test Specimens in the Laboratory

C 470/C 470M Specification for Molds for Forming Concrete Test Cylinders Vertically

E 104 Practice for Maintaining Constant Relative Humidity by Means of Aqueous Solutions

3. Terminology

3.1 Terminology used in this test method is defined in Terminology C 125.

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *equilibrium density*, *n*—the density as determined in 8.2 reached by structural lightweight concrete after exposure to relative humidity of 50 ± 5 % and a temperature of 23 ± 2 °C (73.5 ± 3.5 °F) for a period of time sufficient to reach constant mass.

3.2.2 *oven-dry density*—the density as determined in 8.3 reached by structural lightweight concrete after being placed in a drying oven at 110 ± 5 °C (230 ± 9 °F) for a period of time sufficient to reach constant mass.

4. Summary of Test Method

4.1 This test method provides procedures for determining the oven-dry and equilibrium densities of structural lightweight concrete, by calculation or measurement. The calculated oven-dry density is determined from batch quantities and volume of a given batch of concrete. The calculated equilibrium density is approximated by adding a fixed quantity to the oven-dry density. Measured densities are obtained from determinations of the mass of cylindrical specimens after specified treatments.

5. Significance and Use

5.1 The measured or calculated equilibrium density of structural lightweight concrete determines whether specified density requirements have been met. Unless otherwise specified, determine equilibrium density by calculation using the procedures in 9.2.

5.2 Test Method C 138/C 138M shall be used to determine the density of freshly mixed lightweight concrete for compliance with concrete placement specifications.

NOTE 1—The fresh density of lightweight aggregate concrete is a function of mixture proportions, air content, water demand, and the specific density and moisture content of the lightweight aggregate. Decrease in density of a specific lightweight concrete is due to moisture loss that, in turn, is a function of aggregate moisture content, ambient conditions, and the ratio of the surface area to the volume of the concrete member. For most structural lightweight concretes, equilibrium density is approached at about 90 days. For most high-strength lightweight concretes, equilibrium density is approached at about 180 days. Extensive tests demonstrate that despite variations in the initial moisture content of lightweight aggregate, the equilibrium density will be approximately 50 kg/m^3 (3.0 lb/ft^3) greater than the oven-dry density.

[1] This test method is under the jurisdiction of ASTM Committee C09 on Concrete and Concrete Aggregates and is the direct responsibility of Subcommittee C09.21 on Lightweight Aggregates and Concrete.

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[2] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

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6. Apparatus

6.1 *Tamping Rod, Mallet, Measure, Balance, and Molds*—These shall conform to the requirements of Test Method C 138/C 138M and Specification C 470/C 470M.

6.1.1 *Measure*—A 14-L (0.5-ft^3) measure shall be the standard (see Note 3).

6.2 *Controlled Humidity Enclosure*—A room controlled at 50 ± 5 % relative humidity and 23 ± 2 °C (73.5 ± 3 °F) or a small chamber meeting the requirements of Practice E 104.

6.3 *Drying Oven*—An oven of appropriate size capable of maintaining a uniform temperature of 110± 5 °C (230 ± 9 °F), and an average evaporation rate of at least 25 g/h. Determine evaporation rate in accordance with Test Method C 88.

7. Sampling, and Making, and Curing Test Specimens

7.1 *Sampling*—Sample field-mixed concrete in accordance with Practice C 172.

7.2 *Specimens for Determining Equilibrium Density and Oven-dry Density*—Determine the equilibrium density and oven-dry density on 150 by 300-mm (6 by 12-in.) concrete cylinders.

7.2.1 Make test cylinders in accordance with Practice C 192/C 192M or C 31/C 31M, whichever is applicable. Make three cylinders for equilibrium density measurements, and make three cylinders for oven-dry density measurements.

7.3 *Curing Specimens*:

7.3.1 Unless otherwise specified, test cylinders used for the determination of equilibrium density shall be cured in accordance with Practice C 192/C 192M or the standard curing procedure in Practice C 31/C 31M.

NOTE 2—Cylinders may be stripped after 24 h and wrapped securely with a plastic sheet or bag to prevent loss of moisture, or may remain in covered molds until the time of test.

7.3.2 Unless otherwise specified, for the first 24 h or until the time of test, store the test cylinders used for the determination of oven-dry density under conditions that maintain a temperature adjacent to the cylinders in the range from 16 to 27 °C (60 to 80 °F) and that prevent loss of moisture from the cylinders.

8. Procedure

8.1 *Measurement of Freshly Mixed Concrete Density*—Determine the density of the freshly mixed concrete in accordance with Test Method C 138/C 138M.

NOTE 3—Numerous observations indicate that the same compactive effort used on smaller concrete specimens will cause the fresh densities to be higher. The fresh density as determined from measurements on 150 by 300-mm (6 by 12-in.) cylinders of lightweight concrete consolidated by rodding, in accordance with Practice C 192/C 192M or Practice C 31/C 31M will average 40 kg/m^3 (2.5 lb/ft^3) higher than the fresh density as measured using a 14-L (0.5-ft^3) measure in accordance with Test Method C 138/C 138M.

8.2 *Measurement of Equilibrium Density*—To measure the equilibrium density, remove the cylinders from their curing condition on the seventh day after molding and immerse in water at 23 ± 2 °C (73.5 ± 3.5 °F) for 24 h. Measure the apparent mass of the cylinders while suspended and completely submerged in water and record as "C," the mass of the suspended-immersed cylinder. Remove from the water and allow to drain for 1 min by placing the cylinder on a 9.5-mm (⅜-in.) or coarser sieve cloth. Remove visible water with a damp cloth, determine the mass and record as "B," the mass of the saturated-surface-dry cylinder. Dry the cylinders with all surfaces exposed, in a controlled humidity enclosure as described in 6.2 until the mass of the specimen changes not more than 0.5 % (gain or loss) in successive determinations of mass 28 days apart. Determine the mass of the dried cylinders and record as "A," the mass of the dried cylinder. Calculate the equilibrium density of the concrete from Eq 1 and 2.

$$E_m\,(Density,\, kg/m^3) = (A \times 997) / (B-C) \quad (1)$$

$$E_m\,(Density,\, lb/ft^3) = (A \times 62.3) / (B-C)) \quad (2)$$

where:

E_m = measured equilibrium density, kg/m^3(lb/ft^3,
A = mass of cylinder as dried, kg (lb),
B = mass of saturated surface-dry cylinder, kg (lb), and
C = apparent mass of suspended-immersed cylinder, kg (lb).

8.3 *Measurement of Oven-Dry Density*—After 24 h but not to exceed 32 h, remove the cylinders from the mold (see Note 4). Measure the apparent mass of the cylinders while suspended and completely submerged in water and record as "G" the mass of the suspended-immersed cylinders. Remove from the water and allow to drain for 1 min by placing the cylinders on a 9.5-mm (⅜-in.) or coarser sieve cloth. Remove visible water with a damp cloth, determine the mass and record as "F," the mass of the saturated surface-dry cylinders. Place the cylinders in the drying oven at 110 ± 5 °C (230 ± 9 °F) for 72 h. Allow cylinders to cool for at least thirty minutes but not more than 1 hour and determine the mass. Repeat oven-drying, cooling, and determination of mass at 24-h intervals until the change in mass is not more than 0.5 %. Record this mass as "D", the mass of the oven-dried cylinder. Determine the oven-dry density from Eq 3 and 4.

$$O_m(Density,\, kg/m^3) = (D \times 997) / (F-G) \quad (3)$$

$$O_m\,(Density,\, lb/ft^3) = (D \times 62.3) / (F-G)) \quad (4)$$

where:

O_m = measured oven-dry density, kg/m^3(lb/ft^3),
D = mass of oven-dry cylinder, kg (lb),
F = mass of saturated surface-dry cylinder, kg (lb), and
G = apparent mass of suspended-immersed cylinder, kg (lb).

NOTE 4—Determination of oven-dry density may be specified to begin at an age other than 24-h.

9. Calculation

9.1 *Calculation of Oven-Dry Density*—Where mixture quantities, aggregate moisture content, and the volume of the concrete batch are known, calculate an oven-dry density using Eq 5.

$$O_c = (M_{df} + M_{dc} + 1.2\,M_{ct}) / V \quad (5)$$

where:

O_c = calculated oven-dry density, kg/m^3 (lb/ft^3),

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M_{df} = mass of dry fine aggregate in batch, kg(lb),
M_{dc} = mass of dry coarse aggregate in batch, kg(lb),
M_{ct} = mass of cement in batch, kg (lb),
1.2 = factor to approximate the mass of cement plus chemically combined water, and
V = volume of concrete produced by the batch m^3 (ft^3).

9.2 *Calculation of Approximate Equilibrium Density*—Using the oven-dry density determined in accordance with 8.3 or 9.1, calculate the approximate equilibrium density from Eq 6 and 7.

$$E_c = O_c + 50 \text{ kg/m}^3 \ (3 \text{ lb/ft}^3) \quad (6)$$

or

$$E_c = O_m + 50 \text{ kg/m}^3 \ (3 \text{ lb/ft}^3) \quad (7)$$

where:
E_c = calculated equilibrium density (see Note 1).

10. Report

10.1 When oven-dry and equilibrium densities are determined by measurements, the report shall include following information:

10.1.1 Fresh density, kg/m^3 (lb/ft^3).
10.1.2 Mass of suspended-immersed cylinder, kg (lb).
10.1.3 Mass of saturated surface dry cylinder, kg (lb).
10.1.4 Mass of cylinder after reaching equilibrium, kg (lb).
10.1.5 Equilibrium density reported to nearest 10 kg/m^3 (0.5 lb/ft^3).
10.1.6 Age at which equilibrium was reached, days.
10.1.7 Mass of oven-dry cylinder, kg (lb).
10.1.8 Oven-dry density rounded to the nearest 10 kg/m^3 (0.5 lb/ft^3).

10.2 When oven-dry and approximate equilibrium densities are determined by calculation, report the following information:

10.2.1 Fresh density, kg/m^3 (lb/ft^3).
10.2.2 Mass of cement and dry aggregates, batched, kg (lb).
10.2.3 Volume of concrete produced from the batch, m^3 (ft^3).
10.2.4 Calculated oven-dry density, to the nearest 10 kg/m^3 (0.5 lb/ft^3).
10.2.5 Calculated approximate equilibrium density, to the nearest 10 kg/m^3 (0.5 lb/ft^3).

11. Precision and Bias

11.1 *Precision*—The precision of this test method has not yet been determined, but an industry-wide multilaboratory testing program is being coordinated. The precision statements will be included when the data is compiled and reviewed.

11.2 *Bias*—Bias for this test method cannot be determined since there is no reference standard available for comparison.

12. Keywords

12.1 equilibrium density; lightweight concrete; oven-dry density

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Designation: C 586 – 05

Standard Test Method for Potential Alkali Reactivity of Carbonate Rocks as Concrete Aggregates (Rock-Cylinder Method)[1]

This standard is issued under the fixed designation C 586; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

This standard has been approved for use by agencies of the Department of Defense.

1. Scope

1.1 This test method covers the determination of the expansion of a specimen of carbonate rock while immersed in a solution of sodium hydroxide (NaOH) at room temperature. The length changes occurring during such immersion indicate the general level of reactivity of the rock and whether tests should be made to determine the effect of aggregate prepared from the rock upon the volume change in concrete.

1.2 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

1.3 The values stated in SI units are to be regarded as the standard. The inch-pound units in parentheses are provided for information only.

2. Referenced Documents

2.1 *ASTM Standards:* [2]

C 294 Descriptive Nomenclature for Constituents of Concrete Aggregates

C 295 Guide for Petrographic Examination of Aggregates for Concrete

C 1105 Test Method for Length Change of Concrete Due to Alkali-Carbonate Rock Reaction

D 75 Practice for Sampling Aggregates

D 1248 Specification for Polyethylene Plastics Extrusion Materials for Wire and Cable

E 177 Practice for Use of the Terms Precision and Bias in ASTM Test Methods

3. Terminology

3.1 For definitions of terms relating to aggregates used in this test method, refer to Descriptive Nomenclature C 294.

4. Summary of Test Method

4.1 Small rock cylinders are immersed in a solution of NaOH except when removed for determination of length change. The length change of each specimen is periodically determined.

5. Significance and Use

5.1 This test method is intended to give a relatively rapid indication of the potential expansive reactivity of certain carbonate rocks that may be used as concrete aggregates. The test method has been successfully used in (*1*) research and (*2*) preliminary screening of aggregate sources to indicate the presence of material with a potential for deleterious expansion when used in concrete.

5.2 The test method is intended as a research and screening method rather than as the basis of a specification requirement. It is intended to supplement data from field service records, petrographic examinations according to Guide C 295, and tests of aggregate in concrete according to Test Method C 1105.

5.3 Alkalies participating in the expansive reactions with aggregate constituents in concrete usually are derived from the hydraulic cement; under certain circumstances they may be derived from other constituents of concrete or from external sources. Two types of alkali reactivity of aggregates are recognized: (*1*) alkali-silica reaction involving certain siliceous rocks, minerals, and artificial glasses, and (*2*) alkali carbonate reaction involving dolomite in certain calcitic dolomites, dolomitic limestones, and dolostones. This test method is not suitable as a means to detect alkali-silica reaction.

6. Apparatus and Reagents

6.1 *1 N Sodium Hydroxide Solution*—Dissolve 40 ± 1 g of reagent-grade sodium hydroxide (NaOH) in distilled water, dilute to 1 L and store in a polyethylene bottle.

[1] This test method is under the jurisdiction of ASTM Committee C09 on Concrete and Concrete Aggregates and is the direct responsibility of Subcommittee C 09.26 on Chemical Reactions.

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6.2 *Sawing, Drilling, and Grinding Equipment*, suitable for preparing test specimens of the dimensions given in Section 8. This will require one or more rock saws, depending upon the size of the original sample, a drill press equipped with a small diamond core barrel for removing the cylindrical core, and a lap, grinder, or suitable modified lathe for shaping the ends of the specimens.

6.3 *Storage Bottles*, approximately 50 to 100-mL capacity with caps and openings of sufficient size to facilitate removal of specimens. The polyethylene bottle shall be selected to ensure that the solution will not be modified by reaction with the material composing the container, including pigments or other additives or by transpiration of phases through the walls of the container. Bottles with wall thickness not less than 0.50 mm (0.020 in.) and composed of high density polyethylene meeting the requirements of Specification D 1248 for materials of Type III, Class A, are suitable.

6.4 *Length Comparator*, for convenient and rapid measurement of lengths of specimens, the comparator shall be of such design as to provide, permit, or include the following characteristics. One type of comparator which has been found satisfactory is shown in Fig. 1.

6.4.1 A positive means of contact with the conical ends of the specimen to ensure reproducible measurement of length. A

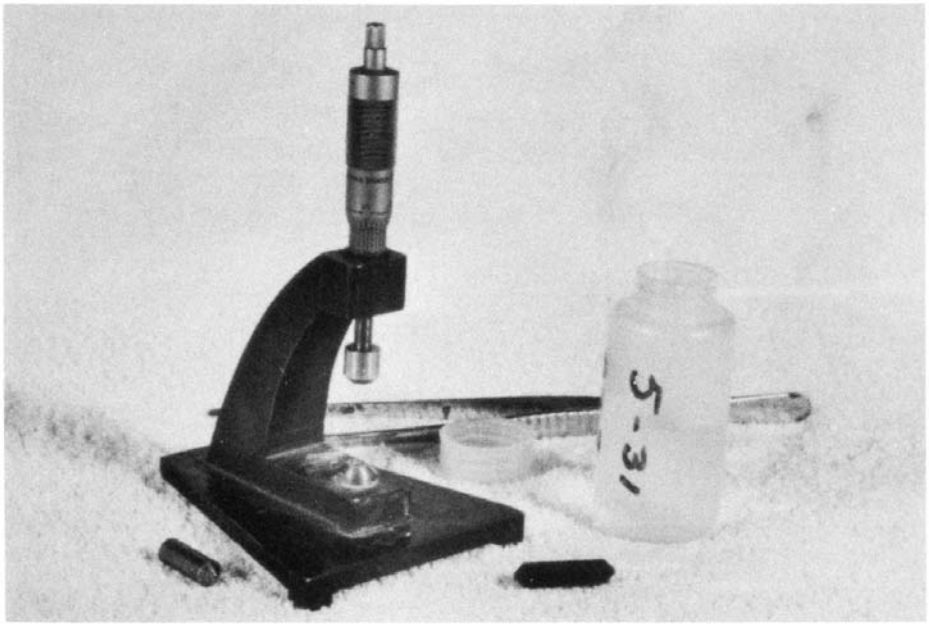

FIG. 1 A Typical Length Comparator

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variety of contact points have been used successfully. Care should be exercised to ensure that when using specimens with conical ends as described in 8.3, contact is made on the end along a circle which is concentric about the long axis of the specimen. If the measuring device is a barrel micrometer, it shall have a ratchet stop to produce a constant pressure on the specimen,

6.4.2 A high-grade barrel or dial micrometer graduated to read in 0.001 or 0.002–mm (0.0001–in.) units, and accurate within 0.002 mm (0.0001 in.) in any 0.020–mm (0.0010–in.) range, and within 0.004 mm (0.0002 in.) in any 0.200–mm (0.0100–in.) range. The measuring device should be calibrated throughout its range to determine both periodic and cumulative errors for proper correction of observed data.

6.4.3 A sufficient range to allow for small differences among gage lengths of various specimens. If care is taken in the fabrication of the specimens, a measuring device with a travel of not less than 7.5 mm (0.3 in.) provides ample range in the instrument, and

6.4.4 A standard or reference shall be used for checking the measuring device at regular intervals. The bar that serves as a reference for the length comparator shall have an over-all length of 35 ± 2 mm (1.38 ± 0.08 in.) The length of the bar shall be known to an accuracy of 0.002 mm (0.0001 in.). The bar shall be fused silica or a steel alloy having a coefficient of thermal expansion not greater than 1.0×10^{-6}°C. Each end shall be machined to the same shape as that of the rock specimens. If a steel alloy is used, it shall be polished (See Note 1). The reference bar shall be placed in the instrument in the same position each time a length measurement is made. The micrometer setting of the measuring device shall be checked by use of the reference bar at least at the beginning and end of the readings made within a half day when the apparatus is kept in a room maintained at constant temperature. It shall be checked more often when kept in a room where temperature is not constant.

NOTE 1—Steel alloys with low thermal expansion coefficient should not be heat treated because they lose their low coefficient of thermal expansion when so treated.

7. Sampling

7.1 Sample the rock in accordance with the applicable requirements of Practice D 75, except that the sample mass of each discernable stratum shall be at least 1 kg, and individual pieces shall be not less than 75 × 75 × 75 mm in size.

7.2 Sampling should be under the direction of an individual capable of distinguishing differences in lithology, and the sample of rock should be taken to represent only the particular lithology under consideration bearing in mind the limitations and significance of this method as stated in Section 5. Each sample of rock should be in one piece of sufficient size for preparing the necessary test specimens.

7.3 One test specimen will sufficiently represent the sample of rock unless shale seams or other discontinuities are present or the bedding is not discernible. In these cases, prepare and test 3 mutually perpendicular specimens. Of such three specimens that one showing the greatest length change after 28 days of immersion in alkali solution as determined in 9.7 shall be used. Discard the remaining two.

8. Test Specimens

8.1 Test specimens shall be in the form of right circular cylinders or square prisms with conical or plane parallel ends, unless otherwise specified.

8.2 The specimen shall have an over-all length of 35 ± 5 mm (1.38 ± 0.20 in.) and a diameter or sides of 9 ± 1 mm (0.35 ± 0.04 in.) for cylinders and prisms respectively. Care shall be exercised in the preparation of the specimens to avoid alteration of the cylindrical surface by polishing or with materials which will affect the rate of entry of alkali solution into the rock.

8.3 The included angle of the conical ends shall be approximately 120°.

8.4 Fabricate specimens having flat–end faces in such a manner as to ensure that the faces are parallel to each other and perpendicular to the major axis of the specimen (see Note 2).

NOTE 2—End faces parallel to each other and perpendicular to the major axis of the specimen can be made by turning the specimen in a small lathe and using tool steel to cut the ends.

9. Procedure

9.1 Place a position mark on the specimen to permit placing the specimen in the comparator in the same position during subsequent measurements.

9.2 Measure the length of the test specimen.

9.3 Immerse the specimen in distilled water at a room temperature in the range of 20 to 27.5 °C (68 to 81.5 °F).

9.4 At intervals, remove the specimen, blot to remove excess surface water and measure until the change in length during a 24-h water immersion period does not exceed 0.02 % as calculated in 10.1. The length when in this condition is taken as the reference length. The reference length is usually achieved after 1 to 4 days of immersion.

9.5 Immerse the water-saturated specimens in a bottle containing a minimum of 35 mL of 1*N* NaOH solution per specimen at room temperature and seal. Immerse no more than two specimens in a bottle.

9.6 Measure the length of the specimens after 7, 14, 21, and 28 days of immersion in NaOH solution and at 4-week intervals thereafter. If the tests continue beyond 1 year, make measurements at 12-week intervals.

9.7 When measurements are made, remove the specimen from the bottle, rinse with distilled water, blot to remove excess surface water and determine its length in the same position as during the initial measurement.

9.8 After measurement, immediately return the specimen to the bottle and reseal.

9.9 Replace the solution every 6 months during the testing period.

10. Calculation

10.1 Calculate the length change to the nearest 0.01 % of the reference length as follows:

$$\Delta l = [(l_1 - l_0)/l_0] \times 100 \quad (1)$$

where:

Δl = % length change at test age,

l_1 = length in mm (in.) at test age, and

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l_0 = reference length after equilibrium in water, as outlined in 9.4.

11. Report

11.1 Report the following:

11.1.1 Identification number,

11.1.2 Type and source of rock,

11.1.3 Specimen shape and dimensions if other than right circular cylinder,

11.1.4 Length change in percent to the nearest 0.01 % at each time of measurement. Where no times of measurement are specifically requested, data should be presented for at least the following ages: 1, 4, 8, and 16 weeks and the age at the final measurement.

11.1.5 Significant features revealed by examination of specimen during and after storage in alkali solution, such as cracking, warping, splitting, etc., and

11.1.6 Other significant information as deemed necessary, such as petrographic and chemical analyses.

12. Precision and Bias

12.1 *Precision*:

12.1.1 If the results of replicate specimens measured by the same operator and which presumably represent the same material, differ by more than 0.10 percentage point for expansions less than 1.0 %, it is highly probable that the specimens represent rocks that are significantly different in chemical composition, texture, or both.

12.1.2 The single-operator, single-comparator, single-specimen precision has been found to be ±0.02 percentage point (3S) as defined in Practice E 177.

12.1.3 The multi-operator, single-comparator, single-specimen precision has been found to be ±0.03 percentage point (3S) as defined in Practice E 177.

12.1.4 The multi-operator, multi-comparator, single-specimen precision has been found to be ±0.05 percentage point (3S) as defined in Practice E 177.

12.1.5 In a single laboratory, single operator study of the range of expansion of pairs of rock cylinders from 29 samples of rock from a single quarry (each pair of cylinders cut from a different sample block approximately 75 × 75 × 50 mm in size), the following data were found:

12.1.5.1 For pairs of specimens giving average expansion of less than 0.50 %, the average standard deviation was found to be 0.0255 %[3]; therefore, the difference in expansion between pairs of cylinders cut from a single block should only exceed 0.072 %[3] one time in twenty when the average expansion is less than 0.50 %.

12.1.5.2 For pairs of specimens giving average expansion of more than 0.50 %, the average standard deviation was found to be 0.095 %[3]; therefore, the difference in expansion between pairs of cylinders cut from a single block should only exceed 0.269 %[3] one time in twenty when the average expansion is more than 0.50 %.

12.2 *Bias*—The procedure in this test method for measuring expansion has no bias because the expansion can be defined only in terms of this test method.

13. Keywords

13.1 aggregate; alkali reactivity; carbonate rocks; concrete; deleterious expansion

[3] These numbers represent, respectively, the (1s) and (d2s) limits as described in Practice C 670.

APPENDIX

(Nonmandatory Information)

X1. Interpretation of Results

X1.1 Since the expansion caused by reactions between cement alkalies and carbonate aggregates is sensitive to subtle changes in aggregate lithology, the results of measurements should be interpreted with full recognition of the variables which would affect the results obtained. The acceptance or rejection of aggregate sources based solely on the results of this test is not recommended since, in commercial production, expansive and nonexpansive materials may occur in close proximity and the securing of samples adequately representative of the variability of the production of the source is a difficult task and requires the efforts of an individual trained to distinguish differences in lithology.

X1.2 The relationship of the test results to the behavior of large quantities of rock from a given source will depend upon the degree to which the petrographic and chemical properties of the rock vary within the source.

X1.3 Research results have indicated that the expansive behavior of aggregate in concrete is qualitatively predicted by the results of the rock cylinder test. Quantitative prediction of the expansion of concrete containing reactive aggregate depends upon (*1*) the degree of aggregate reactivity, (*2*) the amount of reactive constituent, (*3*) the alkali content of the cement, and (*4*) the environment. Appreciable expansion should indicate the need for further testing. In the light of current knowledge, it appears that expansions in excess of 0.10 % are indicative of chemical reaction and should warrant additional testing preferably in concrete using Test Method C 1105. Usually expansive tendencies are evident after 28 days of immersion in alkali, however, exceptions to this have been noted. Deleterious expansion of concrete appears to depend

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upon the magnitude and rate of aggregate expansion and the time at which it begins; however, quantitative predictions of concrete expansion in service solely from results of this test method are not possible.

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Designation: C 587 – 04

Standard Specification for Gypsum Veneer Plaster[1]

This standard is issued under the fixed designation C 587; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

This standard has been approved for use by agencies of the Department of Defense.

1. Scope*

1.1 This specification covers calcined gypsum mixed at the mill with other ingredients to control working quality and setting time; specifically designed as a veneer plaster to be applied over gypsum base for veneer plasters, masonry or concrete surfaces to a maximum thickness of ¼ in. (6.4 mm) providing a surface ready for decoration.

NOTE 1—Specification C 843 contains application procedures for gypsum veneer plaster.

1.2 This specification covers test methods for determining the physical properties of gypsum veneer plasters and sets forth minimum requirements that must be met.

1.3 The values stated in inch-pound units are to be regarded as the standard. The SI (metric) values given in parentheses are approximate and are provided for information purposes only.

1.4 The text of this standard references notes and footnotes which provide explanatory material. These notes and footnotes shall not be considered as requirements of the standard.

1.5 The following safety hazards caveat applies only to the Test Methods portion, Section 5 of this specification: *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

2. Referenced Documents

2.1 *ASTM Standards:* [2]

C 11 Terminology Relating to Gypsum and Related Building Materials and Systems

C 473 Test Methods for Physical Testing of Gypsum Panel Products

C 843 Specification for Application of Gypsum Veneer Plaster

C 1396/C 1396M Specification for Gypsum Board

3. Terminology

3.1 *Definitions:*

3.1.1 Definitions of terms shall be in accordance with Terminology C 11 and Specification C 843.

3.2 *Definition of Term Specific to This Standard:*

3.2.1 *gypsum veneer plaster systems*, *n*—veneer plaster applied in accordance with Specification C 843 to gypsum base for veneer plasters.

4. Physical Properties

4.1 *Joint Strength*—Gypsum veneer plaster systems applied in accordance with Specification C 843 shall be tested in accordance with 5.9. The breaking load shall be not less than the parallel to surfacing loads specified in Specification C 1396/C 1396M.

4.2 *Bond Strength*—The bond strength of the gypsum veneer plaster to the gypsum veneer base and, where applicable, between the base coat plaster and the finish coat shall not delaminate when tested in accordance with 5.6.

4.3 *Impact Strength*—Gypsum veneer plaster systems shall not crack or lose bond beyond the impact area when tested in accordance with 5.7.

4.4 *Flexure*—Gypsum veneer plaster systems shall exhibit crack resistance within the field of the gypsum base for veneer plasters such that radial or random cracking shall extend not more than ½ in. (13 mm) from the break line at failure when tested in accordance with 5.8. At rupture of the panel the veneer plaster shall be securely bonded to the face paper.

5. Test Methods

5.1 *Materials*—Gypsum Base for Veneer Plaster, see Specification C 1396/C 1396M.

5.2 *Sampling*—Sample not less than 1 % of the packages, but not less than 5 packages. Select packages to be sampled at random. Take samples both from the outer portion and the center of each package. Thoroughly mix the materials so obtained to provide a composite sample of not less than 15 lb

[1] This specification is under the jurisdiction of ASTM Committee C11 on Gypsum and Related Building Materials and Systems and is the direct responsibility of Subcommittee C11.01 on Specifications and Test Methods for Gypsum Products.

Current edition approved Dec. 1, 2004. Published December 2004. Originally approved in 1966. Last previous edition approved in 2002 as C 587 – 02.

[2] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

***A Summary of Changes section appears at the end of this standard.**

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(6.8 kg). Place this composite sample immediately in a clean, dry, airtight container for delivery to the laboratory.

5.3 *Test Unit Preparation*—From the sample, prepare panels of veneer plaster system and cut four 2 ft (600 mm) square, and three 12 by 16 in. (300 by 400 mm) specimens.

5.4 *Conditioning*—Condition specimens to constant weight at a temperature of 85 ± 15 °F (29.5 ± 8.5 °C) and relative humidity of 50 ± 2 % (see Note 2). Test specimens individually after constant weight is reached.

NOTE 2—Laboratory test results indicate that conditioning temperatures may range from 70 to 100 °F (21 to 38 °C) without significantly affecting the results. However, relative humidity is critical. Therefore, specimens shall be tested within 10 min upon removal from the conditioning chamber.

5.5 *Number of Tests*—Run each test in triplicate.

5.6 *Bond Strength*:

5.6.1 *Significance and Use*—The bond strength test is designed to evaluate the bond of veneer plaster to veneer plaster base and between the base coat and finish coat. The degree of correlation between these test methods and service performance has not been determined.

5.6.2 *Procedure*—Select three 2 ft (600 mm) square specimens. Raise each specimen and slam the back side (face not treated with veneer plaster) on a bare concrete floor repeatedly until the specimen is broken.

5.6.3 *Report*—Report whether the sample passes or fails the bond test. The sample fails if the bond to the veneer base or between the finish coast and base coat delaminates on any one of the specimens.

5.6.4 *Precision and Bias*—No information is presented about either the precision or bias of the bond test since the test result is nonquantitative.

5.7 *Impact Strength*:

5.7.1 *Significance and Use*—The impact strength is designed to test the effect of impact from a hard object on the surface of the veneer plaster. The degree of correlation between this test method and service performance has not been determined.

5.7.2 *Apparatus*:

5.7.2.1 A stand with a solid, flat base at least 2 ft (600 mm) square with a means of holding the steel ball and releasing it from a height of 36 in. above the base, without imparting additional force.

5.7.2.2 A 1½ in. (38 mm) diameter polished steel ball weighing 7.8 ± 0.1 oz (221 ± 3 g).

5.7.3 *Procedure*—Select one 2 ft (600 mm) square. Place the specimen horizontally, with the plaster surface face up, on the base of the apparatus . Drop the steel ball three times onto different areas of the panel surface.

5.7.4 *Report*—Report whether the sample passes or fails the impact test. The sample fails if there is a loss of bond or cracking beyond the impact area on any one of the drops.

5.7.5 *Precision and Bias*—No information is presented about either the precision or bias of the impact test since the test result is nonquantitative.

5.8 *Flexure*:

5.8.1 *Significance and Use*—The flexure test is designed to test the effect on the resistance to cracking and bond of the veneer plaster to the veneer plaster base while being flexed. The degree of correlation between this test method and service performance has not been determined.

5.8.2 *Apparatus*—Use the apparatus described in Test Methods C 473 for Method B.

5.8.3 *Procedure*—Select three 12 by 16 in. (300 by 400 mm) specimens. Subject each specimen to a continuous, midpoint, loading applied at a rate of 1 in./min ± 5 s (25 mm/min ± 5 s) downward to the back of the panel (plaster surface in tension) supported over a clear span of 14 in. (356 mm) until failure.

5.8.4 *Report*—Report whether the sample passes or fails the flexure test. The sample fails if any one of the specimens shows cracking more than ½ in. (13 mm) from the break line or if the bond of the veneer plaster to the paper fails.

5.8.5 *Precision and Bias*—No information is presented about either the precision or bias of the flexure test since the test result is nonquantitative.

5.9 *Joint Strength*:

5.9.1 *Significance and Use*—The joint strength test is designed to test strength of the joint between two adjacent gypsum veneer panels that have been covered with veneer plaster. The degree of correlation between this test method and service performance has not been determined.

5.9.2 *Apparatus*—Use the apparatus described in Test Methods C 473 for Method B.

5.9.3 *Specimen Preparation*—Cut two 8 by 12-in. (200 by 300-mm) pieces of gypsum base for veneer plaster for each specimen to be tested. One 12-in. edge of each piece shall be the paper-bound edge. Place the two pieces of gypsum base for veneer plaster face down with the paper-bound edges forming the joint. Apply a pregummed tape over the joint. (The tape will keep the joint from flexing during the specimen preparation.) Turn face up and apply joint tape and gypsum veneer plaster in accordance with Specification C 843 using the method titled "Reinforcement Secured and Embedded with Veneer Plaster."

5.9.4 *Procedure*—Condition the specimen and determine the flexural strength in accordance with Test Methods C 473 Method B. Apply the load parallel to and directly over the back of the joint.

5.9.5 *Report*—Calculate and report the average breaking load in pound-force or newtons, rounded to the nearest 1 lbf (N).

5.9.6 *Precision and Bias*—The precision and bias for measuring joint strength are essentially as specified in Test Methods C 473.

6. Inspection

6.1 Inspection of the gypsum veneer plaster shall be agreed upon between the purchaser and the supplier as part of the purchase agreement.

7. Rejection and Rehearing

7.1 Rejection of gypsum veneer plaster that fails to conform to the requirements of this specification shall be reported to the producer or supplier promptly and in writing. The notice of

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rejection shall contain a statement documenting how the gypsum veneer plaster has failed to conform to the requirements of this specification.

8. Certification

8.1 When specified in the purchase agreement, a manufacturer's or supplier's report shall be furnished at the time of shipment certifying that the product is in compliance with this specification.

9. Packaging and Package Marking

9.1 Gypsum veneer plaster shall be dry and free from lumps, and shall be shipped in packages.

9.2 When shipped for resale, the following information shall be legibly marked on each package or on a tag of suitable size attached thereto:

9.2.1 Name of producer or supplier,

9.2.2 Brand,

9.2.3 Description, and

9.2.4 Net or gross weight, or both, of package.

10. Keywords

10.1 gypsum; gypsum veneer plaster; plaster; veneer plaster

SUMMARY OF CHANGES

Committee C11 has identified the location of selected changes to this specification since the last issue, C 587 – 02, which may impact the use of this specification. (Approved December 1, 2004)

(*1*) Replaced Specification C 588/C 588M with Specification C 1396/C 1396M throughout.

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Designation: C 593 – 06

Standard Specification for Fly Ash and Other Pozzolans for Use With Lime for Soil Stabilization[1]

This standard is issued under the fixed designation C 593; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope*

1.1 This specification covers the qualification of fly ash and other pozzolans for use with lime in plastic, nonplastic mixtures and other mixtures that affect lime pozzolanic reaction required by soil stabilization. Evaluation of pozzolans containing available lime, such as Class C fly ash, is given consideration. Pozzolans covered include artificial pozzolans such as fly ash, and natural pozzolans, such as diatomite and pumicite, in either raw or calcined state.

1.2 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

2. Referenced Documents

2.1 *ASTM Standards:* [2]

C 25 Test Methods for Chemical Analysis of Limestone, Quicklime, and Hydrated Lime

C 39/C 39M Test Method for Compressive Strength of Cylindrical Concrete Specimens

C 50 Practice for Sampling, Sample Preparation, Packaging, and Marking of Lime and Limestone Products

C 51 Terminology Relating to Lime and Limestone (as used by the Industry)

C 109/C 109M Test Method for Compressive Strength of Hydraulic Cement Mortars (Using 2-in. or [50-mm] Cube Specimens)

C 110 Test Methods for Physical Testing of Quicklime, Hydrated Lime, and Limestone

C 305 Practice for Mechanical Mixing of Hydraulic Cement Pastes and Mortars of Plastic Consistency

C 311 Test Methods for Sampling and Testing Fly Ash or Natural Pozzolans for Use in Portland-Cement Concrete

C 670 Practice for Preparing Precision and Bias Statements for Test Methods for Construction Materials

C 821 Specification for Lime for Use with Pozzolans

D 1557 Test Methods for Laboratory Compaction Characteristics of Soil Using Modified Effort (56,000 ft-lbf/ft^3(2,700 kN-m/m^3))

3. Terminology

3.1 For definitions of terms specific to this specification, see Terminology C 51.

4. Physical Properties

4.1 Pozzolans for use with lime in plastic mixtures, when tested in accordance with the procedures of Sections 7-9, shall conform to the requirements prescribed in Table 1.

4.2 Pozzolans for use with lime in nonplastic mixtures shall conform to the requirements of Table 1, except the lime-pozzolan strength requirement, and in addition shall be tested in accordance with the procedures of Section 10.

NOTE 1—If the minimum value of the vacuum saturation strength specified in 4.2 of this specification is reduced, sufficient documentation shall be provided to the user to enable the determination of a satisfactory minimum residual strength for the given material in its intended use. Such documentation should include at least the following: (*1*) determination of a minimum residual strength requirement that will enable the material to perform its structural function in the pavement system; and (*2*) a rational analysis, using actual climatic data, that will show the severity of exposure of the material to cyclic freeze-thaw action.

TABLE 1 Physical Requirements

Water-soluble fraction, max, %	10.0
Fineness, amount retained, when wet sieved:	
No. 30 (600-μm) sieve, max, %	2.0
No. 200 (75-μm) sieve, max, %	30.0
Lime-pozzolan strength, minimum compressive strength, psi (MPa):	
At 7 days, 130 ± 3 °F (54 ± 2 °C)	600 (4.1)
After additional 21 days, 73± 3 °F (23 ± 2 °C)	600 (4.1)
Compressive strength, min, psi (MPa)	400 (2.8)
Vacuum saturation strength, min, psi (MPa)	400 (2.8)

5. Sampling

5.1 Sample pozzolan in accordance with the applicable provisions of Test Methods C 311, except take one 10-lb (4.5-kg) sample from approximately each 400 tons (350 metric tons) of pozzolan.

[1] This specification is under the jurisdiction of ASTM Committee C07 on Lime and is the direct responsibility of Subcommittee C07.02 on Specifications and Guidelines.

Current edition approved Nov. 15, 2006. Published December 2006. Originally approved in 1966. Last previous edition approved in 2005 as C 593 – 05.

[2] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

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5.2 The sampling procedures and techniques shall be consistent from original sample to project completion.

TEST METHODS

6. Significance and Use

6.1 This test method states various procedures that are recommended to quantify various aspects of the lime enhanced pozzolanic reaction. These tests are intended to qualify sources of fly ash and other pozzolans to meet specified job or project criteria as related to soil stabilization.

7. Water-Soluble Fraction

7.1 *Procedure*—Place 10 g of a dried pozzolan sample (dried to constant weight in an oven at 221 to 230 °F (105 to 110 °C)) in a 200-mL Erlenmeyer flask and add 100 mL of distilled water at 73 ± 3 °F (23 ± 2 °C). Shake well by hand until no lumps can be observed; then with a mechanical shaker or stirring device, agitate at laboratory room temperature for a period of 1 h. Pour the material into a weighed Gooch or sintered-glass crucible, and wash all residue from the flask into the crucible with distilled water from a wash bottle. Wash the residue in the crucible free of adhering solution by repeated washings with distilled water. Dry the crucible to constant weight in an oven at 221 °F (105 °C).

7.2 *Calculation*—Calculate the percentage of water-soluble fraction by multiplying the loss in weight in grams by 10.

8. Fineness

8.1 Test in accordance with Test Methods C 110, except that the sample shall be 100 g of the dried pozzolan.

9. Lime-Pozzolan Strength Development

9.1 Test the pozzolan in accordance with the applicable portions of Test Method C 109/C 109M and Practice C 305, and in accordance with the following:

9.2 *Apparatus*:

9.2.1 *Oven*, closed, vapor-type.

9.3 *Materials*:

9.3.1 *Hydrated Lime*—Where possible, the lime shall be the same as that to be used on the job and shall meet the requirements of Specification C 821.

9.3.2 *Sand*—The sand shall be graded standard sand as required by Test Method C 109/C 109M.

9.4 *Number of Test Specimens*—Three specimens shall be prepared for each age at which a strength test is desired.

9.5 *Proportioning, Consistency, and Mixing*—Batches shall be of a size sufficient to make six specimens and shall consist of proportions of dry materials as follows:

Hydrated lime	180 g
Pozzolan (dry basis)	360 g
Graded standard sand	1480 g

9.5.1 The amount of mixing water, measured in millilitres, shall be such as to produce a flow of 65 to 75 as determined in accordance with 9.6, and shall be expressed as weight percent of the combined lime and pozzolan. The lime and pozzolan shall be blended together in a closed container. Mixing shall be done in accordance with the procedure described in Practice C 305, except that it shall be amended to read "Add the blended lime and pozzolan to the water and allow it to stand for 1 min. Then start the mixer and mix at slow speed (140 ± 5 rpm) for 30 s."

9.6 *Determination of Flow*—Determine the flow in accordance with Test Method C 109/C 109M, except that the number of drops of the flow table shall be 10 drops in 6 s instead of 25 drops in 15 s. If the flow is less than the specified limit, the material used for the flow test may be returned to the mixing bowl and additional water added, the batch mixed for 1½ min, and a new flow taken. This operation may be repeated until a flow within the specified range is obtained. If the flow exceeds the range specified, discard the batch and give a new batch a new trial until a flow within range is obtained.

9.7 *Molding Test Specimens*—Immediately after the completion of the flow test, mold specimens in accordance with Test Method C 109/C 109M.

9.8 *Storage of Test Specimens*—When molding is completed, place the filled mold in the vapor immediately above water at 130 ± 3 °F (54 ± 2 °C) in a closed vapor oven with the top surface protected from the drip. Allow the specimens in the molds to remain in the vapor for a period of 7 days, after which remove them from the vapor and cool to 73 ± 3 °F (23 ± 2 °C) in air saturated sufficiently that no drying takes place during the cooling. When the specimens are cool, remove them from the molds, and store them at 73 ± 3 °F (23 ± 2 °C) at 95 to 100 % relative humidity until time of the compressive strength test.

10. Compressive Strength Development and Freeze-Thaw Resistance of Nonplastic Mixtures

10.1 *Materials*:

10.1.1 *Hydrated Lime*—Where possible, the lime shall be the same as that to be used on the job and shall meet the applicable requirements of Specification C 821. Prior to usage, the lime shall be stored in a sealed container to prevent carbonation.

10.1.2 *Pozzolan*—The pozzolan used in this test shall be the same as intended for use on the job.

10.1.3 *Aggregate*—Where possible, the aggregate used in this test shall be the same as intended for use on the job. When using job aggregates, discard the material, if any, retained on the ¾-in. (19.0-mm) sieve. If the aggregate fraction between the ¾-in. and No. 4 (4.75-mm) sieve does not contain free surface moisture, then that fraction of the aggregate shall be soaked for 24 h and towel dried to obtain a saturated surface dry condition. If job aggregates are not available, graded standard sand as specified in Test Method C 109/C 109M shall be used.

10.2 *Number of Specimens*—Three specimens shall constitute one test for the compressive strength test with three additional specimens for the freeze-thaw test.

10.3 *Proportioning*—The proportion of dry materials by weight shall be, where possible, the same proportions as intended for use on the job. If graded standard sand is used as the aggregate, the proportions of dry materials by weight shall be as follows:

Hydrated lime	4 %
Pozzolan	24 %
Graded standard sand	72 %

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The amount of mixing water shall be the optimum moisture content as determined by Method C of Test Methods D 1557, except that the 5-lift requirement is replaced with 3 lifts and Note 1 is not to be used. In determining the moisture-density relationship, mix dry materials in a Lancaster PC Mixer, or its equivalent, for 1 min, or until the mixture is uniform in color and texture, plus an additional 3 min after the water is added in order to obtain the first point on the moisture-density curve. The original sample may be reused for subsequent trials. The batch shall be mixed for an additional minute after the water has been added for each subsequent trial.

10.4 *Mixing and Molding Test Specimens*— After the optimum moisture content is obtained by the above procedure, a batch large enough to make three 4.0 by 4.6-in. (102 by 117-mm) cylinders (approximately 15 lb (7 kg)) shall be mixed in the following manner: Mix the dry materials in a Lancaster PC Mixer, or its equivalent, for 1 min or until the mixture is uniform in color and texture, followed by the addition of water that will give optimum moisture content and an additional 3 min of mixing. Mold the specimens immediately in accordance with Method C of Test Methods D 1557, except as previously noted. Each layer should be scarified to a depth of ¼ in. (6 mm) before the next layer is compacted in order to assure a good bond between the layers. Weigh a representative sample of the mixture, using a container with a tight lid to assure that no moisture is lost while determining the weight of the sample. Dry to constant weight and calculate the actual moisture content of the sample. After molding, weigh each sample in the mold to determine the uniformity of molded weights of the specimens and then carefully remove from the mold by the use of a sample extruded, such as a jack or lever frame.

10.5 *Curing of Test Specimens*—Immediately after the specimens are removed from the mold, reweigh the specimens and place in a sealed container (½-gal (2-L) or 1-gal (4-L) can with double friction lids) to prevent loss of moisture. Place the specimens in the sealed containers carefully in a room or cabinet with forced-air circulation maintained at 100 ± 3 °F (38 ± 2 °C) for a 7-day period. After this period, remove the specimens from the container, reweigh, and allow to cool to room temperature. Submerge the specimens for compressive strength testing in water for 4 h, remove, allow to drain on a nonabsorbent surface, and cap and test within 1 h of the time of removal from the water.

10.6 *Number of Test Specimens*:

10.6.1 Three specimens shall be tested in accordance with Test Method C 39/C 39M; no *l*/*d* correction will be considered in the computation of the compressive strength.

10.6.2 Three specimens shall be tested for freeze-thaw resistance after being cured in accordance with 10.5 (without the 4-h soaking period) by means of the vacuum saturation strength testing procedure described in Section 11.

11. Vacuum Saturation Strength Testing Procedure

11.1 *Equipment*:

11.1.1 *Vacuum Saturation Chamber*—The vacuum saturation chamber is a 12-in. (305-mm) high by 12-in. inside diameter stainless steel cylindrical section welded to a ½-in. (12.7-mm) thick by 14-in. (356-mm) diameter stainless steel base plate. The wall thickness of the cylindrical section is ⅜ in. (9.5 mm). The lid of the vacuum saturation chamber is a poly(methylmethacrylate) (PMMA) plate 1 in. (13 mm) thick and 14 in. in diameter. Both the PMMA lid and top of the vacuum cylinder are grooved for a ¼-in. (6.4-mm) circular O-ring seal having an inside diameter of 12⅛ in. (308 mm). The lid is fastened to the chamber by six equally spaced threaded ¼-in. rods which pass along the outside wall of the cylindrical section and thread into the base plate.

11.1.1.1 A sketch of the vacuum saturation chamber described above is shown in Fig. 1. A vacuum saturation chamber

FIG. 1 Pictorial View of Vacuum Saturation Equipment

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of equivalent size and capability is permitted under this specification. Vacuum desiccators can also be used for this purpose.

11.1.1.2 A ¼-in. (6.4-mm) vacuum line connection is located 1 in. (13 mm) below the top of the vacuum chamber and a ⅜-in. (9.5-mm) water line connection with control valve is located at the base of the vacuum chamber. The vacuum line is connected to a commercial vacuum pump and the water line is connected to a reservoir of desired water. The vacuum is controlled by a pressure valve at the vacuum pump.

11.1.1.3 The specimen support plate inside of the chamber is constructed of ½-in. (12.7-mm) thick PMMA which is 11½ in. (292 mm) in diameter. The support plate sits on three 1½-in. (38.1-mm) long legs which elevate it off of the bottom of the chamber. The specimen support plate is perforated (approximately ten ⅛-in. (3.2-mm) diameter holes per square inch) so as to allow complete access of water to the specimens during saturation. For an equivalent size vacuum saturation chamber, a specimen support plate similar to that described above must be provided.

11.1.1.4 The vacuum saturation chamber must be of sufficient size to hold the same number of Proctor-sized specimens for vacuum saturation testing as the number of specimens tested for compressive strength.

11.1.2 *Vacuum System*—A system capable of maintaining a vacuum of 24 in. Hg (11.8 psi) for a minimum of 30 min is required.

11.2 *Procedure*:

11.2.1 At the end of the curing period, remove the specimens from the curing room and allow approximately 2 h to reach equilibrium with room temperature. The specimens should remain sealed in the containers during this 2-h equilibration period in order to prevent moisture loss.

11.2.2 Place the cured specimens in an upright position on the specimen support plate within the vacuum chamber. Place the lid on the vacuum chamber and evacuate the chamber to a pressure of 24 in. Hg gradually over a period of not less than 45 s and hold for 30 min in order to remove air from the voids in the specimens. After the 30-min de-airing period, flood the vacuum chamber with water at room temperature to a depth sufficient to cover the specimens. Remove the vacuum and then soak the specimens for 1 h at atmospheric pressure.

11.2.3 At the end of the soaking period, remove the specimens from the water and allow to drain for approximately 2 min on a nonabsorptive surface. After the free surface water has drained, immediately test the specimens for unconfined compressive strength in accordance with Test Method C 39/C 39M.

11.3 *Report*—Report of the compressive strength and vacuum saturation strength tests shall include the following:

11.3.1 Identification of each material used in the preparation of the specimens,

11.3.2 Percentage by dry weight of each of the constituents,

11.3.3 Actual percentage moisture content of mixture,

11.3.4 Actual dry unit weight of each specimen, nearest lb/ft^3 or g/cm^3,

11.3.5 Percentage of maximum dry unit weight of each specimen,

11.3.6 Cross-sectional area of each specimen, in. ^{2} or cm^2,

11.3.7 Maximum failure load of each specimen, lbf or N,

11.3.8 Compressive strength of each specimen, to nearest 5 psi or 50 kPa, and

11.3.9 Vacuum saturation strength of each specimen, to nearest 5 psi or 50 kPa.

11.3.10 The average compressive strength of the three specimens tested shall be designated as the test value for evaluation by this specification. The average vacuum saturation strength of the three specimens tested shall be designated as the test value for evaluation by this specification.

12. Available Lime Index of Fly Ash

12.1 The available lime index may be determined using the Available Lime Index Method of Test Methods C 25 (Hydrated Lime Procedure). See also Practice C 50, Terminology C 51, and Specification C 821.

12.2 The precision for pulverized coal fly ash, using the procedure of 12.1, is as follows:

12.2.1 The single operator standard deviation has been found to be 0.095 %.[3] Therefore, results of two properly conducted tests by the same operator on the same material should not differ by more than 0.268 %.[3]

12.2.2 The multilaboratory standard deviation has been found to be 0.264 %.[3] Therefore, results of two properly conducted tests from two different laboratories on identical samples should not differ by more than 0.75 %.[3]

13. Storage and Inspection

13.1 Pozzolans shall be stored in such a manner as to permit easy access for proper inspection and identification of each shipment. Reasonable facilities shall be provided the purchaser for careful sampling and inspection either at the source or at the site of the work, as may be specified by the purchaser.

14. Rejection

14.1 Pozzolan may be rejected if it fails to meet any of the requirements of this specification.

14.2 Packages varying more than 5 % from the stated weight may be rejected; and if the average weight of the packages in any shipment, as shown by weighing 50 packages taken at random, is less than that specified, the entire shipment may be rejected.

15. Packaging and Package Marking

15.1 When pozzolan is delivered in packages, the name and brand and the weight of material contained therein shall be plainly marked on each package. Similar information shall be provided in shipping invoices accompanying the shipment of packaged or bulk pozzolans.

16. Keywords

16.1 compressive strength; fly ash; freeze-thaw resistance; lime; pozzolan; soil stabilization

[3] These numbers represent, respectively, the (1s) and (d2s) limits as described in Practice C 670.

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SUMMARY OF CHANGES

Committee C07 has identified the location of selected changes to this specification since the last issue, C 593 – 05, that may impact the use of this specification. (Approved November 15, 2006)

(*1*) Replaced reference to Type N Lime (Specification C 207) to Lime Used with Pozzolans (Specification C 821) in 9.3.1 and 10.1.1.

(*2*) Revised 1.2, 9.5, and 9.7 to change the safety caveat and remove references to mortar.

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Designation: C 595/C 595M – 09

Standard Specification for Blended Hydraulic Cements[1]

This standard is issued under the fixed designation C 595/C 595M; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

This standard has been approved for use by agencies of the Department of Defense.

1. Scope*

1.1 This specification pertains to blended hydraulic cements for both general and special applications, using slag or pozzolan, or both, with portland cement or portland cement clinker or slag with lime.

NOTE 1—This specification prescribes ingredients and proportions, with some performance requirements whereas Performance Specification C 1157 is a hydraulic cement specification in which performance criteria alone govern the products and their acceptance.

1.2 The values stated in either SI units or inch-pound units are to be regarded separately as standard. The values stated in each system may not be exact equivalents; therefore, each system shall be used independently of the other. Combining values from the two systems may result in non-conformance with the standard. Values in SI units [or inch-pound units] shall be obtained by measurement in SI units [or inch-pound units] or by appropriate conversion, using the Rules for Conversion and Rounding given in IEEE/ASTM SI 10, of measurements made in other units [or SI units]. Values are stated in only SI units when inch-pound units are not used in practice.

1.3 The text of this standard refers to notes and footnotes which provide explanatory material. These notes and footnotes (excluding those in tables and figures) are not requirements of the standard.

2. Referenced Documents

2.1 *ASTM Standards:*[2]

C 109/C 109M Test Method for Compressive Strength of Hydraulic Cement Mortars (Using 2-in. or [50-mm] Cube Specimens)
C 114 Test Methods for Chemical Analysis of Hydraulic Cement
C 150 Specification for Portland Cement
C 151 Test Method for Autoclave Expansion of Hydraulic Cement
C 157/C 157M Test Method for Length Change of Hardened Hydraulic-Cement Mortar and Concrete
C 183 Practice for Sampling and the Amount of Testing of Hydraulic Cement
C 185 Test Method for Air Content of Hydraulic Cement Mortar
C 186 Test Method for Heat of Hydration of Hydraulic Cement
C 187 Test Method for Normal Consistency of Hydraulic Cement
C 188 Test Method for Density of Hydraulic Cement
C 191 Test Methods for Time of Setting of Hydraulic Cement by Vicat Needle
C 204 Test Methods for Fineness of Hydraulic Cement by Air-Permeability Apparatus
C 219 Terminology Relating to Hydraulic Cement
C 226 Specification for Air-Entraining Additions for Use in the Manufacture of Air-Entraining Hydraulic Cement
C 227 Test Method for Potential Alkali Reactivity of Cement-Aggregate Combinations (Mortar-Bar Method)
C 265 Test Method for Water-Extractable Sulfate in Hydrated Hydraulic Cement Mortar
C 311 Test Methods for Sampling and Testing Fly Ash or Natural Pozzolans for Use in Portland-Cement Concrete
C 430 Test Method for Fineness of Hydraulic Cement by the 45-μm (No. 325) Sieve
C 465 Specification for Processing Additions for Use in the Manufacture of Hydraulic Cements
C 563 Test Method for Approximation of Optimum SO_3 in Hydraulic Cement Using Compressive Strength
C 688 Specification for Functional Additions for Use in Hydraulic Cements
C 821 Specification for Lime for Use with Pozzolans
C 1012 Test Method for Length Change of Hydraulic-Cement Mortars Exposed to a Sulfate Solution

[1] This specification is under the jurisdiction of ASTM Committee C01 on Cement and is the direct responsibility of Subcommittee C01.10 on Hydraulic Cements for General Concrete Construction.

Current edition approved June 15, 2009. Published July 2009. Originally approved in 1967. Last previous edition approved in 2008 as C 595 – 08a.

[2] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

***A Summary of Changes section appears at the end of this standard.**

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C 1157 Performance Specification for Hydraulic Cement
IEEE/ASTM SI 10 Standard for Use of the International System of Units (SI): the Modern Metric System

3. Terminology

3.1 *Definitions*—The terms used in this specification are defined in Terminology C 219, except for the following terms:

3.1.1 *binary blended cement*, *n*—a blended hydraulic cement consisting of portland cement with either a slag cement or a pozzolan.

3.1.2 *ternary blended cement*, *n*—a blended hydraulic cement consisting of portland cement with either a combination of two different pozzolans, or slag cement and a pozzolan.

4. Classification

4.1 This specification applies to the following types of blended cement that generally are intended for use as indicated.

4.1.1 Blended hydraulic cements for general concrete construction.

4.1.1.1 *Type IS*—Portland blast-furnace slag cement.

4.1.1.2 *Type IP*—Portland-pozzolan cement.

4.1.1.3 *Type IT*—Ternary blended cement.

4.2 *Reporting*:

4.2.1 The naming practice for blended cements shall be made by adding the suffix (X) to the type designation under 4.1.1, where (X) equals the targeted percentage of slag or pozzolan in the product expressed as a whole number by mass of the final blended product, within the allowable variation as stated in 14.3.

4.2.2 The naming practice for ternary blended cements shall be made by adding the suffixes (AX) and (BY) to the Type IT designation under 4.1.1, where:

A is either "S" for slag cement, or "P" for pozzolan, whichever is present in larger amount by mass, and
X is the targeted percentage by mass of constituent A, and
B is either "S" for slag cement, or "P" for pozzolan, and
Y is the targeted percentage by mass of constituent B.

Both X and Y values are expressed as a whole number by mass of the final blended product, within the allowable variation as stated in 14.3. If X and Y are the same, the order is interchangeable.

NOTE 2—Examples of the naming practice per 4.2.1 and 4.3 are shown below (all percentages by mass):

Binary blended cement with 80 % portland cement and 20 % slag cement = IS(20).
Binary blended cement with 85 % portland cement and 15 % pozzolan = IP(15).
Ternary blended cement with 70 % portland cement, 20 % slag cement and 10 % pozzolan = IT(S20)(P10).
Ternary blended cement with 65 % portland cement, 25 % of one pozzolan and 10 % of another pozzolan = IT(P25)(P10).

4.2.3 A simplified naming practice is used in this standard for practicality and clarity when referring to specific requirements for binary and ternary blended cements that are applicable to a range of products or in ternary blended cements when requirements are applicable to only one constituent within a specific range (%). (See Note 3)

NOTE 3—Examples of the simplified naming practices per 4.2.3 are shown below:

1) An example when requirements are applicable to a range of products can be found in Table 1, where the maximum SO_3 content of 3 % applies to: binary blended cements with slag cement contents <70 %, indicated as IS(<70); ternary blended cements with a pozzolan content less than the slag cement content and the slag cement content is less than 70 %, indicated as IT(P<S<70).

2) An example when requirements are applicable to only one constituent within a specific range (%) of that constituent can be found in 8.2, where testing is required only when the slag cement content is <25 %. Because the requirement is based on the slag cement content only with no relation to the pozzolan content, a simplified naming practice is employed and the range of ternary blended cements are indicated as Type IT(S<25).

4.3 *Special Properties*:

4.3.1 Air-entraining cement, when desired by the purchaser, shall be specified by adding the suffix (A) to any of the above types. The air-entraining option is specified in combination with any of the other special properties where required.

NOTE 4—A given mass of blended cement has a larger absolute volume than the same mass of portland cement. This should be taken into consideration in purchasing cements and in proportioning concrete mixtures.

4.3.2 Moderate sulfate resistance or moderate heat of hydration, or both, when desired by the purchaser, shall be specified by adding the suffix (MS) or (MH), respectively, to the type designation under 4.1.1.

4.3.3 High sulfate resistance, when desired by the purchaser, shall be specified by adding the suffix (HS) to the type designation under 4.1.1.

NOTE 5—Special characteristics attributable to slag or pozzolan will vary based on quantities contained within the blended cements.

4.3.4 Low heat of hydration, when desired by the purchaser, shall be specified by adding the suffix (LH) to the type designation under 4.1.1.

TABLE 1 Chemical Requirements

Cement Type[A,B]	Applicable Test Method	IS(< 70), IT(P<S<70)	IS(≥ 70), IT(S≥70)	IP, IT(P>S)
Magnesium oxide (MgO), max, %	C 114	...	...	6.0
Sulfate reported as SO_3, max, %[C]	C 114	3.0	4.0	4.0
Sulfide reported as S^{2-}, max, %	C 114	2.0	2.0	...
Insoluble residue, max, %	C 114	1.0	1.0	...
Loss on ignition, max, %	C 114	3.0	4.0	5.0

[A] The chemical requirements in this table are applicable to all air-entrained cement equivalents.
[B] The requirements of Type IT(P>S) shall apply to ternary blended cements with equal pozzolan and slag cement contents.
[C] When it has been demonstrated by Test Method C 563 that the optimum SO_3 exceeds a value 0.5 % less than the specification limit, an additional amount of SO_3 is permissible provided that, when the cement with the additional calcium sulfate is tested by Test Method C 265, the calcium sulfate in the hydrated mortar at 24 ± ¼ h, expressed as SO_3, does not exceed 0.50 g/L. When the manufacturer supplies cement under this provision, he will, upon request, supply supporting data to the purchaser.

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5. Ordering Information

5.1 Orders for material under this specification shall include the following:

5.1.1 Specification number,

5.1.2 Type or types required,

5.1.2.1 Indicate allowable slag or pozzolan % maximum or minimum, or both, if required.

5.1.3 Optional special properties required (see 4.3):

5.1.3.1 MS if moderate sulfate resistance is required;

5.1.3.2 HS if high sulfate resistance is required;

5.1.3.3 MH if moderate heat of hydration is required;

5.1.3.4 LH if low heat of hydration is required;

5.1.3.5 A if air entraining is required;

5.1.3.6 Accelerating addition, if required;

5.1.3.7 Retarding addition, if required;

5.1.3.8 Water reducing addition, if required;

5.1.3.9 Water reducing and accelerating addition, if required; and

5.1.3.10 Water reducing and retarding addition, if required.

5.1.4 Certification, if desired (see Section 14).

NOTE 6—It is important to check for availability of various options. Some multiple options are mutually incompatible or unattainable.

6. Materials and Manufacture

6.1 *Blast-Furnace Slag*—Blast-Furnace slag shall be the nonmetallic product, consisting essentially of silicates and aluminosilicates of calcium and other bases, that is developed in a molten condition simultaneously with iron in a blast furnace.

6.2 *Granulated Blast-Furnace Slag*—Granulated blast-furnace slag shall be the glassy granular material formed when molten blast-furnace slag is rapidly chilled, as by immersion in water.

6.3 *Slag Cement*—See Terminology C 219.

6.4 *Portland Cement*—See Terminology C 219. For purposes of this specification, portland cement meeting the requirements of Specification C 1157 or Specification C 150 are suitable. Portland cement or other hydraulic materials, or both, containing high free lime are not prohibited from use as long as the autoclave test limits for the blended cement are met.

6.5 *Portland Cement Clinker*—Portland cement clinker shall be partially fused clinker consisting primarily of hydraulic calcium silicates.

6.6 *Pozzolan*—Pozzolan shall be a siliceous or siliceous and aluminous material, which in itself possesses little or no cementitious value but which will, in finely divided form and in the presence of moisture, chemically react with calcium hydroxide at ordinary temperatures to form compounds possessing cementitious properties.

6.7 *Hydrated Lime*—Hydrated lime used as part of a blended cement shall meet the requirements of Specification C 821, except that when interground in the production process there shall be no minimum fineness requirement.

6.8 *Air-Entraining Addition*—When air-entraining cement is specified, an addition meeting the requirements of Specification C 226 shall be used.

6.9 When processing additions are used in the manufacture of cement, they shall have been shown to meet the requirements of Specification C 465 in the amounts used or greater, (see Section 14.2).

6.10 When functional additions (used at the sole option of the purchaser) are used they shall have been shown to meet the requirements of Specification C 688 when tested with the cement to be used, in the amount used or greater, (see Section 14.2).

6.11 *Other Additions*—The cement covered by this specification shall contain no additions except as provided for above except that water or calcium sulfate (see Terminology C 219), or both, if added, shall be in amounts so that the limits shown in Table 1 for sulfate reported as SO_3 and loss on ignition are not exceeded.

6.12 *Binary Blended Cement*—Binary blended cement shall be a hydraulic cement consisting of an intimate and uniform blend (see Note 7) produced either by intergrinding portland cement clinker with a pozzolan or a granulated blast-furnace slag, or a slag cement, or by blending portland cement with a pozzolan or a slag cement, or a combination of intergrinding and blending. The maximum constituent requirements of 6.14 and 6.16 shall apply.

6.13 *Ternary Blended Cement*—Ternary blended cement shall be a hydraulic cement consisting of an intimate and uniform blend (see Note 7) produced either by intergrinding portland cement clinker with 1) two different pozzolans, 2) granulated blast-furnace slag or slag cement and a pozzolan; or by blending portland cement with 1) two different pozzolans or 2) slag cement and a pozzolan, or 3) a combination of intergrinding and blending. The maximum constituent requirements of 6.14 and 6.16 shall apply.

6.14 *Portland Blast-Furnace Slag Cement*—Portland blast-furnace slag cement shall be a hydraulic cement in which the slag cement constituent is up to 95 % by mass of the blended cement. Binary or ternary blended cement with a slag cement content equal to or exceeding 70 % by mass, is permitted to contain hydrated lime.

NOTE 7—The attainment of an intimate and uniform blend of two or more types of fine materials is difficult. Consequently, adequate equipment and controls must be provided by the manufacturer. The purchasers should assure themselves of the adequacy of the blending operation.

6.15 *Air-Entraining Portland Blast-Furnace Slag Cement*—Air-entraining portland blast-furnace slag cement shall be portland blast-furnace slag cement to which sufficient air-entraining addition has been added so that the resulting product complies with the air content of mortar requirements.

6.16 *Portland-Pozzolan Cement*—Portland-pozzolan cement shall be a hydraulic cement in which the pozzolan constituent is up to 40 % by mass of the blended cement.

6.17 *Air-Entraining Portland-Pozzolan Cement*—Air-entraining portland-pozzolan cement shall be portland-pozzolan cement to which sufficient air-entraining addition has been added so that the resulting product complies with the air content of mortar requirements.

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7. Chemical Composition

7.1 Cement of the type specified shall conform to the applicable chemical requirements prescribed in Table 1.

7.2 If the purchaser has requested the manufacturer to state in writing the composition of the blended cement purchased, the composition of the cement furnished shall conform to that shown in the statement within the following tolerances (see Note 8).

	Tolerance, ± %
Silicon dioxide (SiO_2)	3
Aluminum oxide (Al_2O_3)	2
Calcium oxide (CaO)	3

NOTE 8—This means that if the manufacturer's statement of the composition says" SiO_2: 32 %," the cement when analyzed, shall be found to contain between 29 and 35 % SiO_2.

8. Physical Properties

8.1 *Blended Cement*—Blended cement of the type specified shall conform to the applicable physical requirements prescribed in Table 2.

8.2 *Pozzolan or Slag*—Pozzolan or granulated blast-furnace slag or slag cement that is to be blended with cement shall be tested in the same state of subdivision as that in which it is to be blended. Pozzolan shall conform to the fineness requirement and the activity index requirement of Table 3. Slag cement that is to be used for portland blast-furnace slag cements Type IS(< 25) or ternary blended cements Type IT(S<25) shall conform to the activity index requirement of Table 3. Such pozzolan, or granulated blast-furnace slag, or slag cement that is to be interground with portland cement clinker shall, before testing for conformance with requirements of Table 3, be ground in the laboratory to a fineness at which it is believed to be present in the finished cement. It is the manufacturer's responsibility to decide on the fineness at which the testing is to be carried out, and when requested to do so by a purchaser, to report the information upon which the decision was based.

8.3 Pozzolan for use in the manufacture of portland-pozzolan cement, Type IP(< 15) and IP(< 15)-A or ternary blended cements Type IT(P<15) and Type IT(P<15)-A, shall meet the requirements of Table 3 when tested for mortar expansion of pozzolan as described in 10.1.13. If the alkali content of the clinker to be used for the production lots changes by more than 0.2 % total as equivalent Na_2O, calculated as $Na_2O + 0.658\ K_2O$, from that of the clinker with which the acceptance tests were carried out, the pozzolan shall be retested to show compliance with the requirements of Table 3.

9. Sampling

9.1 Sample the materials in accordance with the following methods:

9.1.1 *Sampling Blended Cements*—Practice C 183.

9.1.1.1 When the purchaser desires that the cement be sampled and tested to verify compliance with this specification, perform sampling and testing in accordance with Practice C 183.

9.1.1.2 Practice C 183 is not designed for manufacturing quality control and is not required for manufacturer's certification.

9.1.2 *Sampling Pozzolan*—Test Methods C 311. One 2 kg [4 lb] sample shall be taken from approximately each 360 Mg [400 tons] of pozzolan.

10. Test Methods

10.1 Determine the applicable properties enumerated in this specification in accordance with the following test methods:

10.1.1 *Chemical Analysis*—Test Methods C 114, with the special provisions noted therein applicable to blended cement analyses.

10.1.2 *Fineness by Sieving*—Test Method C 430.

10.1.3 *Fineness by Air-Permeability Apparatus*—Test Method C 204.

10.1.4 *Autoclave Expansion*—Test Method C 151, except that, in the case of portland blast-furnace slag cement IS(≥70) or ternary blended cement IT(S≥70), the test specimens shall remain in the moist cabinet for a period of 48 h before being measured for length, and the neat cement shall be mixed for not less than 3 min nor more than 3½ min.

10.1.5 *Time of Setting*—Test Method C 191.

10.1.6 *Air Content of Mortar*—Test Method C 185, using the actual specific gravity of the cement, if it differs from 3.15 by more than 0.05, in calculating the air content.

10.1.7 *Compressive Strength*—Test Method C 109/C 109M.

10.1.8 *Heat of Hydration*—Test Method C 186.

10.1.9 *Normal Consistency*—Test Method C 187, except that in the case of portland blast-furnace slag cement IS(≥70) or ternary blended cement IT(S≥70), the paste shall be mixed for not less than 3 min nor more than 3½ min.

10.1.10 *Specific Gravity*—Test Method C 188.

10.1.11 *Water Requirement*—The mass of mixing water added to the six-cube batch in accordance with Test Method C 109/C 109M, as a percentage of the total cementing ingredients.

10.1.12 *Mortar Expansion of Blended Cement*—Test Method C 227, using crushed Pyrex glass No. 7740[3] as aggregate and the grading prescribed in Table 4.

10.1.13 *Mortar Expansion of Pozzolan for Use in Portland-Pozzolan Cement Types IP(< 15) and IP(< 15)-A or Ternary Blended Cement Types IT(P<15) and IT(P<15)-A*—Using the pozzolan and the clinker or cement that are to be used together in the production of the blended cement, prepare portland-pozzolan cements Types IP(< 15) and IP(< 15)-A or Ternary Blended Cement Types IT(P<15) and IT(P<15)-A containing 2.5, 5, 7.5, 10, 12.5, and 15 mass % of the pozzolan. These blends shall be tested in accordance with Test Method C 227 using a sand judged to be a nonreactive by the mortar bar test in Test Method C 227. The expansion of the mortar bars shall be measured at 91 days, and all the six blends shall meet the expansion requirement in Table 3.

10.1.14 *Drying Shrinkage*—Test Method C 157/C 157M. Make three specimens using the proportion of dry materials of

[3] Pyrex Glass No. 7740 is available as lump cullet from the Corning Glass Works, Corning, NY; this is the sole source of supply of the apparatus known to the committee at this time. If you are aware of alternative suppliers, please provide this information to ASTM International Headquarters. Your comments will receive careful consideration at a meeting of the responsible technical committee,[1] which you may attend.

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TABLE 2 Physical Requirements

Cement Type[A,B]	Applicable Test Method	IS(< 70), IT(P<S<70), IP, IT(P>S)	IS(< 70) (MS), IT(P<S<70) (MS), IP (MS), IT(P>S) (MS)	IS(< 70) (HS), IT(P<S<70) (HS), IP (HS), IT(P>S) (HS)	IS(≥ 70), IT(S≥70)	IP (LH),[C] IT(P>S) (LH)[C]
Fineness	C 204, C 430	[D]	[D]	[D]	[D]	[D]
Autoclave expansion, max, %	C 151	0.80	0.80	0.80	0.80	0.80
Autoclave contraction, max, %[E]	C 151	0.20	0.20	0.20	0.20	0.20
Time of setting, Vicat test:[F]	C 191					
Set, minutes, not less than		45	45	45	45	45
Set, hours, not more than		7	7	7	7	7
Air content of mortar, volume %, max[A]	C 185	12	12	12	12	12
Compressive strength, min[A], MPa [psi]:	C 109/C 109M					
3 days		13.0 [1890]	11.0 [1600]	11.0 [1600]	... ...	... ...
7 days		20.0 [2900]	18.0 [2610]	18.0 [2610]	5.0 [720]	11.0 [1600]
28 days		25.0 [3620]	25.0 [3620]	25.0 [3620]	11.0 [1600]	21.0 [3050]
Heat of hydration, max, kJ/kg [cal/g]:[G]	C 186					
7 days		290 [70]	290 [70]	290 [70]	... ...	250 [60]
28 days		330 [80]	330 [80]	330 [80]	... ...	290 [70]
Water requirement, max weight % of cement	C 109/C 109M	...	...	...	...	64
Drying shrinkage, max, %	C 157/C 157M	...	...	...	...	0.15
Mortar expansion, max, %:[H]	C 227					
14 days,		0.020	0.020	0.020	0.020	0.020
8 weeks,		0.060	0.060	0.060	0.060	0.060
Sulfate resistance, max, %:[I]	C 1012					
Expansion at 180 days		(0.10)[J]	0.10	0.05	...	(0.10)[J]
Expansion at 1 year				0.10	...	

[A] Air-entrained cements shall have a mortar air content of 19 ± 3 % by volume and the minimum compressive strength shall be no less than 80 % of the comparable non-air-entrained cement type.
[B] The requirements of Type IT(P>S), including MS, HS, or LH, as appropriate, shall apply to ternary blended cements with equal pozzolan and slag cement contents.
[C] Applicable only when higher strengths at early ages are not required or when low heat is required.
[D] Both amount retained when wet sieved on 45-μm (No. 325) sieve and specific surface by air permeability apparatus, m^2/kg, shall be reported on all mill test reports requested under 14.4.
[E] The specimens shall remain firm and hard and show no signs of distortion, cracking, checking, pitting, or disintegration when subjected to the autoclave expansion test.
[F] Time of setting refers to initial setting time in Test Method C 191. The time of setting of cements containing a user-requested accelerating or retarding functional addition need not meet the limits of this table, but shall be stated by the manufacturer.
[G] Applicable only when moderate (MH) or low (LH) heat of hydration is specified, in which case the strength requirements shall be 80 % of the values shown in the table.
[H] The test for mortar expansion is an optional requirement to be applied only at the purchaser's request and is not required unless the cement will be used with alkali-reactive aggregate.
[I] In the testing of HS cement, testing at one year shall not be required when the cement meets the 180-day limit. An HS cement failing the 180-day limit shall not be rejected unless it also fails the one-year limit.
[J] Optional sulfate resistance criterion that applies only if specifically invoked.

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TABLE 3 Requirements for Pozzolan for Use in Blended Cements and for Slag for Use in Portland Blast-Furnace Slag Cement Type IS(< 25) and Ternary Blended Cement Type IT(S<25)

Pozzolan and Slag, as applicable	Applicable Test Method	
Fineness:	C 430	
Amount retained when wet-sieved on 45-μm (No. 325) sieve, max, %		20.0
Alkali reactivity of pozzolan for use in Types IP(< 15); IT(P<15) and IP(< 15)-A; IT(P<15)-A cements, six tests, mortar bar	C 227	
expansion at 91 days, max, %		0.05
Activity index with portland cement, at 28 days, min, %	(see Annex A1)	75

1 part of cement to 2.75 parts of Test Method C 109/C 109M graded Ottawa sand. Use a curing period of 6 days and an air storage period of 28 days. Report the linear contraction during air storage based on an initial measurement after the 6-day water-curing period.

10.1.15 *Activity Index with Portland Cement*—Test in accordance with Annex A1.

10.1.16 *Sulfate Resistance*—see Test Method C 1012.

11. Testing Time Requirements

11.1 The following periods from time of sampling shall be allowed for the completion of testing:

3-day test	8 days
7-day test	12 days
14-day test	19 days
28-day test	33 days
8-week test	61 days

12. Inspection

12.1 Facilities shall be provided to the purchaser for careful inspection and sampling of the finished cement. Inspection and sampling of finished cement shall be at the mill or distribution site controlled by the manufacturer, or at any other location as agreed by the purchaser and seller.

12.2 The manufacturer shall provide suitable facilities to enable the inspector to check the relative masses of the constituents used, and the intergrinding or blending operation used to produce the cement. The plant facilities for intergrinding or blending and inspection shall be adequate to ensure compliance with the provisions of this specification.

13. Rejection

13.1 At the option of the purchaser, cement shall be rejected if it fails to meet any of the requirements of this specification applicable to the cement. Such rejection shall apply to an optional requirement only if that option has been invoked for the cement.

13.2 When the purchaser requires, cement in bulk storage for a period greater than six months shall be resampled and retested and, at the option of the purchaser, shall be rejected if it fails to meet any of the applicable requirements of this specification. Cement so rejected shall be the responsibility of the owner of record at the time of sampling for retest.

13.3 When the purchaser requires, packages more than 2 % below the mass marked thereon shall be rejected; or if the average mass of packages in any shipment, as shown by determining the mass of 50 packages taken at random, is less than that marked on the packages, the entire shipment, at the option of the purchaser, shall be rejected.

TABLE 4 Aggregate Grading Requirements for Mortar Expansion Test

Sieve Size		Weight %
Passing	Retained on	
4.75-mm (No. 4)	2.36-mm (No. 8)	10
2.36-mm (No. 8)	1.18-mm (No 16)	25
1.18-mm (No. 16)	600-μm (No. 30)	25
600-μm (No. 30)	300-μm (No. 50)	25
300-μm (No. 50)	150-μm (No. 100)	15

14. Certification

14.1 At the request of the purchaser, the manufacturer shall state in writing the source, amount, and composition of the essential constituents used in manufacture of the finished cement and the composition of the blended cement purchased.

14.2 At the request of the purchaser, the manufacturer shall state in writing the nature, amount, and identity of any processing, functional, or air-entraining addition used; and also, if requested, shall supply test data showing compliance of any such processing addition with the provisions of Specification C 465 and of any such functional addition with the provisions of Specification C 688, and of any such air-entraining addition with the provisions of Specification C 226.

14.3 At the request of the purchaser, the manufacturer shall also state in writing that the amount of pozzolan or slag in the finished cement will not vary more than ± 5.0 mass % of the finished cement from lot to lot or within a lot.

14.4 Upon request of the purchaser in the contract or order, a manufacturer's certification shall be furnished indicating that the material was tested during production or transfer in accordance with this specification, that it complies with this specification, and a report of the test results shall be furnished at the time of shipment (to include both amount retained on the 45-μm (No. 325) sieve and specific surface by the air permeability method).

15. Packaging and Package Marking

15.1 When the cement is delivered in packages, the words, "portland blast-furnace slag cement," "portland-pozzolan cement," or "ternary blended cement" as appropriate; the type of cement, name and brand of the manufacturer, and the mass of the cement contained therein, shall be plainly marked on each package. When the cement contains a functional addition listed in 5.1.3.5-5.1.3.10, the type of functional addition shall be plainly marked on each package. Similar information shall be provided in the shipping documents accompanying the shipment of packaged or bulk cement. All packages shall be in good condition at the time of inspection.

16. Storage

16.1 The cement shall be stored in such a manner as to permit easy access for proper inspection and identification of

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each shipment, and in a suitable weathertight building that will protect the cement from dampness and minimize warehouse set.

17. Keywords

17.1 blended hydraulic cement; fly ash cement; hydraulic cement; portland blast-furnace slag cement; portland pozzolan cement; pozzolanic cement; slag; granulated blast furnace slag

ANNEX

(Mandatory Information)

A1. ACTIVITY INDEX WITH PORTLAND CEMENT

A1.1 Specimen Preparation

A1.1.1 Mold, cure, and test the specimens from a control mix and from a test mix in accordance with Test Method C 109/C 109M. The portland cement used in the control mix shall meet the requirements of Specification C 150, and shall be the type, and if available, the brand of cement to be used in the work. Make three-cube batches as follows: (For 6- or 9-cube batches, double or triple, respectively, the amounts of dry ingredients.)

A1.1.1.1 *Control Mix*:

250 g of portland cement
687.5 g of graded Ottawa sand
X mL of water required for flow of 100 to 115

A1.1.1.2 *Pozzolan Test Mix*:

162.5 g of portland cement
g of pozzolan:
87.5 × sp gr of the sample/sp gr of the portland cement
687.5 g of graded Ottawa sand
Y mL of water required for flow of 100 to 115

A1.1.1.3 *Slag Test Mix*:

75 g of portland cement
g of slag:
175 × sp gr of the slag/sp gr of the portland cement
687.5 g of graded Ottawa sand
Z mL of water required for flow of 100 to 115

A1.2 Storage of Specimens

A1.2.1 After molding, place the specimens and molds (on the base plates) in the moist room or closet at 23.0 ± 2.0 °C [73.5 ± 3.5 °F] for 20 to 24 h. While in the moist room or closet, protect the surface from dripping water. Remove the molds from the moist room or closet and remove the cubes from the molds. Place the cubes in close-fitting metal or glass containers (Note A1.1), seal the containers airtight, and store at 38.0 ± 2.0 °C [100.0 ± 3.5 °F] for 27 days. Allow the specimens to cool to 23.0 ± 2.0 °C [73.5 ± 3.5 °F] before testing.

NOTE A1.1—Use any metal container having a capacity of three cubes if it can be sealed airtight by soldering. Containers of light-tinned sheet metal with inside dimensions of 52 by 52 by 160 mm [2 by 2 by 6.25 in.] have been found to be satisfactory. Wide-mouth Mason jars of 1-L capacity have been found to be satisfactory, provided care is taken to prevent breakage.

(**Warning**—Fresh hydraulic cementitious mixtures are caustic and may cause chemical burns to skin and tissue upon prolonged exposure.)[4]

A1.3 Compressive Strength Test

A1.3.1 Determine the compressive strength of the three specimens of the control mix and of the test mix at an age of 28 days in accordance with Test Method C 109/C 109M.

A1.4 Calculation

A1.4.1 Calculate the activity index with portland cement as follows:

$$\text{Activity index with portland cement} = (A/B) \times 100 \qquad \text{(A1.1)}$$

where:

A = average compressive strength of test mix cubes, MPa, and
B = average compressive strength of control mix cubes, MPa.

A1.5 Precision and Bias

A1.5.1 *Precision*—Single operator precision, on blended cements using fly ash is essentially the same as on fly ash/cement blends in Research Report C09-1001[5] and it was found to have 3.8 % coefficient of variation (1s %). This indicates that results of two properly conducted tests by the same operator are not expected to differ by more than 10.7 % (d2s) of the average of two results. Since the test is performed solely for the purpose of manufacturer certification of raw material quality, no multilaboratory precision is applicable.

A1.5.2 *Bias*—Since there are no standard reference materials, bias cannot be determined.

[4] Section on Safety, Manual of Cement Testing, *Annual Book of ASTM Standards*, Vol 04.01.

[5] Supporting data have been filed at ASTM International Headquarters and may be obtained by requesting Research Report RR: C09-1001.

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SUMMARY OF CHANGES

Committee C01 has identified the location of selected changes to this specification since the last issue, C 595 – 08a, that may impact the use of this specification. (Approved June 15, 2009)

(*1*) Revised Sections 3, 4, 6, 8, 10, 15, and Tables 1-3.

(*2*) Revised the standard as a dual-units specification.

Committee C01 has identified the location of selected changes to this specification since the last issue, C 595 – 08, that may impact the use of this specification. (Approved December 15, 2008)

(*1*) Revised 6.10.

(*2*) Deleted old Note 5 and renumbered subsequent notes.

(*3*) Revised the "IP(LH)" value for "Compressive strength, min: 28 days" in Table 2.

Committee C01 has identified the location of selected changes to this specification since the last issue, C 595 – 07, that may impact the use of this specification. (Approved January 1, 2008)

(*1*) Revised Table 1.

(*2*) Revised A1.2.1.

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Designation: C 596 – 09

Standard Test Method for Drying Shrinkage of Mortar Containing Hydraulic Cement[1]

This standard is issued under the fixed designation C 596; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope*

1.1 This test method determines the change in length on drying of mortar bars containing hydraulic cement and graded standard sand.

1.2 The values stated in SI units are to be regarded as standard. When combined standards are referenced, the selection of measurement system is at the user's discretion subject to the requirements of the referenced standard.

1.3 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.* (**Warning**—*Fresh hydraulic cementitious mixtures are caustic and may cause chemical burns to skin and tissue upon prolonged exposure).*[2]

2. Referenced Documents

2.1 *ASTM Standards:*[3]

C157/C157M Test Method for Length Change of Hardened Hydraulic-Cement Mortar and Concrete

C219 Terminology Relating to Hydraulic Cement

C305 Practice for Mechanical Mixing of Hydraulic Cement Pastes and Mortars of Plastic Consistency

C490/C490M Practice for Use of Apparatus for the Determination of Length Change of Hardened Cement Paste, Mortar, and Concrete

C511 Specification for Mixing Rooms, Moist Cabinets, Moist Rooms, and Water Storage Tanks Used in the Testing of Hydraulic Cements and Concretes

C778 Specification for Standard Sand

C1005 Specification for Reference Masses and Devices for Determining Mass and Volume for Use in the Physical Testing of Hydraulic Cements

C1437 Test Method for Flow of Hydraulic Cement Mortar

E177 Practice for Use of the Terms Precision and Bias in ASTM Test Methods

3. Terminology

3.1 The term "drying shrinkage" is defined as the decrease in length of the test specimen, where the decrease is caused by any factor other than externally applied forces under stated conditions of temperature, relative humidity and evaporation rate in the environment; the term includes the net effect of a variety of phenomena tending to bring about both increases and decreases in length during the period in which the test specimens under consideration are stored in the environment and in which a number of processes, including hydration of the cement, are taking place at a variety of rates.

3.2 Other terms used in this test method are defined in Terminology C219.

4. Significance and Use

4.1 This test method establishes a selected set of conditions of temperature, relative humidity and rate of evaporation of the environment to which a mortar specimen of stated composition shall be subjected for a specified period of time during which its change in length is determined and designated "drying shrinkage".

4.2 The drying shrinkage of mortar as determined by this test method has a linear relation to the drying shrinkage of concrete made with the same cement and exposed to the same drying conditions.[4] Hence this test method may be used when

[1] This test method is under the jurisdiction of ASTM Committee C01 on Cement and is the direct responsibility of Subcommittee C01.31 on Volume Change.

Current edition approved Dec. 1, 2009. Published January 2010. Originally approved in 1967. Last previous edition approved in 2007 as C 596 – 07.

[2] Section on Safety, *Manual of Cement Testing, Annual Book of Standards,* Vol 04.01.

[3] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

[4] Data pertaining to the relation of the drying shrinkage of mortar test specimens and of the drying shrinkage of concrete test specimens as affected by the cement under specified laboratory test conditions, may be found in RR/120:C-1, available from ASTM Headquarters; in a report of the California Division of Highways. "Significance of the Test for Contraction of Mortar in Air with Respect to Performance of Cements in Concrete," Oct. 18, 1961; and in the paper by Mardulier, F. J., Schneider, A. M., and Stockett, A. L., "An Analysis of Drying Shrinkage. Data for Portland Cement Mortar and Concrete," *Journal of Materials,* JMLSA, Am. Soc. Testing Mats., Vol 2, No. 4, 1967, pp. 829–842. A relevant paper by H. T. Arni entitled "The Significance of the Correlation Coefficient for Analyzing Engineering Data" was published in *Materials Research and Standards,* MTRSA, Am. Soc. Testing Mats., Vol. 11, No. 5, 1971, pp. 16–19.

***A Summary of Changes section appears at the end of this standard.**

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it is desired to develop data on the effect of a hydraulic cement on the drying shrinkage of concrete made with that cement.

5. Apparatus

5.1 *Weighing Devices and Weights*—Weighing devices and weights used in determining the mass of materials for mortar mixtures shall conform to the requirements of Specification C1005.

5.2 *Glass Graduates*—Glass graduates of suitable capacities shall conform to the requirements of Specification C1005.

5.3 *Molds*—Molds shall conform to the requirements of Practice C490/C490M for mortars.

5.4 *Trowel*—The trowel shall have a straight-edged steel blade 100 to 150 mm in length.

5.5 *Tamper*—The tamper shall conform to the requirements of Test Method C157/C157M.

5.6 *Demolding Apparatus*—The demolding apparatus shall conform to the requirements of Test Method C157/C157M.

5.7 *Length Comparator*—The length comparator shall conform to the requirements of Practice C490/C490M.

6. Temperature and Humidity

6.1 *Laboratory*—The temperature of the laboratory, dry materials, and mixing water, and the relative humidity of the air in the laboratory shall conform to the requirements of Specification C511.

6.2 *Moist Storage Facility*—The temperature and humidity of the air in the moist storage facility shall conform to the requirements of Specification C511.

6.3 *Drying Room and Controls*—The drying room and controls shall conform to the requirements of Test Method C157/C157M.

7. Graded Standard Sand

7.1 The graded standard sand shall conform to Specification C778.

8. Number of Test Specimens

8.1 Make at least four test specimens (Note 1).

NOTE 1—Although the number of test specimens may consist of four specimens from a single batch of mortar, it is preferable that twelve specimens be made with four specimens being made from each of three batches, with each batch being made on a different day.

9. Preparation of Molds

9.1 Prepare the specimen molds as required by Practice C490/C490M.

10. Preparation of Test Specimens

10.1 *Mortar Proportions*—A batch of mortar shall consist of 750 g of cement, 1500 g of graded standard sand, and an amount of mixing water sufficient to produce a flow of 110 ± 5 %. The flow shall be determined in conformance with the procedure as described in Test Method C1437.

10.2 *Mixing Mortar*—Mix the mortar in a mechanical mixer as required by Practice C305.

10.3 *Molding of Specimens*—Mold the specimens as required by Test Method C157/C157M.

11. Curing, Storage, and Taking Comparator Readings of Test Specimens

11.1 Cure, store, and take comparator readings of the test specimens as required by Test Method C157/C157M, except as follows:

11.1.1 Moist cure the specimens in the molds for 24 h ± 30 min. If the strength of the specimens is insufficient to allow proper removal from the mold at 24 h, moist cure in the mold for 48 h ± 30 min.

11.1.2 Remove the specimens from the molds and cure in lime-saturated water for 48 h. If the specimens have been moist cured in the mold for 48 h, cure in lime-saturated water for 24 h.

11.1.3 At the age of 72 h ± 30 min remove the specimens from water, wipe with damp cloth and immediately obtain a length comparator reading for each specimen. Then place the specimens in air storage for 25 days. Obtain a length comparator reading for each specimen after 4, 11, 18, and 25 days of air storage.

12. Calculation

12.1 Calculate the length change of each specimen at each age of air drying by subtracting the initial comparator reading, taken after removal from water storage, from the comparator reading taken at each age of air drying and express as millionths and as the percent of the effective gage length. Do not prefix a shrinkage value with a minus sign.

12.2 Report the average change in unit length, expressed as millionths, and as a percent of the effective gage length of four specimens from the same batch of mortar as the drying shrinkage of the mortar. If any one test specimen is manifestly faulty, discard it. If more than one test specimen is discarded, do not report the results and repeat the test on a new batch of mortar. If more than one batch of mortar has been tested, report the average result of the individual batches. When the experimenter is clearly aware that a gross deviation from prescribed experimental procedure has taken place, discard the resultant observation, whether or not it agrees with the rest of the data and without recourse to statistical tests for outliers.

NOTE 2—An approximation of ultimate drying shrinkage of mortar may be determined by plotting the shrinkage values as a function of the reciprocal of the time. The time includes the moist curing period. An example of the method is given in Fig. 1 where a logarithmic scale is used for the drying shrinkage values and a reciprocal scale for the total time in weeks.

13. Precision and Bias

13.1 *Precision*:

13.1.1 The single-laboratory-operator multibatch-day precision has been found to be 0.0223 (1S %) and the single-operator multilaboratory-batch-day precision has been found to be 6.6 (R1S %) as defined in Practice E177, therefore 95 % percent of the time two test results (each the average of four determinations of properly conducted tests) obtained by the same operator on different days should not differ by more than 70 millionths, and the test results (each the average of four determinations of properly conducted tests) obtained by two laboratories should not differ by more than 25 % of their mean.

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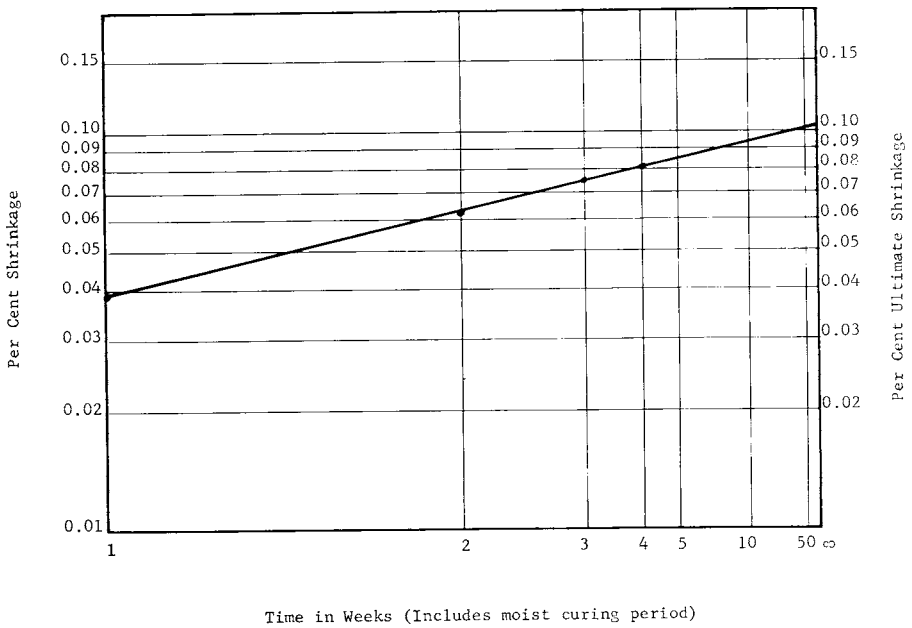

FIG. 1 Ultimate Drying Shrinkage of Mortar

13.1.2 *Repeatability*—Where a test result is the average of four specimens from a single batch, the difference between duplicate results by the same operator should not be considered suspect unless it exceeds 70 millionths. Where a test result is the average of twelve specimens, four specimens being tested from each of three batches, the difference between duplicate results by the same operator should not be considered suspect unless it exceeds 40 millionths.

13.1.3 *Reproducibility*—The average result of four or twelve specimens reported by one laboratory should not be considered suspect unless it differs from that of another laboratory by more than 25 % of their mean.

13.2 *Bias*—No justifiable statement can be made on the bias of this test method since no reference samples are available.

14. Keywords

14.1 drying shrinkage; hydraulic cement; method; mortar

SUMMARY OF CHANGES

Committee C01 has identified the location of selected changes to this test method since the last issue, C 596 – 07, that may impact the use of this test method. (Approved December 1, 2009)

(*1*) Revised the standard throughout to remove informational units.

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Designation: C597 – 09

Standard Test Method for Pulse Velocity Through Concrete[1]

This standard is issued under the fixed designation C597; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

This standard has been approved for use by agencies of the Department of Defense.

1. Scope*

1.1 This test method covers the determination of the propagation velocity of longitudinal stress wave pulses through concrete. This test method does not apply to the propagation of other types of stress waves through concrete.

1.2 The values stated in SI units are to be regarded as standard. No other units of measurement are included in this standard.

1.3 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

2. Referenced Documents

2.1 *ASTM Standards:*[2]

C125 Terminology Relating to Concrete and Concrete Aggregates

C215 Test Method for Fundamental Transverse, Longitudinal, and Torsional Resonant Frequencies of Concrete Specimens

C823 Practice for Examination and Sampling of Hardened Concrete in Constructions

E1316 Terminology for Nondestructive Examinations

3. Terminology

3.1 *Definitions*—Refer to Terminology C125 and the section related to ultrasonic examination in Terminology E1316 for definitions of terms used in this test method.

4. Summary of Test Method

4.1 Pulses of longitudinal stress waves are generated by an electro-acoustical transducer that is held in contact with one surface of the concrete under test. After traversing through the concrete, the pulses are received and converted into electrical energy by a second transducer located a distance L from the transmitting transducer. The transit time T is measured electronically. The pulse velocity V is calculated by dividing L by T.

5. Significance and Use

5.1 The pulse velocity, V, of longitudinal stress waves in a concrete mass is related to its elastic properties and density according to the following relationship:

$$V = \sqrt{\frac{E\,(1-\mu)}{\rho\,(1+\mu)(1-2\,\mu)}} \quad (1)$$

where:

E = dynamic modulus of elasticity,
μ = dynamic Poisson's ratio, and
ρ = density.

5.2 This test method is applicable to assess the uniformity and relative quality of concrete, to indicate the presence of voids and cracks, and to evaluate the effectiveness of crack repairs. It is also applicable to indicate changes in the properties of concrete, and in the survey of structures, to estimate the severity of deterioration or cracking. When used to monitor changes in condition over time, test locations are to be marked on the structure to ensure that tests are repeated at the same positions.

5.3 The degree of saturation of the concrete affects the pulse velocity, and this factor must be considered when evaluating test results (Note 1). In addition, the pulse velocity in saturated concrete is less sensitive to changes in its relative quality.

NOTE 1—The pulse velocity in saturated concrete may be up to 5 % higher than in dry concrete.[3]

5.4 The pulse velocity is independent of the dimensions of the test object provided reflected waves from boundaries do not complicate the determination of the arrival time of the directly transmitted pulse. The least dimension of the test object must exceed the wavelength of the ultrasonic vibrations (Note 2).

NOTE 2—The wavelength of the vibrations equals the pulse velocity

[1] This test method is under the jurisdiction of ASTM Committee C09 on Concrete and Concrete Aggregates and is the direct responsibility of Subcommittee C09.64 on Nondestructive and In-Place Testing.

Current edition approved Dec. 15, 2009. Published February 2010. Originally approved in 1967. Last previous edition approved in 2002 as C597–02. DOI: 10.1520/C0597-09

[2] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

[3] Bungey, J. H., *Testing of Concrete in Structures*, 2nd ed., Chapman and Hall, 1989, p. 52.

***A Summary of Changes section appears at the end of this standard.**

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divided by the frequency of vibrations. For example, for a frequency of 54 kHz and a pulse velocity of 3500 m/s, the wavelength is 3500/54000 = 0.065 m.

5.5 The accuracy of the measurement depends upon the ability of the operator to determine precisely the distance between the transducers and of the equipment to measure precisely the pulse transit time. The received signal strength and measured transit time are affected by the coupling of the transducers to the concrete surfaces. Sufficient coupling agent and pressure must be applied to the transducers to ensure stable transit times. The strength of the received signal is also affected by the travel path length and by the presence and degree of cracking or deterioration in the concrete tested.

NOTE 3—Proper coupling can be verified by viewing the shape and magnitude of the received waveform. The waveform should have a decaying sinusoidal shape. The shape can be viewed by means of outputs to an oscilloscope or digitized display inherent in the device.

5.6 The results obtained by the use of this test method are not to be considered as a means of measuring strength nor as an adequate test for establishing compliance of the modulus of elasticity of field concrete with that assumed in the design. The longitudinal resonance method in Test Method C215 is recommended for determining the dynamic modulus of elasticity of test specimens obtained from field concrete because Poisson's ratio does not have to be known.

NOTE 4—When circumstances permit, a velocity-strength (or velocity-modulus) relationship may be established by the determination of pulse velocity and compressive strength (or modulus of elasticity) on a number of samples of a concrete. This relationship may serve as a basis for the estimation of strength (or modulus of elasticity) by further pulse-velocity tests on that concrete. Refer to ACI 228.1R[4] for guidance on the procedures for developing and using such a relationship.

5.7 The procedure is applicable in both field and laboratory testing regardless of size or shape of the specimen within the limitations of available pulse-generating sources.

NOTE 5—Presently available test equipment limits path lengths to approximately 50-mm minimum and 15-m maximum, depending, in part, upon the frequency and intensity of the generated signal. The upper limit of the path length depends partly on surface conditions and partly on the characteristics of the interior concrete under investigation. A preamplifier at the receiving transducer may be used to increase the maximum path length that can be tested. The maximum path length is obtained by using transducers of relatively low resonant frequencies (20 to 30 kHz) to minimize the attenuation of the signal in the concrete. (The resonant frequency of the transducer assembly determines the frequency of vibration in the concrete.) For the shorter path lengths where loss of signal is not the governing factor, it is preferable to use resonant frequencies of 50 kHz or higher to achieve more accurate transit-time measurements and hence greater sensitivity.

5.8 Since the pulse velocity in steel is up to double that in concrete, the pulse-velocity measured in the vicinity of the reinforcing steel will be higher than in plain concrete of the same composition. Where possible, avoid measurements close to steel parallel to the direction of pulse propagation.

[4] "In-Place Methods to Estimate Concrete Strength," ACI 228.1R, American Concrete Institute, Farmington Hills, MI.

6. Apparatus

6.1 The testing apparatus, shown schematically in Fig. 1, consists of a pulse generator, a pair of transducers (transmitter and receiver), an amplifier, a time measuring circuit, a time display unit, and connecting cables.

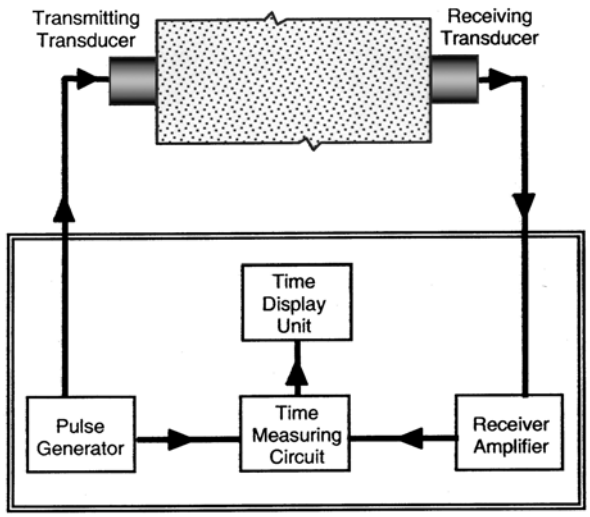
6.1.1 *Pulse Generator and Transmitting Transducer*—The pulse generator shall consist of circuitry for generating pulses of voltage (Note 6). The transducer for transforming these electronic pulses into wave bursts of mechanical energy shall have a resonant frequency in the range from 20 to 100 kHz (Note 7). The pulse generator shall produce repetitive pulses at a rate of at least 3 pulses per second. The time interval between pulses shall exceed the decay time for the transmitting transducer. The transducer shall be constructed of piezoelectric, magnetostrictive, or other voltage-sensitive material, and housed for protection. A triggering pulse shall be produced to start the time measuring circuit.

NOTE 6—The pulse voltage affects the transducer power output and the maximum penetration of the longitudinal stress waves. Voltage pulses of 500 to 1000 V have been used successfully.

NOTE 7—Transducers with higher resonant frequencies have been used successfully in relatively small laboratory specimens.

6.1.2 *Receiving Transducer and Amplifier*—The receiving transducer shall be similar to the transmitting transducer. The voltage generated by the receiver shall be amplified as necessary to produce triggering pulses to the time-measuring circuit. The amplifier shall have a flat response between one half and three times the resonant frequency of the receiving transducer.

6.1.3 *Time-Measuring Circuit*—The time-measuring circuit and the associated triggering pulses shall be capable of providing an overall time-measurement resolution of at least 1 μs. Time measurement is initiated by a triggering voltage from the pulse generator, and the time measuring circuit shall operate at the repetition frequency of the pulse generator. The time-measuring circuit shall provide an output when the received pulse is detected, and this output shall be used to



NOTE 1—It is advantageous to incorporate the pulse generator, time measuring circuit, receiver amplifier, and time display into one unit.

FIG. 1 Schematic of Pulse Velocity Apparatus

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determine the transit time displayed on the time-display unit. The time-measuring circuit shall be insensitive to operating temperature in the range from 0 to 40°C and voltage changes in the power source of ±15 %.

6.1.4 *Display Unit*—A display unit shall indicate the pulse transit time to the nearest 0.1 µs.

6.1.5 *Reference Bar*—For units that use manual zero-time adjustment, provide a bar of metal or other durable material for which the transit time of longitudinal waves is known. The transit time shall be marked permanently on the reference bar. The reference bar is optional for units that perform automatic zero-time adjustment.

6.1.6 *Connecting Cables*—Where pulse-velocity measurements on large structures require the use of long interconnecting cables, use low-capacitance, shielded, coaxial cables.

6.1.7 *Coupling Agent*—A viscous material (such as oil, petroleum jelly, water soluble jelly, moldable rubber, or grease) to ensure efficient transfer of energy between the concrete and the transducers. The function of the coupling agent is to eliminate air between the contact surfaces of the transducers and the concrete. Water is an acceptable coupling agent when ponded on the surface, or for underwater testing.

7. Procedure

7.1 *Functional Check of Equipment and Zero-time Adjustment*—Verify that the equipment is operating properly and perform a zero-time adjustment.

7.1.1 *Units with Automatic Zero-Time Adjustment*—Apply coupling agent to the transducer faces and press the faces together. The instrument uses a microprocessor to record this delay time, which is subtracted automatically from subsequent transit time measurements.

NOTE 8—A reference bar may be used to verify that the zero-time adjustment has been performed correctly.

7.1.2 *Units with Manual Zero-Time Adjustment*—Apply coupling agent to the ends of the reference bar, and press the transducers firmly against the ends of the bar until a stable transit time is displayed. Adjust the zero reference until the displayed transit time agrees with the value marked on the bar.

7.1.3 Check the zero adjustment on an hourly basis during continuous operation of the instrument, and every time a transducer or connecting cable is changed. If zero-time adjustment cannot be accomplished, do not use the instrument until it has been repaired.

7.2 *Determination of Transit Time*:

7.2.1 For testing existing construction, select test locations in accordance with Practice C823, or follow the requirements of the party requesting the testing, whichever is applicable.

7.2.2 For best results, locate the transducers directly opposite each other. Because the beam width of the vibrational pulses emitted by the transducers is large, it is permissible to measure transit times across corners of a structure but with some loss of sensitivity and accuracy. Measurements along the same surface shall not be used unless only one face of the structure is accessible since such measurements may be indicative only of surface layers, and calculated pulse velocities will not agree with those obtained by through transmission (Note 9).

NOTE 9—One of the sources of uncertainty in surface tests is the lengths of the actual travel paths of the pulses. Hence, individual readings are of little value. Surface tests, however, have been used to estimate the depth of a lower quality surface layer by making multiple measurements of transit time with varying distances between the transducers. From the plot of travel time versus spacing, it may be possible to estimate the depth of the lower quality concrete.[5]

7.2.3 Apply an appropriate coupling agent (such as water, oil, petroleum jelly, grease, moldable rubber, or other viscous materials) to the transducer faces or the test surface, or both. Press the faces of the transducers firmly against the surfaces of the concrete until a stable transit time is displayed, and measure the transit time (Note 10). Determine the straight-line distance between centers of transducer faces.

NOTE 10—The quality of the coupling is critically important to the accuracy and maximum range of the method. Inadequate coupling will result in unstable and inaccurate time measurements, and will significantly shorten the effective range of the instrument. Repeat measurements should be made at the same location to minimize erroneous readings due to poor coupling.

8. Calculation

8.1 Calculate the pulse velocity as follows:

$$V = L/T \quad (2)$$

where:

V = pulse velocity, m/s,
L = distance between centers of transducer faces, m, and
T = transit time, s.

9. Report

9.1 Report at least the following information:

9.1.1 Location of test or identification of specimen.

9.1.2 Location of transducers.

9.1.3 Distance between centers of transducer faces, reported to a precision of at least 0.5 % of the distance.

9.1.4 Transit time, reported to a resolution of at least 0.1 µs.

9.1.5 Pulse velocity reported to the nearest 10 m/s.

10. Precision and Bias

10.1 *Precision*:

10.1.1 Repeatability of results have been investigated using devices with CRT displays. It is expected that the repeatability with digital display devices will be better than stated as follows.

10.1.2 Tests involving three test instruments and five operators have indicated that for path lengths from 0.3 to 6 m through sound concrete, different operators using the same instrument or one operator using different instruments will achieve repeatability of test results within 2 %. For longer path lengths through sound concrete, attenuation of the signal will decrease the absolute repeatability of the transit-time measurement, but the longer transit time involved will result in a calculation of velocity having the same order of accuracy.

10.1.3 In the case of tests through badly cracked or deteriorated concrete, the variation of the results are substantially

[5] Chung, H. W., and Law, K. S., "Assessing Fire Damage of Concrete by the Ultrasonic Pulse Technique," *Cement, Concrete, and Aggregates*, CCAGDP, Vol 7, No. 2, Winter, 1985, pp. 84–88.

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increased. Attenuation is affected by the nature of the deterioration and the resonant frequency of the transducers. Differences between operators or instruments may result in differences in test results as large as 20 %. In such cases, however, calculated velocities will be sufficiently low as to indicate clearly the presence of distress in the concrete tested.

10.2 *Bias*—Bias of this test method has not been determined.

11. Keywords

11.1 concrete; longitudinal stress wave; nondestructive testing; pulse velocity; ultrasonic testing

SUMMARY OF CHANGES

Committee C09 has identified the location of selected changes to this test method since the last issue, C597–02, that may impact the use of this test method. (Approved December 15, 2009)

(*1*) Revised 6.1.1 by adding a requirement that the time interval between pulses has to exceed the decay time of the transmitter, and the listing of transducer materials was deleted.
(*2*) Revised the requirements for the display unit in 6.1.4 and deleted reference to cathode ray tubes.
(*3*) Revised the reporting requirement for transit time in 9.1.4 to a resolution of at least 0.1 μs.
(*4*) Revised the description of the reference bar in 6.1.5 to clarify that the bar is not required with units that use automatic zero-time adjustment.
(*5*) Revised the procedure in 7.1 to address units that use automatic zero-time adjustment and units that use manual zero-time adjustment.

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Designation: C 602 – 07

Standard Specification for Agricultural Liming Materials[1]

This standard is issued under the fixed designation C 602; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

This standard has been approved for use by agencies of the Department of Defense.

1. Scope*

1.1 This specification covers agricultural liming materials, such as quicklime (burnt lime), hydrated lime, limestone, (calcitic and dolomitic), marl, shells, and by-products including slag, and other materials.

1.2 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

2. Referenced Documents

2.1 *ASTM Standards:* [2]

C 25 Test Methods for Chemical Analysis of Limestone, Quicklime, and Hydrated Lime

C 50 Practice for Sampling, Sample Preparation, Packaging, and Marking of Lime and Limestone Products

C 110 Test Methods for Physical Testing of Quicklime, Hydrated Lime, and Limestone

C 125 Terminology Relating to Concrete and Concrete Aggregates

D 3176 Practice for Ultimate Analysis of Coal and Coke

E 11 Specification for Wire Cloth and Sieves for Testing Purposes

3. Terminology

3.1 *Definitions:*

3.1.1 *agricultural liming material*—a product whose calcium and magnesium compounds are capable of neutralizing soil acidity.

3.1.2 *air-cooled blast-furnace slag and granulated blast-furnace slag*—air-cooled blast-furnace slag and granulated blast furnace slag as defined in Terminology C 125.

3.1.3 *calcium carbonate equivalent (C.C.E.)*—the acid-neutralizing capacity (of an agricultural liming material) of the material expressed as weight percent of calcium carbonate.

4. Chemical Classifications

4.1 Agricultural liming materials shall be classified in terms of calcium carbonate equivalent (C.C.E.), as shown in Table 1.

TABLE 1 Agricultural Liming Materials

Material	Calcium Carbonate Equivalent (C.C.E.), percent
Quicklime	not less than 140
Hydrated lime	not less than 110
Limestone	not less than 80
Slag	not less than 80
Shells	not less than 80

NOTE 1—Marl and some by-product liming materials are used for neutralizing soil acidity, but due to their varying composition, their chemical limits are not included. In some economic circumstances limestone, slag, and shells of less than 80 % C.C.E. may be used.

5. Sieve Analysis Classifications for Agricultural Limestone

5.1 Agricultural limestone shall be classified according to the minimum percentages passing the No. 8 (2.36-mm) and No. 60 (250-µm) sieves conforming to Specification E 11, as shown in Table 2.

TABLE 2 Classification for Agricultural Limestone

Class Designation	Passing No. 8 (2.36-mm) Sieve, min, percent	Passing No. 60 (250-µm) Sieve, min, percent
S	100	100
T	99	75
O	95	55
N	90	40
E	80	25

NOTE 2—These classifications apply where the agricultural limestone is obtained by the normal crushing procedure and the product contains the fines of fracture. In some economic circumstances, coarser products are

[1] This specification is under the jurisdiction of ASTM Committee C07 on Lime and is the direct responsibility of Subcommittee C07.02 on Specifications and Guidelines.

Current edition approved June 15, 2007. Published July 2007. Originally approved in 1967. Last previous edition approved in 2006 as C 602 – 06a.

[2] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

***A Summary of Changes section appears at the end of this standard.**

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used. The No. 60 (250-µm) sieve was selected because research has shown that this sieve gives a more accurate representation of the particle size distribution of most agricultural limestones presently produced than a finer or coarser sieve. The No. 8 (2.36-mm) sieve is used to control the upper limit on the amount of coarse limestone particles that may be in the product.

6. Sieve Analysis Classifications for Agricultural Slag

6.1 *Air-Cooled Blast-Furnace Slag*—Air-cooled blast-furnace slag shall be classified the same as agricultural limestone as shown in Section 5.

6.2 *Granulated Blast-Furnace Slag*—Granulated blast-furnace slag shall be classified in accordance with the minimum percentages passing the No. 8 (2.36-mm) and the No. 60 (250-µm) sieves.

7. Particle Size Requirements for Hydrated Lime and Quicklime

7.1 Hydrated lime and quicklime for agricultural use shall be classified in accordance with the minimum percentages passing the No. 8 (2.36-mm) and No. 60 (250-µm) sieves, as follows:

	Min. %	
Passing Sieve No.	Hydrated Lime	Quicklime
8 (2.36 mm)	100	95
60 (250 µm)	97	35

8. Sampling

8.1 Sampling shall be conducted using the procedures specified in Practice C 50.

9. Chemical Methods

9.1 Reagent grade chemicals or equivalent and water purity shall be used as specified in Test Methods C 25.

9.2 The analytical sample for chemical methods relative to this standard shall be pulverized to pass a 60 mesh sieve.

9.3 The following chemical parameters are to be determined using the methods as specified in Test Methods C 25.

9.3.1 Calcium carbonate equivalent, and

9.3.2 *Total calcium and magnesium*—determination can be made either gravimetrically or by EDTA titration.

SIEVE ANALYSIS OF AGRICULTURAL LIMING MATERIALS

10. Preparation of Sample

10.1 Dry the sample to constant weight at 110 ± 5 °C and store in an airtight container. Obtain the sample from a larger sample of the material to be tested by the use of a riffle or a sample splitter in accordance with Practice D 3176, or by the method of quartering. The sample for sieve analysis shall have a weight of 100 to 150 g.

10.2 Where limestone contains clay, some agglomeration of fine particles may occur. The agglomerates must be broken by rolling the dry sample with a hard rubber roller on a hard rubber mat or by some equally effective means that does not result in crushing the limestone.

11. Procedure

11.1 Sieve analysis shall be conducted using the procedures in Test Methods C 110. Sieve the sample through No. 8 (2.36-mm) and No. 60 (250-µm) sieves. Determine the weight of liming material passing each sieve on a scale or balance sensitive to at least 0.1 g. Calculate the amount of liming material passing the sieves to the nearest whole percentage of the total weight of the dry sample.

12. Report

12.1 Report the following results for agricultural liming materials:

12.1.1 *Percentage Calcium Carbonate Equivalent*—The percentage calcium carbonate equivalent (C.C.E.) shall be reported on the as-received basis. Calculate as follows:

$$\text{C.C.E. (as-received)} = [1-(\%\ \text{moisture} \div 100)] \times \text{C.C.E. (oven-dry)} \quad (1)$$

12.1.2 *Percentage Moisture*—Calculate as follows:

$$\text{Moisture, \%} = \frac{\text{Weight of sample (as received)} - \text{oven-dry weight}}{\text{Weight of sample (as received)}} \times 100 \quad (2)$$

12.1.3 *Percentage Calcium and Magnesium*—The percentages of elemental calcium and elemental magnesium on the basis of the as-received sample.

12.1.4 *Sieve Analysis*—The amount of dried sample passing the No. 8 (2.36-mm) and No. 60 (250-µm) sieves as a percentage of the total weight of the dried sample with the figures rounded to the nearest whole percentage point.

13. Keywords

13.1 agricultural liming materials; agricultural limestone; calcium carbonate equivalent; hydrated lime; lime by-products; limestone; quicklime; slag

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SUMMARY OF CHANGES

Committee C07 has identified the location of selected changes to this specification since the last issue, C 602 – 06a, that may impact the use of this specification. (Approved June 15, 2007)

(*1*) Revised 11.1.

Committee C07 has identified the location of selected changes to this specification since the last issue, C 602 – 06, that may impact the use of this specification. (Approved December 15, 2006)

(*1*) Replaced outdated term “burnt lime” with “quicklime” throughout.

Committee C07 has identified the location of selected changes to this specification since the last issue, C 602 – 95a(2001), that may impact the use of this specification. (Approved July 1, 2006)

(*1*) Revised 1.2.

(*2*) Revised Section 8.

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Designation: C 617 – 09a

Standard Practice for Capping Cylindrical Concrete Specimens[1]

This standard is issued under the fixed designation C 617; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

This standard has been approved for use by agencies of the Department of Defense.

1. Scope*

1.1 This practice covers apparatus, materials, and procedures for capping freshly molded concrete cylinders with neat cement and hardened cylinders and drilled concrete cores with high-strength gypsum plaster or sulfur mortar.

1.2 The values stated in inch-pound units are to be regarded as standard. The values given in parentheses are mathematical conversions to SI units that are provided for information only and are not considered standard.

1.3 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use. For specific precaution statements see 4.3.1 and 6.2.4.1.*

2. Referenced Documents

2.1 *ASTM Standards:*[2]

C 109/C 109M Test Method for Compressive Strength of Hydraulic Cement Mortars (Using 2-in. or [50-mm] Cube Specimens)

C 150 Specification for Portland Cement

C 472 Test Methods for Physical Testing of Gypsum, Gypsum Plasters and Gypsum Concrete

C 595 Specification for Blended Hydraulic Cements

C 1231/C 1231M Practice for Use of Unbonded Caps in Determination of Compressive Strength of Hardened Concrete Cylinders

2.2 *ANSI Standard:*[3]

B46.1 Standard for Surface Texture (Surface, Roughness, Waviness and Lay)

3. Significance and Use

3.1 This practice describes procedures for providing plane surfaces on the ends of freshly molded concrete cylinders, hardened cylinders, or drilled concrete cores when the end surfaces do not conform with the planeness and perpendicularity requirements of applicable standards. Practice C 1231/C 1231M describes alternative procedures using unbonded caps or pad caps.

4. Capping Equipment

4.1 *Capping Plates*—Neat cement caps and high-strength gypsum-plaster caps shall be formed against a glass plate at least ¼ in. (6 mm) thick, a machined metal plate at least 0.45 in. (11 mm) thick, or a polished plate of granite or diabase at least 3 in. (76 mm) thick. Sulfur mortar caps shall be formed against similar metal or stone plates except that the recessed area which receives molten sulfur shall not be deeper than ½ in. (12 mm). In all cases, plates shall be at least 1 in. (25 mm) greater in diameter than the test specimen and the working surfaces shall not depart from a plane by more than 0.002 in. (0.05 mm) in 6 in. (152 mm). The surface roughness of newly finished metal plates shall not exceed that set forth in Table 4 of American National Standard B46.1, or 125 µin. (3.2 µm) for any type of surface and direction of lay. The surface, when new, shall be free of gouges, grooves, or indentations beyond those caused by the finishing operation. Metal plates that have been in use shall be free of gouges, grooves, and indentations greater than 0.010 in. (0.25 mm) deep or greater than 0.05 in.^{2}(32 mm^2) in surface area.

NOTE 1—A Rockwell hardness of 48 HRC is suggested for capping plates of devices used to form sulfur mortar caps.

4.2 *Alignment Devices*—Suitable alignment devices, such as guide bars or bull's-eye levels, shall be used in conjunction with capping plates to ensure that no single cap will depart from perpendicularity to the axis of a cylindrical specimen by more than 0.5° (approximately equivalent to ⅛ in. in 12 in. (3.2 mm in 305 mm)). The same requirement is applicable to

[1] This practice is under the jurisdiction of ASTM Committee C09 on Concrete and Concrete Aggregates and is the direct responsibility of Subcommittee C09.61 on Testing for Strength.

Current edition approved July 1, 2009. Published August 2009. Originally approved in 1968. Last previous edition approved in 2009 as C 617 – 09.

[2] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

[3] Available from American National Standards Institute (ANSI), 25 W. 43rd St., 4th Floor, New York, NY 10036, http://www.ansi.org.

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the relationship between the axis of the alignment device and the surface of a capping plate when guide bars are used. In addition, the location of each bar with respect to its plate must be such that no cap will be off-centered on a test specimen by more than 1/16 in. (2 mm).

4.3 *Melting Pots for Sulfur Mortars*—Pots used for melting sulfur mortars shall be equipped with automatic temperature controls and shall be made of metal or lined with a material that is nonreactive with molten sulfur.

4.3.1 **Warning**—Melting pots equipped with peripheral heating will ensure against accidents during reheating of cooled sulfur mixture that have a crusted-over surface. When using melting pots not so equipped, a build-up of pressure under the hardened surface crust on subsequent reheating may be avoided by use of a metal rod that contacts the bottom of the pot and projects above the surface of the fluid sulfur mix as it cools. The rod should be of sufficient size to conduct enough heat to the top on reheating to melt a ring around the rod first and thus avoid the development of pressure. A large metal ladle can be substituted for the rod.

4.3.1.1 Use sulfur melting pots in a hood to exhaust the fumes to outdoors. Heating over an open flame is dangerous because the flash point of sulfur is approximately 440 °F (227 °C) and the mixture can ignite due to overheating. Should the mixture start to burn, covering will snuff out the flame. The pot should be recharged with fresh material after the flame has been extinguished.

5. Capping Materials

5.1 The strength of the capping material and the thickness of the caps shall conform to the requirements of Table 1.

5.1.1 If sulfur mortar, high strength gypsum plaster and other materials except neat cement paste are to be used to test concrete with a strength greater than 7000 psi (50 MPa), the manufacturer or the user of the material must provide documentation:

5.1.1.1 That the average strength of 15 cylinders capped with the material is not less than 98 percent of the average strength of 15 companion cylinders capped with neat cement paste or 15 cylinders ground plane to within 0.002 in. (0.05 mm).

5.1.1.2 That the standard deviation of the strengths of the capped cylinders is not greater than 1.57 times that of the standard deviation of the reference cylinders.

5.1.1.3 That the cap thickness requirements were met in the qualification tests, and

TABLE 1 Compressive Strength and Maximum Thickness of Capping Materials

Cylinder Compressive Strength psi (MPa)	Minimum Strength of Capping Material	Maximum Average Thickness of Cap	Maximum Thickness Any Part of Cap
500 to 7000 psi (3.5 to 50 MPa)	5000 psi (35 MPa) or cylinder strength whichever is greater	1/4 in. (6 mm)	5/16 in. (8 mm)
greater than 7000 psi (50 MPa)	Compressive strength not less than cylinder strength, except as provided in 5.1.1	1/8 in. (3 mm)	3/16 in. (5 mm)

5.1.1.4 Of the hardening time of the caps used in the qualification tests.

5.1.2 Additionally, the qualification test report must include the compressive strength of 2 in. cubes of the material qualified and of neat cement paste cubes, if used. Capping materials conforming to these requirements is permitted to be used for cylinders with strengths up to 20 percent greater than the concrete tested in these qualification tests. The manufacturer must requalify lots of material manufactured on an annual basis or whenever there is a change in the formulation or the raw materials. The user of the material must retain a copy of the qualification results, and the dates of manufacture of material qualified and of the material currently being used. See Table 2.

5.1.3 The compressive strength of capping materials shall be determined by testing 2 in. cubes following the procedure described in Test Method C 109/C 109M. Except for sulfur mortars, molding procedures shall be as in Test Method C 109/C 109M unless other procedures are required to eliminate large entrapped air voids. See Test Methods C 472 for alternative compaction procedures. Cure cubes in the same environment for the same length of time as the material used to cap specimens.

5.1.4 The strength of the capping material shall be determined on receipt of a new lot and at intervals not exceeding three months. If a given lot of the capping material fails to conform to the strength requirements, it shall not be used, and strength tests of the replacement material shall be made weekly until four consecutive determinations conform to specification requirements.

5.2 *Neat Hydraulic Cement Paste*:

5.2.1 Make qualification tests of the neat hydraulic cement paste prior to use for capping to establish the effects of water-cement ratio and age on compressive strength of 2 in. (50 mm) cubes.

NOTE 2—The cements used generally conform to Specification C 150 Types I, II or III; however, Specification C 595 blended cements, calcium aluminate or other hydraulic cements producing acceptable strength may be used.

5.2.2 Mix the neat cement paste to the desired consistency at a water-cement ratio equal to or less than that required to produce the required strength, generally 2 to 4 h before the paste is to be used (Note 3). Remix as necessary to maintain acceptable consistency (Note 4). Some retempering of the paste is acceptable if the required water-cement ratio is not exceeded. Optimum consistency is generally produced at water-cement ratios of 0.32 to 0.36 by mass for Type I and Type II cements and 0.35 to 0.39 by mass for Type III cements.

NOTE 3—Freshly mixed pastes tend to bleed, shrink, and make unacceptable caps. The 2 to 4 h period is generally appropriate for portland cements.

NOTE 4—The required consistency of the paste is determined by the appearance of the cap when it is stripped. Fluid paste results in streaks in the cap. Stiff paste results in thick caps.

5.3 *High-Strength Gypsum Cement Paste*:

5.3.1 No fillers or extenders may be added to neat high-strength gypsum cement paste subsequent to the manufacture of the cement. (Note 5) Qualification tests shall be made to

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TABLE 2 Sample Report of Qualification of a Capping Material

NOTE—Manufacturer: Testing Supplies Co.
Capping Material: Super Strong AAA-Sulfor mortar
Lot: 12a45 Date Tested: 11/3/98
Signed by:_____ (testing agency and responsible official)

Item	Capping Material	Control Cylinders	Ratio	Criteria	Pass/Fail
		Concrete Cylinder Test Data			
Type of capping material	Sulfur	Ground			
Average Concrete Strength, psi [MPa]	11 061 (76.2)	11 008 (75.9)	1.005	>0.98 Xc	Pass
Standard Deviation, psi [MPa]	376 (2.59)	250 (1.72)	1.504	≤1.57 C	Pass
Number of cylinders tested	15	15			
Cap age when cylinders tested	7 days	na			
		Capping Material Test Data			
Average cap thickness, in. [mm]	0.11 (2.8)	na			
Compressive strength of 2 in. [50 mm] cubes, psi (MPa)	12 195 (91)				
Cube age when tested.	7 days				
Maximum concrete strength qualified, psi (MPa)				1.2 Av. Str = 13 273 (91.5)[A]	

[A] Nominally a specified strength of 11 000 psi (75 MPa) and perhaps somewhat higher.

determine the effects of water-cement ratio and age on compressive strength of 2 in. (50 mm) cubes. Retarders may be used to extend working time, but their effects on required water-cement ratio and strength must be determined. (Note 6)

NOTE 5—Low-strength molding plaster, plaster of paris, or mixtures of plaster of paris and portland cement are unsuitable for capping.

NOTE 6—The water-gypsum cement ratio should be between 0.26 and 0.30. Use of low water-cement ratios and vigorous mixing will usually permit development of 5000 psi (35 MPa) at ages of 1 or 2 h. Higher water-gypsum cement ratios extend working time, but reduce strength.

5.3.2 Mix the neat gypsum cement paste at the desired water-cement ratio and use it promptly since it sets rapidly.

5.4 *Sulfur Mortar*:

5.4.1 Proprietary or laboratory prepared sulfur mortars are permitted if allowed to harden a minimum of 2 h before testing concrete with strength less than 5000 psi (35 MPa). For concrete strengths of 5000 psi or greater, sulfur mortar caps must be allowed to harden at least 16 h before testing, unless a shorter time has been shown to be suitable as specified in 5.1.1.

5.4.2 *Determination of Compressive Strength*—Prepare test specimens using a cube mold and base plate conforming to the requirements of Test Method C 109/C 109M and a metal cover plate conforming in principle to the design shown in Fig. 1 (Note 7). Bring the various parts of the apparatus to a temperature of 68 to 86 °F (20 to 30 °C), lightly coat the surfaces that will be in contact with the sulfur mortar with mineral oil, and assemble near the melting pot. Bring the temperature of the molten-sulfur mortar in the pot within a range of 265 to 290 °F (129 to 143 °C), stir thoroughly, and

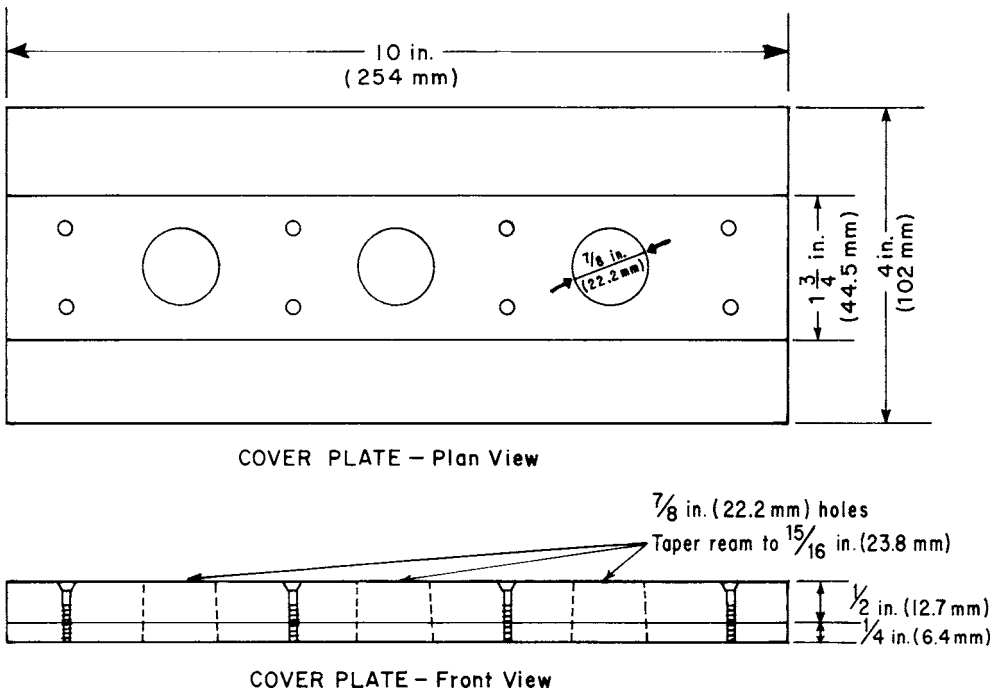

FIG. 1 Sketch of Cover Plate for 2-in. (50-mm) Cube Mold

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begin casting cubes. Using a ladle, or other suitable pouring device, quickly fill each of the three compartments until the molten material reaches the top of the filling hole. Allow sufficient time for maximum shrinkage, due to cooling, and solidification to occur (approximately 15 min) and refill each hole with molten material (Note 8). After solidification is complete, remove the cubes from the mold without breaking off the knob formed by the filling hole in the cover plate. Remove oil, sharp edges, and fins from the cubes and check the planeness of the bearing surfaces in the manner described in Test Method C 109/C 109M. After storage at room temperature to the desired age, but not less than 2 h, test cubes in compression following the procedure described in Test Method C 109/C 109M, and calculate the compressive strength.

NOTE 7—If desired, a plane phenol formaldehyde (bakelite) plate of ⅛-in. (3-mm) thickness, provided with three appropriately spaced filling holes, may be inserted between the cover plate and the mold to slow the rate of cooling of test specimens.

NOTE 8—The second filling helps to prevent the formation of a large void or shrinkage pipe in the body of a cube. However, such defects may occur no matter how much care is exercised, and it therefore is advisable to inspect the interior of tested sulfur mortar cubes for homogeneity whenever the strength values obtained are significantly lower than anticipated.

6. Capping Procedures

6.1 *Freshly Molded Cylinders*—Use only neat portland cement pastes (Note 9) to cap freshly molded cylinders. Make caps as thin as practicable. Do not apply the neat paste to the exposed end until the concrete has ceased settling in the molds, generally from 2 to 4 h after molding. During the molding of the cylinder, strike off the upper end even with or slightly below the plane of the rim of the mold. Remove free water and laitance from the top of the specimen immediately before capping. Form the cap by placing a conical mound of paste on the specimen and then gently pressing a freshly oiled capping plate on the conical mound until the plate contacts the rim of the mold. A very slight twisting motion may be required to extrude excess paste and minimize air voids in the paste. The capping plate must not rock during this operation. Carefully cover the capping plate and mold with a double layer of damp burlap and a polyethylene sheet to prevent drying. Removal of the capping plate after hardening may be accomplished by tapping the edge with a rawhide hammer in a direction parallel to the plane of the cap.

NOTE 9—Type I neat cement caps generally require at least 6 days to develop acceptable strength and Type III neat cement caps at least 2 days. Dry concrete specimens will absorb water from freshly mixed neat cement paste and produce unsatisfactory caps. Neat cement paste caps will shrink and crack on drying and, therefore, should be used only for specimens that are to be moist cured continuously until time of testing.

NOTE 10—High-strength gypsum caps soften and deteriorate on contact with water and cannot be used on freshly mixed concrete or stored in a moist room for more than very brief periods.

6.2 *Hardened Concrete Specimens*:

6.2.1 *General*—If an end of a specimen has a coating or deposit of oily or waxy materials that would interfere with the bond of the cap, remove such coatings or deposits. If necessary, the ends of a specimen may be slightly roughened with a steel file or wire brush to produce proper adhesion of the cap. If desired, capping plates may be coated with a thin layer of mineral oil or grease to prevent the capping material from adhering to the surface of the plate.

6.2.2 *End Condition*—The distance of any point on an uncapped end from a plane that passes through the highest point of the end surface and is perpendicular to the axis of the cylinder shall not exceed ⅛ in. (3 mm) (Note 11). If the end exceeds this limit, the end of the cylinder shall be cut, lapped or ground prior to capping.

NOTE 11—This provision is to control the difference between the thickest and thinnest parts of a cap. The distance may be checked using a square with one blade touching the cylinder parallel to the cylinder axis and the other blade touching the highest point on the end of the cylinder. The distance between the blade of the square and the lowest point on the end of the cylinder is measured.

6.2.3 *Capping with High-Strength Gypsum Plaster or Neat Cement Paste*—Mix the paste as described in 5.2 and 5.3. Do not exceed the water-cement ratio determined in qualification tests. Form the caps as described in 6.1 using capping plates described in 4.1 to achieve the alignment required in 4.2 (Note 12). Generally, capping plates may be removed within 45 min with gypsum cement pastes and after 12 h with neat cement paste, without visibly damaging the cap.

NOTE 12—A number of methods have been used to obtain the desired perpendicularity of the cap to the axis of the cylinder. A mound of paste can be placed on a capping plate and the specimen lowered into it. A bull's-eye level on the top of the cylinder helps obtain alignment. A mound of paste can be placed on top of the cylinder and a capping plate pressed into it, again using the bull's-eye level. A better system is to make a half-height mold with a vertical split so that it can be slipped over the hardened cylinder. A clamp is used to position the mold and to ensure the required cap thickness. The mound of paste can then be placed either on a capping plate or on top of the cylinder and pressed until the plate contacts the mold. As Noted earlier, very stiff paste may require excessive pressure and produce thick or defective caps.

6.2.4 *Capping with Sulfur Mortar*—Prepare sulfur mortar for use by heating to a temperature between 265 and 290 °F (129 to 143 °C) as determined by an all-metal thermometer inserted near the center of the mass. Check the temperature at approximately hourly intervals during capping. Empty the pot and recharge with fresh material at intervals to ensure that the oldest material in the pot has not been used more than five times. When capping concrete cylinders with a compressive strength of 5000 psi (35 MPa) or greater, it is not permitted to reuse compound recovered from the capping operation or old caps. Fresh sulfur mortar must be dry at the time it is placed in the pot as dampness may cause foaming. Keep water away from molten sulfur mortar for the same reason. The capping plate or device should be warmed before use to slow the rate of hardening and permit the production of thin caps. Oil the capping plate lightly and stir the molten sulfur mortar immediately prior to pouring each cap. The ends of moist cured specimens shall be dry enough at the time of capping to preclude the formation of steam or foam pockets under or in the cap larger than ¼ in. (6 mm) in diameter. Replace caps with steam pockets or voids larger than ¼ in. (6 mm) (Note 13). To ensure that the cap is bonded to the surface of the specimen, the end of the specimen shall not be oiled prior to the application of the cap. When using a vertical device, pour

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the mortar onto the surface of the capping plate, lift the cylinder above the plate and contact the cylinder sides with the guides, slide the cylinder down the guides onto the capping plate while keeping constant contact with the alignment guides. The cylinder end should continue to rest on the capping plate with cylinder sides in positive contact with the alignment guides until the mortar has hardened. Use sufficient material to cover the cylinder end after the sulfur mortar solidifies.

NOTE 13—Periodically, the sulfur mortar cap should be examined after testing for air or steam pockets in the cap. Before testing, the cap can be tapped with a coin or rubbed with a light metal implement to see if a hollow sound can be detected. Caps with hollow areas should be removed and recapped.

6.2.4.1 **Warning**—Hydrogen sulfide gas may be produced during capping when sulfur mortar is contaminated with organic materials such as paraffin or oil. The gas is colorless and has a notoriously bad odor of rotten eggs; however, the odor should not be relied upon as a warning sign, since the sensitivity to the odor disappears rapidly on exposure. High concentrations are lethal and less concentrated dosages may produce nausea, stomach distress, dizziness, headache, or irritation of the eyes. For this and other reasons, the melting pot must be located under a hood with an exhaust fan and that capping area must be well ventilated.

6.2.5 *Daily Check*:

6.2.5.1 During each day's capping operation, check the planeness of the caps prior to compression testing on at least three specimens, selected at random, representing the start, middle, and end of the run. Check planeness with a straightedge and feeler gage, making a minimum of three measurements on different diameters to ensure that the surface of the caps do not depart from a plane by more than 0.002 in. (0.05 mm). Check also for hollow areas (Note 13). Record the results of these determinations in the quality control documentation for the laboratory. If caps fail to satisfy the planeness requirement or have hollow areas, remove and reapply the caps.

6.2.5.2 During each day's compressive strength testing operation, check the thickness of caps on at least three specimens, selected at random, from the start, middle, and end of that day's operation. After completing the compression test, recover at least six pieces of capping material from the top of the selected specimen (Note 14). The pieces shall be selected at random and be distributed over the entire area of the cap. The selected pieces shall have debonded completely from the concrete. Measure and record the thicknesses of the pieces to the nearest 0.01 in. (0.2 mm) using a micrometer, caliper or other thickness measurement device. Compare the average and maximum thicknesses with the values in Table 1. Record the results of the thickness determinations in the quality control documentation for the laboratory.

NOTE 14—Caps may be removed by using a hammer and sharp chisel. Place the chisel tip at the bond line and nearly parallel with the plane of the cap so as to create a wedging action when the chisel is struck with the hammer. Recovery of the entire cap may be simplified by placing duct tape over the cap prior to attempting its removal. The tape will keep the pieces of capping material from being dispersed during removal and will simplify the selection of pieces uniformly distributed over the cap area.

7. Protection of Specimens After Capping

7.1 Maintain moist cured specimens in a moist condition between the completion of capping and the time of testing by returning them to moist storage or wrapping them with a double layer of wet burlap. Do not store specimens with gypsum plaster caps immersed in water or for more than 4 h in a moist room. Protect plaster caps from dripping water.

7.2 Do not test capped specimens before the capping material has sufficient time to develop the strength required in 5.1.

8. Keywords

8.1 capping; concrete; compressive strength; cores; cylinders; gypsum cement paste; neat hydraulic cement paste; sulfur mortar

SUMMARY OF CHANGES

Committee C09 has identified the location of selected changes to this practice since the last issue, C 617 – 09, that may impact the use of this practice. (Approved July 1, 2009)

(*1*) Revised 6.2.4 to provide the acceptable temperature range for the molten sulfur mortar.

Committee C09 has identified the location of selected changes to this practice since the last issue, C 617 – 98(2003), that may impact the use of this practice. (Approved May 1, 2009)

(*1*) Revised 6.2.3.

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Designation: C 618 – 08a

Standard Specification for Coal Fly Ash and Raw or Calcined Natural Pozzolan for Use in Concrete[1]

This standard is issued under the fixed designation C 618; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

This standard has been approved for use by agencies of the Department of Defense.

1. Scope*

1.1 This specification covers coal fly ash and raw or calcined natural pozzolan for use in concrete where cementitious or pozzolanic action, or both, is desired, or where other properties normally attributed to fly ash or pozzolans may be desired, or where both objectives are to be achieved.

NOTE 1—Finely divided materials may tend to reduce the entrained air content of concrete. Hence, if a fly ash or natural pozzolan is added to any concrete for which entrainment of air is specified, provision should be made to ensure that the specified air content is maintained by air content tests and by use of additional air-entraining admixture or use of an air-entraining admixture in combination with air-entraining hydraulic cement.

1.2 The values stated in SI units are to be regarded as standard. No other units of measurement are included in this standard.

1.3 The text of this standard references notes and footnotes, which provide explanatory information. These notes and footnotes (excluding those in tables and figures) shall not be considered as requirements of the standard.

2. Referenced Documents

2.1 *ASTM Standards:*[2]

C 125 Terminology Relating to Concrete and Concrete Aggregates

C 311 Test Methods for Sampling and Testing Fly Ash or Natural Pozzolans for Use in Portland-Cement Concrete

3. Terminology

3.1 *Definitions:*

3.1.1 The terms used in this specification are defined in Terminology C 125.

3.1.2 *fly ash*—the finely divided residue that results from the combustion of ground or powdered coal and that is transported by flue gasses.

NOTE 2—This definition of fly ash does not include, among other things, the residue resulting from: (*1*) the burning of municipal garbage or any other refuse with coal; (*2*) the injection of lime directly into the boiler for sulfur removal; or (*3*) the burning of industrial or municipal garbage in incinerators commonly known as "incinerator ash."

4. Classification

4.1 *Class N*—Raw or calcined natural pozzolans that comply with the applicable requirements for the class as given herein, such as some diatomaceous earths; opaline cherts and shales; tuffs and volcanic ashes or pumicites, calcined or uncalcined; and various materials requiring calcination to induce satisfactory properties, such as some clays and shales.

4.2 *Class F*—Fly ash that meets the applicable requirements for this class as given herein. This class of fly ash has pozzolanic properties.

4.3 *Class C*—Fly ash that meets the applicable requirements for this class as given herein. This class of fly ash, in addition to having pozzolanic properties, also has some cementitious properties.

NOTE 3—Class F fly ash is typically produced from burning anthracite or bituminous coal, but may also be produced from subbituminous coal and from lignite. Class C fly ash is typically produced from burning lignite or subbituminous coal, and may also be produced from anthracite or bituminous coal. Class C fly ashes contain total calcium contents, expressed as calcium oxide (CaO), higher than 10 %.

5. Ordering Information

5.1 The purchaser shall specify any supplementary optional physical requirements.

5.2 The purchaser shall indicate which procedure, A or B, shall be used when specifying requirements for effectiveness in contribution to sulfate resistance under Table 3.

6. Chemical Composition

6.1 Fly ash and natural pozzolans shall conform to the requirements as to chemical composition prescribed in Table 1.

NOTE 4—The chemical component determinations and the limits placed

[1] This specification is under the jurisdiction of ASTM Committee C09 on Concrete and Concrete Aggregates and is the direct responsibility of Subcommittee C09.24 on Supplementary Cementitious Materials.

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[2] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

***A Summary of Changes section appears at the end of this standard.**

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TABLE 1 Chemical Requirements

	Class		
	N	F	C
Silicon dioxide (SiO_2) plus aluminum oxide (Al_2O_3) plus iron oxide (Fe_2O_3), min, %	70.0	70.0	50.0
Sulfur trioxide (SO_3), max, %	4.0	5.0	5.0
Moisture content, max, %	3.0	3.0	3.0
Loss on ignition, max, %	10.0	6.0[A]	6.0

[A]The use of Class F pozzolan containing up to 12.0 % loss on ignition may be approved by the user if either acceptable performance records or laboratory test results are made available.

TABLE 2 Physical Requirements

	Class		
	N	F	C
Fineness:			
Amount retained when wet-sieved on 45 μm (No. 325) sieve, max, %	34	34	34
Strength activity index: [A]			
With portland cement, at 7 days, min, percent of control	75[B]	75[B]	75[B]
With portland cement, at 28 days, min, percent of control	75[B]	75[B]	75[B]
Water requirement, max, percent of control	115	105	105
Soundness: [C]			
Autoclave expansion or contraction, max, %	0.8	0.8	0.8
Uniformity requirements:			
The density and fineness of individual samples shall not vary from the average established by the ten preceding tests, or by all preceding tests if the number is less than ten, by more than:			
Density, max variation from average, %	5	5	5
Percent retained on 45-μm (No. 325), max variation, percentage points from average	5	5	5

[A] The *strength* activity index with portland cement is not to be considered a measure of the compressive strength of concrete containing the fly ash or natural pozzolan. The mass of fly ash or natural pozzolan specified for the test to determine the *strength* activity index with portland cement is not considered to be the proportion recommended for the concrete to be used in the work. The optimum amount of fly ash or natural pozzolan for any specific project is determined by the required properties of the concrete and other constituents of the concrete and is to be established by testing. *Strength* activity index with portland cement is a measure of reactivity with a given cement and is subject to variation depending on the source of both the fly ash or natural pozzolan and the cement.

[B] Meeting the 7 day or 28 day *strength* activity index will indicate specification compliance.

[C] If the fly ash or natural pozzolan will constitute more than 20 % by mass of the cementitious material in the project mixture, the test specimens for autoclave expansion shall contain that anticipated percentage. Excessive autoclave expansion is highly significant in cases where water to cementitious material ratios are low, for example, in block or shotcrete mixtures.

on each do not predict the performance of the fly ash or natural pozzolan with hydraulic cement in concrete, but collectively help describe composition and uniformity of the material.

7. Physical Properties

7.1 Fly ash and natural pozzolans shall conform to the physical requirements prescribed in Table 2. Supplementary optional physical requirements are shown in Table 3.

8. Methods of Sampling and Testing

8.1 Sample and test the fly ash or natural pozzolan in accordance with the requirements of Test Methods C 311.

8.2 Use cement of the type proposed for use in the work and, if available, from the mill proposed as the source of the cement, in all tests requiring the use of hydraulic cement.

9. Storage and Inspection

9.1 The fly ash or natural pozzolan shall be stored in such a manner as to permit easy access for proper inspection and identification of each shipment.

9.2 Inspection of the material shall be made as agreed upon by the purchaser and the seller as part of the purchase contract.

10. Rejection

10.1 The purchaser has the right to reject material that fails to conform to the requirements of this specification. Rejection shall be reported to the producer or supplier promptly and in writing.

10.2 The purchaser has the right to reject packages varying more than 5 % from the stated weight. The purchaser also has the right to reject the entire shipment if the average weight of the packages in any shipment, as shown by weighing 50 packages taken at random, is less than that specified.

10.3 The purchaser has the right to require that material in storage prior to shipment for a period longer than 6 months after testing be retested. The purchaser has the right to reject such material if it fails to meet the fineness requirements.

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TABLE 3 Supplementary Optional Physical Requirements

NOTE 1—These optional requirements apply only when specifically requested.

	Class		
	N	F	C
Increase of drying shrinkage of mortar bars at 28 days, max, difference, in %, over control[A]	0.03	0.03	0.03
Uniformity Requirements:			
In addition, when air-entraining concrete is specified, the quantity of air-entraining agent required to produce an air content of 18.0 vol % of mortar shall not vary from the average established by the ten preceding tests or by all preceding tests if less than ten, by more than, %	20	20	20
Effectiveness in Controlling Alkali-Silica Reaction:[B]			
Expansion of test mixture as percentage of low-alkali cement control, at 14 days, max, %	100	100	100
Effectiveness in Contributing to Sulfate Resistance:[C]			
Procedure A:			
Expansion of test mixture:			
For moderate sulfate exposure after 6 months exposure, max, %	0.10	0.10	0.10
For high sulfate exposure after 6 months exposure, max, %	0.05	0.05	0.05
Procedure B:			
Expansion of test mixture as a percentage of sulfate resistance cement control after at least 6 months exposure, max,%	100	100	100

[A] Determination of compliance or noncompliance with the requirement relating to increase in drying shrinkage will be made only at the request of the purchaser.

[B] Fly ash or natural pozzolans meeting this requirement are considered as effective in controlling alkali silica reactions as the use of the low-alkali control cement used in the evaluation. However, the fly ash or natural pozzolan shall be considered effective only when used at percentages by mass of the total cementitious material equal to or exceeding that used in the tests and when the alkali content of the cement to be used does not exceed that used in the tests by more than 0.05 %. See Appendix XI, Test Methods C 311.

[C] Fly ash or natural pozzolan shall be considered effective only when the fly ash or natural pozzolan is used at percentages, by mass, of the total cementitious material within 2 % of those that are successful in the test mixtures or between two percentages that are successful, and when the C_3A content of the project cement is less than, or equal to, that which was used in the test mixtures. See Appendix X2 of Test Method C 311.

11. Packaging and Package Marking

11.1 When the fly ash or natural pozzolan is delivered in packages, the class, name, and brand of the producer, and the weight of the material contained therein, shall be plainly marked on each package. Similar information shall be provided in the shipping invoices accompanying the shipment of packaged or bulk material.

12. Keywords

12.1 fly ash; natural pozzolan; pozzolans

SUMMARY OF CHANGES

Committee C09 has identified the location of selected changes to this specification since the last issue, C 618 – 08, that may impact the use of this specification. (Approved October 1, 2008)

(*1*) Revised Table 3 to remove the optional requirement for the multiple factor and the associated table footnote A.

Committee C09 has identified the location of selected changes to this specification since the last issue, C 618 – 05, that may impact the use of this specification. (Approved March 1, 2008)

(*1*) Revised 4.2, 4.3, Note 3, and Footnote C of Table 3.

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Designation: C 631 – 09

Standard Specification for Bonding Compounds for Interior Gypsum Plastering[1]

This standard is issued under the fixed designation C 631; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope*

1.1 This specification covers minimum requirements for bonding compounds for adhering interior gypsum plaster to structurally sound surfaces.

1.2 This specification also covers test methods for determining performance requirements and physical properties.

1.3 The values stated in inch-pound units are to be regarded as standard. The values given in parentheses are mathematical conversions to SI units that are provided for information only and are not considered standard.

1.4 The following safety hazards caveat pertains only to the test methods described in this specification: *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

2. Referenced Documents

2.1 *ASTM Standards:*[2]

C 11 Terminology Relating to Gypsum and Related Building Materials and Systems

C 28/C 28M Specification for Gypsum Plasters

C 472 Test Methods for Physical Testing of Gypsum, Gypsum Plasters and Gypsum Concrete

C 511 Specification for Mixing Rooms, Moist Cabinets, Moist Rooms, and Water Storage Tanks Used in the Testing of Hydraulic Cements and Concretes

3. Terminology

3.1 *Definitions*—For definitions relating to gypsum and related building materials and systems, see Terminology C 11.

4. Physical Properties

4.1 *General*—The bonding compound shall be a film forming, non-oxidizing, non-toxic, non-flammable composition suitable for application by brush, roller, and spray. The compound shall be tinted to show, by visual inspection, where it has been applied. The tinting material shall not show through the material being bonded. The surfaces to which bonding compounds are applied shall be relatively smooth, clean, and dry. Surface coatings shall be removed if their nature indicates an unsatisfactory condition. Surfaces shall be prepared in accordance with the manufacturer's directions.

4.2 *Consistency*—The bonding compound shall be of a homogeneous nature with no settling of the solids. The compound shall be free of foreign matter, and when applied in accordance with the manufacturer's directions, shall cover evenly.

4.3 *Film Characteristics*—A dry film of the bonding compound shall be uniform and smooth and shall remain flexible. The film shall not be noticeably affected by mild acid or alkali.

5. Performance Requirements

5.1 *Bonding Capability*—A dry film of bonding compound shall be capable of bonding gypsum plaster immediately after drying and 10 days after drying when tested as specified in Section 12.

5.2 *Degradation*—Bonding compound that separates shall be able to be re-mixed to a uniform consistency when tested as specified in Section 10.

5.3 *High Temperature Stability*—The bond strength shall be not less than 20 psi (138 kPa) when tested as specified in Section 9.

5.4 *Freeze-Thaw Stability*—The bond strength shall be not less than 20 psi (138 kPa) when tested as specified in Section 11.

5.5 *Bond Strength*—Bond strength of a fresh sample or a 30 day old sample shall be not less than 20 psi (138 kPa) when tested as specified in Section 12.

6. Sampling

6.1 Take a sample of not less than 1 kg from each shipment or consignment for analysis and tests. Except in special cases, take the sample from not less than three separate containers,

[1] This specification is under the jurisdiction of ASTM Committee C11 on Gypsum and Related Building Materials and Systems and is the direct responsibility of Subcommittee C11.02 on Specifications and Test Methods for Accessories and Related Products.

Current edition approved May 1, 2009. Published May 2009. Originally approved in 1988. Last previous edition approved in 2004 as C 631 – 95a(2004).

[2] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

***A Summary of Changes section appears at the end of this standard.**

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chosen at random. In addition, take samples from containers that appear to be nonrepresentative, and test separately. Immediately place the samples in airtight glass containers and transport to the testing laboratory in these containers. Take precautions to reduce evaporation or drying to a minimum. Thoroughly mix the bonding compound in the container if there is a tendency for liquid phase separation.

7. Apparatus

7.1 *Moist Cabinet*—Specification C 511.

7.2 *Oven*—A forced draft type oven, having a temperature controlled at 140 ± 5 °F (60 ± 3 °C) for high temperature tests and 100 ± 5 °F (38 ± 3 °C) for drying of the briquets.

7.3 *Freezer*—A freezer having a controlled temperature of – 10 ± 2 °F (-23 ± 1 °C).

7.4 *Balance*—A balance capable of weighing at least 2500 g at a precision of 0.1 g.

7.5 *Timing Device*—A standard clock or watch with second hand.

7.6 *Tamper*—A tamper made up of a nonabsorptive, nonabrasive, non-brittle material and having a cross section of ½ in. by 1 in. (13 by 25 mm) and approximately 5 to 6 in. (130 to 150 mm) long. The tamping face shall be flat and at right angles to the length of the tamper.

7.7 *Straight Edge*—A steel straight edge not less than 4 in. (100 mm) long and not less than 1⁄16 in. (1.6 mm) nor more than ⅛ in. (3.2 mm) in thickness.

7.8 *Spatula*—A spatula with a metal blade 6 in. (150 mm) in length and ½ in. (13 mm) in width, with straight edges.

7.9 *Paint Brush*—A standard 1 in. (25 mm) wide brush, with natural or synthetic bristles.

7.10 *Testing Machine*—Any type that is of sufficient capacity and that is capable of applying the load continuously and without shock at the rate of 0.05 in. (1.27 mm)/min, with provision for adjustment of the rate of loading.

7.11 *Briquet Molds*—The molds for making test specimens shall be made of metal not attacked by the plaster mortar and shall have sufficient material in the sides to prevent spreading during molding. Gang molds, when used, shall be of the type shown in Fig. 1. The dimensions of the briquet molds shall conform to the following requirements: width of mold, between inside faces, at waist line of the briquet, 1 in. (25.4 mm) with permissible variations of ±0.01 in. (0.25 mm) for molds in use and ±0.005 in. (0.13 mm) for new molds; thickness of molds measured at the point of greatest thickness on either side of the mold at the waist line, 1 in. (25.4 mm) with permissible variations of + 0.004 in. (0.10 mm) and – 0.002 in. (0.05 mm) for new molds and – 0.02 in. (0.5 mm) for molds in use. The inside faces at the waist line shall have a vertical slot 0.03 in. (0.75 mm) wide by 0.06 in. (1.5 mm) deep to accept the divider. The briquet specimens shall conform to the dimensional requirements shown in Fig. 2.

7.12 *Divider*—Sheet brass 0.02 in. (0.05 mm) thick, 1.1 in. (27.8 mm) wide by 1 in. (25.4 mm) high.

7.13 *Clips for Briquet Testing Machine*— The clips for holding the tension test specimen shall be in accordance with Fig. 3.

8. Conditioning

8.1 *Room Temperature and Humidity*— Maintain the air temperature in the vicinity of the mixing and testing area, 70 ± 5 °F (21 ± 3 °C). Maintain the relative humidity at 50 ± 2 %.

8.2 *Temperature of the Mixing Water*— 72 ± 2 °F (22 ± 1 °C).

9. High Temperature Test

9.1 *Significance and Use*—This test method provides procedures for evaluating the bond strength of adhesives after being exposed to accelerated aging at high temperature.

9.2 *Specimen Preparation*—For each test specimen, transfer the bonding compound, taken from the sample obtained, into a standard 1 pt (400 mL) glass container.

9.3 *Procedure*—Place the specimen in the oven for 30 days. Remove the container, allow the compound to cool to room temperature, mix the compound to a uniform consistency, and test as specified in Section 12.

9.4 *Test and Retests*—Test six briquets and report the average of the test results. If the result of any one of the six tests varied more than 15 % from the average, reject it and report the average of the other five tests. If the results from more than two tests vary more than 15 % from the average, reject the series and retest.

9.5 *Precision and Bias*—The precision and bias of the High Temperature Test for determining bond strength after exposure to high temperature is essentially the same as specified in the test method for bond strength, 12.7.

10. Degradation Test

10.1 *Significance and Use*—This test method simulates the effects of high temperature storage on the physical properties of bonding compound.

10.2 *Specimen Preparation*—For each test, transfer the bonding compound, from the sample obtained, into a standard 1 pt (400 mL) glass container.

10.3 *Procedure*—Place the specimen in the oven for 15 days. Remove the container from the oven and examine the

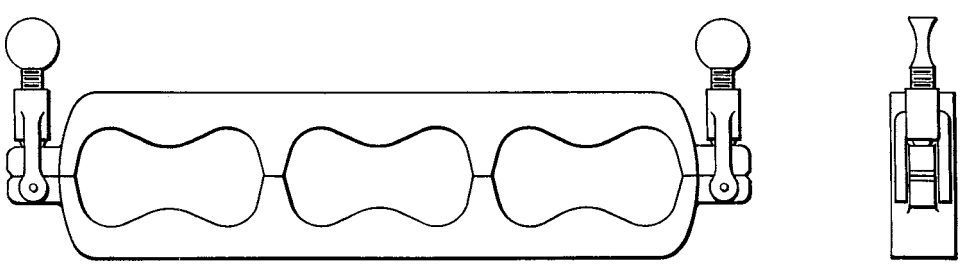

FIG. 1 Briquet Gang Mold

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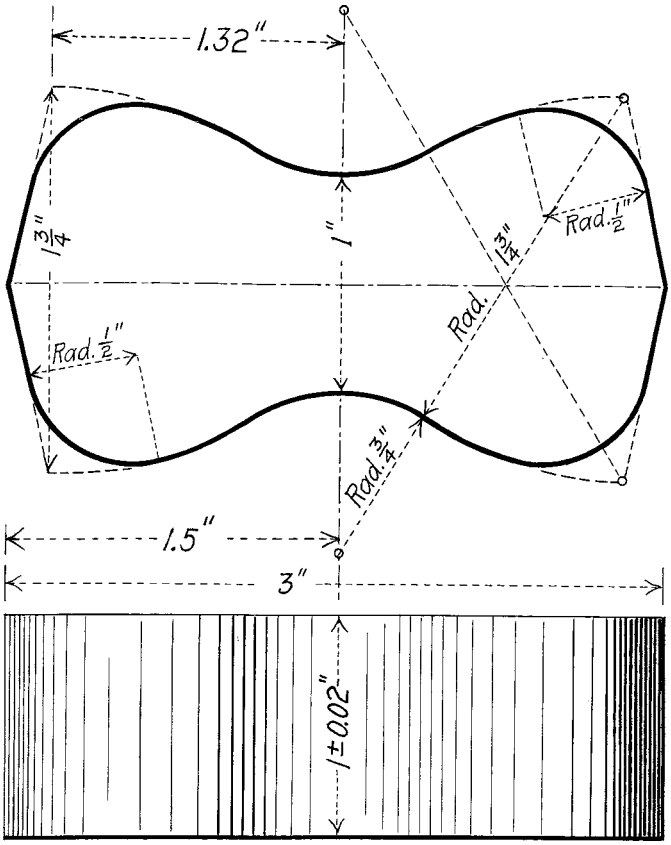

NOTE 1—1 in. = 25.4 mm

FIG. 2 Briquet Specimen for Tensile Strength Test

contents for settling and separation. Place the container back in the oven for an additional 15 days. Remove the container and examine the contents again for settling and separation. Allow the compound to come to room temperature, and mix to a uniform consistency. Mix by hand, stirring with a wood, metal, or plastic paddle for not more than 5 min.

10.4 *Tests and Retests*—Bonding compound that fails to be remixed to a uniform consistency shall be considered to have failed the test.

10.5 *Report*—Determine the extent of settling and separation by measuring, and report as a percentage of the height of the specimen in the clear glass container, represented by the location of the liquid/solid interface.

10.6 *Precision and Bias*—No information is presented about either the precision or bias of the degradation test for measuring settling, separation, or the ability to be mixed to a uniform consistency since the test result is nonquantitative.

11. Freeze-Thaw Cycle Test

11.1 *Significance and Use*—This test method provides procedures for determining the bond strength of bonding compounds after being exposed to accelerated storage conditions of alternate freezing and thawing.

11.2 *Specimen Preparation*—For each test specimen, transfer the bonding compound, taken from the sample obtained, into a standard 1 pt (400 mL) glass container having a screw on or friction fit cover.

11.3 *Procedure*—Place a covered specimen in the freezer for 16 h. Remove the specimen and allow to thaw at room temperature for 8 h. Repeat this procedure for 5 cycles. After the fifth cycle, allow the compound to come to room temperature, and then test as specified in Section 12.

11.4 *Tests and Retests*—Test six briquets and report the average of the test results. If the result of any one of the six tests varies more than 15 % from the average, reject it and report the average of the other five tests. If the results from more than two tests vary more than 15 % from the average, reject the series and retest.

11.5 *Precision and Bias*—The precision and bias of the freeze-thaw cycle test for determining bond strength after exposure to alternate freezing and thawing are essentially the same as specified in the test method for bond strength, 12.7.

12. Bond Strength Test

12.1 *Significance and Use*—This test method provides a method for determining the relative ability of bonding compound, after being subject to various simulated conditions of aging and exposure to temperature extremes, to adhere cementitious materials to a properly prepared substrate.

12.2 *Materials*:

12.2.1 *Gauging Plaster*—Specification C 28/C 28M, at normal consistency (Test Methods C 472).

12.2.2 *Retarder*—Sodium citrate.

12.3 *Preparation of Briquets*:

12.3.1 Prepare not less than six briquets for each series of tests.

12.3.2 Partition the briquet molds by placing the divider in the slots formed at the waist of the mold.

12.3.3 Add the plaster to the required amount of water and allow to soak for 30 s. Add approximately 0.1 g of retarder per 100 g of plaster to achieve a 2 to 3 h plaster set.

12.3.4 Prepare the molds by coating them with a thin film of mineral oil. Support the molds on a lightly oiled glass or metal plate. Protect the divider from contamination with oil (wrap in plastic food wrap) and carefully insert into the mold slots.

12.3.5 Cast the briquets immediately after completely mixing the mortar; half fill the molds and puddle the mortar uniformly with the tamper, taking care not to displace the divider. Slightly over fill the molds with additional mortar and repeat the puddling. After the mortar has set, cut off the excess to a plane surface flush with the top of the mold, using a broad knife or similar implement.

12.3.6 Immediately after molding, place the molds, on the base plate, into the moist cabinet for not less than 16 h.

12.3.7 Remove the briquets from the mold and store them at room temperature and humidity for not less than 48 h.

12.3.8 Examine the specimens, and discard any that have air holes or excessively rough surfaces.

12.4 *Procedure*:

12.4.1 Apply the bonding compound, in accordance with the producer's directions, to the flat waist surface of the briquet by means of a paint brush.

12.4.2 Remove the divider from the mold. Place the half briquet, coated with bonding compound, into the mold. Fill the remaining space in the mold with gypsum plaster, mixed and molded as specified in 12.2.

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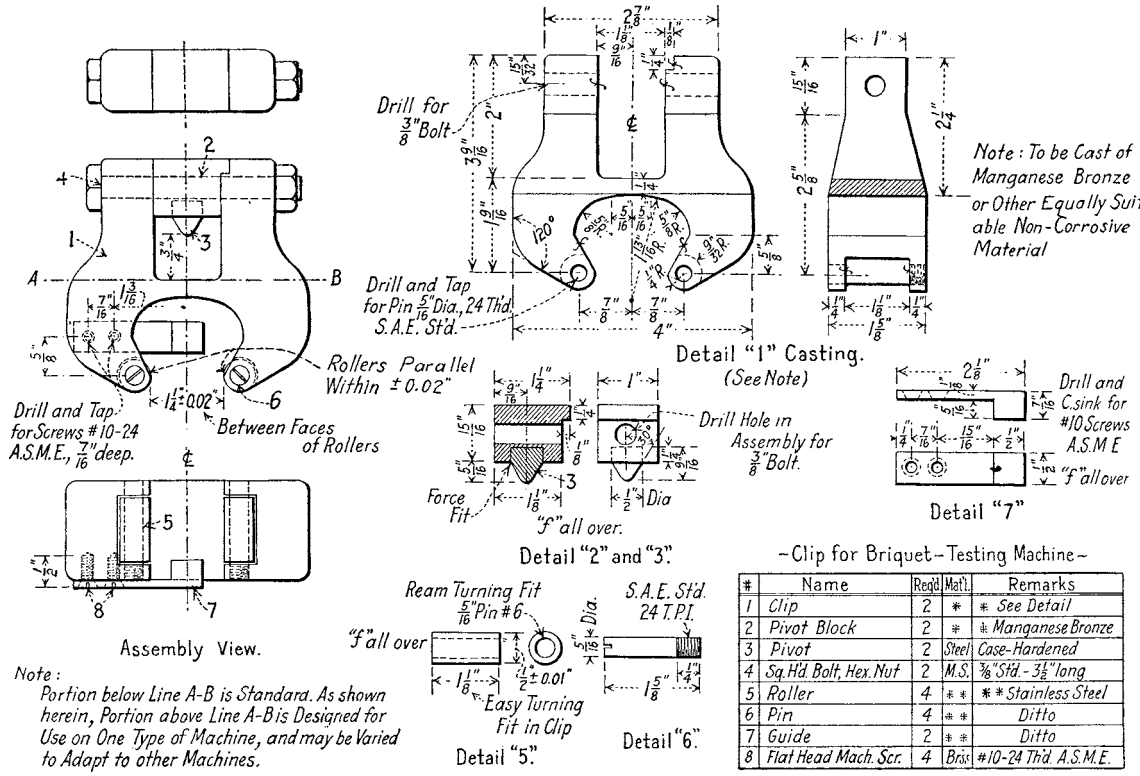

~Clip for Briquet-Testing Machine~

#	Name	Reqd	Mat'l.	Remarks
1	Clip	2	*	* See Detail
2	Pivot Block	2	*	* Manganese Bronze
3	Pivot	2	Steel	Case-Hardened
4	Sq. Hd. Bolt, Hex. Nut	2	M.S.	3/8" Std. - 3 1/2" long
5	Roller	4	* *	* * Stainless Steel
6	Pin	4	* *	Ditto
7	Guide	2	* *	Ditto
8	Flat Head Mach. Scr.	4	Brass	#10-24 Thd. A.S.M.E.

NOTE 1—1 in. = 25.4 mm

FIG. 3 Clips for Briquet Testing Machine

12.4.3 The time between coating the briquet with compound and casting the plaster against it shall be immediately after the compound has dried, or as recommended by the manufacturer, except when otherwise specified for a ten day waiting period.

12.4.4 Place the filled briquet mold in the moist cabinet for not less than 16 h. Remove the briquets from the molds as soon as they are thoroughly hardened, but retain them in the moist cabinet for not less than 16 h.

12.4.5 The briquets are then dried to constant weight in a forced draft oven maintained at 100 ± 5 °F (38 ± 3 °C) and a relative humidity not more than 50 %.

12.5 *Test Method*—Test the briquets immediately after removing them from the oven. Remove any loose particles or flash from the surfaces that will be in contact with the clips of the testing machine. Make sure the bearing surfaces of the clips are clean and free of sand, and the roller bearings are lubricated and maintained to ensure freedom of turning. Keep the stirrups supporting the clips free of accumulations. Keep the pivots in proper adjustment so that the clips swing freely on the pivots without binding the stirrups. Carefully center the briquets in the clips and apply the load continuously at the rate of 0.05 in. (1.27 mm)/min.

12.6 *Tests and Retests*—Test six briquets and report the average of the test results. If the result of any one of the six tests varies more than 15 % from the average, reject it and report the average of the other five tests. If the results from more than two tests vary more than 15 % from the average, reject the series and retest.

12.7 *Precision and Bias*—Precision and bias have not been determined for the test method specified.

13. Inspection

13.1 Inspection of the bonding compound shall be agreed upon between the producer or purchaser and the supplier as part of the purchase agreement.

14. Rejection

14.1 Rejection of bonding compound that fails to conform to the requirements of this specification shall be reported to the producer or supplier promptly and in writing. The notice of rejection shall contain a statement documenting how the product has failed to conform to the requirements of this specification.

15. Certification

15.1 When specified in the purchase agreement, the producer or supplier shall furnish a report certifying that, at the time of shipment, the bonding compound is in compliance with the requirements of this specification.

16. Packaging and Package Marking

16.1 *Packaging*—The bonding compound shall be packed in standard commercial containers. The containers shall be so constructed as to ensure acceptance by common or other carriers for safe transportation to the point of delivery, unless otherwise specified in the purchase order.

16.2 *Marking*—Shipping containers shall be marked with the name of the bonding compound, the quantity contained therein, the name, brand, or trademark of the producer or supplier, the shelf life, the batch number, and the ASTM designation.

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17. Keywords

17.1 bond; bonding compound; compound; plaster

SUMMARY OF CHANGES

Committee C11 has identified the location of selected changes to this specification since the last issue, C 631 – 95a(2004), that may impact the use of this specification. (Approved May 1, 2009)

(*1*) Revised 16.1.

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Designation: C637 – 09

Standard Specification for Aggregates for Radiation-Shielding Concrete[1]

This standard is issued under the fixed designation C637; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

This standard has been approved for use by agencies of the Department of Defense.

1. Scope*

1.1 This specification covers special aggregates for use in radiation-shielding concretes in which composition or high specific gravity, or both, are of prime consideration.

1.2 The values stated in SI units are to be regarded as standard. No other units of measurement are included in this standard.

1.3 The following precautionary caveat pertains only to the test method portion, Section 8, of this specification:*This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

2. Referenced Documents

2.1 *ASTM Standards:*[2]

C33 Specification for Concrete Aggregates

C127 Test Method for Density, Relative Density (Specific Gravity), and Absorption of Coarse Aggregate

C128 Test Method for Density, Relative Density (Specific Gravity), and Absorption of Fine Aggregate

C131 Test Method for Resistance to Degradation of Small-Size Coarse Aggregate by Abrasion and Impact in the Los Angeles Machine

C136 Test Method for Sieve Analysis of Fine and Coarse Aggregates

C535 Test Method for Resistance to Degradation of Large-Size Coarse Aggregate by Abrasion and Impact in the Los Angeles Machine

C638 Descriptive Nomenclature of Constituents of Aggregates for Radiation-Shielding Concrete

3. Classification

3.1 Aggregates covered by this specification include:

3.1.1 Natural mineral aggregates of either high density or high fixed water content, or both. These include aggregates that contain or consist predominately of materials such as barite, magnetite, hematite, ilmenite, and serpentine.

3.1.2 Synthetic aggregates such as iron, steel, ferrophosphorus and boron frit or other boron compounds (see Descriptive Nomenclature C638).

3.1.3 Fine aggregate consisting of natural or manufactured sand including high-density minerals. Coarse aggregate may consist of crushed ore, crushed stone, or synthetic products, or combinations or mixtures thereof.

4. Composition and Relative Density (Specific Gravity)

4.1 Table 1 gives data on chemical composition and relative density (specific gravity) of aggregate materials covered by this specification.

4.2 The purchaser shall specify the minimum specific gravity for each size and type of aggregate.

4.2.1 *Uniformity of Specific Gravity*—The relative density (specific gravity) SSD (saturated surface-dry) of successive shipments of aggregate shall not differ by more than 3 % from that of the sample submitted for source approval tests. The average specific gravity of the total shipment shall be equal to or greater than the specified minimum.

4.3 The purchaser shall specify the minimum fixed water content of hydrous ores. If the design temperature, *T,* is different from that given in 8.1.3.5, the purchaser shall specify the value of *T.*

4.3.1 *Uniformity of Fixed Water Content*—For hydrous aggregates the fixed water content of successive shipments of aggregate shall not be less than 95 % of the specified minimum value. The average fixed water content of the total shipment shall be equal to or exceed the specified minimum value.

5. Aggregate Grading

5.1 *Sieve Analysis*—Fine and coarse aggregates for conventionally placed concrete shall be graded within the limits given in Specification C33, except that with the approval of the purchaser, as much as 20 % of the material passing the 9.5-mm

[1] This specification is under the jurisdiction of ASTM Committee C09 on Concrete and Concrete Aggregates and is the direct responsibility of Subcommittee C09.41 on Pre-placed Aggregate Concrete for Radiation Shielding.

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[2] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

***A Summary of Changes section appears at the end of this standard.**

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TABLE 1 Composition and Relative Density (Specific Gravity) of Aggregates Covered by This Specification

Predominant Constituent	Class of Material	Chemical Composition of Principal Constituent[A]	Relative Density (Specific Gravity) of Available Aggregates
Serpentine[B]	crushed stone, hydrous siliente	$Mg_3Si_2O_5(OH)_4$	2.4 to 2.65
Limonite[C]	crushed stone, hydrous iron ore	$(HFeO_2)_x(H_2O)_y$	3.4 to 3.8
Goethite[C]	crushed stone, hydrous iron ore	$HFeO_2$	3.5 to 4.5
Barite	gravel or crushed stone	$BaSO_4$	4.0 to 4.4
Ilmenite	crushed stone, iron ore	$FeTiO_3$	4.2 to 4.8
Hematite	crushed stone, iron ore	Fe_2O_3	4.6 to 5.2
Magnetite	crushed stone, iron ore	$FeFe_2O_4$	4.6 to 5.2
Iron	manufactured from iron/steel	Fe	6.5 to 7.5
Ferrophosphorous[D]	synthetic	Fe_nP	5.8 to 6.3
Boron Frit[E]	synthetic	B_2O_3, Al_2O_3, SiO_2, CaO	2.6 to 2.8
Boron Carbide	synthetic	B_4C, B_2O_3, C	2.5
Calcium Boride	synthetic	C_aB_6, C	2.5

[A] When it is necessary to minimize the production of long-lived secondary radiation in the shield, or to avoid using materials having inherent radioactivity, the purchaser should specify limits on the contents of objectionable elements.

[B] The fixed water content of serpentine ranges from 10 to 13 percent by weight.

[C] The fixed water content of limonite and goethite ranges from 8 to 12 percent by weight.

[D] Ferrophosphorus when used in Portland cement concrete will generate flammable and possibly toxic gases which can develop high pressures if confined. See Clendenning, T. G., Kellam, B., and MacInnis, C., "Hydrogen Evolution from Ferrophosphorous Aggregate in Portland Cement Concrete," *Journal of the American Concrete Institute, No. 12,* December 1968. (*Proceedings*, Vol 65, pp. 1021–1028), and Mather, Bryant, discussion of Davis, Harold S., "Concrete for Radiation Shielding—In Perspective," and closure by author in "Concrete for Nuclear Reactors," *Journal of the American Concrete Institute* SP-34, Vol 1, 1972, pp. 11–13.

[E] The fixed water content of boron frit is less than 0.5 %.

(⅜ -in.) sieve may also pass the 150-µm (No. 100) sieve, with up to 10 % passing the 75-µm (No. 200) sieve if the material passing the 75-µm (No. 200) sieve is essentially free of clay or shale.

5.1.1 Fine and coarse aggregates for preplaced aggregate concrete shall be graded according to the requirements of Table 2 and as follows:

Relative Density (Specific Gravity) of Fine Aggregate	Grading of Aggregate	
	Coarse Aggregate	Fine Aggregate
Up to 3.0	Grading 1	Grading 1
Greater than 3.0	Grading 1	Grading 2
Full range	Grading 2	Grading 2

TABLE 2 Grading Requirements for Coarse and Fine Aggregates for Preplaced Aggregate Concrete

Sieve Size	Percentage Passing	
	Grading 1 For 37.5-mm (1½ -in.) Nominal Maximum Size Aggregate	Grading 2 For 25-mm (1-in.) Nominal Maximum Size Aggregate
Coarse Aggregate		
50-mm (2-in.)	100	. . .
37.5-mm (1½ in.)	95 to 100	100
25.0-mm (1-in.)	40 to 80	95 to 100
19.0-mm (¾ in.)	20 to 45	40 to 80
12.5-mm (½-in.)	0 to 10	0 to 15
9.5-mm (⅜-in.)	0 to 2	0 to 2
Fine Aggregate		
2.36-mm (No. 8)	100	. . .
1.18-mm (No. 16)	95 to 100	100
600-µm (No. 30)	55 to 80	75 to 95
300-µm (No. 50)	30 to 55	45 to 65
150-µm (No. 100)	10 to 30	20 to 40
75-µm (No. 200)	0 to 10	0 to 10
Fineness modulus	1.30 to 2.10	1.00 to 1.60

5.1.2 When boron frit is used as part of the fine aggregate, the grading shall be such that 100 % passes the 4.75-mm (No. 4) sieve and not more than 5 % passes the 600-µm (No. 30) sieve.

5.2 *Fineness Modulus*—If the fineness modulus of the fine aggregate varies more than 0.2 from the value corresponding to that of the sample submitted for acceptance, the fine aggregate shall be rejected unless suitable adjustments are made in concrete proportions to compensate for the difference in grading.

6. Deleterious Substances

6.1 Fine and coarse aggregates shall meet the requirements of Specification C33.

6.2 Boron frit shall not contain more than 2.0 % of water soluble material.

NOTE 1—This limit is based on concrete mixtures containing no more than 300 kg/m^3(500 lb/yd^3) of boron frit.

7. Abrasion Resistance of Coarse Aggregate

7.1 Coarse aggregate shall have an abrasion loss not greater than 50 % when tested in accordance with Test Method C131, or Test Method C535, as applicable. Coarse aggregate failing to meet this requirement may be used, provided it can be shown that it produces satisfactory strengths in concrete of the proportions selected for the work.

8. Methods of Sampling and Testing

8.1 Sample and test the aggregates in accordance with the methods cited in Specification C33 as applicable, except as follows:

8.1.1 *Relative Density (Specific Gravity)*—Determine the relative density (specific gravity), saturated surface-dry, of fine aggregate in accordance with Test Method C128, and of coarse aggregate in accordance with Test Method C127, except that the mass of the test sample for fine and coarse aggregate shall be approximately the specified mass multiplied by the ratio:

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relative density (*specific gravity*)/2.65

using for relative density (specific gravity) the higher value given in Table 1.

8.1.2 *Grading* — Test Method C136, except that the mass of the test sample for fine and coarse aggregate shall be approximately the specified mass multiplied by the ratio:

relative density (*specific gravity*)/2.65

using for relative density (specific gravity) the higher value given in Table 1.

8.1.3 *Fixed Water Content*—When 90 % or more of the weight loss on ignition of the aggregate is due to fixed water content, determine the fixed water content, *F,* by the loss-on-ignition test according to 8.1.3.1. When less than 90 % of the loss on ignition is due to fixed water content, determine the fixed water content by the train method (8.1.3.2). In case of dispute, use results obtained by the train method as the basis for acceptance or rejection of the aggregate. Use the train method to demonstrate that 90 % or more of the weight lost during ignition is fixed water. When loss-on-ignition tests are being made on aggregate samples from the same source, also determine the fixed water content of the first sample and each tenth sample thereafter by the train method.

8.1.3.1 For the loss-on-ignition test crush a representative sample of aggregate weighing 20 to 50 g *(W)* to pass the 4.75-mm (No. 4) sieve. Heat the sample to constant weight at a temperature, *T,* in a furnace, open to the atmosphere. Cool the heated sample in a desiccator and then weigh it, (W_t). Place the sample in the oven again, heat at the ignition temperature, *t,* cool in a desiccator, and determine the final weight (W_t). Constant weight may be considered to have been attained when further heating at the design temperature *T* causes or would cause less than 0.1 % additional weight loss.

8.1.3.2 In the train test, heat approximately 1 g *(W′)* of the finely ground sample to constant weight (W'_T) at a temperature of *T.* Then heat the sample W'_T in a stream of argon gas at the ignition temperature *t.* Pass water vapor and gaseous material driven from the heated sample through magnesium perchlorate. The gain in weight (W'_g) of the magnesium perchlorate is an indication of the fixed water content of the sample at temperature *T.* Also determine the dehydrated weight (W'_t) of the sample at the ignition temperature *t.*

8.1.3.3 Compute the fixed water content at temperature *T* by one of the following equations:

Ignition Test:

$$F, \text{ percent} = [(W_T - W_t)/W_T] \times 100 \quad (1)$$

where:
W_T = sample heated to constant weight, g, and
W_t = heated and cooled sample, g.

Train Test:

$$F, \text{ percent} = [(W'_g - W'_T) \times 100 \quad (2)$$

where:
W'_g = gain in weight of sample, g, and
W'_T = dehydrated weight, g.

8.1.3.4 Determine the percent of nonhydrous volatile material, *V,* as follows:

Train Test:

$$V, \text{ percent} = \{[W' - (W'_t + W'_g)]/W'_T\} \times 100 \quad (3)$$

where:
W' = sample weight, g,
W'_t = dehydrated weight of sample, g,
W'_g = gain in weight of sample, g, and
W'_T = sample heated to constant weight, g.

8.1.3.5 Water vapor driven from the sample by heating at temperature *T* is considered as part of the nonhydrous volatile material. Absorbed water at 110°C is not considered as part of the nonhydrous volatile material. Determine percent absorption by Test Methods C127 and C128.

8.1.3.6 Temperature values shall be as follows:

	Design Temperature, *T*	Ignition Temperature, *t*
Hydrous Aggregate	°C	°C
Iron ore	110	500
Serpentine	300	900

Heat the sample until it reaches constant weight at the specified temperature, unless otherwise approved. Determine weights after sample has been cooled in a desiccator to room temperature. Duplicate determinations of fixed water content should check to within 0.3 %.

8.1.4 *Water-Soluble Material in Boron Frit*—Place a 5.00-g sample passing a 600-µm (No. 30) sieve and retained on a 300-µm (No. 50) sieve in contact with 100 mL of distilled water at 20 ± 5°C for 16 h. Filter, wash with about 200-mL of hot (70 ± 5°C) water, and dry at 125 ± 10°C for 1 h. Weigh the residue, *s,* to the nearest 0.01 g. Calculate the percentage of water soluble material (W_s) to the nearest 0.1 % as follows:

$$W_3 = [(5.00 - s)/s] \times 100$$

where:

s = residue, g

9. Precision and Bias

9.1 *Precision* — The following precision statement addresses the test of the water-soluble material in Boron Frit. The precision for fixed water content by either the loss on ignition test or by the train test method has not been evaluated.

9.1.1 Data from one laboratory was available for estimating the precision of water-soluble material in boron frit, therefore, only a within-laboratory estimate of precision is made. The estimate is based on 15 replicate analyses of 5 lots of frit produced by one company. The 15 replicates were determined on 5 separate days, 3 replicates per day. The mean water soluble material ranged from 1.23 to 1.75 % among the 5 lots.

9.1.2 *Within-laboratory Precision*—The within-laboratory standard deviation among individual determinations of water-soluble material in boron frit is 0.224 %.[3] Therefore, two

[3] These numbers represent, respectively, the 1s and d2s limits as described in Practice C670.

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analyses of the same material should differ by no more than 0.627 %[3] in 95 % of cases.

9.2 *Bias*—Since there is no accepted reference material suitable for determining the bias of this test method, no statement on bias is made.

10. Keywords

10.1 aggregates; boron frit; calcium boride; high-density aggregates; high water-content aggregates; hydrous aggregates; radiation shielding concrete

SUMMARY OF CHANGES

Committee C09 has identified the location of selected changes to this specification since the last issue, C637 – 98a(2003), that may impact the use of this specification. (Approved December 15, 2009)

(*1*) Revised the standard throughout to replace all instances of "specific gravity" with "relative density (specific gravity)."

(*2*) Revised 1.2 and 8.1.3.6 to delete non-SI units.

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Designation: C638 – 09

Standard Descriptive Nomenclature of Constituents of Aggregates for Radiation-Shielding Concrete[1]

This standard is issued under the fixed designation C638; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

This standard has been approved for use by agencies of the Department of Defense.

1. Scope*

1.1 This descriptive nomenclature is intended to give accurate descriptions of some common or important naturally occurring and synthetic constituents of aggregates for radiation-shielding concrete, that, at the same time, are not common or important constituents of concrete aggregates in general use. While most of the minerals and rocks discussed below may occur in small quantities in aggregates in general use, they are not major constituents of such aggregates. Common constituents of aggregates in general use are described in Descriptive Nomenclature C294. Radiation-shielding concrete often contains such aggregates, but other special aggregates are used in some circumstances.

1.2 The synthetic aggregates included are ferrophosphorus and boron frit.

1.3 The descriptions are not adequate to permit the identification of materials, since accurate identification of natural and synthetic aggregate constituents in many cases can only be made by a qualified geologist, mineralogist, or petrographer, using the apparatus and procedures of those sciences.

1.4 The values stated in SI units are to be regarded as standard. No other units of measurement are included in this standard.

2. Referenced Documents

2.1 *ASTM Standards:*[2]

C294 Descriptive Nomenclature for Constituents of Concrete Aggregates

3. Types of Materials

3.1 Two classes of materials are described below. The first class consists of minerals and rocks formed from them, and synthetic materials, that have high relative density (specific gravity) and in addition contain substantial proportions of atoms of high or moderately high atomic weight. They are referred to as heavy or high-density aggregates. The second class consists of minerals and synthetic glasses of substantial boron content that are particularly effective in absorbing thermal neutrons without producing highly penetrating gamma rays. The boron-frit glasses are included because of their frequent use.

HEAVY AGGREGATES

4. Descriptions of Naturally Occurring Constituents

4.1 Members of this group have higher relative density (specific gravity) than aggregates in general use. Six are iron minerals, of which five are important iron ore minerals and the sixth is an ore of titanium. Two are barium minerals worked as the principal sources of barium salts. The other is ferrophosphorus, a mixture of synthetic iron phosphides.

4.2 The constituents are described below first as minerals, and then as major constituents of ores when their aspect as major constituents of ores affects the behavior of ores as concrete aggregates.

5. Iron Minerals and Ores

5.1 *Hematite (Fe_2O_3)*—Hematite has a hardness of 5 to 6 on Mohs' scale (will be scratched by hard steel), and a relative density (specific gravity) of 5.26 when pure. The color varies from bright red to dull red to steel gray; luster varies from metallic to submetallic to dull; the streak is cherry red or reddish brown; it is nonmagnetic.

5.1.1 *Hematite Ores*—Rocks of which hematite is the major constituent vary from one deposit to another, and within the deposit, in specific gravity, toughness, compactness, amount of impurities, degree of weathering, and suitability for use as concrete aggregate. Hematite appears to be the iron ore mineral most exploited as a source of iron. The ores of the Lake Superior region are banded sedimentary ores consisting of layers rich in hematite, and sometimes goethite, iron silicates, such as stilpnomelane, minnesotaite, greenalite, grunerite, and iron carbonate, alternating with silica-rich layers of chert or fine-grained quartz or a mixture. The Birmingham, AL ores are

[1] This descriptive nomenclature is under the jurisdiction of ASTM Committee C09 on Concrete and Concrete Aggregates and is the direct responsibility of Subcommittee C09.41 on Pre-placed Aggregate Concrete for Radiation Shielding.

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oolitic with hematite replacements of oölites and fossils in a matrix that ranges from fine-grained earthy hematite, with or without calcite, to crystalline calcite. Hematite ores dust in handling, with the dust ranging in color from moderate red to dusky red to moderate reddish brown (5R 4/6 to 5R 3/4 to 10R 4/6).[3]

5.2 *Ilmenite ($FeTiO_3$ with minor Mg and Mn)*—Ilmenite has a hardness of 5 to 6 and relative density (specific gravity) of 4.72 ± 0.04 when pure. The color is iron black with metallic to submetallic luster; the streak is black; it is feebly magnetic.

5.2.1 *Ilmenite Ores*—These ores consist of crystalline ilmenite with either magnetite or hematite and constituents of the associated gabbroic or anorthositic rocks. Massive ilmenite ores can form coarsely crystalline massive tough rocks but vary, from deposit to deposit, and within a deposit, in relative density (specific gravity), composition, hardness, and suitability for use as concrete aggregate. Many ilmenite ores consist of ilmenite disseminated in rock rather than concentrated as a major rock-forming mineral. Ilmenite concentrated from beach sands is usually altered to a variable degree, and its mechanical properties probably differ from those of unaltered ilmenite. One of the most widely used types of heavy aggregates is ilmenite ore.

5.3 *Lepidocrocite ($FeO(OH)$)*—Lepidocrocite has a hardness of 5 and relative density (specific gravity) of 4.09 when pure. The color varies from ruby red to reddish brown and the streak is dull orange. Lepidocrocite and goethite occur together, and lepidocrocite may be a constituent of goethite and limonite ores.

5.4 *Goethite ($HFeO_2$)*—Goethite has the same chemical composition as lepidocrocite but crystallizes differently. The hardness is 5 to 5½ and the relative density (specific gravity) is 4.28 ± 0.01 when pure and 3.3 to 4.3 in massive goethite. The color varies with the form, from crystals that are blackish brown with imperfect adamantine-metallic luster, to dull or silky luster in fibrous varieties; massive goethite is yellowish brown to reddish brown; clayey material is brownish yellow to ocher yellow. The streak is brownish yellow to ocher yellow.

5.4.1 *Goethite Ores*—These ores range from hard tough massive rocks to soft crumbling earths; these alterations frequently occur within fractions of an inch.

5.5 *Limonite*—A general name for hydrous iron oxides of unknown composition frequently cryptocrystalline goethite with adsorbed and capillary water, and probably mixtures of such goethite with similar lepidocrocite or hematite, or both, with adsorbed and capillary water[4]. The relative density (specific gravity) ranges from 2.7 to 4.3 and the color from brownish black through browns to yellows. Limonite deposits range from recognizable crystalline goethite to dull massive material of indefinite composition, and therefore, properly limonite. Limonites of high iron content are also called brown iron ores. Frequently they contain sand, colloidal silica, clays, and other impurities.

5.6 *Magnetite ($FeFe_2O_4$)*—Magnetite has a hardness of 5½ to 6½ and relative density (specific gravity) of 5.17 when pure. It is strongly magnetic; the color is black with metallic to semimetallic luster; the streak is black.

5.6.1 *Magnetite Ores*—These ores can form dense, tough, usually coarse-grained rocks with few impurities. Magnetite ores are associated with metamorphic or igneous or sedimentary rocks, and therefore, the impurities associated with magnetite ores may include a wide variety of rock-forming and accessory minerals. Magnetite occurs in association with hematite and ilmenite; magnetic ores are widely distributed, but many are not suitable for use as heavy aggregate because the magnetite occurs disseminated through rock rather than as a major rock-forming mineral. One of the most widely used types of heavy aggregates is magnetite ore.

6. Barium Minerals

6.1 *Witherite ($BaCO_3$)*—Witherite has a hardness of 3 to 3½ and a relative density (specific gravity) of 4.29 when pure. The color ranges from colorless to white to grayish or many pale colors. Like calcite and aragonite, witherite is decomposed with effervescence by dilute hydrochloric acid (HCl). Witherite, the second most common barium mineral, occurs with barite and galena. England is the chief producer of witherite, and barium-containing heavy aggregates in Great Britain might be expected to contain witherite as a major constituent.

6.2 *Barite* ($BaSO_4$) (also, but improperly, called barytes)—Barite has a hardness of 3 to 3½ and a relative density (specific gravity) of 4.50 when pure. The color ranges from colorless to white to many usually pale colors.

6.2.1 Barite is the most common barium mineral and the major barium ore. It occurs in veins transecting many kinds of rocks, concentrated in sedimentary rocks, and as residual nodules in clays formed by the solution of sedimentary rocks. In many of its occurrences it is accompanied by clay or a calcium sulfate mineral (gypsum or anhydrite) or both. Although barite from residual deposits is often weathered, it is possible to obtain clean, well-graded barite aggregate.

7. Ferrophosphorus

7.1 Ferrophosphorus, a material produced in the production of phosphorus, consists of a mixture of iron phosphides, and has been used as coarse and fine aggregate in radiation-shielding concrete. Published relative density (specific gravity) range from 5.72 to 6.50 for coarse aggregate. The coarse aggregate is reported to degrade easily and has been associated with extreme retardation of set in concrete. Ferrophosphorus in concrete releases flammable, and possibly toxic, gases which can develop high pressures if confined[5].

7.2 Several iron phosphides are known, including silver gray to blue gray Fe_2P, with relative density (specific gravity)

[3] National Research Council, Washington, DC, *Rock Color Chart* (1948) reissued 1964 by Geological Soc. Am., New York, NY.

[4] Palache, Charles, et al., *The System of Mineralogy of J. D. Dana and E. S. Dana, Vol 1, Elements, Sulfides, Sulfosalts, Oxides,* Ed. 7, New York, NY, 1944, p 685.

[5] Clendenning, T. G., Kellam, B., and MacInnis, C., "Hydrogen Evolution from Ferrophosphorous Aggregate in Portland Cement Concrete," *Journal of the American Concrete Institute* , No 12, December 1968, *Proceedings*, Vol 65, pp. 1021–1028.

Mather, Bryant, discussion of Davis, Harold S., "Concrete for Radiation Shielding—In Perspective," and closure by author in" Concrete for Nuclear Reactors," ACI SP-34, Vol 1, 1972 , pp 11–13.

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TABLE 1 Commercially Important Boron Minerals

Name	Chemical Composition	Solubility in Cold Water	Produced
Borax	$Na_2B_4O_7.10H_2O$	1.6g/100 mL at 10°C: 3.86 g/ 100 mL at 30°C	United States, Argentina, Chile
Kernite	$Na_2B_4O_7.4H_2O$	slowly soluble	United Stats, Argentina
Colemanite	$Ca_2B_6O_{11}.5H_2O$	0.09 g/100 mL	United States, Turkey, USSR
Ulexite	$NaCaB_5O_9.8H_2O$	slightly decomposed with loss of Na_2O	United States, Turkey, USSR, Argentina, Chile
Sassolite (boricacid)	H_3BO_3	5.15 g/100mL	Italy
Tncalconite	$Na_2B_4O_7.5H_2O$	like borax	common dehydration product of borax
Priceite	$Ca_4B_{10}O_{19}.7H_2O$	insoluble	Turkey, USSR, United States
Inyoite	$Ca_2B_6O_{11}.13H_2O$	relatively insoluble	USSR, United States
Hydroboracite	$CaMgB_6O_{11}.6H_2O$	relatively insoluble	USSR
Szaibelyite	(Mg, Mn)(BO_2)(OH)	insoluble	USSR

of 6.50, FeP_2 with relative density (specific gravity) of 5.07, and Fe_3P and FeP. Ferrophosphorus aggregates are silver gray but develop some rusty staining on exposure.

BORON-CONTAINING MATERIALS

8. Boron Minerals

8.1 The gamma rays that result from neutron capture by the lighter isotope of boron, boron-10, are much less penetrating than those which result from neutron capture by hydrogen; and for this reason boron and boron compounds are often used in neutron shields. The unusually high capture capability of boron-10 permits its use in relatively small quantities. Boron is most frequently incorporated in the concrete as borate minerals or synthetic boron frits. Both methods of incorporating boron cause some retardation of time of setting of the concrete, which can be counteracted by the use of a suitable accelerator. The experience recorded in the United States suggests that the cost of synthetic frits, which is higher than the cost of borate, may be counterbalanced by uniform composition of the frits, which permits effective control of the properties of the concrete.

8.2 Minerals that are commercially important sources of boron are principally sodium, calcium, and magnesium borate precipitates from waters in arid volcanic regions, or alteration products of such precipitates (Table 1)[6]. These hydrated minerals include some that are easily altered by changes in relative humidity and temperature. Some of them are soluble in or partly decomposed by cold water. Clay, gypsum, and salt are found in borate deposits. The presence of one or more of these in varying unknown amounts in a borate ore used in shielding concrete may cause problems in making concrete with controlled strength, setting time, volume stability, and workability, aside from the problem of varying degrees of retardation as the time composition, and thus the solubility, of the borate ore may range from lot to lot or within a lot.

8.3 Borate production in the United States is virtually limited to borax and borax derivates obtained from natural brines at Searles Lake, CA, and brines produced by treating borates from the Kramer deposit at Boron, CA. California colemanite deposits, which also contain ulexite, are apparently not regularly worked but colemanite ores have been obtained from them for use in shielding concrete. Turkish borate ores, which have been referred to as "borocalcite," but probably are ulexite or colemanite or mixtures of the two, have been used in shielding concrete in Germany and Japan[7].

8.4 Boron minerals that are stable and insoluble are usually not available in large quantities for use as aggregates. The recorded exceptions are described below.

8.4.1 *Paigeite*—$((Fe^{++}Mg)Fe^{+++}BO_5)$—Paigeite has a hardness of 5 and specific gravity ranging from 4.7 at the paigeite end to 3.6 at the ludwigite end of the paigeite-ludwigite series. It is coal black or greenish black and insoluble in water, and tough. It is a high-temperature mineral occurring with magnetite in contact metamorphic deposits. Paigeite has been used as a heavy boron-containing aggregate in Japan.

8.4.2 *Tourmaline* $(Na(Mg, Fe, Mn, Li, Al)_3Al_6[Si_6O_{18}]\cdot(BO_3)_3(OH,F)_4)$—Tourmaline has a hardness of 7 and specific gravity ranging from 3.03 to 3.25; it ranges widely in color, but common varieties are brown or black. It is characteristically a mineral of granites, pegmatites, and pneumatolytic veins, but persists as a detrital mineral in sediments. Concrete having effective neutron-shielding characteristics has been described in which the coarse aggregate was serpentine and the fine aggregate a tourmaline sand concentrate.

9. Boron-Frit Glasses

9.1 Boron-frit glasses are clear, colorless, synthetic glasses produced by fusion and quenching used in making ceramic glazes. They may be obtained in many compositions, but those most useful in shielding concrete contain calcium, relatively high amounts of silica and alumina, and low amounts of alkalies. Increased silica and alumina decrease the solubility of the frits and thus diminish their retarding effect in shielding concrete. When there is a hazard from secondary radiation, limits on allowable proportions of sodium and potassium may be imposed.

10. Keywords

10.1 aggregates; boron; concrete; iron; minerals

[6] Compiled from: Smith, W. C., "Borax and Borates," Gillson, J. L., ed., *Industrial Rocks and Minerals*, 3rd Ed., American Institute of Mining, Metallurgical, and Petroleum Engineers, New York, NY, 1960, pp 103–118, and Palache, C., Berman, H., and Frondel, C., *Dana's System of Mineralogy* , 7th ed., Vol II, John Wiley and Sons, New York, NY 1951.

[7] Henrie, J. O., "Properties of Nuclear Shielding Concrete, " *Journal of the American Concrete Institute*, Vol *31*, July 1959, *Proceedings* , Vol 56, pp 37–46.

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SUMMARY OF CHANGES

Committee C09 has identified the location of selected changes to this descriptive nomenclature since the last issue, C638–92(2002), that may impact the use of this descriptive nomenclature. (Approved December 1, 2009)

(*1*) Added units statement in new 1.4.

(*2*) Replaced all instances of "specific gravity" with "relative density (specific gravity)" throughout the standard.

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Designation: C 641 – 09

Standard Test Method for Iron Staining Materials in Lightweight Concrete Aggregates[1]

This standard is issued under the fixed designation C 641; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

This standard has been approved for use by agencies of the Department of Defense.

1. Scope*

1.1 This test method covers the testing of lightweight concrete aggregates to evaluate the potential degree of staining from iron compounds.

1.2 The values stated in SI units are to be regarded as the standard. The inch-pound values given in parentheses are provided for information only.

1.3 *This standard does not purport to address the safety problems associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

2. Referenced Documents

2.1 *ASTM Standards:*[2]

C330 Specification for Lightweight Aggregates for Structural Concrete

C331 Specification for Lightweight Aggregates for Concrete Masonry Units

C702 Practice for Reducing Samples of Aggregate to Testing Size

D75 Practice for Sampling Aggregates

E11 Specification for Woven Wire Test Sieve Cloth and Test Sieves

E832 Specification for Laboratory Filter Papers

3. Significance and Use

3.1 This test method evaluates the potential degree of staining attributable to the presence of iron compounds in a lightweight aggregate sample primarily by means of a visual classification method. Such compounds may or may not produce stains on the surface of the concrete in which the aggregate is incorporated.

4. Apparatus

4.1 *Balance*—A balance or scale accurate to within 0.1 % of the test load at any point within the range of use.

4.2 *Sieves*— 9.5-mm (⅜-in.) and 600-µm (No. 30) sieves conforming to Specification E11.

4.3 *Filter Paper*—shall comply with Specification E832 class E2 with a minimum diameter of 250 mm.

4.4 *Cheesecloth Wrapping*—Two thicknesses, reagent grade cheesecloth, approximately 457 mm (18 in.) square is sufficient for wrapping each sample.

4.5 *Steam Bath*—Any suitable apparatus that will meet the requirement of the test procedure. Water in the steam bath, and makeup water, shall be iron-free water or distilled water.

NOTE 1—An oven top glassware sterilizer made of nonferrous materials is satisfactory.

5. Reagents

5.1 *Purity of Reagents*—Reagent grade chemicals shall be used in all tests. Unless otherwise indicated, it is intended that all reagents shall conform to the specifications of the Committee on Analytical Reagents of the American Chemical Society, where such specifications are available.[3]

5.2 *Purity of Water*—Unless otherwise indicated, references to water shall be understood to mean distilled water or water of equal purity.

5.3 *Concentration of Reagents*:

5.3.1 *Concentrated Acid and Ammonium Hydroxide*—When reagents are specified by name it shall be understood that concentrated reagents of the following specific gravity are intended:

Hydrochloric acid (HCl)	sp gr 1.19
Ammonium hydroxide (NH_4OH)	sp gr 0.90

5.3.2 *Diluted acid* is described in terms of the number of volumes of the concentrated reagent to be added to a given number of volumes of water. Thus HCl (1 + 2) means 1 volume of HCl (sp gr 1.19) added to 2 volumes of water.

[1] This test method is under the jurisdiction of ASTM Committee C09 on Concrete and Concrete Aggregates and is the direct responsibility of Subcommittee C09.21 on Lightweight Aggregates and Concrete.

Current edition approved Oct. 1, 2009. Published November 2009. Originally approved in 1969. Last previous edition approved in 2007 as C 641 – 07. DOI: 10.1520/C0641-09.

[2] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

[3] "Reagent Chemicals, American Chemical Society Specifications," Am. Chemical Soc., Washington, DC. For suggestions on the testing of reagents not listed by the American Chemical Society, see "Reagent Chemicals and Standards," by Joseph Rosin, D. Van Nostrand Co., Inc., New York, NY, and the "United States Pharmacopeia."

***A Summary of Changes section appears at the end of this standard.**

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6. Sampling

6.1 Sample in accordance with Practice D75.

6.2 After reducing a field sample to an appropriate size in accordance with Practice C702, thoroughly dry the aggregate and prepare by sieving material to pass the 9.5-mm (⅜-in.) sieve and is retained on the 600-µm (No. 30) sieve.

7. Procedure

7.1 Select two portions each weighing 100 g from the aggregate sample prepared for test.

7.2 Crimp the edges of two filter papers to form cup-shaped receptacles approximately 130 mm (5 in.) in diameter and 60 mm (2½ in.) in depth. Place one of the 100-g portions in each filter cup, spreading to a uniform depth. Fold the sides of the cup to the center and press in that position.

7.3 Wrap both portions of the prepared sample, one on top of the other, in cheesecloth. Saturate with distilled water and expose to steam in the steam bath for 16 h, adding distilled water as make-up water as required.

7.4 Remove from the steam bath, and carefully remove the aggregate from the filter papers. Wash both papers in water, place on a watch glass, and oven dry at a temperature of 110 ± 5 °C (230 ± 9 °F). The insoluble products of the decomposition of iron compounds in the aggregate will be deposited on the filter paper as red, green, or black stains.

7.5 Rate the extent of staining on the filter papers by the Visual Classification Method.

7.5.1 *Visual Classification Method*—Evaluate the extent and intensity of the stains on the filter paper in accordance with the photographic stain index reference standards shown in Figs. 1-5: The photographic stain index ranges from No Stain (stain index = 0) to a Very Heavy Stain (stain index = 100).

7.6 When required by Specification C330 and Specification C331, follow the procedure of the Chemical Analysis Method.

7.6.1 Chemical Analysis Method—The iron deposits may be dissolved from the filter papers by careful application of HCl from a dropping bottle and rinsing with hot distilled water from a wash bottle. Otherwise, dissolve the iron compound on the washed and dried filter papers by digesting in HCl (1 + 1) and filtering out the residue of filter pulp washing thoroughly with hot water. Precipitate the iron in the filtrate as ferric hydroxide $Fe(OH)_3$ by adding NH_4OH dropwise to neutralize the acid using methyl red indicator solution. Redissolve the $Fe(OH)_3$ precipitate using 10 cm^3 of HCl (1 + 1) and determine the iron quantitatively as Fe_2O_3 by standard titration procedures.

NOTE 2—The iron may be determined by using other standard quantitative procedures.

8. Calculation

8.1 Calculate the determined Fe_2O_3 to the nearest 0.01 mg (to be reported to the nearest 0.1) as follows:

$$Fe_2O_3, \text{ mg/200 g} = E \times V \quad (1)$$

where:

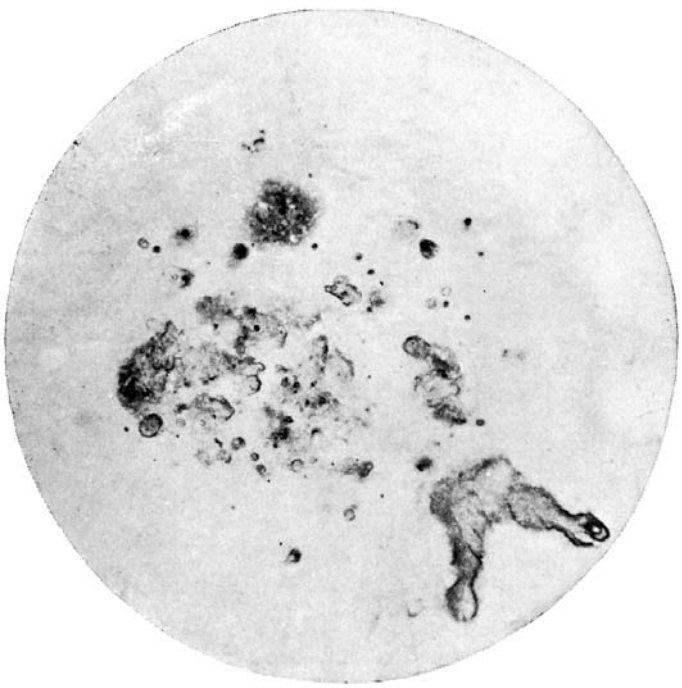
E = Fe_2O_3 equivalent of standard titration solution, mg/mL,

V = millilitres of standard titration solution required by the stains from the 200-g sample.

9. Report

9.1 The report shall include the following:

9.1.1 Identification of the sample,



Stain Index = 100

FIG. 1 Visual Degree of Staining

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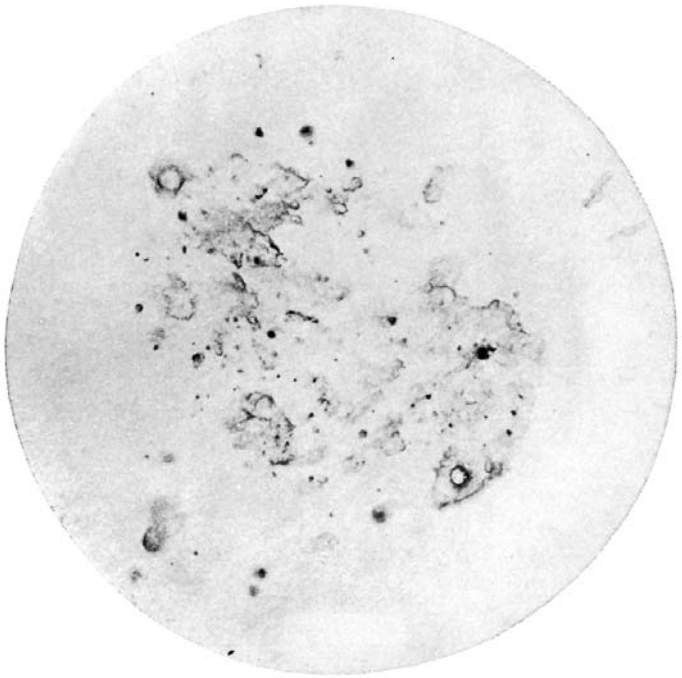
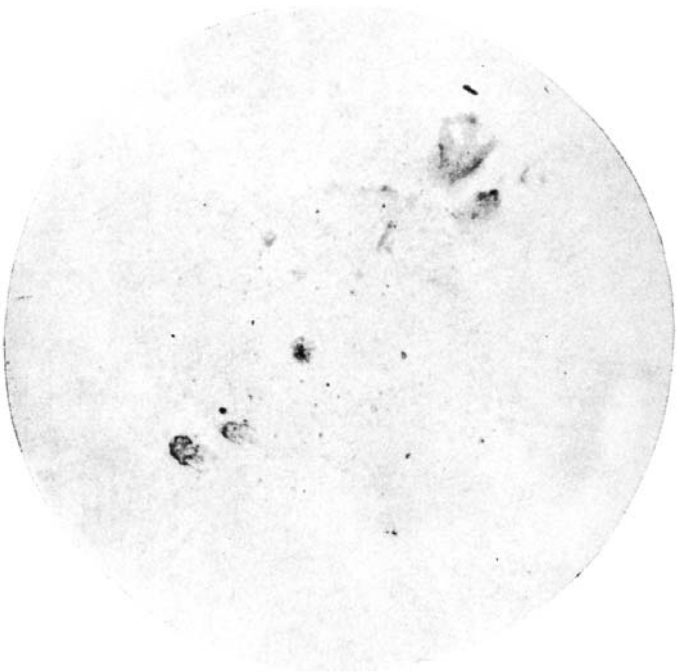


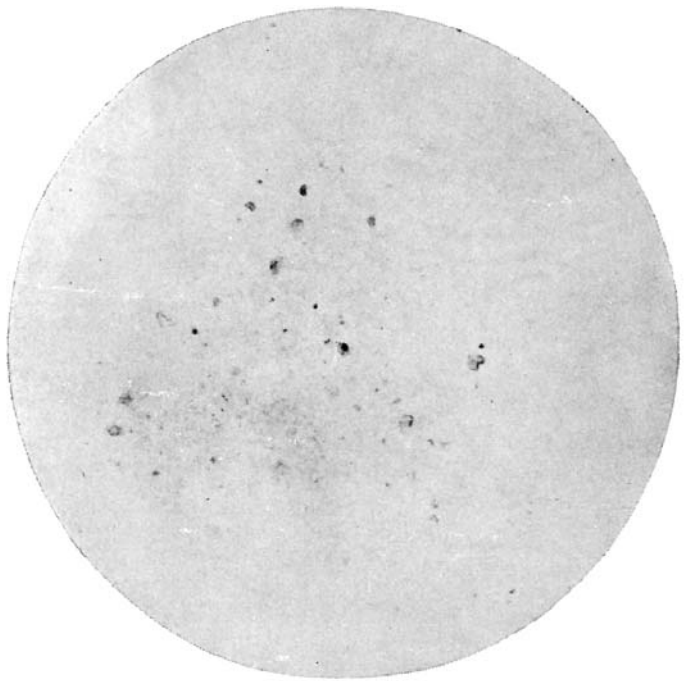
Stain Index = 80

FIG. 2



Stain Index = 60

FIG. 3



Stain Index = 40

FIG. 4

9.1.2 Stain index, as evaluated by the Visual Classification Method, when required, and

9.1.3 Iron content as milligrams of Fe_2O_3 per 200 g of sample evaluated by the Chemical Analysis Method.

10. Precision and Bias

10.1 *Precision*—The precision of this test method has not yet been determined, but an interlaboratory testing program is underway. The precision statements will be included when the data are compiled and reviewed.

10.2 *Bias*—Bias for this test method cannot be determined since there is no reference standard available for comparison.

11. Keywords

11.1 iron; lightweight aggregate; staining

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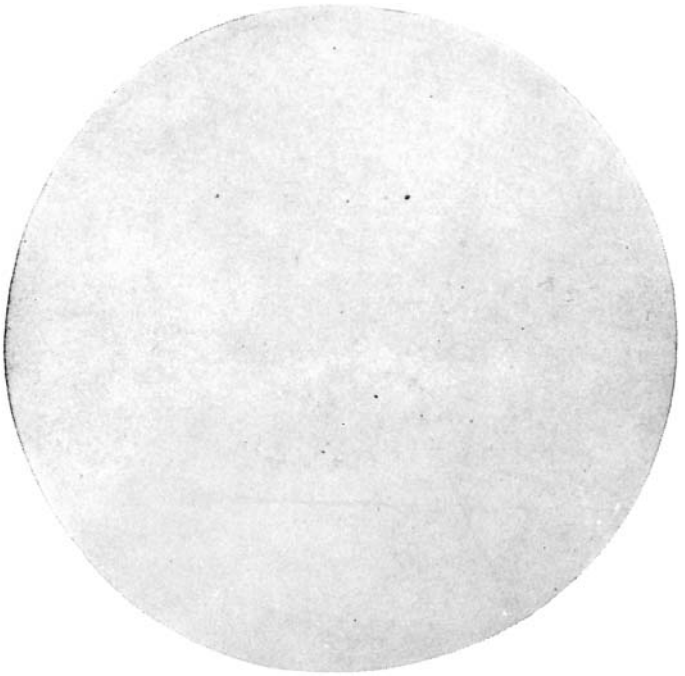

Stain Index = 20

FIG. 5

SUMMARY OF CHANGES

Committee C09 has identified the location of selected changes to this test method since the last issue, C 641 – 07, that may impact the use of this test method. (Approved October 1, 2009)

(*1*) Revised 4.3.

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Designation: C 642 – 06

Standard Test Method for Density, Absorption, and Voids in Hardened Concrete[1]

This standard is issued under the fixed designation C 642; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope*

1.1 This test method covers the determinations of denisty, percent absorption, and percent voids in hardened concrete.

1.2 The text of this test method references notes and footnotes which provide explanatory information. These notes and footnotes (excluding those in tables and figures) shall not be considered as requirements of this standard.

1.3 The values stated in SI units are to be regarded as the standard.

2. Significance and Use

2.1 This test method is useful in developing the data required for conversions between mass and volume for concrete. It can be used to determine conformance with specifications for concrete and to show differences from place to place within a mass of concrete.

3. Apparatus

3.1 *Balance*, sensitive to 0.025 % of the mass of the specimen.

3.2 *Container*, suitable for immersing the specimen and suitable wire for suspending the specimen in water.

4. Test Specimen

4.1 Whenever possible, the sample shall consist of several individual portions of concrete, each to be tested separately. The individual portions may be pieces of cylinders, cores, or beams of any desired shape or size, except that the volume of each portion shall be not less than 350 cm^3 (or for normal weight concrete, approximately 800 g); and each portion shall be free from observable cracks, fissures, or shattered edges.

5. Procedure

5.1 *Oven-Dry Mass*—Determine the mass of the portions, and dry in an oven at a temperature of 100 to 110 °C for not less than 24 h. After removing each specimen from the oven, allow it to cool in dry air (preferably in a desiccator) to a temperature of 20 to 25 °C and determine the mass. If the specimen was comparatively dry when its mass was first determined, and the second mass closely agrees with the first, consider it dry. If the specimen was wet when its mass was first determined, place it in the oven for a second drying treatment of 24 h and again determine the mass. If the third value checks the second, consider the specimen dry. In case of any doubt, redry the specimen for 24-h periods until check values of mass are obtained. If the difference between values obtained from two successive values of mass exceeds 0.5 % of the lesser value, return the specimens to the oven for an additional 24-h drying period, and repeat the procedure until the difference between any two successive values is less than 0.5 % of the lowest value obtained. Designate this last value *A*.

5.2 *Saturated Mass After Immersion*—Immerse the specimen, after final drying, cooling, and determination of mass, in water at approximately 21 °C for not less than 48 h and until two successive values of mass of the surface-dried sample at intervals of 24 h show an increase in mass of less than 0.5 % of the larger value. Surface-dry the specimen by removing surface moisture with a towel, and determine the mass. Designate the final surface-dry mass after immersion *B*.

5.3 *Saturated Mass After Boiling*—Place the specimen, processed as described in 5.2, in a suitable receptacle, covered with tap water, and boil for 5 h. Allow it to cool by natural loss of heat for not less than 14 h to a final temperature of 20 to 25 °C. Remove the surface moisture with a towel and determine the mass of the specimen. Designate the soaked, boiled, surface-dried mass *C*.

5.4 *Immersed Apparent Mass*—Suspend the specimen, after immersion and boiling, by a wire and determine the apparent mass in water. Designate this apparent mass *D*.

6. Calculation

6.1 By using the values for mass determined in accordance with the procedures described in Section 5, make the following calculations:

$$\text{Absorption after immersion, \%} = [(B - A)/A] \times 100 \quad (1)$$

$$\text{Absorption after immersion and boiling, \%} = [(C - A)/A] \times 100 \quad (2)$$

$$\text{Bulk density, dry} = [A/(C - D)]\cdot\rho = g_1 \quad (3)$$

$$\text{Bulk density after immersion} = [B/(C - D)]\cdot\rho \quad (4)$$

[1] This test method is under the jurisdiction of ASTM Committee C09 on Concrete and Concrete Aggregates and is the direct responsibility of Subcommittee C09.69 on Miscellaneous Tests.

Current edition approved July 1, 2006. Published August 2006. Originally approved in 1969. Last previous edition approved in 1997 as C 642 – 97.

***A Summary of Changes section appears at the end of this standard.**

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$$\text{Bulk density after immersion and boiling} = [C/(C-D)]\cdot\rho \quad (5)$$

$$\text{Apparent density} = [A/(A-D)]\cdot\rho = g_2 \quad (6)$$

$$\text{Volume of permeable pore space (voids), \%} = (g_2 - g_1)/g_2 \times 100 \quad (7)$$

$$\text{or } (C-A)/(C-D) \times 100$$

where:

A = mass of oven-dried sample in air, g
B = mass of surface-dry sample in air after immersion, g
C = mass of surface-dry sample in air after immersion and boiling, g
D = apparent mass of sample in water after immersion and boiling, g
g_1 = bulk density, dry, Mg/m^3 and
g_2 = apparent density, Mg/m^3
ρ = density of water = 1 Mg/m^3 = 1 g/cm^3.

7. Example

7.1 Assume a sample having the following characteristics:

7.1.1 Mass of the solid part of the specimen = 1000 g.

7.1.2 Total volume of specimen (including solids, "permeable" voids, and "impermeable" voids) = 600 cm^3.

7.1.3 Absolute density of solid part of specimen = 2.0 Mg/m^3.

7.1.4 Void space in specimen contains initially only air (no water).

7.2 Then, it follows that there are 500 cm^3 of solids and 100 cm^3 of voids making up the specimen, and the void content is ⅙ = 16.67 %.

7.3 Assume that on immersion 90 mL of water is absorbed.

7.4 Assume that after immersion and boiling 95 mL of water is absorbed.

7.5 Based on the assumptions given in 7.1-7.4 above, the data that would be developed from the procedures given in Section 5 would be as follows:

7.5.1 Oven-dry mass, A = 1000 g.

7.5.2 Mass in air after immersion, B = 1090 g.

7.5.3 Mass in air after immersion and boiling, C = 1095 g.

7.5.4 Apparent mass in water after immersion and boiling, D = 495 g.

NOTE 1—Since loss of mass in water is equal to mass of displaced water, and volume of specimen = 600 cm^3, mass of specimen in water after immersion and boiling is 1095 – 600 = 495 g.

7.6 By using the data given above to perform the calculations described in Section 6, the following results will be obtained (Note 2):

$$\text{Absorption after immersion, \%} = [(B - A(/A] \times 100 = [(1090 - 1000)/1000] \times 100 = 9.0 \quad (8)$$

$$\text{Absorption after immersion and boiling, \%} = [(C - A)/A] \times 100 = [(1095 - 1000)/1000] \times 100 = 9.5 \quad (9)$$

$$\text{Bulk density, dry} = [A/(C-D)]\cdot\rho = [1000/(1095 - 495)] \times 1 = 1.67\ Mg/m^3 = g_1 \quad (10)$$

$$\text{Bulk density after immersion} = [B/(C-D)]\cdot\rho = [1090/(1095 - 495)] \times 1 = 1.82 \quad (11)$$

$$\text{Bulk density after immersion and boiling} = [C/(C-D)]\,\rho = [1095/(1095 - 495)] \times 1 = 1.83\ Mg/m^3 \quad (12)$$

$$\text{Apparent density} = [A/(A-D)]\,\rho = [1000/(1000 - 495)] \times 1 = 1.98\ Mg/m^3 = g_2 \quad (13)$$

$$\text{Volume of permeable voids, \%} \quad (14)$$

$$= [(g_2 - g_1)/g_2] \times 100 = [(1.98 - 1.67)/1.98] \times 100$$

$$= 15.8, \text{ or } [(C - A)/(C - D)] \times 100$$

$$= [(1095 - 1000)/(1095 - 495)] \times 100 = 15.7$$

NOTE 2—This test method does not involve a determination of absolute density. Hence, such pore space as may be present in the specimen that is not emptied during the specified drying or is not filled with water during the specified immersion and boiling or both is considered "impermeable" and is not differentiated from the solid portion of the specimen for the calculations, especially those for percent voids. In the example discussed it was assumed that the absolute density of the solid portion of the specimen was 2.0 Mg/m^3, the total void space was 16.67 %, and the impermeable void space was 5 cm^3. The operations, if performed, and the calculations, if performed as described, have the effect of assuming that there are 95 cm^3 of pore space and 505 cm^3 of solids, and indicate that the solid material, therefore, has an apparent density of 1.98 rather than the absolute density of 2.00 Mg/m^3 and the specimen has a percentage of voids of 15.8 rather than 16.67.

Depending on the pore size distribution and the pore entry radii of the concrete and on the purposes for which the test results are desired, the procedures of this test method may be adequate, or they may be insufficiently rigorous. In the event that it is desired to fill more of the pores than will be filled by immersion and boiling, various techniques involving the use of vacuum treatment or increased pressures may be used. If a rigorous measure of total pore space is desired, this can only be obtained by determining absolute density by first reducing the sample to discrete particles, each of which is sufficiently small so that no impermeable pore space can exist within any of the particles. If the absolute density were determined and designated g_3, then:

$$\text{Total void volume, \%} = (g_3 - g_1)/g_3 \times 100 \quad (15)$$

$$= (2.00 - 1.67)/2.00 \times 100 = 16.5$$

8. Precision and Bias

8.1 *Precision*—At present there are insufficient data available to justify attempting to develop a precision statement for this test method.

8.2 *Bias*—Bias for this test method cannot be determined since there is no reference standard available for comparison.

9. Keywords

9.1 absorption; concrete-hardened; density; voids

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SUMMARY OF CHANGES

Committee C09 has identified the location of selected changes to this test method since the last issue, C 642 – 97, that may impact the use of this test method. (Approved July 1, 2006)

(*1*) Added new 1.3.

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Designation: C 645 – 09a

Standard Specification for Nonstructural Steel Framing Members[1]

This standard is issued under the fixed designation C 645; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

This standard has been approved for use by agencies of the Department of Defense.

1. Scope*

1.1 This specification covers nonstructural steel framing members in interior construction assemblies.

1.2 The values stated in inch-pound units are to be regarded as standard. The values given in parentheses are mathematical conversions to SI units that are provided for information only and are not considered standard.

1.3 The following safety hazards caveat pertains only to the test methods portion, Sections 9 and 10, of this specification: *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

2. Referenced Documents

2.1 *ASTM Standards:*[2]

A653/A653M Specification for Steel Sheet, Zinc-Coated (Galvanized) or Zinc-Iron Alloy-Coated (Galvannealed) by the Hot-Dip Process

A1003/A1003M Specification for Steel Sheet, Carbon, Metallic- and Nonmetallic-Coated for Cold-Formed Framing Members

C11 Terminology Relating to Gypsum and Related Building Materials and Systems

C475/C475M Specification for Joint Compound and Joint Tape for Finishing Gypsum Board

C1396/C1396M Specification for Gypsum Board

C754 Specification for Installation of Steel Framing Members to Receive Screw-Attached Gypsum Panel Products

C1002 Specification for Steel Self-Piercing Tapping Screws for the Application of Gypsum Panel Products or Metal Plaster Bases to Wood Studs or Steel Studs

2.2 *AISI Standard:*

S100 North American Specification for the Design of Cold-Formed Steel Structural Members, 2007 edition[3]

AISI COSP Code of Standard Practice for Cold-Formed Steel Structural Framing Committee on Framing Standards, 2005 Edition[3]

2.3 *ICC-ES Document*[4]

ICC-ES-AC86 Acceptance Criteria for Steel Studs and Gypsum-Board Interior Nonload-Bearing Walls—Complete Construction—AC86—Approved July 1995 (Editorially revised September 2005) (Formerly ICBO AC86 dated July 1995)

3. Terminology

3.1 *Definitions*—Definitions shall be in accordance with Terminology C11.

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *members*, *n*—in screw application of gypsum board, studs, runners (track), hat furring channels, main beams and cross furring members of grid suspension systems or other items manufactured in accordance with this specification.

3.2.2 *nonstructural wall stud*, *n*—a member in a steel framed wall system which is limited to a lateral (transverse) load of not more than 10 lb/ft^2 (480 Pa), a superimposed vertical load, exclusive of sheathing materials, of not more than 100 lbf/ft (1460 N/m), or a superimposed vertical load of not more than 200 lbs (890 N).

4. Materials and Manufacture

4.1 Members shall be manufactured from steel meeting the requirements of Specification A1003/A1003M.

[1] This specification is under the jurisdiction of ASTM Committee C11 on Gypsum and Related Building Materials and Systems and is the direct responsibility of Subcommittee C11.02 on Specifications and Test Methods for Accessories and Related Products.

Current edition approved Nov. 15, 2009. Published December 2009. Originally approved in 1970. Last previous edition approved in 2009 as C 645 – 09.

[2] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

[3] Available from American Iron and Steel Institute (AISI), 1140 Connecticut Ave., NW, Suite 705, Washington, DC 20036, http://www.steel.org.

[4] Available from ICC Evaluation Services, Inc., 5360 Workman Mill Road, Whittier, CA 90601, www.icc-es.org.

***A Summary of Changes section appears at the end of this standard.**

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4.2 Members shall have a protective coating conforming to Specification A653/A653M – G 40 minimum or shall have a protective coating with an equivalent corrosion resistance.

4.3 Members shall be manufactured from steel having a minimum thickness, individual measurement of 0.0179 in. (0.455 mm) before application of protective coating.

5. Dimensions and Permissible Variations

5.1 Studs and rigid furring channels shall have a configuration and steel thickness such that the system in which they are used will carry the design transverse loads without exceeding either the allowable stress of the steel or the allowable design deflection. Main beams and cross furring of grid suspension systems shall be limited to a deflection of L/240. The manufacturer shall supply sufficient data for calculating design performance.

NOTE 1—Allowable deflection varies depending on the cladding used and architectural requirements. Detailed requirements shall be specified in application specifications.

5.1.1 Members, except main beams of grid suspension systems, shall be sufficiently rigid to permit penetration of the screw.

5.1.2 Minimum width of face to which gypsum board is screw-attached shall be not less than 1¼ in. (32 mm).

5.1.3 Minimum lip dimension shall be 3⁄16 in. (5 mm). See Fig. 1.

5.2 Members shall be manufactured within the limits as shown in Table 1 and Fig. 2.

5.3 *Rigid Furring Channels*—Minimum depth shall be ⅞ in. (22 mm). Minimum width of furring attachment flanges (see Fig. 3) shall be ½ in. (12.7 mm).

5.4 Grid suspension systems include main beams and cross furring members which mechanically interlock to form a modular supporting network. Length tolerance for grid suspension members shall be ±1⁄16 in. (1.59 mm).

5.5 Runners (track) shall be formed in a U-shaped configuration, having web depth compatible with those of the studs of the same nominal size. The runners (track) shall be designed such that when the studs are placed in both the top and bottom

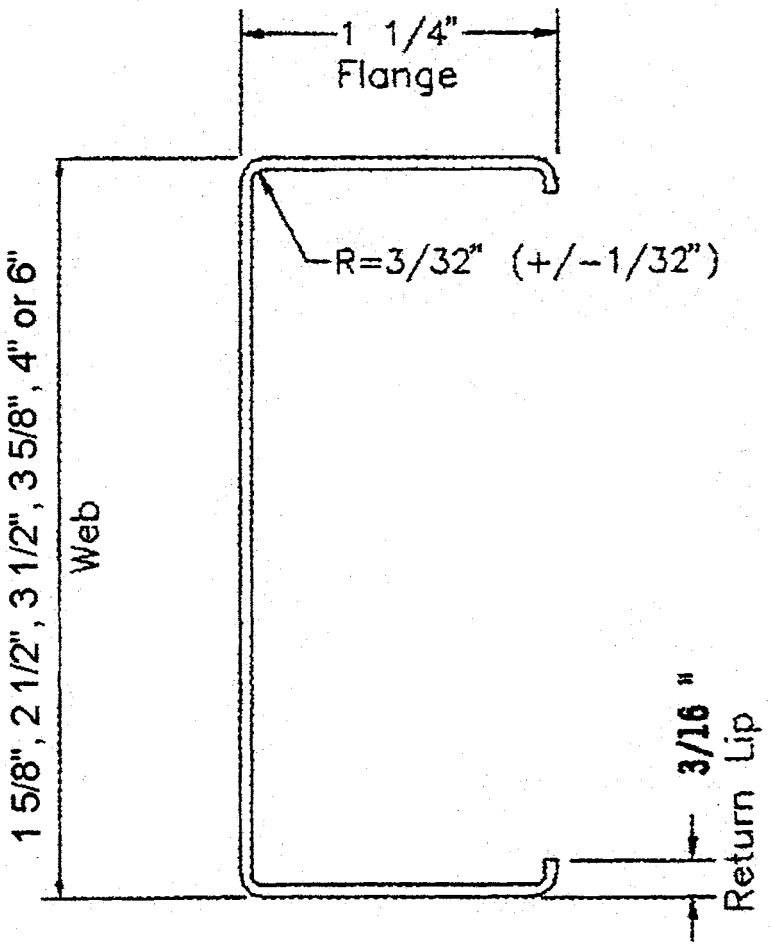

FIG. 1 Minimum Drywall Stud Cross Section

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TABLE 1 Manufacturing Tolerances

Dimension[A]	Item Checked	Drywall Studs, in. (mm)	Drywall Track, in. (mm)
A	length	+ ⅛ (3.18) – ¼ (6.35)	+ 1 (25.40) – ¼ (6.35)
B[B]	web width	+ 1/32 (0.79) – 1/32 (0.79)	+ ⅛ (3.18) – 0 (0)
C	flare overbend	+ 1/16 (1.59) – 1/16 (1.59)	+ 0 (0) – 3/16 (4.76)
D	hole center width	+ ⅛ (3.18) – ⅛ (3.18)	NA
E	hole center length	+ ¼ (6.35) – ¼ (6.35)	NA
F	crown	+ ⅛ (3.18) – ⅛ (3.18)	+ ⅛ (3.18) – ⅛ (3.18)
G	camber	1/32 per ft (0.79) ½ max (12.7)	1/32 per ft (0.79) ½ max (12.7)
H	bow	1/32 per ft (0.79) ½ max (12.7)	1/32 per ft (0.79) ½ max (12.7)
I	twist	1/32 per ft (0.79) ½ max (12.7)	1/32 per ft (0.79) ½ max (12.7)

[A] All measurements shall be taken not less than 1 ft (305 mm) from the end.
[B] Outside dimension for stud; inside for track.

runners (track), they are held by friction. Minimum height of flanges shall be 1 in. (25 mm).

6. Edges

6.1 Members shall be manufactured in such a fashion as to minimize burrs and sharp edges.

7. Cutouts

7.1 Cutouts shall not reduce the performance of the members in the gypsum board construction assembly below the specified performance requirements.

8. Sectional Properties

8.1 The sectional properties of members shall be computed in accordance with AISI S100 (See Tables 2 and 3 and Figs. 1 and 3).

9. Performance Requirements

9.1 *Penetration*—When tested in accordance with Section 10, members shall be capable of pulling the head of the screw below the surface of the gypsum board in less than 2 s without spin out.

9.2 Members that can show certified third party testing in accordance with ICC-ES-AC86 (Approved July 1995—Editorially Revised September 2005) and conform to the limiting height tables in Specification C754 need not meet the minimum thickness limitation set forth in 4.3 or the minimum section properties set forth in 8.1.

10. Penetration Test

10.1 *Significance and Use*—This test method provides a procedure for evaluating the member's ability to pull the head of a screw below the surface of gypsum wallboard. It shall be used to determine compliance with this specification. The degree of performance of this test method with service performance has not been determined.

10.2 *Apparatus shall satisfy the following*:

10.2.1 *Power-Driven Drill Screw Gun*, capable of 4000 rpm (free spindle speed) with a depth-sensitive nose piece, supplied with a screw driving bit to fit the screw used in the test.

10.2.2 *Stop Watch*, capable of being read to the nearest 0.1 s.

10.3 *Materials shall satisfy the following*:

10.3.1 *Gypsum Wallboard*—Specification C1396/C1396M, Type X, 5/8 in. (16 mm) thick.

10.3.2 *Screws*—Specification C1002, Type S, minimum 1 in. (25.4 mm) long.

10.3.3 *Paper Joint Tape*—Specification C475/C475M.

10.4 *Sampling*—One member shall be selected from each bundle or package but not more than ten from any one shipment for testing.

10.5 *Specimen Preparation*:

10.5.1 Each member to be tested shall be cut into test specimens not less than 18 in. (460 mm) long.

10.5.2 For each test, one piece of gypsum wallboard, 6 in. (150 mm) square, shall be cut from not less than 12 in. (300 mm) from the edge or end of the gypsum wallboard.

10.5.3 For each test, four pieces of paper joint tape, 2 in. (50 mm) square shall be cut.

10.6 *Procedure*—

10.6.1 Assemble the member, gypsum wallboard and paper joint tape on a rigid, flat surface. (See Fig. 4 for studs, Fig. 5 for furring channels.)

10.6.2 Prior to performing the test, drive several screws without the paper joint tape to set the depth of the nose piece on the screw gun, allowing the screws to be driven below the surface of the wallboard without breaking the gypsum wallboard face paper.

10.6.3 Drive the screw through the paper joint tape, using the screw gun, while applying a force (dead weight and applied force) of 30 lbf (112.2 N). Drive the screw until the nosepiece of the screw gun has either stopped and seated the screw or the screw spins out. Record if the screw has spun out and if it exceeds 2 s to seat the screw in the gypsum wallboard.

10.7 *Number of Tests and Retests*:

10.7.1 A sample consisting of five specimens of members shall be tested.

10.7.2 If not more than one of the test specimens fails to meet the requirements, the sample has met the requirements.

10.7.3 If two of the five test specimens fail to meet the requirements, two additional test specimens shall be chosen for retesting. If either of the two additional test specimens fail, the sample has failed to meet the requirements of this test.

10.8 *Report*—Report shall indicate the total number of specimens tested and the number of specimens meeting the requirements of this specification.

10.9 *Precision and Bias*—No statement is made about either the precision or bias of this test method since the result merely states whether or not there is conformance to the criteria for success specified in the procedure.

11. Inspection

11.1 Inspection of the members shall be agreed upon between the purchaser and the producer or supplier as part of the purchase agreement.

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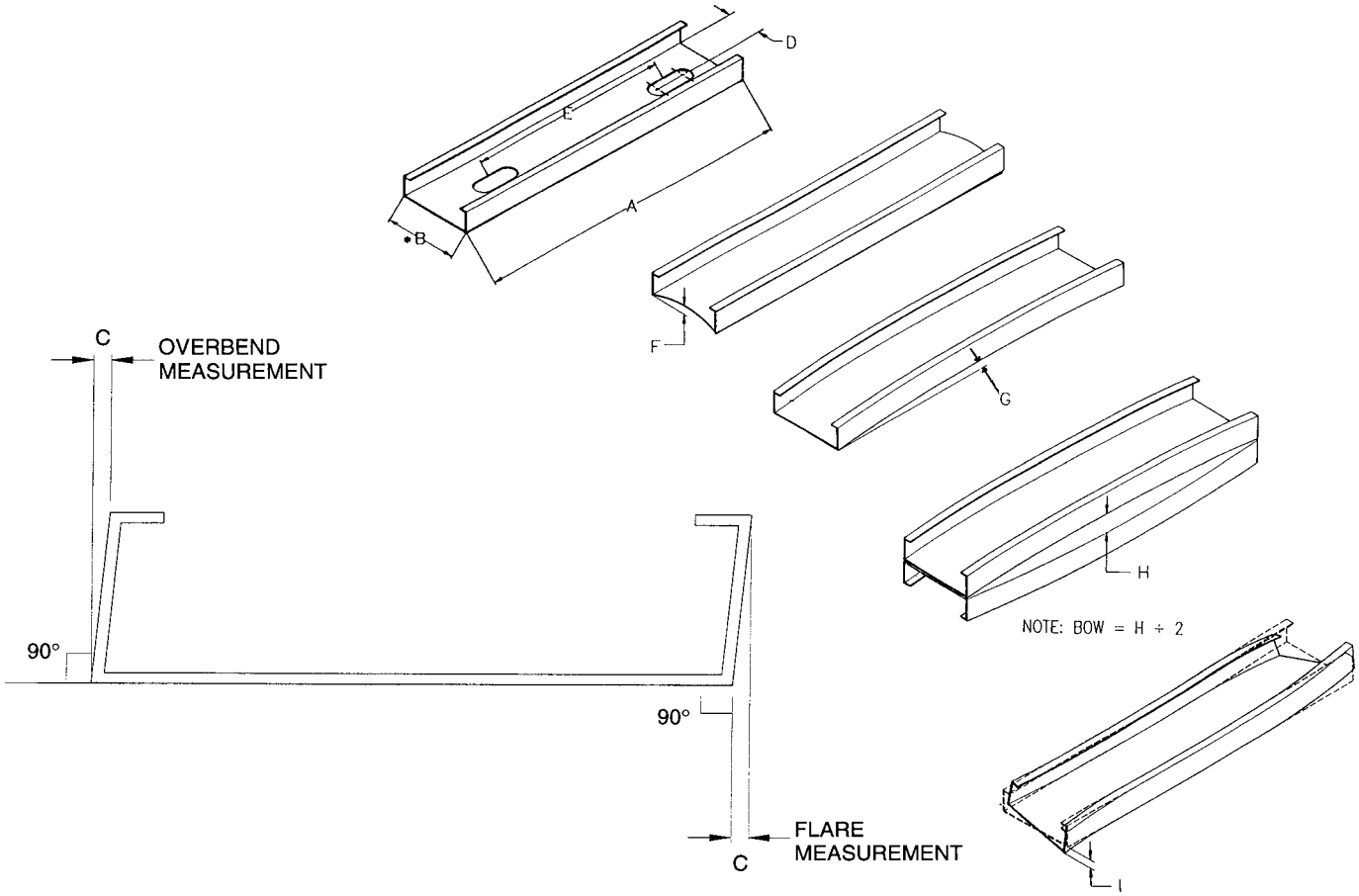

FIG. 2 Manufacturing Tolerances

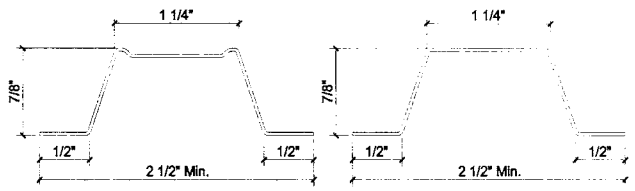

FIG. 3 Hat Furring Channel Cross Section

12. Rejection

12.1 When specified in the purchase agreement, members that fail to conform to the requirements of the specification shall be rejected. Rejection shall be reported to the producer or supplier promptly and in writing. The notice of rejection shall contain a statement documenting how the member has failed to conform to the requirements of this specification and the purchase agreement.

13. Certification

13.1 When specified in the purchase agreement, a producer's or supplier's report shall be furnished at the time of shipment certifying that the product is in compliance with this specification.

14. Marking and Identification

14.1 Groups of like members shall be marked with a label, or a tag attached thereto. Marking shall include the rollformer's identification (name, logo, or initials), length, quantity and rollformer's member designator including member depth, flange size, and minimum steel thickness in mils or inches, exclusive of protective coating.

14.2 In addition to the marking referenced in 14.1, individual members shall have a legible label, stencil, or embossment, at a maximum distance of 96 in. (2440 mm) on center, on the member, with the following minimum information:

14.2.1 The rollformer's identification (that is, name, logo or initials).

14.2.2 The minimum steel thickness, in mils or inches, exclusive of protective coating.

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TABLE 2 Minimum Section Properties for Various Studs

Section Designator[A]	Stud Depth		Design Thickness		Minimum Base Metal Thickness[B]		Gross Area[C]		Effective Properties[C,D]			
									Ix[E]		Mn/Ω[F]	
	in. (mm)		in. (mm)		in.	(mm)	in^2	(mm^2)	in^4	(1000 mm^4)	(in-k)	(N-m)
162S125-18	1.625	41	0.0188	0.478	0.0179	0.454	0.080	52	0.034	14	0.61	69
162S125-30	1.625	41	0.0312	0.792	0.0296	0.752	0.132	85	0.060	25	1.19	134
162S125-33	1.625	41	0.0346	0.879	0.0329	0.835	0.145	94	0.066	27	1.37	155
250S125-18	2.500	64	0.0188	0.478	0.0179	0.454	0.097	63	0.910	38	1.03	116
250S125-30	2.500	64	0.0312	0.792	0.0296	0.752	0.159	102	0.159	66	2.09	236
250S125-33	2.500	64	0.0346	0.879	0.0329	0.835	0.176	114	0.175	73	2.40	272
350S125-18	3.500	89	0.0188	0.478	0.0179	0.454	0.115	74	0.203	84	1.42	161
350S125-30	3.500	89	0.0312	0.792	0.0296	0.752	0.190	123	0.346	144	2.96	335
350S125-33	3.500	89	0.0346	0.879	0.0329	0.835	0.210	135	0.382	159	3.45	390
362S125-18	3.625	92	0.0188	0.478	0.0179	0.454	0.118	76	0.221	92	1.48	167
362S125-30	3.625	92	0.0312	0.792	0.0296	0.752	0.194	125	0.376	157	3.08	348
362S125-33	3.625	92	0.0346	0.879	0.0329	0.835	0.215	138	0.415	173	3.59	406
400S125-18[G]	4.000	102	0.0188	0.478	0.0179	0.454	0.125	81	0.281	117	1.64	185
400S125-30	4.000	102	0.0312	0.792	0.0296	0.752	0.206	133	0.474	197	3.44	388
400S125-33	4.000	102	0.0346	0.879	0.0329	0.835	0.228	147	0.524	218	4.01	453
600S125-30	6.000	152	0.0312	0.792	0.0296	0.752	0.268	173	1.223	513	5.39	609
600S125-33	6.000	152	0.0346	0.879	0.0329	0.835	0.297	192	1.378	574	6.32	714

[A] The section designator defines the cold-formed steel framing member dimensions.
Example: 350S125-18
350 designates the member web depth in 100ths of an inch, 350 = 3.50 in. (88.9 mm)
S designates the type of member, S = Stud
125 designates the member flange width in 100ths of an inch, 125 = 1.25 in. (31.8 mm)
–18 designates the minimum base metal thickness in mils, 18 = 0.0179 in. (0.454 mm)
–30 designates the minimum base metal thickness in mils, 30 = 0.0296 in. (0.752 mm)
–33 designates the minimum base metal thickness in mils, 33 = 0.0329 in. (0.836 mm)
[B] Minimum base metal thickness is 95 % of Design Thickness.
[C] Properties are based on a centerline radius of 3⁄32 in. (2.38 mm), see Fig. 1.
[D] Effective properties are calculated in accordance with AISI S100 and are based on a yield strength, Fy = 33 ksi.
[E] Moment of inertia, Ix, given is for deflection calculations.
[F] Allowable moment is taken as the lowest value based on local or distortional buckling. For distortional buckling, K_Φ= 0 and β = 1.
[G] Where noted, member web height-to-thickness ratio exceeds 200, web stiffeners required at supports.

TABLE 3 Hat Furring Channel Section Properties

Design Thickness		Minimum Base Metal Thickness[A]		Gross Area[B]		Effective Properties[B,C,D]			
						I_x[E]		Mn/Ω[F]	
in	(mm)	in	(mm)	in^2	(mm^2)	in^4 [D]	(mm^4)[D]	in-k	(N-m)
0.0188	0.477	0.0179	0.453	0.0702	45.29	0.0086	3563	0.32	36.16
0.0283	0.719	0.0269	0.683	0.1046	67.48	0.0131	5440	0.54	61.02
0.0312	0.792	0.0296	0.752	0.1152	74.32	0.0143	5953	0.61	68.98
0.0346	0.879	0.0329	0.835	0.1270	81.94	0.0157	6531	0.66	74.58

[A] Minimum base metal thickness is 95 % of Design Thickness.
[B] Properties are based on a centerline radius of 3⁄32 in. (2.38 mm).
[C] Effective properties are given as the minimum value for either positive or negative bending.
[D] Effective properties calculated in accordance with AISI S100 and are based on Fy = 33 ksi (227 MPa).
[E] Moment of inertia given is for deflection calculations.
[F] Allowable moment based on local buckling.

14.2.3 The minimum yield strength in ksi (MPa) if other than 33 ksi (230 MPa).

14.2.4 The minimum protective coating weight, G-XX, if other than as specified in Section 4.

15. Protection

15.1 Material shall be protected during shipment as required. When specified in the purchase order, the members shall be packaged in accordance with the purchaser's instructions.

15.2 Material shall be received and stored in accordance with AISI COSP, paragraph F3.

16. Keywords

16.1 furring channels; grid suspension systems; gypsum board; runners; screws; section properties; spinout; studs

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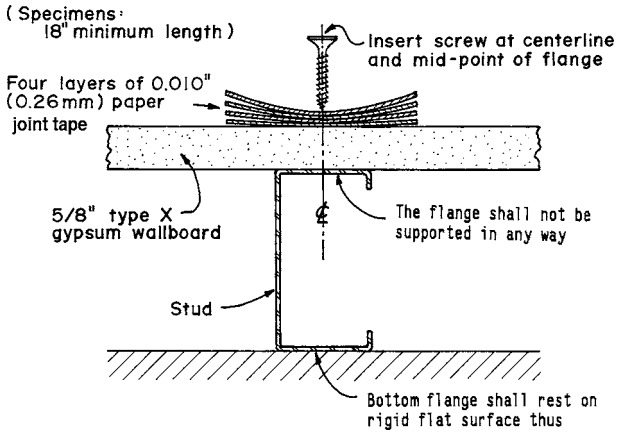
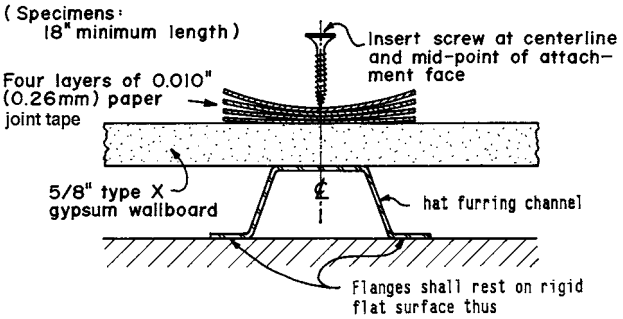


FIG. 4 Studs



NOTE 1—Wallboard specimens shall be taken a minimum of 12 in. (305 mm) from either edge and either end of wallboard panel.

FIG. 5 Hat Furring Channels

APPENDIX

X1. COLOR CODING FOR MEMBERS

X1.1 Color code individual members or bundles of like members in accordance with Table X1.1.

TABLE X1.1 Color Codes for Members

NOTE 1—Minimum base metal thickness is 95 % of the design thickness.

Color	Minimum Base Metal Thickness, mils	Minimal Decimal Equivalent,	
		in.	(mm)
None	18	0.0179	(0.4550
Black	27	0.0269	(0.683)
Pink	30	0.0296	(0.752)
White	33	0.0329	(0.836)

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SUMMARY OF CHANGES

Committee C11 has identified the location of selected changes to this specification since the last issue, C 645 – 09, that may impact the use of this specification. (Approved November 15, 2009)

(*1*) Revised 10.6.3, 10.7, 10.8, Tables 2 and 3 and Referenced Documents.

Committee C11 has identified the location of selected changes to this specification since the last issue, C 645 – 08a, that may impact the use of this specification. (Approved July 15, 2009)

(*1*) Revised Section 10.

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Designation: C 666/C 666M – 03 (Reapproved 2008)

Standard Test Method for Resistance of Concrete to Rapid Freezing and Thawing[1]

This standard is issued under the fixed designation C 666/C 666M; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

This standard has been approved for use by agencies of the Department of Defense.

1. Scope

1.1 This test method covers the determination of the resistance of concrete specimens to rapidly repeated cycles of freezing and thawing in the laboratory by two different procedures: Procedure A, Rapid Freezing and Thawing in Water, and Procedure B, Rapid Freezing in Air and Thawing in Water. Both procedures are intended for use in determining the effects of variations in the properties of concrete on the resistance of the concrete to the freezing-and-thawing cycles specified in the particular procedure. Neither procedure is intended to provide a quantitative measure of the length of service that may be expected from a specific type of concrete.

1.2 The values stated in either inch-pound units or SI units shall be regarded separately as standard. The SI units are shown in brackets. The values stated may not be exact equivalents; therefore each system must be used independently of the other. Combining values from the two units may result in nonconformance.

1.3 All material in this test method not specifically designated as belonging to Procedure A or Procedure B applies to either procedure.

1.4 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

2. Referenced Documents

2.1 *ASTM Standards:* [2]

C 157/C 157M Test Method for Length Change of Hardened Hydraulic-Cement Mortar and Concrete

C 192/C 192M Practice for Making and Curing Concrete Test Specimens in the Laboratory

C 215 Test Method for Fundamental Transverse, Longitudinal, and Torsional Resonant Frequencies of Concrete Specimens

C 233 Test Method for Air-Entraining Admixtures for Concrete

C 295 Guide for Petrographic Examination of Aggregates for Concrete

C 341/C 341M Practice for Length Change of Cast, Drilled, or Sawed Specimens of Hydraulic-Cement Mortar and Concrete

C 490 Practice for Use of Apparatus for the Determination of Length Change of Hardened Cement Paste, Mortar, and Concrete

C 494/C 494M Specification for Chemical Admixtures for Concrete

C 670 Practice for Preparing Precision and Bias Statements for Test Methods for Construction Materials

C 823 Practice for Examination and Sampling of Hardened Concrete in Constructions

3. Significance and Use

3.1 As noted in the scope, the two procedures described in this test method are intended to determine the effects of variations in both properties and conditioning of concrete in the resistance to freezing and thawing cycles specified in the particular procedure. Specific applications include specified use in Specification C 494/C 494M, Test Method C 233, and ranking of coarse aggregates as to their effect on concrete freeze-thaw durability, especially where soundness of the aggregate is questionable.

3.2 It is assumed that the procedures will have no significantly damaging effects on frost-resistant concrete which may be defined as (*1*) any concrete not critically saturated with water (that is, not sufficiently saturated to be damaged by freezing) and (*2*) concrete made with frost-resistant aggregates

[1] This test method is under the jurisdiction of ASTM Committee C09 on Concrete and Concrete Aggregates and is the direct responsibility of Subcommittee C09.67 on Resistance to the Environment.

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[2] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

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and having an adequate air-void system that has achieved appropriate maturity and thus will prevent critical saturation by water under common conditions.

3.3 If as a result of performance tests as described in this test method concrete is found to be relatively unaffected, it can be assumed that it was either not critically saturated, or was made with "sound" aggregates, a proper air-void system, and allowed to mature properly.

3.4 No relationship has been established between the resistance to cycles of freezing and thawing of specimens cut from hardened concrete and specimens prepared in the laboratory.

4. Apparatus

4.1 *Freezing-and-Thawing Apparatus*:

4.1.1 The freezing-and-thawing apparatus shall consist of a suitable chamber or chambers in which the specimens may be subjected to the specified freezing-and-thawing cycle, together with the necessary refrigerating and heating equipment and controls to produce continuously, and automatically, reproducible cycles within the specified temperature requirements. In the event that the equipment does not operate automatically, provision shall be made for either its continuous manual operation on a 24-h a day basis or for the storage of all specimens in a frozen condition when the equipment is not in operation.

4.1.2 The apparatus shall be so arranged that, except for necessary supports, each specimen is: (*1*) for Procedure A, completely surrounded by not less than 1⁄32 in. [1 mm] nor more than 1⁄8 in. [3 mm] of water at all times while it is being subjected to freezing-and-thawing cycles, or (*2*) for Procedure B, completely surrounded by air during the freezing phase of the cycle and by water during the thawing phase. Rigid containers, which have the potential to damage specimens, are not permitted. Length change specimens in vertical containers shall be supported in a manner to avoid damage to the gage studs.

NOTE 1—Experience has indicated that ice or water pressure, during freezing tests, particularly in equipment that uses air rather than a liquid as the heat transfer medium, can cause excessive damage to rigid metal containers, and possibly to the specimens therein. Results of tests during which bulging or other distortion of containers occurs should be interpreted with caution.

4.1.3 The temperature of the heat-exchanging medium shall be uniform within 6 °F [3 °C] throughout the specimen cabinet when measured at any given time, at any point on the surface of any specimen container for Procedure A or on the surface of any specimen for Procedure B, except during the transition between freezing and thawing and *vice versa*.

4.1.3.1 Support each specimen at the bottom of its container in such a way that the temperature of the heat-exchanging medium will not be transmitted directly through the bottom of the container to the full area of the bottom of the specimen, thereby subjecting it to conditions substantially different from the remainder of the specimen.

NOTE 2—A flat spiral of 1⁄8-in. [3-mm] wire placed in the bottom of the container has been found adequate for supporting specimens.

4.1.4 For Procedure B, it is not contemplated that the specimens will be kept in containers. The supports on which the specimens rest shall be such that they are not in contact with the full area of the supported side or end of the specimen, thereby subjecting this area to conditions substantially different from those imposed on the remainder of the specimen.

NOTE 3—The use of relatively open gratings, metal rods, or the edges of metal angles has been found adequate for supporting specimens, provided the heat-exchanging medium can circulate in the direction of the long axis of the rods or angles.

4.2 *Temperature-Measuring Equipment*, consisting of thermometers, resistance thermometers, or thermocouples, capable of measuring the temperature at various points within the specimen chamber and at the centers of control specimens to within 2 °F [1 °C].

4.3 *Dynamic Testing Apparatus*, conforming to the requirements of Test Method C 215.

4.4 *Optional Length Change Test Length Change Comparator*, conforming to the requirements of Specification C 490. When specimens longer than the nominal 11¼ in. [285 mm] length provided for in Specification C 490 are used for freeze-thaw tests, use an appropriate length reference bar, which otherwise meets the Specification C 490 requirements. Dial gage micrometers for use on these longer length change comparators shall meet the gradation interval and accuracy requirements for Specification C 490 for either the inch or millimetre calibration requirements. Prior to the start of measurements on any specimens, fix the comparator at an appropriate length to accommodate all of the specimens to be monitored for length change.

4.5 *Scales*, with a capacity approximately 50 % greater than the mass of the specimens and accurate to at least 0.01 lb [0.5 g] within the range of ±10 % of the specimen mass will be satisfactory.

4.6 *Tempering Tank*, with suitable provisions for maintaining the temperature of the test specimens in water, such that when removed from the tank and tested for fundamental transverse frequency and length change, the specimens will be maintained within -2 °F and +4 °F (-1 °C and +2 °C) of the target thaw temperature for specimens in the actual freezing-and-thawing cycle and equipment being used. The use of the specimen chamber in the freezing-and-thawing apparatus by stopping the apparatus at the end of the thawing cycle and holding the specimens in it shall be considered as meeting this requirement, provided the specimens are tested for fundamental transverse frequency within the above temperature range. It is required that the same target specimen thaw temperature be used throughout the testing of an individual specimen since a change in specimen temperature at the time of length measurement can affect the length of the specimen significantly.

5. Freezing-and-Thawing Cycle

5.1 Base conformity with the requirements for the freezing-and-thawing cycle on temperature measurements of control specimens of similar concrete to the specimens under test in which suitable temperature-measuring devices have been imbedded. Change the position of these control specimens frequently in such a way as to indicate the extremes of temperature variation at different locations in the specimen cabinet.

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5.2 The nominal freezing-and-thawing cycle for both procedures of this test method shall consist of alternately lowering the temperature of the specimens from 40 to 0 °F [4 to -18 °C] and raising it from 0 to 40 °F [-18 to 4 °C] in not less than 2 nor more than 5 h. For Procedure A, not less than 25 % of the time shall be used for thawing, and for Procedure B, not less than 20 % of the time shall be used for thawing (Note 4). At the end of the cooling period the temperature at the centers of the specimens shall be 0 ± 3 °F [-18 ± 2 °C], and at the end of the heating period the temperature shall be 40 ± 3 °F [4 ± 2 °C], with no specimen at any time reaching a temperature lower than -3 °F [-19 °C] nor higher than 43 °F [6 °C]. The time required for the temperature at the center of any single specimen to be reduced from 37 to 3 °F [3 to -16 °C] shall be not less than one half of the length of the cooling period, and the time required for the temperature at the center of any single specimen to be raised from 3 to 37 °F [-16 to 3 °C] shall be not less than one half of the length of the heating period. For specimens to be compared with each other, the time required to change the temperature at the centers of any specimens from 35 to 10 °F [2 to -12 °C] shall not differ by more than one sixth of the length of the cooling period from the time required for any specimen and the time required to change the temperature at the centers of any specimens from 10 to 35 °F [-12 to 2 °C] shall not differ by more than one third of the length of the heating period from the time required for any specimen.

NOTE 4—In most cases, uniform temperature and time conditions can be controlled most conveniently by maintaining a capacity load of specimens in the equipment at all times. In the event that a capacity load of test specimens is not available, dummy specimens can be used to fill empty spaces. This procedure also assists greatly in maintaining uniform fluid level conditions in the specimen and solution tanks.

The testing of concrete specimens composed of widely varying materials or with widely varying thermal properties, in the same equipment at the same time, may not permit adherence to the time-temperature requirements for all specimens. It is advisable that such specimens be tested at different times and that appropriate adjustments be made to the equipment.

5.3 The difference between the temperature at the center of a specimen and the temperature at its surface shall at no time exceed 50 °F [28 °C].

5.4 The period of transition between the freezing-and-thawing phases of the cycle shall not exceed 10 min, except when specimens are being tested in accordance with 8.3.

6. Sampling

6.1 Constituent materials for concrete specimens made in the laboratory shall be sampled using applicable standard methods.

6.2 Samples cut from hardened concrete are to be obtained in accordance with Practice C 823.

7. Test Specimens

7.1 The specimens for use in this test method shall be prisms or cylinders made and cured in accordance with the applicable requirements of Practice C 192/C 192M and Specification C 490.

7.2 Specimens used shall not be less than 3 in. [75 mm] nor more than 5 in. [125 mm] in width, depth, or diameter, and not less than 11 in. [275 mm] nor more than 16 in. [405 mm] in length.

7.3 Test specimens may also be cores or prisms cut from hardened concrete. If so, the specimens should not be allowed to dry to a moisture condition below that of the structure from which taken. This may be accomplished by wrapping in plastic or by other suitable means. The specimens so obtained shall be furnished with gage studs in accordance with Test Method C 341/C 341M.

7.4 For this test the specimens shall be stored in saturated lime water from the time of their removal from the molds until the time freezing-and-thawing tests are started. All specimens to be compared with each other initially shall be of the same nominal dimensions.

8. Procedure

8.1 Molded beam specimens shall be cured for 14 days prior to testing unless otherwise specified. Beam specimens sawed from hardened concrete shall be moisture-conditioned by immersing in saturated lime water at 73.4 ± 3 °F [23.0 ± 2.0 °C] for 48 h prior to testing unless otherwise specified.

8.2 Immediately after the specified curing or conditioning period, bring the specimen to a temperature within -2 °F and +4 °F [-1 °C and +2 °C] of the target thaw temperature that will be used in the freeze-thaw cycle and test for fundamental transverse frequency, determine the mass and average length and cross section dimensions of the concrete specimen within the tolerance required in Test Method C 215, and determine the initial length comparator reading (optional) for the specimen with the length change comparator. Protect the specimens against loss of moisture between the time of removal from curing and the start of the freezing-and-thawing cycles.

8.3 Start freezing-and-thawing tests by placing the specimens in the thawing water at the beginning of the thawing phase of the cycle. Remove the specimens from the apparatus, in a thawed condition, at intervals not exceeding 36 cycles of exposure to the freezing-and-thawing cycles, test for fundamental transverse frequency and measure length change (optional) with the specimens within the temperature range specified for the tempering tank in 4.6, determine the mass of each specimen, and return them to the apparatus. To ensure that the specimens are completely thawed and at the specified temperature place them in the tempering tank or hold them at the end of the thaw cycle in the freezing-and-thawing apparatus for a sufficient time for this condition to be attained throughout each specimen to be tested. Protect the specimens against loss of moisture while out of the apparatus and turn them end-for-end when returned. For Procedure A, rinse out the container and add clean water. Return the specimens either to random positions in the apparatus or to positions according to some predetermined rotation scheme that will ensure that each specimen that continues under test for any length of time is subjected to conditions in all parts of the freezing apparatus. Continue each specimen in the test until it has been subjected to 300 cycles or until its relative dynamic modulus of elasticity reaches 60 % of the initial modulus, whichever occurs first, unless other limits are specified (Note 5). For the optional

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length change test, 0.10 % expansion may be used as the end of test. Whenever a specimen is removed because of failure, replace it for the remainder of the test by a dummy specimen. Each time the specimen is tested for fundamental frequency (Note 6) and length change, make a note of its visual appearance and make special comment on any defects that develop (Note 7). When it is anticipated that specimens may deteriorate rapidly, they should be tested for fundamental transverse frequency and length change (optional) at intervals not exceeding 10 cycles when initially subjected to freezing and thawing.

NOTE 5—It is not recommended that specimens be continued in the test after their relative dynamic modulus of elasticity has fallen below 50 %.

NOTE 6—It is recommended that the fundamental longitudinal frequency be determined initially and as a check whenever a question exists concerning the accuracy of determination of fundamental transverse frequency, and that the fundamental torsional frequency be determined initially and periodically as a check on the value of Poisson's ratio.

NOTE 7—In some applications, such as airfield pavements and other slabs, popouts may be defects that are a concern. A popout is characterized by the breaking away of a small portion of the concrete surface due to internal pressure, thereby leaving a shallow and typically conical spall in the surface of the concrete through the aggregate particle. Popouts may be observed as defects in the test specimens. Where popouts are a concern, the number and general description should be reported as a special comment. The aggregates causing the popout may be identified by petrographic examination as in Practice C 295.

8.4 When the sequence of freezing-and-thawing cycles must be interrupted store the specimens in a frozen condition.

NOTE 8—If, due to equipment breakdown or for other reasons, it becomes necessary to interrupt the cycles for a protracted period, store the specimens in a frozen condition in such a way as to prevent loss of moisture. For Procedure A, maintain the specimens in the containers and surround them by ice, if possible. If it is not possible to store the specimens in their containers, wrap and seal them, in as wet a condition as possible, in moisture-proof material to prevent dehydration and store in a refrigerator or cold room maintained at 0 ± 3 °F [-18 ± 2 °C]. Follow the latter procedure when Procedure B is being used. In general, for specimens to remain in a thawed condition for more than two cycles is undesirable, but a longer period may be permissible if this occurs only once or twice during a complete test.

9. Calculation

9.1 *Relative Dynamic Modulus of Elasticity*—Calculate the numerical values of relative dynamic modulus of elasticity as follows:

$$P_c = (n_1^2/n^2) \times 100 \quad (1)$$

where:

P_c = relative dynamic modulus of elasticity, after c cycles of freezing and thawing, percent,
n = fundamental transverse frequency at 0 cycles of freezing and thawing, and
n_1 = fundamental transverse frequency after c cycles of freezing and thawing.

NOTE 9—This calculation of relative dynamic modulus of elasticity is based on the assumption that the mass and dimensions of the specimen remain constant throughout the test. This assumption is not true in many cases due to disintegration of the specimen. However, if the test is to be used to make comparisons between the relative dynamic moduli of different specimens or of different concrete formulations, P_c as defined is adequate for the purpose.

9.2 *Durability Factor*—Calculate the durability factor as follows:

$$DF = PN/M \quad (2)$$

where:

DF = durability factor of the test specimen,
P = relative dynamic modulus of elasticity at N cycles, %,
N = number of cycles at which P reaches the specified minimum value for discontinuing the test or the specified number of cycles at which the exposure is to be terminated, whichever is less, and
M = specified number of cycles at which the exposure is to be terminated.

9.3 *Length Change in Percent (optional)*—Calculate the length change as follows:

$$L_c = \frac{(l_2 - l_1)}{L_g} \times 100 \quad (3)$$

where:

L_c = length change of the test specimen after C cycles of freezing and thawing, %,
l_1 = length comparator reading at 0 cycles,
l_2 = length comparator reading after C cycles, and
L_g = the effective gage length between the innermost ends of the gage studs as shown in the mold diagram in Specification C 490.

10. Report

10.1 Report the following data such as are pertinent to the variables or combination of variables studied in the tests:

10.2 *Properties of Concrete Mixture*:

10.2.1 Type and proportions of cement, fine aggregate, and coarse aggregate, including maximum size and grading (or designated grading indices), and ratio of net water content to cement,

10.2.2 Kind and proportion of any addition or admixture used,

10.2.3 Air content of fresh concrete,

10.2.4 Density of fresh concrete,

10.2.5 Consistency of fresh concrete,

10.2.6 Air content of the hardened concrete, when available,

10.2.7 Indicate if the test specimens are cut from hardened concrete, and if so, state the size, shape, orientation of the specimens in the structure, and any other pertinent information available, and

10.2.8 Curing period.

10.3 *Mixing, Molding, and Curing Procedures*—Report any departures from the standard procedures for mixing, molding, and curing as prescribed in Section 7.

10.4 *Procedure*—Report which of the two procedures was used.

10.5 *Characteristics of Test Specimens*:

10.5.1 Dimensions of specimens at 0 cycles of freezing and thawing,

10.5.2 Mass of specimens at 0 cycles of freezing and thawing,

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10.5.3 Nominal gage length between embedded ends of gage studs, and

10.5.4 Any defects in each specimen present at 0 cycles of freezing and thawing.

10.6 *Results*:

10.6.1 Values for the durability factor of each specimen, calculated to the nearest whole number, and for the average durability factor for each group of similar specimens, also calculated to the nearest whole number, and the specified values for minimum relative dynamic modulus and maximum number of cycles (Note 9),

10.6.2 Values for the percent length change of each specimen and for the average percent length change for each group of similar specimens (Note 10),

10.6.3 Values of mass loss or gain for each specimen and average values for each group of similar specimens, and

10.6.4 Any defects in each specimen which develop during testing, and the number of cycles at which such defects were noted.

NOTE 10—It is recommended that the results of the test on each specimen, and the average of the results on each group of similar specimens, be plotted as curves showing the value of relative modulus of elasticity or percent length change against time expressed as the number of cycles of freezing and thawing.

11. Precision and Bias

11.1 The data used to develop the precision statements were obtained using apparatus and measurements in inch-pound units.

11.2 *Dynamic Modulus*:

11.2.1 *Within-Laboratory Precision (Single Beams)*—Criteria for judging the acceptability of durability factor results obtained by the two procedures in the same laboratory on concrete specimens made from the same batch of concrete or from two batches made with the same materials are given in Table 1. Precision data for length change (optional) are not available at this time.

TABLE 1 Within-Laboratory Durability Factor Precision for Single Beams

NOTE—The values given in Columns 2 and 4 are the standard deviations that have been found to be appropriate for Procedures A and B, respectively, for tests for which the average durability factor is in the corresponding range given in Column 1. The values given in Columns 3 and 5 are the corresponding limits that should not be exceeded by the difference between the results of two single test beams.

Range of Average Durability Factor	Procedure A		Procedure B	
	Standard Deviation[A]	Acceptable Range of Two Results[A]	Standard Deviation[A]	Acceptable Range of Two Results[A]
0 to 5	0.8	2.2	1.1	3.0
5 to 10	1.5	4.4	4.0	11.4
10 to 20	5.9	16.7	8.1	22.9
20 to 30	8.4	23.6	10.5	29.8
30 to 50	12.7	35.9	15.4	43.5
50 to 70	15.3	43.2	20.1	56.9
70 to 80	11.6	32.7	17.1	48.3
80 to 90	5.7	16.0	8.8	24.9
90 to 95	2.1	6.0	3.9	11.0
Over 95	1.1	3.1	2.0	5.7

[A] These numbers represent the (1S) and (D2S) limits as described in Practice C 670.

NOTE 11—The between-batch precision of durability factors has been found to be the same as the within-batch precision. Thus the limits given in this precision statement apply to specimens from different batches made with the same materials and mix design and having the same air content as well as to specimens from the same batch.

NOTE 12—The precision of this method for both procedures has been found to depend primarily on the average durability factor and not on the maximum N or minimum P specified for terminating the test nor on the size of the beams within limits. The data on which these precision statements are based cover maximum N's from 100 to 300 cycles, and minimum P's from 50 to 70 percent of E_0. The indexes of precision are thus valid at least over these ranges.

11.2.1.1 The different specimen sizes represented by the data include the following: 3 by 3 by 16-in [75 by 75 by 405-mm]; 3 by 3 by 16¼-in. [75 by 75 by 420-mm]; 3 by 4 by 16-in. [75 by 100 by 405-mm]; 3½ by 4½ by 16-in. [90 by 115 by 405-mm]; 3 by 3 by 11-in. [75 by 75 by 280-mm]; and 3½ by 4 by 16-in. [90 by 100 by 405-mm]; and 4 by 3 by 16-in. [100 by 75 by 405-mm]. The first dimension given represents the direction in which the specimens were vibrated in the test for fundamental transverse frequency. The most commonly used size was 3 by 4 by 16-in. [75 by 100 by 405-mm].

11.2.2 *Within-Laboratory Precision (Averages of Two or More Beams)*—Specifications sometimes call for comparisons between averages of two or more beams. Tables 2 and 3 give appropriate standard deviations and acceptable ranges for the two procedures for two averages of the number of test beams shown.

11.2.3 *Multilaboratory Precision*—No data are available for evaluation of multilaboratory precision. It is believed that a multilaboratory statement of precision is not appropriate because of the limited possibility that two or more laboratories will be performing freezing-and-thawing tests on the same concretes.

11.3 *Length Change*:

11.3.1 *Within-Laboratory Precision*—The single operator coefficient of variation has been determined to be 29.9 %. Therefore, results of two properly conducted tests by the same operator on samples from the same batch of concrete, using the same freeze-thaw apparatus and the same length comparator, should not differ from each other by more than 84.6 % of the average.

11.3.2 *Multilaboratory Precision*—No data are available for multilaboratory precision. It is believed that a multilaboratory statement of precision is not appropriate because of the limited possibility that two or more laboratories will be performing freezing-and-thawing tests on the same concretes.

11.4 *Bias*—This test method has no bias because the values determined can be defined only in terms of this test method.[3]

12. Keywords

12.1 accelerated testing; concrete-weathering tests; conditioning; freezing and thawing; resistance-frost

[3] Supporting data for the precision statement for length change have been filed at ASTM International Headquarters and may be obtained by requesting Research Report RR:C09–1017.

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TABLE 2 Within-Laboratory Durability Factor Precision for Averages of Two or More Beams—Procedure A

Range of Average Durability Factor	Number of Beams Averaged									
	2		3		4		5		6	
	Standard Deviation[A]	Acceptable Range[A]	Standard Deviation[A]	Acceptable Range[A]	Standard Deviation[A]	Acceptable Range[A]	Standard Deviation[A]	Acceptable Range[A]	Standard Deviation[A]	Acceptable Range[A]
0 to 5	0.6	1.6	0.5	1.3	0.4	1.1	0.4	1.0	0.3	0.9
5 to 10	1.1	3.1	0.9	2.5	0.8	2.2	0.7	2.0	0.6	1.8
10 to 20	4.2	11.8	3.4	9.7	3.0	8.4	2.7	7.5	2.4	6.8
20 to 30	5.9	16.7	4.8	13.7	4.2	11.8	3.7	10.6	3.4	9.7
30 to 50	9.0	25.4	7.4	20.8	6.4	18.0	5.7	16.1	5.2	14.7
50 to 70	10.8	30.6	8.8	25.0	7.6	21.6	6.8	19.3	6.2	17.6
70 to 80	8.2	23.1	6.7	18.9	5.8	16.4	5.2	14.6	4.7	13.4
80 to 90	4.0	11.3	3.3	9.2	2.8	8.0	2.5	7.2	2.3	6.5
90 to 95	1.5	4.2	1.2	3.5	1.1	3.0	0.9	2.7	0.9	2.4
Above 95	0.8	2.2	0.6	1.8	0.5	1.5	0.5	1.4	0.4	1.3

[A] These numbers represent the (1S) and (D2S) limits as described in Practice C 670.

TABLE 3 Within-Laboratory Durability Factor Precision for Averages of Two or More Beams—Procedure B

Range of Average Durability Factor	Number of Beams Averaged									
	2		3		4		5		6	
	Standard Deviation[A]	Acceptable Range[A]	Standard Deviation[A]	Acceptable Range[A]	Standard Deviation[A]	Acceptable Range[A]	Standard Deviation[A]	Acceptable Range[A]	Standard Deviation[A]	Acceptable Range[A]
0 to 5	0.8	2.1	0.6	1.8	0.5	1.5	0.5	1.4	0.4	1.2
5 to 10	2.9	8.1	2.3	6.6	2.0	5.7	1.8	5.1	1.7	4.7
10 to 20	5.7	16.2	4.7	13.2	4.1	11.5	3.6	10.3	3.3	7.4
20 to 30	7.4	21.0	6.1	17.2	5.3	14.9	4.7	13.3	4.3	12.2
30 to 50	10.9	30.8	8.9	25.1	7.7	21.8	6.9	19.5	6.3	17.8
50 to 70	14.2	40.2	11.6	32.9	10.1	28.5	9.0	25.5	8.2	23.2
70 to 80	12.1	34.2	9.9	27.9	8.5	24.2	7.6	11.6	7.0	19.7
80 to 90	6.2	17.6	5.0	14.4	4.4	12.5	3.9	11.1	3.6	10.2
90 to 95	2.8	7.8	2.3	6.4	2.0	5.5	1.7	4.9	1.6	4.5
Above 95	1.4	4.1	1.2	3.3	1.0	2.9	0.9	2.6	0.8	2.3

[A] These numbers represent the (1S) and (D2S) limits as described in Practice C 670.

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Designation: C 670 – 03

Standard Practice for Preparing Precision and Bias Statements for Test Methods for Construction Materials[1]

This standard is issued under the fixed designation C 670; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

This standard has been approved for use by agencies of the Department of Defense.

1. Scope *

1.1 This practice supplements Practice E 177, in order to provide guidance in preparing precision and bias statements for ASTM test methods pertaining to certain construction materials (Note 1). Recommended forms for precision and bias statements are included. A discussion of the purpose and significance of these statements for the users of those test methods is also provided.

NOTE 1—Although under the jurisdiction of Committee C-9, this practice was developed jointly by Committees C-1, D-4, and C-9, and has been endorsed by all three committees. It has subsequently been adopted for use by Committee D-18.

2. Referenced Documents

2.1 *ASTM Standards:*

C 109/C 109M Test Method for Compressive Strength of Hydraulic Cement Mortars (Using 2-in. or [50-mm] Cube Specimens)[2]

C 802 Practice for Conducting an Interlaboratory Test Program to Determine the Precision of Test Methods for Construction Materials[3]

E 177 Practice for Use of the Terms Precision and Bias in ASTM Test Methods[4]

3. Terminology

3.1 *Definitions of Terms Specific to This Standard:*

3.2 *one-sigma limit (1s)*—the fundamental statistic underlying all indexes of precision is the standard deviation of the population of measurements characteristic of the test method when the latter is applied under specifically prescribed conditions (a given system of causes). The terminology "one-sigma limit" (abbreviated (1s)) is used in Practice E 177 to denote the estimate of the standard deviation or sigma that is characteristic of the total statistical population. The one-sigma limit is an indication of the variability (as measured by the deviations above and below the average) of a large group of individual test results obtained under similar conditions.

3.2.1 *single-operator one-sigma limit*—the one-sigma limit for single-operator precision is a quantitative estimate of the variability of a large group of individual test results when the tests have been made on the same material by a single operator using the same apparatus in the same laboratory over a relatively short period of time. This statistic is the basic one used to calculate the single-operator index of precision given in the precision statement for guidance of the operator.

3.2.2 *multilaboratory one-sigma limit*—the one-sigma limit for multilaboratory precision is a quantitative estimate of the variability of a large group of individual test results when each test has been made in a different laboratory and every effort has been made to make the test portions of the material as nearly identical as possible. Under normal circumstances the estimates of one-sigma limit for multilaboratory precision are larger than those for single-operator precision, because different operators and different apparatus are being used in different laboratories for which the environment may be different.

3.2.3 *one-sigma limit in percent (1s%)*—in some cases the coefficient of variation is used in place of the standard deviation as the fundamental statistic. This statistic is termed the "one-sigma limit in percent" (abbreviated (1s%)) and is the appropriate standard deviation (1s) divided by the average of the measurements and expressed as a percent. When it is appropriate to use (1s%) in place of (1s) is discussed in Section 6.

3.3 *Acceptable Range of Results*:

3.3.1 *acceptable difference between two results*—the "difference two-sigma limit (d2s)" or "difference two-sigma limit in percent (d2s%)," as defined in Practice E 177, has been selected as the appropriate index of precision in most precision statements. These indexes indicate a maximum acceptable difference between two results obtained on test portions of the same material under the applicable system of causes described in 4.1.1 and 4.1.2 (or whatever other system of causes is appropriate). The (d2s) index is the difference between two individual test results that would be equaled or exceeded in the

[1] This practice is under the jurisdiction of ASTM Committee C09 on Concrete and Concrete Aggregates and is the direct responsibility of Subcommittee C09.94 on Evaluation of Data.

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[2] *Annual Book of ASTM Standards*, Vol 04.01.

[3] *Annual Book of ASTM Standards*, Vol 04.02.

[4] *Annual Book of ASTM Standards*, Vol 14.02.

***A Summary of Changes section appears at the end of this standard.**

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long run in only 1 case in 20 in the normal and correct operation of the method. The (d2s%) index is the difference between two individual test results expressed as a percent of their average that meets the same requirements. These indexes are calculated by multiplying the appropriate standard deviation (1s) or coefficient of variation (1s%) by the factor $2\sqrt{2}$ (equal to 2.83).

3.3.2 *acceptable range of more than two results*—in cases where the test method calls for more than two test results to be obtained, the range (difference between highest and lowest) of the group of test results must be compared to a maximum acceptable range for the applicable system of causes and number of test results. The range for different numbers of test results including two that would be equaled or exceeded in only 1 case in 20 is obtained by multiplying the appropriate standard deviation (1s) or coefficient of variation (1s%) by the appropriate factor from the second column of Table 1 (Note 2):

NOTE 2—It is important to note that when more than two test results are obtained, an index of precision for the difference between two results can not be used as a criterion for judging acceptability of the range of the group or for other pairs of results selected from the group.

3.3.3 *variations for single operators*—the system of causes designated for obtaining the quantitative guide to acceptable performance by an operator as stated in 4.1.1 leads to single-operator precision, using the system of modifiers given in Practice E 177 (Note 3). When two results by the same operator differ by more than (d2s) or (d2s%) or the range of more than two results exceeds that obtained by the method described in 3.2.2 there is a significantly large probability that an error has occurred and retests should be made as directed in Note 4.

NOTE 3—Single-operator precision is often referred to as "repeatability," and multilaboratory precision is often referred to as "reproducibility."

NOTE 4—It is beyond the scope of this practice to describe in detail what action should be taken in all cases when results occur that differ by more than the (d2s) limits or by more than the maximum allowable range. Such an occurrence is a warning that there may have been some error in the test procedure, or some departure from the prescribed conditions of the test on which the limits appearing in the test method are based; for example, faulty or misadjusted apparatus, improper conditions in the laboratory, etc. In judging whether or not results are in error, information other than the difference between two test results is needed. Often a review of the circumstances under which the test results in question were obtained will reveal some reason for a departure. In this case the data should be discarded and new test results obtained and evaluated separately. If no physical reason for a departure is found, retests should still be made, but the original tests should not be completely ignored. If the second set of results also differs by more than the applicable limit, the evidence is very strong that something is wrong or that a real difference exists between the two samples tested. If the second set produces a result within the limit, it may be taken as a valid test, but the operator or laboratory may then be suspected of producing erratic results, and a closer examination of the procedures would be in order. If knowledge about the test method in question indicates that certain actions may be appropriate in cases where deviant results occur, then such information should be included in the test method, but details of how this should be done will depend upon the particular test method.

TABLE 1 Maximum Acceptable Range

Number of Test Results	Multiplier of (1s) or (1s%) for Maximum Acceptable Range[A]
2	2.8
3	3.3
4	3.6
5	3.9
6	4.0
7	4.2
8	4.3
9	4.4
10	4.5

[A] Values were obtained from Table A7 of "Order Statistics and Their Use in Testing and Estimation," Vol 1, by Leon Harter, Aerospace Research Laboratories, United States Air Force.

3.3.4 *variations between laboratories*—the system of causes designated for obtaining the quantitative guide for acceptance of results by different laboratories as given in 4.1.2 is multilaboratory precision, using the system of modifiers given in Practice E 177 (Note 3). When results differ by more than (d2s) there is a significantly large probability that one or both laboratories are in error or that a difference exists in the portions of material being used for the tests. In such cases, retests should be made. When possible, newly drawn test samples should be used for such retests as directed in Note 4.

3.4 *Number of Tests*:

3.4.1 *single test results*—the number of tests run must be taken into account when evaluating testing variations. Usually, the statistics used in evaluating precision and the indexes of precision based on them are based on the population distribution of single test results. When this is the case, the index of precision may be used in comparing single tests results only, not averages of two or more tests.

3.4.2 *test results based on averages*—if the precision statement is based on test results that are averages of two or more measurements, then the number of measurements averaged must be stated, and in using the index of precision, averages of exactly that number of measurements must be used. In some cases a test result is defined in the method as the average of two or more individual measurements. In such cases the index of precision for a test result applies to a test result as so defined, although indexes of precision for ranges of individual measurements within a laboratory may also be included as described in 3.3.3.

3.4.3 *precision of individual measurements averaged to obtain a test result*—when two or more measurements are averaged to obtain a test result, the range of the individual measurements may be examined to determine whether the latter meet the criterion of being valid individual measurements under the conditions of the test method. The maximum acceptable range for individual measurements is obtained by multiplying the appropriate standard deviation (1s) or, coefficient of variation (1s%) obtained from averages by the appropriate factor from the second column of Table 2 (Note 5). The maximum acceptable range for individual measurements obtained by this method may be included in the precision statement as an index of precision for individual measurements in the same laboratory as described in Example 8.

NOTE 5—This procedure is only valid if the individual measurements are subject to the same sources of variation as the test result. For example, the single-operator precision of Test Method C 109/C 109M mortar cubes is calculated from test results that include a contribution from variation among batches of mortar. Variation among individual cubes from a single batch does not contain this component of variation. Therefore, differences

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TABLE 2 Maximum Acceptable Range of Individual Measurements

Number of Measurements Averaged to Obtain a Test Result	Multiplier of (1s) or (1s%) for Averages to Obtain Maximum Acceptable Range of Individual Measurements[A]
2	3.9
3	5.7
4	7.3
5	8.6
6	9.9
7	11.0
8	12.1
9	13.2
10	14.1

[A] Values were calculated from Table 1.

among individual cubes from a single batch cannot be inferred from the single-operator standard deviation given in Test Method C 109/C 109M and the values in Table 2.

3.4.4 *multilaboratory precision expressed as a maximum allowable difference between two averages*—when the test method calls for the reporting of more than one test result, multi-laboratory precision may be expressed as a maximum allowable difference between averages of such groups, one from each laboratory, and both the (d2s) or (d2s%) limit for individual results and this maximum allowable difference of two averages may be included in the multilaboratory precision statement (Note 6). The maximum allowable difference for averages of a given number of test results, *n*, is obtained by dividing the appropriate (d2s) or (d2s%) limit by the square root of *n*.

NOTE 6—Note that this is not the same as the situation where a test result is defined as the average of two or more individual measurements. A given test method may include both features. It is important to bear in mind, however, that when more than one result is obtained in one or both laboratories, the (d2s) or (d2s%) limit may not be used as a criterion for judging the differences between selected pairs of results from the two laboratories.

3.5 *field versus laboratory tests*—precision indexes for ASTM test methods are normally based on results obtained in laboratories by competent operators using well-controlled equipment on test portions of materials for which precautions have been taken to ensure that they are as nearly alike as possible. Such precautions and the same level of competence may not be practicable for the usual quality control or routine acceptance testing. Therefore, the normal testing variation among laboratories engaged in quality control and acceptance testing of commercial materials may be larger than indicated by the relationship derived from the one-sigma limit for multilaboratory precision. In this case it is recommended that studies be made to determine the one-sigma limit for tests made under field conditions and realistic adjustments in specification tolerances be made accordingly.

4. General Concepts

4.1 A precision statement meeting the requirements of this practice normally contains two main elements described as follows:

4.1.1 *Single-Operator Precision*—A measure of the greatest difference between two results that would be considered acceptable when properly conducted repetitive determinations are made on the same material by a competent operator.

4.1.2 *Multilaboratory Precision*—A measure of the greatest difference between two test results that would be considered acceptable when properly conducted determinations are made by two different operators in different laboratories on portions of a material that are intended to be identical, or as nearly identical as possible.

4.2 *Other Measures of Precision*—The two elements described in 4.1.1 and 4.1.2 involve the main systems of causes of interest to users of test methods involving construction materials. In cases where other systems of causes apply, the appropriate statistics for those systems should be used and the appropriate combination of modifiers given in Practice E 177 should be used to describe those statistics.

4.3 *Use of Indexes of Precision in Specifications*—The indexes of precision described in this practice are to be used as guides to determine (with a prescribed degree of certainty) whether a given series of results can be considered as valid tests under the conditions assumed in the test method. Comparisons of test results with specification limits should be made only after there is reasonable assurance that the determinations are adequate. Writers of specifications have the responsibility of recognizing the variability of results characteristic of a given test method in setting specification limits, but indexes of precision of the test method should never be added to specification limits by the users of those specifications for the purpose of judging acceptance or rejection of materials.

4.4 *Use of Indexes of Precision for Qualifying an Operator*—Indexes of single-operator precision are sometimes used as a basis for qualifying an operator. The assumption is that results that do not differ by more than the stated index are indicative of proper performance of the test. However, this assumption is not necessarily correct. Uniform misunderstanding of instructions or maladjustments of equipment may produce consistent but erroneous test results. Thus, tests conducted for the purpose of qualifying an operator should be made on materials for which the measured characteristic is known, whenever possible, so that accuracy as well as precision can be evaluated. (See Practice E 177 for a discussion of the terms precision and accuracy.)

5. Basis for Precision Statement

5.1 In order to be valid the indexes of precision to be included in the precision statement as guides for the operator must be based on estimates of the precision of the test method obtained from a statistically designed interlaboratory series of tests. This series of tests must involve a sufficient number of laboratories, materials, and replicate measurements so that the results obtained provide reliable estimates of the true precision characteristic of the test method (Note 7). The procedures described in this practice are based on the assumption that the proper estimates of precision have already been obtained. Practice C 802 is a companion document to this one and describes techniques for conducting an interlaboratory study to obtain the needed estimates of precision. In the case where an approved standard test method is revised, the subcommittee having responsibility over the test method should determine whether the change(s) affect the validity of the existing

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precision statement in the standard; and if so, should also revise the precision statement accordingly.

NOTE 7—The requirement of "reliable estimates of the true precision" presupposes an estimate obtained from a properly designed and executed interlaboratory series of tests involving at least 30 degrees of freedom for single-operator precision and at least 10 laboratories.

5.2 For many of the tests under the jurisdiction of Committees C-1, C-9, D-4 and D-18, there is an extensive backlog of interlaboratory test data in the reference sample program of the Cement and Concrete Reference Laboratory (CCRL) and the AASHTO Materials Reference Laboratory (AMRL). Where such data are available, a precision statement can be prepared for each test method based upon a much larger population of data than can normally be assembled in a round-robin program by merely carrying out the mathematical analysis like that illustrated in Appendix X1.

5.3 The Form and Style for ASTM Standards requires that data and details of the experiments used to determine precision and bias be filed as a research report at ASTM International Headquarters.

6. Form of Precision Statement

6.1 *Preface Information*—The Form and Style for ASTM Standards requires that the precision and bias statement include the reference numbers of the research report (paragraph 5.3) and a brief description of the experiments that will permit the user of the test method to judge the reliability of the data. Many precision and bias statements are based on non-SI data that have been converted to SI units. The following examples provide recommended wording for the preface to the precision and bias statement.

6.1.1 *Case 1*—Precision is stated in terms of percentage, such as coefficient of variation. The precision indices are non-dimensional and there would be no need for dual presentations. In this case, it is only necessary to state that the data were obtained in the inch-pound system.

Example 1:

The data used to develop the precision statement were obtained using the/(an earlier) version of this Test Method.

6.1.2 *Case 2*—For a combined standard in which both systems of units are to be used separately:

Example 2:

A. *Inch-pound (SI)*—The data used to develop the precision statement were obtained using the inch-pound version of this Test Method. The precision indices shown in parentheses are exact conversions of the values in inch-pound units.

B. *SI (inch-pound)*—The data used to develop the precision statement were obtained using the inch-pound version of this Test Method. The precision indices shown in SI units are exact conversions of the values in parentheses.

6.1.3 *Case 3*—For a standard that has been hard converted to SI units as standard and the inch-pound units are shown in parentheses for information only:

Example 3:

The data used to develop the precision statement were obtained using the previous inch-pound version of this Test Method. The precision indices are exact conversions of the values shown in parentheses.

6.1.4 *Case 4*—For a standard that has been converted to an SI standard and the inch-pound units have been dropped.

Example 4:

The data used to develop the precision statement were obtained using the previous inch-pound version of this Test Method. The indicated precision indices are exact conversions of the values obtained originally in inch-pound units.

6.2 *Manner of Expression*—If the test data on which the precision statement is to be based indicate that the standard deviation is essentially the same for all levels of the property being tested for which data are available, the one-sigma limit and the difference two-sigma limit shall be given in the precision statement expressed in the units of the measured property.

6.2.1 If the standard deviation is essentially proportional to the average for different levels of the property in question (that is, the coefficient of variation is essentially constant) then the "one-sigma limit in percent" (1s%) and difference two-sigma limit in percent (d2s%) shall be given. "One-sigma limit in percent" is, for the purposes of this practice, the same as the coefficient of variation. It is determined by dividing the standard deviation by the mean (average) value of available results and multiplying by 100. Similarly, "difference two-sigma limit in percent" is obtained by dividing (d2s) by the mean and multiplying by 100. When neither of these conditions is met, the applicable limits for specific ranges of the property shall be stated together with the specific ranges for which they are appropriate. The abbreviations (1s), (1s%), (d2s), and (d2s%) are given in footnotes as shown in the examples.

6.3 *Recommended Form of the Precision Statement*—When the proper estimates of precision are available (Note 7), the precision statement shall be written in the form of the appropriate example as given below for each available estimate of precision (standard deviation or coefficient of variation) and corresponding system of causes.

NOTE 8—Some of the following examples have been taken from test methods current at the time this practice was written and others are hypothetical. None of the examples should be taken as being quantitatively correct, since, even if taken from actual situations, the figures may have been subsequently revised.

6.3.1 *Form of Statements for Which One Estimate of Precision for Each System of Causes Applies*:

Example 1:

Precision—The multilaboratory standard deviation has been found to be 0.75 %[A]. Therefore, results of two properly conducted tests from two different laboratories on samples of the same cement are not expected to differ by more than 2.1 %.[A]

[A] These numbers represent, respectively, the (1s) and (d2s) limits as described in ASTM Practice C 670, for Preparing Precision Statements for Test Methods for Construction Materials.

Example 2:

Precision—The single-operator standard deviation has been found to be 0.045 %.[A] Therefore, results of two properly conducted tests by the same operator on the same material are not expected to differ by more than 0.13 %.[A]

[A] These numbers represent, respectively, the (1s) and (d2s) limits as described in ASTM Practice C 670, for Preparing Precision Statements for Test Methods for Construction Materials.

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Example 3:

Precision—The multilaboratory coefficient of variation has been found to be 5.0 %.[A] Therefore, results of two different laboratories on identical samples of a material are not expected to differ from each other by more than 14 % of their average.[A]

[A] These numbers represent, respectively, the (1s) and (d2s) limits as described in ASTM Practice C 670, for Preparing Precision Statements for Test Methods for Construction Materials.

Example 4:

The single-operator coefficient of variation has been found to be 2.5 %.[A] Therefore, results of two properly conducted tests by the same operator on the same sample using the same viscometer are not expected to differ from each other by more than 7.0 % of their average.[A]

[A] These numbers represent, respectively, the (1s) and (d2s) limits as described in ASTM Practice C 670, for Preparing Precision Statements for Test Methods for Construction Materials.

6.3.2 *Form of Statements for Which the Precision, Measured by Either the Standard Deviation or the Coefficient of Variation, is not Constant over the Range of Values of the Property in Question*:

6.3.2.1 If the precision limit given applies only over a certain range of the property of the material being measured, this shall be indicated by inserting the words "over the range from __ to __ , or "below", or "above" a certain limit after the words "standard deviation" or "coefficient of variation" in the first sentence of the statement. If precision limits have been obtained for more than one range of the property, separate statements shall be written for each range. The applicable range should also be indicated in subparagraph headings if separate subparagraphs are used as follows:

Example 5:

Single-Operator Precision—The single-operator standard deviation has been found to be 1.4°F (0.8°C)[A] for flash points below 220°F (104°C) and 7.1°F (3.9°C)[A] for flash points above 220°F. Therefore, results of two properly conducted tests by the same operator on the same material are not expected to differ from each other by more than 4°F (2.2°C)[A] for flash points below 220°F or by more than 20°F (11.1°C)[A] for flash points above 220°F.

[A] These numbers represent, respectively, the (1s) and (d2s) limits as described in ASTM Practice C 670, for Preparing Precision Statements for Test Methods for Construction Materials.

Example 6:

Multilaboratory Precision—The multilaboratory standard deviation has been found to be 2.1°F (1.2°C)[A] for flash points below 220°F (104°C) and 8.8°F (4.9°C)[A] for flash points above 220°F. Therefore, results of two properly conducted tests on the same material in two different laboratories are not expected to differ from each other by more than 6°F (3.3°C)[A] for flash points below 220°F or by more than 25°F (13.9°C)[A] for flash points above 220°F.

[A] These numbers represent, respectively, the (1s) and (d2s) limits as described in ASTM Practice C 670, for Preparing Precision Statements for Test Methods for Construction Materials.

6.3.2.2 If the precision, whether expressed as an absolute limit or a percent, is not constant over the given range or for all the materials tested, but the limit given is the maximum value of the index of precision, the abbreviation "max" shall be inserted after the closing parenthesis of the abbreviation for the type of limit in the footnote: that is (1s) max, or (1s%) max. Also the word" maximum" shall be inserted in the first sentence of the precision statement. This form should rarely be used, and then only as a last resort. See the Irregular or Nonlinear Relationship Between Standard Deviation, Coefficient of Variation and Average Level section in Practice C 802.

Example 7:

Precision—The maximum single-operator-machine-multibatch coefficient of variation has been found to be 4.25 %.[A] Therefore, results of two properly conducted tests by the same operator of concrete cylinders from two different batches are not expected to differ from each other by more than 12 % of their average.[A]

[A] These numbers represent, respectively, the (1s%) and (d2s%) max limits as described in ASTM Practice C 670, for Preparing Precision Statements for Test Methods for Construction Materials.

6.3.2.3 See Examples 11 and 12 for alternative tabular form of precision statements.

6.4 *Form of Statement for Which a Test Result is Defined as the Average of a Specified Number of Measurements*:

Example 8:

Single-Operator Precision—The single-operator standard deviation of a single test result (where a test result is, as defined in this test method, the average of three separate measurements) has been found to be 2.0 %.[A] Therefore, results of two properly conducted tests (each consisting of the average of three individual measurements) are not expected to differ by more than 5.7 %[A] and the range (difference between highest and lowest) of the three individual measurements used in calculating the average are not expected to exceed 11.4 %.[B]

[A] These numbers represent, respectively, the (1s) and (d2s) limits as described in ASTM Practice C 670, for Preparing Precision Statements for Test Methods for Construction Materials.

[B] Calculated as described in 3.4.3 of Practice C 670.

6.5 *Form of Statements for Which More than One Test Result is Reported*:

Example 9:

Single-Operator Precision—The single-operator standard deviation of a single test result has been found to be 125 psi (861 kPa). Therefore, results of two properly conducted tests by the same operator are not expected to differ by more than 350 psi (2413 kPa).[A] The test method calls for reporting three test results. The range (difference between highest and lowest) of the three test results obtained by the same operator are not expected to exceed 410 psi (2827 kPa).[B]

[A] These numbers represent, respectively, the (1s) and (d2s) limits as described in ASTM Practice C 670, for Preparing Precision Statements for Test Methods for Construction Materials.

[B] Calculated as described in 3.4.3 of Practice C 670.

Example 10:

Multilaboratory Precision—The multilaboratory standard deviation of a single test result has been found to be 225 psi (1551 kPa). Therefore, results of two properly-conducted tests in different laboratories on the same material are not expected to differ by more than 640 psi (4413 kPa).[A] The averages of three test results in two different laboratories are not expected to differ by more than 370 psi (2551 kPa).[B]

[A] These numbers represent, respectively, the (1s) and (d2s) limits as described in ASTM Practice C 670, for Preparing Precision Statements for Test Methods for Construction Materials.

[B] Calculated as described in 3.4.3 of Practice C 670.

6.6 *Alternative Form of the Precision Statement*—In cases where separate statements for a number of different materials or a number of different levels of a property are involved, the form recommended in 6.2 may become cumbersome. In such cases, the statement may be written in table form in accordance with the following examples:

Example 11:

Precision—Criteria for judging the acceptability of solubility test results obtained by this method are given as follows:

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NOTE 9—The figures given in Column 2 are the standard deviations that have been found to be appropriate for the materials and conditions of test described in Column 1. The figures given in Column 3 are the limits that should not be exceeded by the difference between the results of two properly conducted tests.

Material and Type Index	Standard Deviation[A]	Acceptable Range of Two Results[A]
Single-operator precision:		
Asphalts, solubility more than 99 %[B]	0.035	0.10
Tars, liquid grades[C]	0.11	0.31
Tars, semi-solid[A]	0.17	0.48
Multilaboratory precision:		
Asphalts, solubility more than 99 %[C]	0.090	0.26
Tars, liquid grades[C]	0.22	0.61
Tars, semi-solid[C]	0.83	2.34

[A] These numbers represent, respectively, the (1s) and (d2s) limits as described in ASTM Practice C 670, for Preparing Precision Statements for Test Methods for Construction Materials.

[B] Applicable when either carbon disulfide, carbon tetrachloride, trichloroethylene, or benzene are used.

[C] Applicable when carbon disulfide is used.

Example 12:

Precision—Criteria for judging the acceptability of viscosity test results obtained by this method are given as follows:

NOTE 10—The figures given in Column 2 are the coefficients of variation that have been found to be appropriate for the materials and conditions of test described in Column 1. The figures given in Column 3 are the limits that should not be exceeded by the difference between the results of two properly conducted tests expressed as a percent of their mean.

Material and Type Index	Coefficient of Variation (percent of mean)[A]	Acceptable Range of Two Results (percent of mean)[A]
Single-operator precision:		
Asphalt Cements at 275°F (135°C)	0.64	1.8
Liquid asphalts at 140°F (60°C):		
below 3000 cSt	0.53	1.5
3000 cSt and above	0.71	2.0
Multilaboratory precision:		
Asphalt cements at 275°F (135°C)	3.1	8.8
Liquid asphalts at 140°F (60°C):		
below 3000 cSt	1.06	3.0
3000 cSt and above	3.11	9.0

[A] These numbers represent, respectively, the (1s%) and (d2s%) limits as described in this Practice.

7. Bias Statement

7.1 Bias is a systematic error inherent in the test method that contributes to the difference between a population mean of the measurements or test results and an accepted reference or true value. In any test method, tolerances are placed on the accuracy of measuring equipment. All tests made with a given set of equipment which has an error within the permitted tolerance will produce results with a small consistent bias, but that bias is not inherent in the test method and is not included in the bias statement for the test method. There are two conditions which permit the bias of a test method to be estimated: (1) a standard reference sample of known value has been tested by the test method, and (2) the test method has been applied to a sample which has been compounded in such a manner that the true value of the property being measured is known, such as may be the case, for example, in a test for cement content of concrete. Judgment is required to determine whether a potential reference sample is suitable for the purpose. For example, a metal bar of accurately known physical properties might not be suitable for establishing the bias of a test for the corresponding concrete properties because the level of values may differ by an order of magnitude. When it is possible to examine bias, it is necessary to determine whether there are enough data to determine statistically that the mean of the test results is significantly different from the true value. When it is, an absolute measure of bias cannot be made, but confidence limits may be placed on the bias.

7.2 For most test methods there is no reference value available. In those cases a statement based on one of the following may be used:

Example 1:

Bias—The test method has no bias because the values determined can be defined only in terms of the test method.

Example 2:

Bias—Since there is no accepted reference material suitable for determining the bias in this test method, no statement on bias is made.

Example 3:

Bias—No justifiable statement can be made on the bias of this test method because (insert here the reason).

7.3 Where it is possible to determine if bias exists, proceed as follows.

7.3.1 Form at least 30 pairs of results in which X_1 is the known reference value and X_2 is the experimental value. Form the quotient

$$\frac{t = \bar{X}_2 - \bar{X}_1}{s/\sqrt{N}} \quad (1)$$

where:

$\bar{X}_1$ = the mean of the reference values,
$\bar{X}_2$ = the mean of the experimental values,
s = the standard deviation of the differences $(X_2 - X_1)$, and
N = the number of pairs.

This quotient has a t distribution with N−1 degrees of freedom. Reject the hypothesis that no bias exists if t < t½ ½ α or t > t1−½ α. Usually α, the level of significance, will be taken as 0.05. For an α of 0.05 and a sample of 30 pairs, the above inequalities reduce to t < − 2.05 or t > 2.05. Thus if the calculated value of t falls between − 2.05 and 2.05, it is concluded that there is no bias.

7.3.2 Where the value of t falls in the rejection range, the confidence limits for bias are:

$$\bar{X}_2 - \bar{X}_1 + t1/2\,\alpha\, s\sqrt{1/N} \text{ and } \bar{X}_2 - {}^{-}X_1 + t1-1/2\,\alpha\, s\sqrt{1/N} \quad (2)$$

NOTE 11—In the above expression the first value of t is always negative.

7.3.3 In some cases the bias may be a function of level of the quantity being measured. If differences in means for

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different levels are significantly different from each other, the above procedure may be applied to each such level.

7.3.4 Where a test for bias has been made, a statement based on one of the following may be made:

Example 1:

Bias—When experimental results are compared with accepted reference values (or known values from accurately compounded specimens), the test method is found to have no bias.

Example 2:

Bias—When experimental results are compared with accepted reference values (or known values from accurately compounded specimens), the bias of the test method is found with 95 % confidence to lie between 0.0062 and 0.0071.

Example 3:

Bias—When experimental results are compared with accepted reference values (or known values from accurately compounded specimens), the bias of the test method is found with 95 % confidence to lie between − 0.0004 and − 0.0001 in the range of 6 to 10 and between − 0.0006 and − 0.0002 in the range of 10 to 15.

APPENDIX

(Nonmandatory Information)

X1. USE OF CCRL AND AMRL REFERENCE SAMPLE RESULTS FOR PRECISION STATEMENTS

X1.1 *Introduction:*

X1.1.1 Where the test method has been applied to a reference sample distributed by CCRL or AMRL, use the data from Table 1, Summary of Results, analyze them in accordance with Practice C 802, and formulate precision statements conforming to the requirements of this practice.

X1.1.2 The example which follows uses data from Table 1, Summary of Results, of a CCRL reference sample report (shown in Fig. X1.1). Data from tests for AMRL are reported in the same format.

X1.2 *Use of Table I, CCRL Report:*

X1.2.1 The compressive strength data for Samples 35 and 36 are selected for illustrating the use of Table I of the CCRL Reference sample report. They provide four levels of the measured value.

X1.2.2 The procedure consists largely of selecting appropriate values from Table 1of the CCRL report (Fig. X1.1) and placing them in the correct location in the "Approximate Values (Upper 5 % Level) for the Ratio of Highest to Lowest Variance" Table of Practice C 802 (shown in Fig. X1.2).

NOTE X1.1—In this particular example it was necessary to select the most appropriate lines of data to use in CCRL Table I. For the three-day strength results only the complete set of data before elimination of outliers

CCRL REFERENCE SAMPLE PROGRAM

CEMENT SAMPLES NUMBER 35 AND NUMBER 36

PHYSICAL DETERMINATIONS, FINAL REPORT, APRIL 9, 1975

TABLE I SUMMARY OF RESULTS -CONTINUED

		NO OF LABS		SAMPLE NO. 35 AVERAGE	SAMPLE NO. 35 STAND DEV	SAMPLE NO. 35 C.V. 0/0	SAMPLE NO. 36 AVERAGE	SAMPLE NO. 36 STAND DEV	SAMPLE NO. 36 C.V. 0/0	RANDOM ERROR R.E.	RANDOM ERROR C.V.(1) 0/0	RANDOM ERROR C.V.(2) 0/0
AIR CONTENT	PRCNT	169		9.2846+00	1.1057+00	11.909	8.2030+00	1.6417+00	20.014			
AIR CONTENT	PRCNT	167	(10)	9.3329+00	1.0185+00	10.913	8.2269+00	1.6367+00	19.895			
AIR CONTENT	PRCNT	166	(11)	9.3518+00	9.9185-01	10.606	8.2337+00	1.6393+00	19.910			
AC MIX WATER	PRCNT	165		7.0581+01	2.3145+00	3.279	7.0788+01	2.3982+00	3.388	9.9974-01	1.416	1.412
AC MIX WATER	PRCNT	160	(12)	7.9402+01	1.8715+00	2.658	7.0651+01	2.0291+00	2.872	8.0402-01	1.271	1.267
AC MIX WATER	PRCNT	159	(13)	7.0360+01	1.7997+00	2.558	7.0610+01	1.9694+00	2.789	8.9764-01	1.276	1.271
AC FLOW	PRCNT	168		8.6762+01	1.5650+00	4.109	8.7446+01	3.6143+00	4.133	2.9680+00	3.421	3.394
COMP STR 3D	PSI	178		3.0361+03	2.4128+02	8.013	2.3404+03	2.2370+02	9.556	1.8689+02	6.156	7.995
COMP STR 3D	PSI	172	(14)	3.0471+03	2.1698+02	7.121	2.3194+03	1.8837+02	8.122			
COMP STR 3D	PSI	169	(15)	3.0542+03	2.0460+02	6.699	2.3135+03	1.7642+02	7.626			
COMP STR 7D	PSI	178		4.2346+03	2.8097+02	6.635	3.5026+03	2.7698+02	7.908	1.9084+02	4.507	5.448
COMP STR 7D	PSI	171	(16)	4.2525+03	2.4581+02	5.780	3.4897+03	2.3564+02	6.753	1.4513+02	3.413	4.159
COMP STR 7D	PSI	170	(17)	4.2570+03	2.3923+02	5.620	3.4976+03	2.3479+02	6.712	1.3205+02	3.102	3.786
FINENESS AP	SQCM/G	172		3.6056+03	8.9951+01	2.495	3.4319+03	8.7340+01	2.545	4.0536+01	1.374	1.443
FINENESS AP	SQCM/G	164	(14)	3.6081+03	7.8506+01	2.176	3.4335+03	7.2471+01	2.111	3.9767+01	1.102	1.158
FINENESS WT	SQCM/G	80		2.0221+03	1.0426+02	5.156	1.8350+03	9.6496+01	5.259	5.0305+01	2.488	2.741
FINENESS WT	SQCM/G	79	(19)	2.0178+03	9.7608+01	4.837	1.8308+03	8.9296+01	4.878	5.0626+01	2.509	2.765
FINENESS WT	SQCM/G	78	(20)	2.0212+03	9.3684+01	4.635	1.8342+03	8.4339+01	4.598	5.0943+01	2.529	2.777
NO 325 SIEV	PER CT	131		9.0878+01	1.2455+00	1.370	8.7406+01	1.5049+00	1.722			

(10) FOLLOWING LABS ELIMINATED 179 304

(11) FOLLOWING LABS ELIMINATED 246
179 304

(12) FOLLOWING LABS ELIMINATED 21 59 179 304 375

(13) FOLLOWING LABS ELIMINATED 335
21 59 179 304 375

(14) FOLLOWING LABS ELIMINATED 28 29 45 52 145 250

(15) FOLLOWING LABS ELIMINATED 71 152 390
28 29 45 52 145 250

(16) FOLLOWING LABS ELIMINATED 21 28 45 71 145 304 390

(17) FOLLOWING LABS ELIMINATED 250
21 28 45 71 145 304 390

(18) FOLLOWING LABS ELIMINATED 18 26 30 52 91 94 304

(19) FOLLOWING LABS ELIMINATED 144

(20) FOLLOWING LABS ELIMINATED 28
144

FIG. X1.1 Example of Completed Table I, Summary of Results, of a CCRL Reference Sample Report

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TABLE 5 (from ASTM C 802)

Material	Average	Standard Deviation		Coefficient of Variation	
		Within-Laboratory	Between-Laboratory	Within-Laboratory	Between-Laboratory
3 day strength (36)	1-2340	5-187	7-224	11-8.00%	15-9.56%
3 day strength (35)	2-3036		8-243	12-6.16%	16-8.01%
7 day strength (36)	3-3498	6-132	9-235	13-3.79%	17-6.73%
7 day strength (35)	4-4257		10-239	14-3.10%	18-5.62%
Average		160	235		

FIG. X1.2 Placement of Selected Data From Table I of CCRL Reference Sample Report into Table 5 of Practice C 802

permitted a statistically valid estimate of within-laboratory standard deviation (or random error). Thus, no choice was possible. For the 7 day test, the random error could be calculated both with and without outliers. The data with outliers removed were considered preferable.

X1.2.3 Place the information indicated by the circles numbered 1, 2, 3, and 4 in Table I, in order, in the "Average" column of the "Approximate Values (Upper 5 % Level) for the Ratio of Highest to Lowest Variance" Table. Items are placed in order of increasing magnitude.

X1.2.4 Place Circles 5 and 6 in "Within-Laboratory Standard Deviation" column of the "Approximate Values (Upper 5 % Level) for the Ratio of Highest to Lowest Variance" Table in the order shown.

X1.2.5 Place Circles 7, 8, 9, and 10 in order in the" Between-Laboratory Standard Deviation" column of the "Approximate Values (Upper 5 % Level) for the Ratio of Highest to Lowest Variance" Table.

X1.2.6 Place Circles 11, 12, 13, and 14 in order in the "Within-Laboratory Coefficient of Variation" column of the "Approximate Values (Upper 5 % Level) for the Ratio of Highest to Lowest Variance" Table.

X1.2.7 Place Circles 15, 16, 17, and 18 in order in the "Between-Laboratory Coefficient of Variation" column of the "Approximate Values (Upper 5 % Level) for the Ratio of Highest to Lowest Variance" Table.

X1.2.8 As discussed in the Determination of Form of Precision Statement section of Practice C 802, examine the" Approximate Values (Upper 5 % Level) for the Ratio of Highest to Lowest Variance" table to determine whether either the standard deviations or coefficients of variation are independent of level of measurement. Note that in this case the standard deviations are essentially constant.

X1.2.9 Write the precision statement based on standard deviation in accordance with the Estimates of Precision section of this practice, as shown in X1.3. In both cases, the standard deviation is multiplied by $2\sqrt{2}$ to obtain the d2s value, where d2s is the "difference two-sigma limit" as defined in Practice E 177.

X1.3 *Sample Precision Statement:*

X1.3.1 The single-operator standard deviation has been found to be 160 psi (1100 kPa) (the "one-sigma" [1s] limit per Practice C 670) throughout the range 2300 to 4300 psi (15 860 to 29 650 kPa). Therefore, results of two properly conducted tests by the same operator on similar batches are not expected to differ by more than 453 psi (3123 kPa) (d2s limit).

X1.3.2 The multilaboratory standard deviation has been found to be 235 psi (1620 kPa) (1s limit) throughout the range 2300 to 4300 psi (15 860 to 29 650 kPa). Therefore, results of two different laboratories on similar batches are not expected to differ from each other by more than 665 psi (4585 kPa) (d2s limit).

SUMMARY OF CHANGES

Committee C09 has identified the location of selected changes to this standard since the last issue (C 670-96) that may impact the use of this standard.

(1) Editorial revisions were made to sample precision statements.

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Designation: C 672/C 672M – 03

Standard Test Method for Scaling Resistance of Concrete Surfaces Exposed to Deicing Chemicals[1]

This standard is issued under the fixed designation C 672/C 672M; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ϵ) indicates an editorial change since the last revision or reapproval.

1. Scope

1.1 This test method covers the determination of the resistance to scaling of a horizontal concrete surface exposed to freezing-and-thawing cycles in the presence of deicing chemicals. It is intended for use in evaluating this surface resistance qualitatively by visual examination.

1.2 The values stated in either SI units or inch-pound units are to be regarded separately as standard. Within the text, the inch-pound units are shown in brackets. The values stated in each system are not exact equivalents; therefore, each system shall be used independently of the other.

1.3 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

2. Referenced Documents

2.1 *ASTM Standards:* [2]

C 143/C 143M Test Method for Slump of Hydraulic Cement Concrete

C 156 Test Method for Water Retention by Concrete Curing Materials

C 173/C 173M Test Method for Air Content of Freshly Mixed Concrete by the Volumetric Method

C 192/C 192M Practice for Making and Curing Concrete Test Specimens in the Laboratory

C 231 Test Method for Air Content of Freshly Mixed Concrete by the Pressure Method

C 233 Test Method for Air-Entraining Admixtures for Concrete

C 511 Specification for Mixing Rooms, Moist Cabinets, Moist Rooms, and Water Storage Tanks Used in the Testing of Hydraulic Cements and Concretes

3. Significance and Use

3.1 This test method can be used to evaluate the effect of mixture proportioning, surface treatment, curing, or other variables on resistance to scaling.

3.2 This test method is not intended to be used in determining the durability of aggregates or other ingredients of the concrete.

3.3 No relationship has been established between the frost immunity of specimens cut from hardened concrete and specimens prepared in the laboratory.

4. Apparatus

4.1 *Freezing Equipment*—A chest or room of sufficient size to hold the specimens and capable of lowering the temperature of the specimens to −18 ± 3°C [0 ± 5°F] within 16 to 18 h and maintaining this temperature with a full load of specimens.

4.2 *Molds*, of the proper size for the test specimens to be used, and conforming to the requirements of Practice C 192/C 192M.

4.3 *Tamping Rod*, conforming to the requirements of Test Method C 143/C 143M.

4.4 *Small Tools*—Wood strike-off board, steel trowel, and moderately stiff bristle brush suitable for providing the desired texture of the test surface.

4.5 *Slump Cone*, conforming to the requirements of Test Method C 143/C 143M.

4.6 *Air Meter*, conforming to the requirements of Test Method C 173/C 173M or Test Method C 231.

4.7 *Scales*, conforming to the requirements of Practice C 192/C 192M.

4.8 *Concrete Mixer*, conforming to the requirements of Practice C 192/C 192M.

5. Proportioning and Mixing

5.1 *Proportioning*—The air content, cement factor, slump, water-to-cement ratio, and other characteristics of the concrete and its ingredients shall be those appropriate for the purposes for which the tests are to be made. Concrete with the following characteristics has been found useful for the purposes for which this test method is generally used, such as evaluation of a surface treatment for prevention of scaling: (*a*) non-air-entrained; (*b*) cement content, 335 ± 5 kg/m^3[565 ± 10 lb/yd^3]; (*c*) slump, 75 ± 15 mm [3 ± 0.5 in.]; and (*d*) durable

[1] This test method is under the jurisdiction of ASTM Committee C09 on Concrete and Concrete Aggregates and is the direct responsibility of Subcommittee C09.67 on Resistance of Concrete to Its Environment.

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[2] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

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aggregate (Note 1) of 25-mm [1-in.] maximum size. If air-entrained concrete is to be used for comparative purposes, it shall have the same proportions as that with which it is being compared and the air content shall be 6 ± 1 % (Note 2).

NOTE 1—Care should be taken to use an aggregate which has a good performance record in freezing and thawing exposure.

NOTE 2—For additional information pertaining to air-entrained concrete proportions, see Test Method C 233.

5.2 *Mixing and Testing of Freshly Mixed Concrete*—Machine mix and test in conformance with the applicable provisions of Practice C 192/C 192M.

6. Specimens

6.1 Specimens shall have a surface area of at least 0.045 m^2[72 $in.^2$] and be at least 75 mm [3.0 in.] in depth. At least two duplicate specimens for each combination of variables to be tested shall be made.

6.2 *Fabrication of Specimens*:

6.2.1 Coat the inside surface of the mold with a light coat of mineral oil or a suitable nonreactive release material just prior to fabrication of the specimens.

6.2.2 Fill the mold in one layer. Rod one time for each 1400 mm^2[2 $in.^2$] of surface, leaving a slight excess of material after the final rodding. Tap the mold to close any voids and spade around the periphery with a flat trowel. Level the surface with several passes of a wood strike-off board.

6.2.3 After the concrete has stopped bleeding, finish the surface with three sawing-motion passes of a wood strike-off board. Brush the surface with a medium-stiff brush as a final finishing operation unless another method of surface finishing such as steel-troweled surface, burlap drag, or a troweled-in surface treatment is to be evaluated.

6.2.4 After the finishing operation, place a dike about 25 mm [1 in.] wide and 20 mm [¾ in.] high along the perimeter of the top surface of the specimens. The dike may be made of any material that will adhere to the specimen and serve to maintain the brine pond on top of the specimen throughout the period of the test. If the dike is of mortar, it shall be applied immediately after the final finishing operation, and the surface where the mortar is to be applied shall be roughened to provide a mechanical bond. If an epoxy mortar dike is to be formed or a proven satisfactory bonding material is used to bond the dike to the surface, the dike may be applied after the concrete has set. Any pre-applied coating shall be removed from the bond area prior to the application of the dike.

6.2.5 Test specimens may also be slabs meeting the test area requirements cut from hardened concrete in a structure. In this case, the specimens shall not be cut or damaged on the surface to be tested and should not be allowed to dry to a moisture condition below that of the structure from which they have been taken. This may be accomplished by wrapping the specimens in some waterproof material or by other suitable means.

7. Curing

7.1 Except where the method of curing is an element of study or is otherwise specified, cover the specimens with a polyethylene sheet immediately after finishing. The sheet shall not be permitted to contact the concrete surface.

7.2 Remove the specimens from the molds at an age of 20 to 24 h after addition of water to the mix and place in moist storage as provided for in Specification C 511.

7.3 If concretes with differing rates of strength gain are to be compared, maintain the specimens in moist storage until such time as the desired strength level has been obtained. When the desired strength level has been reached, remove the specimens from moist storage and store in air for 14 days at 23.0 ± 2.0°C [73.5 ± 3.5°F] and 45 to 55 % relative humidity.

7.4 For all other concretes, remove the specimens from moist storage at the age of 14 days and store in air for 14 days at 23.0 ± 2.0°C [73.5 ± 3.5°F] and 45 to 55 % relative humidity.

8. Protective Coatings

8.1 If protective coatings are to be evaluated, apply them in accordance with the manufacturer's recommendations regarding quantity and method of application at the age of 21 days. When a material proposed as dual-purpose curing compound/protective coating is being evaluated, apply it at the proper time of application for curing compounds, as described in Test Method C 156.

NOTE 3—When evaluating penetration-type coatings for application to pavement surfaces subject to traffic wear, it may be desirable to abrade the treated surface of the test specimens by sufficient wire brushing to break any films remaining on the surface after drying.

9. Procedure

9.1 After completion of moist and air curing, cover the flat surface of the specimen with approximately 6 mm (¼ in.) of a solution of calcium chloride and water, having a concentration such that each 100 mL of solution contains 4 g of anhydrous calcium chloride.

NOTE 4—Other chemical deicers and different concentrations may be used when there is a need to evaluate their specific effect. In addition, a variation in the procedure may be adopted whereby the deicer is added directly to the ice produced by freezing a 6 mm (¼ in.) layer of fresh water during the freezing portion of the cycle, discarding and flushing the resulting solution off the surface at the end of the thawing portion of the cycle and then repeating the cycle. If this procedure is adopted, it should be recognized that about 100 cycles or more will be required to evaluate a surface treatment.

9.2 Place specimens in a freezing environment for 16 to 18 h. At the end of this time remove them from the freezer and place them in laboratory air at 23 ± 2.0°C [73.5 ± 3.5°F] and a relative humidity of 45 to 55 % for 6 to 8 h. Add water between each cycle as necessary to maintain the proper depth of solution. Repeat this cycle daily, flushing off the surface thoroughly at the end of each 5 cycles. After making a visual examination, replace the solution and continue the test.

NOTE 5—Generally, 50 cycles are sufficient to evaluate a surface or surface treatment. However, where comparative tests are being made, it is recommended that the tests be continued beyond the recommended minimum number of cycles if differences have not developed.

9.3 Either keep specimens frozen during any interruption in the daily cycling or maintain them in a damp condition after removal of solution and flushing surfaces.

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10. Report

10.1 Report the following:

10.1.1 Cement content, water-cement ratio, the kind and amount of any admixture, slump, and air content of mix,

10.1.2 Curing and drying if other than standard,

10.1.3 Type of surface treatment, time of application, and rate of application,

10.1.4 Type of deicer, whether solution or solid, concentration of the solution if used, rate of application, and time of application,

10.1.5 Visual rating of the surface after 5, 10, 15, 25, and every 25 cycles thereafter in accordance with the following scale:

Rating	Condition of Surface
0	no scaling
1	very slight scaling (3 mm [⅛ in.] depth, max, no coarse aggregate visible)
2	slight to moderate scaling
3	moderate scaling (some coarse aggregate visible)
4	moderate to severe scaling
5	severe scaling (coarse aggregate visible over entire surface)

10.1.6 If the test specimens are cut from hardened concrete, the size, shape, orientation of the specimens in the structure, and any other pertinent information available shall be included in the report, and

10.1.7 Photographs or a word description of the surface, or both, also should be included where possible.

11. Precision and Bias

11.1 In statistical analyses of data obtained by the use of this test method, it is necessary to recognize that the ratings are ranks, and as such, may not be appropriately subjected to analyses based on the calculation of averages and standard deviations nor to other techniques that assume continuous distribution of measurement on at least an interval scale. If groups of similar specimens are to be reported or compared with other groups, such nonparametric quantities as the median and the range may be used.

12. Keywords

12.1 concrete-weathering tests; deicing chemicals; freezing and thawing; resistance-frost; resistance-scaling

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Designation: C 672/C 672M – 03

Standard Test Method for Scaling Resistance of Concrete Surfaces Exposed to Deicing Chemicals[1]

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1. Scope

1.1 This test method covers the determination of the resistance to scaling of a horizontal concrete surface exposed to freezing-and-thawing cycles in the presence of deicing chemicals. It is intended for use in evaluating this surface resistance qualitatively by visual examination.

1.2 The values stated in either SI units or inch-pound units are to be regarded separately as standard. Within the text, the inch-pound units are shown in brackets. The values stated in each system are not exact equivalents; therefore, each system shall be used independently of the other.

1.3 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

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C 156 Test Method for Water Retention by Concrete Curing Materials

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C 233 Test Method for Air-Entraining Admixtures for Concrete

C 511 Specification for Mixing Rooms, Moist Cabinets, Moist Rooms, and Water Storage Tanks Used in the Testing of Hydraulic Cements and Concretes

3. Significance and Use

3.1 This test method can be used to evaluate the effect of mixture proportioning, surface treatment, curing, or other variables on resistance to scaling.

3.2 This test method is not intended to be used in determining the durability of aggregates or other ingredients of the concrete.

3.3 No relationship has been established between the frost immunity of specimens cut from hardened concrete and specimens prepared in the laboratory.

4. Apparatus

4.1 *Freezing Equipment*—A chest or room of sufficient size to hold the specimens and capable of lowering the temperature of the specimens to −18 ± 3°C [0 ± 5°F] within 16 to 18 h and maintaining this temperature with a full load of specimens.

4.2 *Molds*, of the proper size for the test specimens to be used, and conforming to the requirements of Practice C 192/C 192M.

4.3 *Tamping Rod*, conforming to the requirements of Test Method C 143/C 143M.

4.4 *Small Tools*—Wood strike-off board, steel trowel, and moderately stiff bristle brush suitable for providing the desired texture of the test surface.

4.5 *Slump Cone*, conforming to the requirements of Test Method C 143/C 143M.

4.6 *Air Meter*, conforming to the requirements of Test Method C 173/C 173M or Test Method C 231.

4.7 *Scales*, conforming to the requirements of Practice C 192/C 192M.

4.8 *Concrete Mixer*, conforming to the requirements of Practice C 192/C 192M.

5. Proportioning and Mixing

5.1 *Proportioning*—The air content, cement factor, slump, water-to-cement ratio, and other characteristics of the concrete and its ingredients shall be those appropriate for the purposes for which the tests are to be made. Concrete with the following characteristics has been found useful for the purposes for which this test method is generally used, such as evaluation of a surface treatment for prevention of scaling: (*a*) non-air-entrained; (*b*) cement content, 335 ± 5 kg/m^3[565 ± 10 lb/yd^3]; (*c*) slump, 75 ± 15 mm [3 ± 0.5 in.]; and (*d*) durable

[1] This test method is under the jurisdiction of ASTM Committee C09 on Concrete and Concrete Aggregates and is the direct responsibility of Subcommittee C09.67 on Resistance of Concrete to Its Environment.

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[2] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

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aggregate (Note 1) of 25-mm [1-in.] maximum size. If air-entrained concrete is to be used for comparative purposes, it shall have the same proportions as that with which it is being compared and the air content shall be 6 ± 1 % (Note 2).

NOTE 1—Care should be taken to use an aggregate which has a good performance record in freezing and thawing exposure.

NOTE 2—For additional information pertaining to air-entrained concrete proportions, see Test Method C 233.

5.2 *Mixing and Testing of Freshly Mixed Concrete*—Machine mix and test in conformance with the applicable provisions of Practice C 192/C 192M.

6. Specimens

6.1 Specimens shall have a surface area of at least 0.045 m^2[72 $in.^2$] and be at least 75 mm [3.0 in.] in depth. At least two duplicate specimens for each combination of variables to be tested shall be made.

6.2 *Fabrication of Specimens*:

6.2.1 Coat the inside surface of the mold with a light coat of mineral oil or a suitable nonreactive release material just prior to fabrication of the specimens.

6.2.2 Fill the mold in one layer. Rod one time for each 1400 mm^2[2 $in.^2$] of surface, leaving a slight excess of material after the final rodding. Tap the mold to close any voids and spade around the periphery with a flat trowel. Level the surface with several passes of a wood strike-off board.

6.2.3 After the concrete has stopped bleeding, finish the surface with three sawing-motion passes of a wood strike-off board. Brush the surface with a medium-stiff brush as a final finishing operation unless another method of surface finishing such as steel-troweled surface, burlap drag, or a troweled-in surface treatment is to be evaluated.

6.2.4 After the finishing operation, place a dike about 25 mm [1 in.] wide and 20 mm [¾ in.] high along the perimeter of the top surface of the specimens. The dike may be made of any material that will adhere to the specimen and serve to maintain the brine pond on top of the specimen throughout the period of the test. If the dike is of mortar, it shall be applied immediately after the final finishing operation, and the surface where the mortar is to be applied shall be roughened to provide a mechanical bond. If an epoxy mortar dike is to be formed or a proven satisfactory bonding material is used to bond the dike to the surface, the dike may be applied after the concrete has set. Any pre-applied coating shall be removed from the bond area prior to the application of the dike.

6.2.5 Test specimens may also be slabs meeting the test area requirements cut from hardened concrete in a structure. In this case, the specimens shall not be cut or damaged on the surface to be tested and should not be allowed to dry to a moisture condition below that of the structure from which they have been taken. This may be accomplished by wrapping the specimens in some waterproof material or by other suitable means.

7. Curing

7.1 Except where the method of curing is an element of study or is otherwise specified, cover the specimens with a polyethylene sheet immediately after finishing. The sheet shall not be permitted to contact the concrete surface.

7.2 Remove the specimens from the molds at an age of 20 to 24 h after addition of water to the mix and place in moist storage as provided for in Specification C 511.

7.3 If concretes with differing rates of strength gain are to be compared, maintain the specimens in moist storage until such time as the desired strength level has been obtained. When the desired strength level has been reached, remove the specimens from moist storage and store in air for 14 days at 23.0 ± 2.0°C [73.5 ± 3.5°F] and 45 to 55 % relative humidity.

7.4 For all other concretes, remove the specimens from moist storage at the age of 14 days and store in air for 14 days at 23.0 ± 2.0°C [73.5 ± 3.5°F] and 45 to 55 % relative humidity.

8. Protective Coatings

8.1 If protective coatings are to be evaluated, apply them in accordance with the manufacturer's recommendations regarding quantity and method of application at the age of 21 days. When a material proposed as dual-purpose curing compound/protective coating is being evaluated, apply it at the proper time of application for curing compounds, as described in Test Method C 156.

NOTE 3—When evaluating penetration-type coatings for application to pavement surfaces subject to traffic wear, it may be desirable to abrade the treated surface of the test specimens by sufficient wire brushing to break any films remaining on the surface after drying.

9. Procedure

9.1 After completion of moist and air curing, cover the flat surface of the specimen with approximately 6 mm (¼ in.) of a solution of calcium chloride and water, having a concentration such that each 100 mL of solution contains 4 g of anhydrous calcium chloride.

NOTE 4—Other chemical deicers and different concentrations may be used when there is a need to evaluate their specific effect. In addition, a variation in the procedure may be adopted whereby the deicer is added directly to the ice produced by freezing a 6 mm (¼ in.) layer of fresh water during the freezing portion of the cycle, discarding and flushing the resulting solution off the surface at the end of the thawing portion of the cycle and then repeating the cycle. If this procedure is adopted, it should be recognized that about 100 cycles or more will be required to evaluate a surface treatment.

9.2 Place specimens in a freezing environment for 16 to 18 h. At the end of this time remove them from the freezer and place them in laboratory air at 23 ± 2.0°C [73.5 ± 3.5°F] and a relative humidity of 45 to 55 % for 6 to 8 h. Add water between each cycle as necessary to maintain the proper depth of solution. Repeat this cycle daily, flushing off the surface thoroughly at the end of each 5 cycles. After making a visual examination, replace the solution and continue the test.

NOTE 5—Generally, 50 cycles are sufficient to evaluate a surface or surface treatment. However, where comparative tests are being made, it is recommended that the tests be continued beyond the recommended minimum number of cycles if differences have not developed.

9.3 Either keep specimens frozen during any interruption in the daily cycling or maintain them in a damp condition after removal of solution and flushing surfaces.

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10. Report

10.1 Report the following:

10.1.1 Cement content, water-cement ratio, the kind and amount of any admixture, slump, and air content of mix,

10.1.2 Curing and drying if other than standard,

10.1.3 Type of surface treatment, time of application, and rate of application,

10.1.4 Type of deicer, whether solution or solid, concentration of the solution if used, rate of application, and time of application,

10.1.5 Visual rating of the surface after 5, 10, 15, 25, and every 25 cycles thereafter in accordance with the following scale:

Rating	Condition of Surface
0	no scaling
1	very slight scaling (3 mm [⅛ in.] depth, max, no coarse aggregate visible)
2	slight to moderate scaling
3	moderate scaling (some coarse aggregate visible)
4	moderate to severe scaling
5	severe scaling (coarse aggregate visible over entire surface)

10.1.6 If the test specimens are cut from hardened concrete, the size, shape, orientation of the specimens in the structure, and any other pertinent information available shall be included in the report, and

10.1.7 Photographs or a word description of the surface, or both, also should be included where possible.

11. Precision and Bias

11.1 In statistical analyses of data obtained by the use of this test method, it is necessary to recognize that the ratings are ranks, and as such, may not be appropriately subjected to analyses based on the calculation of averages and standard deviations nor to other techniques that assume continuous distribution of measurement on at least an interval scale. If groups of similar specimens are to be reported or compared with other groups, such nonparametric quantities as the median and the range may be used.

12. Keywords

12.1 concrete-weathering tests; deicing chemicals; freezing and thawing; resistance-frost; resistance-scaling

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Designation: C 684 – 99 (Reapproved 2003)

Standard Test Method for Making, Accelerated Curing, and Testing Concrete Compression Test Specimens[1]

This standard is issued under the fixed designation C 684; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope

1.1 This test method covers four procedures for making, curing, and testing specimens of concrete stored under conditions intended to accelerate the development of strength. The four procedures are: Procedure A—Warm Water Method, Procedure B—Boiling Water Method, Procedure C—Autogenous Curing Method, and Procedure D—High Temperature and Pressure Method.

1.2 The values stated in SI units are to be regarded as standard. The values given in parentheses are provided for information purposes only.

1.3 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.* See Section 9 and Note 9 and Note 14 for specific warnings and precautions.

2. Referenced Documents

2.1 *ASTM Standards:* [2]

C 31/C 31M Practice for Making and Curing Concrete Test Specimens in the Field

C 39 Test Method for Compressive Strength of Cylindrical Concrete Specimens

C 172 Practice for Sampling Freshly Mixed Concrete

C 177 Test Method for Steady-State Heat Flux Measurements and Thermal Transmission Properties by Means of the Guarded-Hot-Plate Apparatus

C 192/C 192M Practice for Making and Curing Concrete Test Specimens in the Laboratory

C 470 Specification for Molds for Forming Concrete Test Cylinders Vertically

C 617 Practice for Capping Cylindrical Concrete Specimens

C 1231 Practice for Use of Unbonded Caps in Determination of Compressive Strength of Hardened Concrete Cylinders

D 3665 Practice for Random Sampling of Construction Materials

E 105 Practice for Probability Sampling of Materials

E 122 Practice for Calculating Sample Size to Estimate, With a Specified Tolerable Error, the Average for Characteristics of a Lot or Process

E 141 Practice for Acceptance of Evidence Based on the Results of Probability Sampling

3. Terminology

3.1 There are no terms in this standard that require new or other than dictionary definitions.

4. Summary of Test Method

4.1 Concrete specimens are exposed to accelerated curing conditions that permit the specimens to develop a significant portion of their ultimate strength within a time period ranging from 5 to 49 h, depending upon the procedure that is used. Procedures A and B utilize storage of specimens in heated water at elevated curing temperatures without moisture loss. The primary function of the moderately heated water used in Procedure A is to serve as insulation to conserve the heat generated by hydration. The temperature level employed in Procedure B provides thermal acceleration. Procedure C involves storage of specimens in insulated curing containers in which the elevated curing temperature is obtained from heat of hydration of the cement. The sealed containers also prevent moisture loss. Procedure D involves simultaneous application of elevated temperature and pressure to the concrete using special containers. Sampling and testing procedures are the same as for normally cured specimens (see Practice C 172 and Test Method C 39, respectively).

[1] This test method is under the jurisdiction of ASTM Committee C09 on Concrete and Concrete Aggregates and is the direct responsibility of Subcommittee C09.61 on Testing for Strength.

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4.2 Important characteristics of these procedures are shown in Table 1.

5. Significance and Use

5.1 The accelerated curing procedures provide, at the earliest practical time, an indication of the potential strength of a specific concrete mixture. These procedures also provide information on the variability of the production process for use in quality control.

5.2 The accelerated early strength obtained from any of the procedures in this test method can be used to evaluate concrete strengths in the same way conventional 28-day strengths have been used in the past, with suitable changes in the expected strength values. Since the practice of using strength values obtained from standard-cured cylinders at 28 days is long established and widespread, the results of accelerated strength tests are often used to estimate the later-age strength under standard curing. Such estimates should be limited to concretes using the same materials and mixture proportions as those used for establishing the correlation. Appendix X2 provides a procedure to estimate the 90 % confidence interval of the average later-age strength based on accelerated strength test results.

5.3 Correlation between accelerated strength and strength achieved at some later age by using conventional curing methods depends upon the materials comprising the concrete, the mixture proportions, and the specific accelerated test procedure.

5.4 The user shall choose which procedure to use on the basis of experience and local conditions. These procedures, in general, will be practical when a field laboratory is available to house the curing containers and the testing equipment to measure compressive strength within the specified time limits.

6. Interferences

6.1 When wet sieving of the concrete sample is required prior to molding the test specimens due to maximum aggregate size limitations (such as Procedure D, which is limited to 25 mm maximum), consider the effect of wet sieving on the air content and strength of the test specimens.

7. Apparatus

7.1 Equipment and small tools for fabricating specimens, measuring slump, and determining air content shall conform to Practice C 31/C 31M.

7.2 *Molds*:

7.2.1 Cylinder molds for test specimens used in Procedures A, B, and C shall conform to Specification C 470. Paper molds are excluded. When specimens are to be tested without capping, use only reusable molds with machined end plates that can be securely connected to both top and bottom of the mold. The end plates shall produce specimens with bearing surfaces that are plane within 0.05 mm (0.002 in.) and whose ends do not depart from perpendicularity to the axis of the cylinder by more than 0.5° (approximately equivalent to 10 mm/m (⅛ in. in 12 in.). When assembled, the mold assembly is sufficiently tight to permit the filled mold to be turned from the vertical filling position to a horizontal curing position without loss of mortar or damage to the test specimen.

7.2.2 Cylinder molds for Procedure D shall conform to the following:

7.2.2.1 Made of stainless steel,

7.2.2.2 Equipped with removable top and bottom metal plugs and O-ring seals,

7.2.2.3 Equipped with a heating element capable of raising the concrete temperature within the mold to 150 ± 3°C (300 ± 5°F) within 30 ± 5 min, and are capable of maintaining this temperature throughout the time required by the test procedure,

7.2.2.4 Equipped with devices to measure the temperature within each mold to ascertain that the temperature of the concrete satisfies the temperature requirements stated herein, and

7.2.2.5 Equipped with a companion loading component capable of maintaining a pressure of 10.3 MPa ± 0.2 MPa (1500 ± 25 psi) on the concrete during the curing period.

7.3 *Curing Apparatus*:

7.3.1 *Accelerated Curing Tank for Procedures A and B*:

7.3.1.1 The tank is of any configuration suitable for the number of cylinders to be tested. Arrange the cylinders in any configuration that provides a clearance of at least 50 mm (2 in.) between the side of each cylinder and the side of the tank, and at least 100 mm (4 in.) between adjacent cylinders. Maintain the water level at least 100 mm (4 in.) above the tops of the cylinders.

NOTE 1—Provision for an overflow pipe is a convenience in controlling the maximum depth of water. A number of different tanks have been used successfully. Guidelines are given in Appendix X1.

TABLE 1 Characteristics of Accelerated Curing Procedures

Procedure	Molds	Source of Strength Acceleration	Accelerated Curing Temperature °C (°F)	Age Accelerated Curing Begins	Duration of Accelerated Curing	Age at Testing
A. Warm Water	reusable or single-use	heat of hydration	35 (95)	immediately after casting	23.5 h ± 30 min	24 h ± 15 min
B. Boiling Water	reusable or single-use	boiling water	boiling	23 h ± 30 min after casting	3.5 h ± 5 min	28.5 h ± 15 min
C. Autogenous	single-use	heat of hydration	initial concrete temperature augmented by heat of hydration	immediately after casting	48 h ± 15 min	49 h ± 15 min
D. High-Temperature and Pressure	reusable	external heat and pressure	150 (300)	immediately after casting	5 h ± 5 min	5.25 h ± 5 min[A]

[A] Add 30 min if capping with sulfur compound is used.

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7.3.1.2 Equip the tank with environmental control element(s) capable of: (*1*) providing the specified water temperature, (*2*) maintaining the water temperature within ±3°C (±5°F) of the specified value at any point in the water, and (*3*) limiting the temperature drop, after immersion of specimens, to less than 3°C (5°F) and returning to the specified water temperature within 15 min. Thermometers or other temperature recording devices are required, independent of the thermostat, to check the temperature of the water.

NOTE 2—Depending upon the design features of the tank, insulation or mechanical agitation, or both, might be necessary to meet the specified temperature requirements. Electrical immersion heaters controlled by a thermostat are one suitable form of heating elements. For a particular procedure, the size of the heating element required will depend upon the size of the tank and the number of specimens to be cured at one time.

7.3.1.3 The plate supporting the specimens is perforated to permit circulation of the water.

7.3.1.4 A close fitting lid to reduce evaporation is required for Procedure B but is optional for Procedure A.

7.3.2 *Curing Container for Procedure C*:

7.3.2.1 The container consists of thermal insulation meeting heat retention requirements of 12.2.1 and closely surrounding the concrete specimen.

7.3.2.2 The container is capable of being opened to permit insertion and withdrawal of the specimen and has an outer casing and inner liner to protect the insulation from mechanical damage.

7.3.2.3 The container has a maximum-minimum recording thermometer which is not insulated from the concrete specimen (see Note 10).

7.3.2.4 The container has a lid or other means to provide secure closure during the specified curing period. The lid includes a heat seal that satisfies the requirements of 12.2.2.

7.3.2.5 The container is capable of holding either one or two specimens.

NOTE 3—Examples of suitable containers are included in Appendix X1. Any configuration is acceptable provided it meets the performance requirements of 12.2.

7.3.3 *Curing Apparatus for Procedure D*:

7.3.3.1 The curing apparatus consists of a loading system to apply the specified pressure to the concrete specimens and special molds to maintain the concrete specimens at the specified temperature during the curing period. The curing apparatus can be of any configuration suitable for the number of cylindrical specimens to be tested. Appendix X1 describes a successful apparatus designed for curing three specimens.

7.4 *Capping Apparatus*:

7.4.1 If capping of the test specimens is required, use the apparatus specified in Practice C 617 or Practice C 1231.

8. Materials

8.1 Capping compound or pad caps for use when the ends of the test specimens are unsuitable for testing without capping.

9. Hazards

9.1 Observe OSHA requirements and standard laboratory and field safety precautions when sampling, molding, curing, and testing concrete.

9.2 Observe the additional safety measures indicated when using Procedure B to prevent scalding or other burns resulting from the use of boiling water as a curing medium.

9.3 Observe the additional safety measures indicated when using Procedure D to prevent injury due to the high temperature and pressure used for curing.

10. Sampling

10.1 Determine the number of tests required from the concrete lot(s) or process. Use a random or systematic plan that provides the number of tests needed to characterize the strength of the concrete used in the construction.

10.2 If the lot(s) or process is stratified into sublots, locate the samples using a stratified random procedure. If circumstances dictate a non-stratified approach, use a random procedure.

NOTE 4—A stratified random sampling procedure can be implemented by dividing each lot of concrete into a number of equal-sized sublots, and randomly selecting a sample from each sublot. The number of sublots equals the number of samples that were scheduled to be taken from the lot. For example, if the job requirements called for each 500 m^3 of concrete to be treated as a lot and that five samples be obtained from each lot to determine compressive strength, divide the lot into five equal-sized sublots of 100 m^3 each. Randomly obtain one sample from each sublot. Test results from the five samples obtained in this manner provide unbiased estimates of the compressive strength of the 500 m^3 lot. This is the most practical approach to ensure that the samples obtained include the entire range of concrete in the production process. If unequal size sublots occur due to the construction process, weighting of the test results may be appropriate to maintain the fairness and defensibility of the sampling procedure.

NOTE 5—Practice D 3665 contains a table of random numbers, including instructions for use. Practices E 105, E 122, and E 141 contain additional information concerning sampling practices.

10.3 Sample the freshly mixed concrete in accordance with Practice C 172. Record in the job records the location at which the sampled batch is used in the structure.

11. Preparation of Apparatus

11.1 *Methods A and B*:

11.1.1 Activate the environmental control elements at least 1 h prior to the start of a scheduled test to allow the temperature of the water and equipment to stabilize.

11.2 *Method C*:

11.2.1 Conduct the proving tests specified in Section 12 prior to scheduling tests.

11.3 *Method D*:

11.3.1 Clean and check the molds and end plugs before starting a test. Standardize the loading system in accordance with Section 12 prior to scheduling tests.

12. Standardization

12.1 For all methods, verify the calibration of temperature measurement, control, and recording components on a frequent periodic basis. Calibrate such components in accordance with the manufacturer's recommendations or standard laboratory practice.

12.2 *Method C Requirements*:

12.2.1 *Heat Retention*—Place a watertight cylindrical container with internal dimensions of 300 mm (12 in.) in height by

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150 mm (6 in.) in diameter into the autogenous curing container. Fill the container to within 6 mm (¼ in.) of the brim with water at a temperature of 82°C (180°F). Insert a thermocouple into the water and measure the initial temperature of the water with a suitable readout device. Then seal the water container with a cap or plastic bag and close the autogenous container. When the autogenous curing container is stored in still air at 21 ± 1°C (70 ± 2°F), the water temperature requirements are as follows:

Elapsed time, h	°C	°F
12	67 ± 3	152 ± 5
24	58 ± 3	136 ± 6
48	45 ± 4	114 ± 7
72	38 ± 4	100 ± 8

12.2.2 *Tightness Test for Gasket Heat Seal*—When the autogenous curing container is immersed in water to a depth of 150 mm (6 in.) above the joint between the separable parts, no air shall escape through the heat seal within a period of 5 min.

12.2.3 *Stability of the Container*—The container, or any part thereof, shall not display embrittlement, fracturing, or distortion when maintained in an ambient temperature of − 30°C (−20°F) for 72 h, nor softening or distortion when maintained at an ambient temperature of 60°C (140°F) for 72 h. The gasket type heat seal immediately shall recover fully its original thickness after 50 % compression under the temperature conditions specified above.

12.3 *Method D*:

12.3.1 Verify the calibration of the loading component on a periodic basis. If the loading component is also used for compression testing of the specimens, follow the requirements of Test Method C 39.

13. Conditioning

13.1 The relatively short curing periods used for concrete test specimens in this test method require that particular attention be directed to conditioning of equipment and test specimens. Adhere carefully to the specified temperature and time requirements in each method.

14. Procedure

14.1 *Procedure A—Warm Water Method*:

14.1.1 *Preparation of Test Specimens*:

14.1.1.1 Mold the test specimens in accordance with the requirements of Practice C 31/C 31M or Practice C 192/C 192M, whichever is applicable.

14.1.2 *Curing*:

14.1.2.1 If necessary, cover the top of the specimens with a rigid plate to prevent loss of mortar to the water bath.

14.1.2.2 Immediately after molding, place the specimens into the curing tank (Note 6). Maintain the water at the time of immersion and throughout the curing period at 35 ± 3°C (95 ± 5°F).

NOTE 6—If the specimens are cast in molds meeting the requirements of 7.2.1.1 they may be stored horizontally, otherwise they are stored in the curing tank with the long axis vertical.

14.1.2.3 Record the temperature of the curing water either continuously or periodically throughout the curing period.

14.1.2.4 After curing for 23.5 h ± 30 min, remove the specimens from the tank and remove the molds.

14.1.3 *Capping and Testing*:

14.1.3.1 Cap the ends of specimens that are not plane within 0.05 mm (0.002 in.) or that depart from perpendicularity to the central axis by more than 0.5° (approximately equivalent to 10 mm/m (⅛ in. in 12 in.)) as specified in Practice C 617 or Practice C 1231 (see Note 7).

NOTE 7—Grinding of cylinders to achieve the flatness requirements is permitted provided the specimens are tested within the specified time limits.

14.1.3.2 For bonded caps, use capping material that develops, at an age of 30 min when tested in accordance with the provisions of Practice C 617, a strength equal to or greater than the strength of the specimens to be tested.

14.1.3.3 If bonded caps are used, do not test specimens sooner than 30 min after capping.

14.1.3.4 Test the specimens for strength in accordance with Test Method C 39 at the age of 24 h ± 15 min.

14.2 *Procedure B—Boiling Water Method*:

14.2.1 *Preparation of Test Specimens*:

14.2.1.1 Prepare specimens in accordance with 14.1.1.

14.2.2 *Initial Curing*:

14.2.2.1 Cover the specimens to prevent loss of moisture and store so that they will not be disturbed. Maintain the storage area temperature at 21 ± 6°C (70 ± 10°F). Adhere to the requirements of Practice C 31/C 31M in the protection and storage of test specimens.

NOTE 8—Strict attention to the protection and storage of the specimens during this initial period is necessary for meaningful results because of the short total curing period.

14.2.3 *Accelerated Curing*:

14.2.3.1 At 23 h ± 15 min after molding, place the covered molds in the water tank (Note 9). Maintain the temperature of the water at the time of immersion and throughout the curing period at boiling (Note 10).

NOTE 9—**Precaution:** In addition to other precautions, wear appropriate protection for the eyes, face, hands, and arms to prevent injury from the sudden release of steam upon opening the container or immersion of the cyclinder into the boiling water. Lifting tongs are suggested to slowly lower the molds into the boiling water without splashing.

NOTE 10—In confined places, the temperature of the water may be kept just below the boiling point to avoid excessive evaporation. The temperature at which water boils varies because of differences in elevation above sea level. Differences in strengths caused by the differences in temperatures are not believed to be significant, but comparison of results among areas so affected should be supported by appropriate correlations and interpreted with the knowledge of the temperature variations.

14.2.3.2 Record the temperature of the curing water either continuously or periodically throughout the curing period.

14.2.3.3 After curing for 3.5 h ± 5 min, remove the specimens from the boiling water, remove the molds, and allow the specimens to cool at room temperature for at least 1 h prior to capping.

14.2.4 *Capping and Testing*:

14.2.4.1 Cap and test the specimens in accordance with 14.1.3, except that the age at time of test is 28.5 ± 15 min.

14.3 *Procedure C—Autogenous Method*:

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14.3.1 *Preparation of Test Specimens*:

14.3.1.1 Prepare specimens in accordance with 14.1.1.

NOTE 11—Metal, reusable molds with end plates and clamps may be impracticable for Procedure C.

14.3.2 *Curing*:

14.3.2.1 Immediately after molding, cover the mold with a metal plate or a tightly fitted cap and place in a heavy-duty plastic bag from which as much of the entrapped air as possible is expelled prior to tying the neck. (Alternatively, a moisture-tight plastic cap may be used.) Use a plastic bag of sufficient strength to resist punctures and serve as a lifting grip for placing and removing the specimen from the autogenous container.

14.3.2.2 Reset the maximum-minimum thermometer, and, after the specimen is inserted into the container, secure the container lid.

14.3.2.3 Clearly record the time of molding to the nearest 15 min and the temperature of the freshly molded concrete on the outside of the curing container.

14.3.2.4 Store the curing container for at least 12 h in a location not subject to disturbance or direct sunlight, and preferably at a temperature of 21 ± 6°C (70 ± 10°F).

14.3.2.5 At the age of 48 h ± 15 min after the specimen was molded, remove the specimen from the container and remove the mold. Allow to stand at room temperature for 30 min.

14.3.2.6 Record the maximum and minimum temperatures in the container indicated on the thermometer.

NOTE 12—Comparison of the maximum and minimum temperatures with the recorded temperature of the fresh concrete will provide an indication of abnormal or interrupted curing which may cause high or low strength results.

14.3.3 *Capping and Testing*:

14.3.3.1 Cap and test the specimens in accordance with 14.1.3, except that the age at the time of test is 49 h ± 15 min.

NOTE 13—Capping and testing may be performed at an age different from that specified in 14.3.3. Agencies using the procedure have, for convenience, established relationships between test results at 24, 72, and 96 h with those obtained by standard moist curing. However, at 24 h, the relationship is less satisfactory than those obtained by accelerated autogenous curing for 48, 72, or 96 h. Where the curing period is other than that specified in 14.3.3, the age at testing should be the curing period plus 1 h. The tolerance of ±15 min should still apply.

14.4 *Procedure D—High Temperature and Pressure Method*:

14.4.1 *Preparation of Test Specimens*:

14.4.1.1 For the curing apparatus described in Appendix X1, the molds are 75 × 150 mm (3 × 6 in.) cylinders. Seal the molds with their bottom plugs before filling with concrete.

14.4.1.2 Procedure D is limited to concrete containing 25-mm (1-in.) maximum size aggregate. Wet sieve concrete containing aggregate larger than 25 mm (1 in.) in accordance with Practice C 172.

14.4.1.3 Place the concrete in the molds in two equal layers and rod each layer 10 times. Screed the top of the concrete with a special tool (see Fig. X1.3) to achieve the level of concrete required to receive the top metal plug that transmits the designated pressure of 10.3± 0.2 MPa (1500 ± 25 psi) to the concrete in the mold.

14.4.2 *Curing*:

14.4.2.1 Immediately after molding, cover each mold with a metal plug to seal the concrete inside the mold during the curing process.

14.4.2.2 Stack the molds vertically and place them in the loading apparatus described in 7.3.3.1. Apply and maintain a pressure of 10.3 ± 0.2 MPa (1500 ± 25 psi) on the concrete within the molds.

14.4.2.3 Activate the heating element specified in 7.2.2 to elevate the temperature of the specimen to 150 ± 3°C (300 ± 5°F) within 30 ± 5 minutes. The curing period begins when the heating element is activated.

14.4.2.4 The curing period lasts 5 h ± 5 min. During the first 3 h, maintain the specimen temperature at 150 ± 3°C (300± 5°F). After 3 h, turn off the heating element and maintain the pressure at 10.3 ± 0.2 MPa (1500 ± 25 psi) for the remainder of the curing period.

14.4.2.5 At the end of the curing period, release the pressure, remove the molds from the loading apparatus, and extrude the specimens from the molds.

NOTE 14—**Precaution:** The use of high temperature and pressure imposes the need for safety measures to prevent scalding or eye burns resulting from sudden escape of steam upon removal of plugs from the molds. In addition to other precautions, wear eye, face, and hand protection, while removing the specimens from the molds. It is suggested that the plugs be removed by prying in a direction away from the operator.

NOTE 15—Polypropylene plastic liners can be used inside the molds to facilitate extrusion of the cured concrete from the molds.

14.4.3 *Capping and Testing*:

14.4.3.1 Normally the specimens do not need to be capped for testing since the metal plugs produce suitably plane bearing surfaces. If the end surfaces do not meet the requirements of 14.1.3.1, cap the specimens in accordance with 14.1.3.

14.4.3.2 Test the specimens for strength in accordance with Test Method C 39 within 15 min after removing the molds. When capping is required, test the specimens 30 min after capping.

NOTE 16—The loading apparatus used for the curing period can also be designed to function as a suitable compression testing machine (see Appendix X1).

15. Interpretation of Results[3]

15.1 Strength requirements in existing specifications and codes are not based upon accelerated curing; therefore, apply results from this test method in the prediction of specification compliance of strengths at later ages with great caution. As stated in Section 17, the variability of the test method is the same or less than that from traditional methods. Thus, results can be used in rapid assessment of variability for process control and signalling the need for indicated adjustments. On the other hand, the magnitude of the strength values obtained is influenced by the specific combination of materials so that the use of the results from either conventional tests at any arbitrary age or those from this test method must be supported by

[3] Carino, N. J., "Prediction of Potential Concrete Strength at Later Ages," ASTM STP 169C, *Significance of Tests and Properties of Concrete and Concrete Making Materials*, 1994, pp. 140–152.

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experience or correlations developed by the specific agency for the existing local conditions and materials.

15.2 When this test method is used as a means to estimate standard-cured strength at a specified age, statistical methods shall be used to account for the various uncertainties associated with making such estimates. Appendix X2 provides an acceptable procedure for this purpose. Prior to using this test method to estimate standard-cured strength, all interested parties shall agree on the statistical procedures to be used and how the results are to be interpreted. If this test method is used for acceptance testing, the acceptance criterion shall be stated in the project documents.

NOTE 17—A recommended criterion for acceptance of concrete on the basis of accelerated strength testing is that the lower limit of the 90 % confidence interval of the estimated average strength of the sample tested should conform to the acceptance criteria for standard moist-cured cylinders.

16. Report

16.1 Report the following for each test specimen:

16.1.1 Identification number,

16.1.2 Diameter (and length, if not standard) in millimetres (or inches),

16.1.3 Cross-sectional area, in square millimetres (or square inches),

16.1.4 Maximum load, in newtons (or pounds-force),

16.1.5 Compressive strength calculated to the nearest 0.1 MPa (10 psi),

16.1.6 Type of fracture, if other than the usual cone,

16.1.7 Defects in either the specimen or the caps (if used),

16.1.8 Age of the specimens,

16.1.9 Accelerated curing procedure used,

16.1.10 Maximum and minimum temperature to the nearest° C (°F) if Procedure C was used.

16.1.11 If applicable, method of transportation used for shipping the specimens to the laboratory, and

16.1.12 Ambient temperature of the specimen during initial curing in Procedure B or of the container during storage for Procedure C.

17. Precision and Bias

17.1 *Precision*:

17.1.1 The data used to prepare the following precision statements was obtained using measurements in the inch-pound system.

17.1.2 The single-laboratory coefficient of variation for specimens cast from the same batch has been determined as 3.6 % for 150 × 300-mm (6 × 12-in.) cylinders (as used in Procedures A, B, and C) and as 6.7 % for 75 × 150-mm (3 × 6-in.) cylinders (as used in Procedure D) (Note 18). Therefore, for 150 × 300-mm (6 × 12-in.) cylinders tested according to Procedures A, B, and C, individual results of two properly conducted strength tests, by the same laboratory on specimens made from the same batch, should not differ more than 10.1 % of their average. For 75 × 150-mm (3 × 6-in.) cylinders tested according to Procedure D, the maximum acceptable difference between three individual test results is 22.1 %.

17.1.3 The single-laboratory, coefficient of variation for test results among batches cast on different days has been determined as 8.7 % for 150 × 300-mm (6 × 12-in.) cylinders as used in Procedures A, B, and C, and as 20 % for 75 × 150-mm (3 × 6-in.) cylinders as used in Procedure D (Note 19). A test result is the average strength of two specimens for Procedures A, B, and C and the average of three specimens for Procedure D. Therefore, results of two properly conducted strength tests from different batches of the same materials cast on different days should differ by no more than 24.4 % of their average for 150 × 300-mm (6 × 12-in.) cylinders and 56.0 % for 75 × 150-mm (3 × 6-in.) cylinders (Note 19).

NOTE 18—These numbers represent the (1s %) limit as described in Practice C 670.

NOTE 19—These numbers represent, respectively, the (1s %) and (d2s %) limits as described in Practice C 670.

18. Keywords

18.1 accelerated curing; compressive strength; testing

APPENDIXES

(Nonmandatory Information)

X1. CURING APPARATUS

X1.1 Accelerated Curing Tank (Procedures A and B)

X1.1.1 Curing tanks similar to that shown in Fig. X1.1 have been used successfully.

X1.1.2 Properly designed tanks will ensure an almost uniform temperature throughout the tank without the need for a mechanical stirrer. Locate the immersion heaters centrally in the plan and as near to the bottom of the tank as possible. The water above the heater will then be kept in circulation by convection currents.

X1.1.3 For a tank containing two or three specimens, two coupled elements (1500 and 5000 W) have been found suitable for use with Procedure B. While the smaller elements will maintain the specified curing temperature, the larger element is required as a booster to reestablish boiling within the specified time after the specimens have been immersed. Where the tank is to be used solely for Procedure A, the above heaters are also suitable, but a single 3000-W element has also been found suitable. With the 3000-W element, the tank may be of larger

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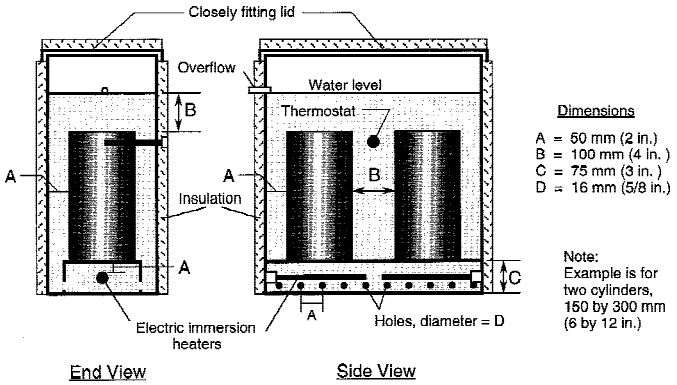

FIG. X1.1 Suggested Design for Accelerated Curing Tank (Procedure A or B)

dimensions to hold more than two or three specimens when used for Procedure A.

X1.1.4 The overflow pipe, closely fitting lid, and exterior insulation are not essential for curing tanks used only for Procedure A.

X1.2 Autogenous Curing Container (Procedure C)

X1.2.1 Satisfactory containers are shown in Fig. X1.2.

X1.2.2 The space for the maximum-minimum thermometer and the means of opening the container, securing when closed, and lifting are not shown.

X1.2.3 A heat seal is required at the joint face between the separable parts of the container. This may be a labyrinth or a gasket type seal provided the requirements of 12.2.1, 12.2.2, and 12.2.3 are met. A suitable gasket is flexible polyurethane foam (32 kg/m^3 or 2 lb/ft^3) maintained when closed at 50 % compression.

X1.2.4 Foamed-in-place closed-cell polyurethane having a density of between 32 and 48 kg/m^3(2 and 3 lb/ft^3) and thermal conductivity equal to or less than 0.02 W/m·K (0.15 Btu·in./h·ft^3°F) in accordance with Test Method C 177 has been found to be a suitable insulating material at the thicknesses specified to meet the heat retention requirements of 12.2.1.

X1.2.5 The maximum-minimum thermometer should cover a range from − 10 to 65°C (20 to 150°F) in 1° increments.

X1.3 High Temperature and Pressure Equipment (Procedure D)

X1.3.1 A satisfactory apparatus for Procedure D is shown in Fig. X1.3.

X1.3.2 Properly designed molds will ensure an almost uniform temperature throughout the concrete. The heater wires are normally spaced closer together near the edges of the mold and further apart in its central region.

X1.3.3 For a 75 × 150-mm (3 × 6-in.) cylindrical mold, a heating element of 100 W will raise and maintain the specified temperature during the curing period. Regular fiberglass insulation with a rating of R20 was found to be sufficient for the suggested heating element and required curing cycle. Each mold has its own electrical circuitry so that if one fails to function, two molds will remain to cure two specimens in a satisfactory manner. The electrical system shall have current indicators, a timer, and a buzzer in order to make the curing procedure automatic and simple to monitor.

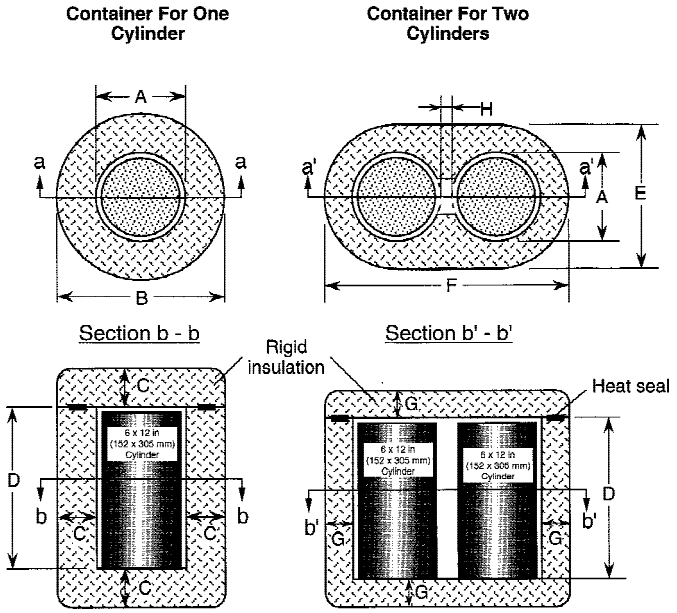

FIG. X1.2 Autogenous Curing Container for One or Two Cylinders (Procedure C)

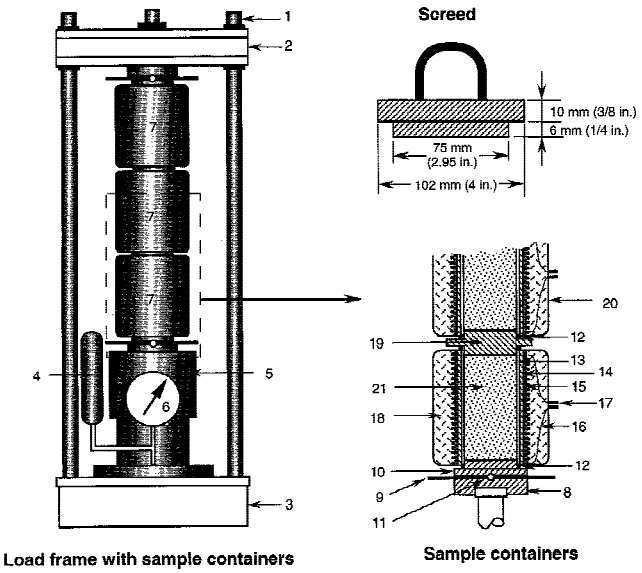

FIG. X1.3 Schematic of High-Temperature and Pressure Curing Apparatus (Procedure D)

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X1.3.4 The hydraulic jack and accumulator shall be equipped with a pressure gage to indicate the pressure being applied to the concrete in the molds. The accumulator shall be calibrated so that it will maintain the required pressure of 10.3 ± 0.2 MPa (1500 ± 25 psi).

X1.3.5 If it is desired to use the apparatus to test the specimens, then the apparatus shall be designed to function as a compression testing machine satisfying the requirements of Test Method C 39.

X2. ESTIMATION OF LATER-AGE STRENGTH

X2.1 Regression Equation

X2.1.1 To estimate the potential later-age strength from a measured early-age accelerated strength, the laboratory must first conduct enough tests to establish the relationship between the two types of strength. This will usually require preparing a series of six to ten mixtures with water-cement ratios varying over the maximum credible range that may be encountered during construction. These mixtures must include similar materials to those that will be used in construction. Ordinary least-squares regression analysis is used to obtain the equation of the line representing the relationship between standard-cured and accelerated strengths **(1,2)**.[4] This relationship is applicable only to the specific materials and accelerated test procedure that were used. To account for the uncertainty in the resulting regression line, confidence bands for the line are established **(1)**. Then, for a new accelerated strength, the confidence interval for the average later-age strength can be estimated. The following procedure and illustrative example are based on earlier work by Wills **(3)** and Carino **(4)**.

X2.1.2 In this discussion, it will be assumed that the relationship between the standard-cured strength (Y) and the accelerated strength (X) can be represented by a straight line with the following equation:

$$Y = a + b\,X \tag{X2.1}$$

However, for some concrete mixtures, the relationship between these two types of strength may not be linear. For these situations, the measured strength values should be transformed by taking their natural logarithms. The natural logarithms of the strengths would be used to obtain the average X and Y values to be used in subsequent calculations. The last step would be to perform exponentiation to convert the computed confidence intervals to strength values.

X2.1.3 Assume that n pairs of (X_i, Y_i) values are obtained from laboratory testing, where X_i and Y_i are the average strengths of accelerated and standard-cured specimens. The intercept, a, and slope, b, of the straight line are determined using the procedure of ordinary least squares **(1)**:

$$b = \frac{S_{xy}}{S_{xx}} \tag{X2.2}$$

$$a = \bar{Y} - b\,\bar{X} \tag{X2.3}$$

where:

$$S_{xy} = \sum (X_i - \bar{X})\,(Y_i - \bar{Y}) \tag{X2.4}$$

$$S_{xx} = \sum (X_i - \bar{X})^2 \tag{X2.5}$$

$$\bar{X} = \sum \frac{X_i}{n} \tag{X2.6}$$

$$\bar{Y} = \sum \frac{Y_i}{n} \tag{X2.7}$$

The residual standard deviation, s_e, of the best-fit line is given by the following:

$$S_e = \sqrt{\frac{1}{n-2}\left(S_{yy} - \frac{S_{xy}^{\,2}}{S_{xx}}\right)} \tag{X2.8}$$

where:

$$S_{yy} = \sum (Y_i - \bar{Y})^2 \tag{X2.9}$$

X2.1.4 To illustrate the procedure, consider the 12 pairs of accelerated and standard-cured, 28-day strengths given in the first two columns of Table X2.1. Each number is the average strength of two cylinders. Using the preceding equations, the following values are to be obtained:

$\bar{X}$ = 16.30 MPa (2366 psi)
$\bar{Y}$ = 38.90 MPa (5646 psi)
S_{xx} = 105.32 (MPa)^2
S_{yy} = 164.14 (MPa)^2
S_{xy} = 125.22 (MPa)^2

The slope of the line is b = 125.22/105.32 = 1.19, and the intercept is a = 38.90 – 1.19× 16.30 = 19.50 MPa (2830 psi).

TABLE X2.1 Values Used in Sample Problem to Illustrate Estimation of Confidence Interval for 28-day Strength

NOTE 1—For an approximate conversion to psi multiply the values by 145.

Accelerated Strength, X_i, MPa	28-day Strength, Y_i, MPa	Estimated Strength, Y, MPa	W_i, MPa	Lower Confidence Limit, MPa	Upper Confidence Limit, MPa
12.06	33.71	33.85	1.50	32.35	35.35
12.15	34.33	33.96	1.48	32.48	35.44
12.96	35.23	34.92	1.30	33.62	36.22
13.85	35.05	35.98	1.12	34.86	37.10
15.19	37.74	37.58	0.92	36.66	38.50
16.09	37.21	38.65	0.86	37.79	39.51
17.08	40.71	39.82	0.89	38.93	40.71
18.15	40.97	41.10	1.02	40.08	42.12
18.24	41.96	41.20	1.03	40.17	42.23
18.42	41.60	41.42	1.06	40.36	42.48
20.12	45.73	43.44	1.41	42.03	44.85
21.28	42.50	44.82	1.69	43.13	46.51
Confidence Interval for Estimated Strength at Accelerated Strength of 17.00 MPa					
17.00		39.73	0.89	38.84	40.62
16.40		39.01	0.86	38.15	
17.60		40.44	0.94		41.38

[4] The boldface numbers in parentheses refer to the list of references at the end of this standard.

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Therefore, the equation of the relationship between accelerated strength (X) and standard-cured strength (Y) is as follows:

$$Y = 19.50 + 1.19\,X \text{ (MPa)} \quad \text{(X2.10)}$$

Fig. X2.1 shows the 12 data pairs and the calculated best-fit line. The residual standard deviation of the line, s_e, is as follows:

$$s_e = \sqrt{\frac{1}{10}\left(164.14 - \frac{125.22^2}{105.32}\right)} = 1.23 \text{ MPa (178 psi)} \quad \text{(X2.11)}$$

X2.2 Confidence Band for Regression Line

X2.2.1 Because of the uncertainties in the estimates of the slope and the intercept of the line, there will be uncertainty when the line is used to estimate the average standard-cured strength from a measured accelerated strength. This uncertainty may be expressed by constructing the 90 % confidence band for the line **(1,5)**. This band is obtained by calculating Y_i for selected values of X_i using the equation of the line and plotting $Y_i \pm W_i$, versus X_i. The term W_i is the half-width of the confidence band at X_i and is given by the following equation:

$$W_i = s_e \sqrt{2F} \sqrt{\frac{1}{n} + \frac{(X_i - \bar{X})^2}{S_{xx}}} \quad \text{(X2.12)}$$

where:

- s_e = residual standard deviation for the best-fit line (Eq X2.8),
- F = value from F-distribution for 2 and n-2 degrees of freedom and significance level 0.10,
- n = number of data points used to establish regression line,
- X_i = selected value of accelerated strength, and
- $\bar{X}$ = grand average value of accelerated strength for all data used to establish the regression line.

The third column in Table X2.1 lists the estimated average 28-day strengths for the accelerated strengths in Column 1. The value of W_i at each value X_i is listed in the fourth column of Table X2.1. Finally, Columns 5 and 6 list the values of the lower and upper 90 % confidence limits, which are shown in Fig. X2.1. Note that the width of the confidence band is narrowest when X_i equals $\bar{X}$, because the second term under the square root sign in Eq X2.12 equals zero.

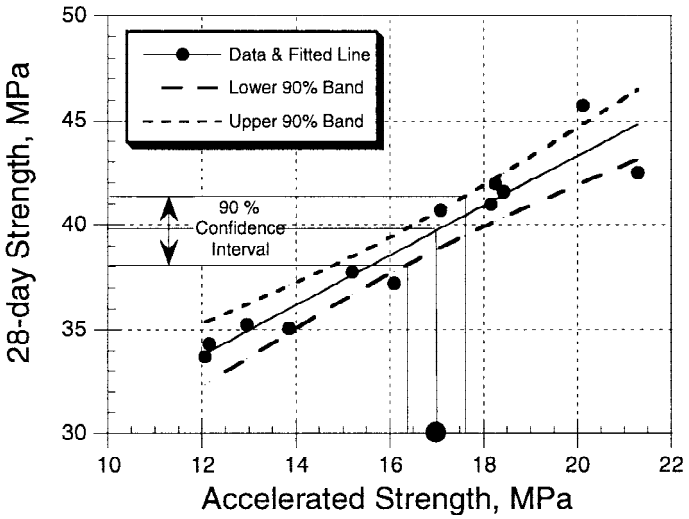

FIG. X2.1 Confidence Bands for the Estimated 28-day Strength Based on Measured Accelerated Strength; 90 % Confidence Interval for an Accelerated Strength of 17.0 MPa are Shown

X2.3 Estimate of Later-Age Strength

X2.3.1 Suppose that the average accelerated strength of two cylinders made in the field from similar concrete is 17.0 MPa (2470 psi). From the regression equation, the estimated average 28-day, standard-cured strength is 39.7 MPa (5760 psi). If the accelerated strength was known without error, the 90 % confidence interval for the average 28-day strength would be 38.8 to 40.6 MPa (5630 to 5890 psi) (see the bottom of Table X2.1). However, the accelerated strength has an uncertainty that is described by the within-batch standard deviation, which can be estimated from the differences between the accelerated strengths of pairs of cylinders **(6)**. Assume that the compressive strengths measured on field-prepared cylinders by the specific accelerated test method has a within-batch coefficient of variation of 3.0 %. Therefore, the standard deviation, s, at an average strength of 17.0 MPa is 0.51 MPa (74 psi). The 90 % confidence interval for the average accelerated strength of the two cylinders is as follows:

$$17.0 \pm z_{0.05}\frac{s}{\sqrt{2}} = 17.0 \pm 1.645 \times 0.51 \times 0.707 = 17.0 \pm 0.6\ MPa\ (2470 \pm 90\ psi) \quad \text{(X2.13)}$$

where $z_{0.05}$ is the value from the standard normal distribution corresponding to 5 % of the area under the curve. Thus the 90 % confidence interval[5] for the average accelerated strength is 16.4 to 17.6 MPa (2380 to 2550 psi). Projecting the limits of this interval to the lower and upper confidence bands of the regression line results in 38.2 to 41.4 MPa (5540 to 6010 psi) for the approximate 90 % confidence interval for the average standard-cured, 28-day strength. Each different measurement of accelerated strength produces a new confidence interval for the average 28-day strength. The use of a personal computer is recommended for implementing the preceding calculations for routine use.

X2.3.2 As the regression equation starts to be used on the project, companion cylinders should be prepared along with cylinders for accelerated testing. The companion cylinders would be subjected to standard curing and tested for compressive strength at the designated age. The measured standard-cured strengths should be compared with the confidence intervals for the estimated strengths based on the companion accelerated strengths. If the measured strengths consistently fall outside the estimated confidence intervals, the reliability of the regression line and its associated statistics is questionable.

[5] The 90 % confidence interval is often interpreted to mean that there is a 90 % probability that the true mean falls within the interval. However, the correct interpretation is as follows: If 100 repeated samples are taken from the same population and the 90 % confidence intervals for the mean are computed in each case, 90 of the intervals would include the true mean. The 90 % confidence band for the regression line has a similar interpretation: If 100 groups of data are taken from the same population and the 90 % confidence bands are computed for the regression equations, 90 % of those bands would include the true regression line for the population. See Mendenhall and Sincich **(7)** for further explanations on the proper interpretation of confidence intervals.

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The new companion results should be added to the data set from the laboratory correlation testing to calculate a new regression line and its corresponding statistics. This new line should be used for subsequent estimates of potential later-age strength. The making of companion sets of accelerated and standard-cured cylinders should be continued until the measured strengths consistently fall within the corresponding calculated confidence intervals. Once the reliability of the procedure has been demonstrated, companion cylinders should be made at random intervals to reconfirm that the procedure continues to be reliable.

X2.4 Summary

X2.4.1 A procedure has been presented to estimate the average standard-cured, 28-day strength from accelerated strength test results. The procedure accounts for the uncertainty in the regression line and in the measured accelerated strength. It is insufficient to simply use the regression equation to convert the accelerated strength to an equivalent 28-day strength. Additional information on the procedure presented in the example may be found in the references by Moore and Taylor **(8)** and in Miller **(5)**. Finally, it is emphasized that a particular regression equation is valid only for a specific accelerated test procedure and combination of materials. Therefore, each laboratory must conduct enough tests with a given set of materials and a certain procedure to establish the regression line and its confidence bands before estimations of standard-cured strengths are possible.

REFERENCES

(**1**) Natrella, M. G., *Experimental Statistics, NBS Handbook 91*, National Bureau of Standards, Washington, DC, August 1963.

(**2**) Draper, N.R., and Smith, H., *Applied Regression Analysis*, 2nd ed., John Wiley & Sons, New York, NY, 1981.

(**3**) Wills, M.H., "Early Assessment of Concrete Quality by Accelerating Compressive Strength Development with Heat (Results of ASTM Cooperative Test Program)," *Journal of Testing and Evaluation*, Vol 3, No. 4, July 1975, pp. 251-262.

(**4**) Carino, N.J., "Prediction of Potential Strength at Later Ages," Chapter 15, *ASTM STP 169C, Significance of Tests and Properties of Concrete and Concrete Making Materials*, Paul Klieger and Joseph F. Lamond, eds., 1994, pp. 140-152.

(**5**) Miller, R.G., *Simultaneous Statistical Inference*, 2nd ed., Springer-Verlag, New York, 1981.

(**6**) "Recommended Practice for Evaluation of Strength Test Results of Concrete," *ACI 214-77(97)*, Reported by ACI Committee 214, American Concrete Institute, Farmington Hills, MI.

(**7**) Mendenhall, W., and Sincich, T., *Statistics for Engineering and the Sciences*, 3rd ed., Dellen Publishing Co., San Francisco, CA, 1992.

(**8**) Moore, J.K., and Taylor, M.A., "Statistical Properties of Techniques for Predicting Concrete Strength and Examples of Their Use," ACI SP-56, *Accelerated Strength Testing*, V.M. Malhotra, ed., American Concrete Institute, 1978, pp. 259-283.

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Designation: C685/C685M – 10

Standard Specification for Concrete Made by Volumetric Batching and Continuous Mixing[1]

This standard is issued under the fixed designation C685/C685M; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

This standard has been approved for use by agencies of the Department of Defense.

1. Scope*

1.1 This specification covers concrete made from materials continuously batched by volume, mixed in a continuous mixer, and delivered to the purchaser in a freshly mixed and unhardened state as hereinafter specified. Requirements for quality of concrete shall be either as hereinafter specified or as specified by the purchaser. When the requirements of the purchaser differ from this specification, the purchaser's specification shall govern. This specification does not cover the placement, consolidation, finishing, curing, or protection of the concrete after delivery to the purchaser. Tests and criteria for batching accuracy and mixing efficiency are specified herein.

1.2 The values stated in either SI units, shown in brackets, or inch-pound units are to be regarded separately as standard. The values stated in each system may not be exact equivalents; therefore, each system shall be used independently of the other. Combining values from the two systems may result in nonconformance with the standard.

1.3 This specification references notes and footnotes which provide explanatory material. These notes and footnotes (excluding those in tables and figures) shall not be considered as requirements of this specification.

1.4 *This standard does not purport to address all the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.* (**Warning**—Fresh hydraulic cementitious mixtures are caustic and may cause chemical burns to skin and tissue upon prolonged use.[2])

2. Referenced Documents

2.1 *ASTM Standards:*[3]

C31/C31M Practice for Making and Curing Concrete Test Specimens in the Field

C33 Specification for Concrete Aggregates

C39/C39M Test Method for Compressive Strength of Cylindrical Concrete Specimens

C94/C94M Specification for Ready-Mixed Concrete

C125 Terminology Relating to Concrete and Concrete Aggregates

C127 Test Method for Density, Relative Density (Specific Gravity), and Absorption of Coarse Aggregate

C136 Test Method for Sieve Analysis of Fine and Coarse Aggregates

C138/C138M Test Method for Density (Unit Weight), Yield, and Air Content (Gravimetric) of Concrete

C143/C143M Test Method for Slump of Hydraulic-Cement Concrete

C150 Specification for Portland Cement

C173/C173M Test Method for Air Content of Freshly Mixed Concrete by the Volumetric Method

C231 Test Method for Air Content of Freshly Mixed Concrete by the Pressure Method

C260 Specification for Air-Entraining Admixtures for Concrete

C330 Specification for Lightweight Aggregates for Structural Concrete

C494/C494M Specification for Chemical Admixtures for Concrete

C567 Test Method for Determining Density of Structural Lightweight Concrete

C595 Specification for Blended Hydraulic Cements

C637 Specification for Aggregates for Radiation-Shielding Concrete

C989 Specification for Slag Cement for Use in Concrete and Mortars

[1] This specification is under the jurisdiction of ASTM Committee C09 on Concrete and Concrete Aggregates and is the direct responsibility of Subcommittee C09.40 on Ready-Mixed Concrete.

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[2] See Section on Safety Precautions, Manual of Aggregate and Concrete Testing, *Annual Book of ASTM Standards*, Vol 04.02.

[3] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

***A Summary of Changes section appears at the end of this standard.**

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C1017/C1017M Specification for Chemical Admixtures for Use in Producing Flowing Concrete
C1064/C1064M Test Method for Temperature of Freshly Mixed Hydraulic-Cement Concrete
C1077 Practice for Laboratories Testing Concrete and Concrete Aggregates for Use in Construction and Criteria for Laboratory Evaluation
C1157 Performance Specification for Hydraulic Cement
C1602/C1602M Specification for Mixing Water Used in the Production of Hydraulic Cement Concrete

2.2 *ACI Documents:*[4]

CP-1 Technician Workbook for ACI Certification of Concrete Field Testing Technician-Grade I
211.1 Standard Practice for Selecting Proportions for Normal, Heavyweight, and Mass Concrete
211.2 Standard Practice for Selecting Proportions for Structural Lightweight Concrete
301 Standard Specifications for Structural Concrete
304.6R Guide for Use of Volumetric-Measuring and Continuous-Mixing Concrete Equipment
305R Hot Weather Concreting
306R Cold Weather Concreting
318 Building Code Requirements for Structural Concrete and Commentary

2.3 *Other Documents:*

Bureau of Reclamation Concrete Manual [5]
VMMB 100-01 Volumetric Mixer Standards of the Volumetric Mixer Manufacturers Bureau[6]

3. Terminology

3.1 *Definitions:* For definitions of terms used in this specification, refer to Terminology C125.

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *manufacturer, n—of concrete,* the producer of the concrete.

3.2.2 *purchaser, n—of concrete,* the buyer of the concrete.

4. Basis of Purchase

4.1 The basis of purchase shall be the cubic yard or cubic metre of fresh concrete as it is continuously discharged from the batching and mixing apparatus.

4.2 The volume of fresh concrete in a given batch shall be determined by, or calculated from, a calibrated indicating device driven directly by the batching apparatus.

NOTE 1—It should be understood that the volume of hardened concrete may be, or may appear to be, less than expected due to waste and spillage, over-excavation, spreading forms, some loss of entrained air, or settlement of wet mixtures, none of which are the responsibility of the manufacturer.

5. Materials

5.1 In the absence of designated applicable specifications covering requirements for quality of materials, the following specifications shall govern:

5.1.1 *Cement*—Cement shall conform to Specification C150, Specification C595, or Specification C1157 (Note 2). The purchaser shall specify the type or types required, but if no type is specified, the requirements of Type I as prescribed in Specification C150 shall apply.

NOTE 2—These different cements will produce concretes of different properties and should not be used interchangeably.

5.1.2 *Aggregates*—Normal weight aggregates shall conform to Specification C33. Lightweight aggregates shall conform to Specification C330 and heavyweight aggregates shall conform to Specification C637.

5.1.3 *Water*—Water shall conform to Specification C1602/C1602M.

5.1.4 *Ground Granulated Blast-Furnace Slag*—Ground granulated blast furnace slag shall conform to Specification C989.

5.1.5 *Air-Entraining Admixtures*—Air-entraining admixtures shall conform to Specification C260. (Note 3)

5.1.6 *Chemical Admixtures*—Chemical admixtures shall conform to either Specification C494/C494M or C1017/C1017M, as applicable (Note 3).

NOTE 3—In any given instance, the required dosage of air-entraining, accelerating, and retarding admixtures may vary. Therefore, a range of dosages should be allowed which will permit obtaining the desired effect.

6. Ordering Information

6.1 In the absence of designated applicable general specifications, the purchaser shall specify the following:

6.1.1 Designated size or sizes of coarse aggregate,

6.1.2 Slump or slumps desired at the point of delivery (see 10.3),

6.1.3 When air-entrained concrete is specified, the air content of samples taken at the point of discharge from the transportation unit (see 10.4 and Table 1 for the total air content and tolerances) (Note 4),

6.1.4 When structural lightweight concrete is specified, the density as fresh density, equilibrium density, or oven-dry density (Note 5), and

6.1.5 Which of Options A, B, or C shall be used as a basis for determining the proportions of the concrete to produce the required quality (see 6.2, 6.3, or 6.4).

NOTE 4—In selecting the specified air content, the purchaser should consider the exposure conditions to which the concrete will be subjected. Air contents less than shown in Table 1 may not give the required resistance to freezing and thawing, which is the primary purpose of air-entrained concrete. Air contents higher than the levels shown may reduce strength without contributing any further improvement of durability.

NOTE 5—The density of fresh concrete, which is the only density determinable at the time of delivery, is always higher than the equilibrium density, or oven-dry density. Definitions of, and methods for determining or calculating equilibrium density and oven-dry density, are covered in Test Method C567.

6.2 *Option A*:

6.2.1 When the purchaser requires the manufacturer to assume full responsibility for the selection of the proportions for the concrete mixture, the purchaser shall also specify the following in addition to the requirements of 6.1.1 through 6.1.5:

[4] Available from American Concrete Institute (ACI), P.O. Box 9094, Farmington Hills, MI 48333-9094, http://www.aci-int.org.
[5] Available from Superintendent of Documents, U.S. Government Printing Office, Washington, DC 20402.
[6] Available from the Volumetric Mixer Manufacturers Bureau, 900 Spring Street, Silver Spring, MD 20910, www.vmmb.org.

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6.2.1.1 Requirements for compressive strength as determined on samples taken from the mixer at the point of discharge and evaluated in accordance with Section 11. The purchaser shall specify the requirements in terms of the compressive strength of standard specimens cured under standard curing conditions for moist curing. Unless otherwise specified, the age at test shall be 28 days, and

6.2.2 At the request of the purchaser, the manufacturer shall, prior to the actual delivery of the concrete, furnish a statement to the purchaser, giving the dry mass of cement and saturated surface-dry mass of fine and coarse aggregate and quantities, type, and name of admixtures (if any) and of water per cubic yard or cubic metre of concrete that will be used in the manufacture of each class of concrete ordered by the purchaser. The manufacturer shall also furnish evidence satisfactory to the purchaser that the materials to be used and proportions selected will produce concrete of the quality specified.

6.3 *Option B*:

6.3.1 When the purchaser assumes responsibility for the proportioning of the concrete mixture, the purchaser shall also specify the following in addition to the requirements of 6.1.1 through 6.1.5:

6.3.1.1 Cement content in bags or pounds per cubic yard or kilograms per cubic metre of concrete, or equivalent units,

6.3.1.2 Maximum allowable water content in gallons per cubic yard or litres or kilograms per cubic metre of concrete or equivalent units, including surface moisture on the aggregates, but excluding water of absorption (Note 6), and

6.3.1.3 If admixtures are required, the type, name, and dosage range to be used. Those employed for air-entrainment or for control of set (acceleration, retardation) shall have maximum limitations set as to dosage. Admixtures shall not be used as a substitute for a portion of specified amounts of cement without the written approval of the purchaser.

NOTE 6—The purchaser, in selecting requirements for which he assumes responsibility should give consideration to requirements for workability, placeability, durability, surface texture, and density, in addition to those for structural design. The purchaser is referred to ACI Standard Practice 211.1 for normal weight concrete, and ACI Standard Practice 211.2 for lightweight concrete, for the selection of proportions that will result in concrete suitable for various types of structures and conditions of exposure. The water-cement ratio of most structural lightweight concretes cannot be determined with sufficient accuracy for use as a specification basis.

6.3.2 At the request of the purchaser, the manufacturer shall, prior to the actual delivery of the concrete, furnish a statement to the purchaser giving the sources, densities, and sieve analyses of the aggregates and the dry mass of cement and saturated surface-dry mass of fine and coarse aggregate and quantities, type, and name of admixture (if any) and of water per cubic yard or cubic metre of concrete that will be used in the manufacture of each class of concrete ordered by the purchaser.

6.4 *Option C*:

6.4.1 When the purchaser requires the manufacturer to assume responsibility for the selection of the proportions for the concrete mixture with the minimum allowable cement content specified, the purchaser shall also specify the following in addition to the requirements of 6.1.1 through 6.1.5:

6.4.1.1 Required compressive strength as determined on samples taken from the mixer at the point of discharge and evaluated in accordance with Section 11. The purchaser shall specify the requirements for strength in terms of tests of standard specimens cured under standard curing conditions for moist curing. Unless otherwise specified, the age at test shall be 28 days.

6.4.1.2 Minimum cement content in bags or pounds per cubic yard or kilograms per cubic metre of concrete (Note 7), and

6.4.1.3 If admixtures are required, the type, name, and dosage range to be used. The cement content shall not be reduced when admixtures are used.

6.4.2 At the request of the purchaser, the manufacturer shall, prior to the actual delivery of the concrete, furnish a statement to the purchaser, giving the dry mass of cement and saturated surface-dry mass of fine and coarse aggregate and quantities, type, and name of admixture (if any) and of water per cubic yard or cubic metre of concrete that will be used in the manufacture of each class of concrete ordered by the purchaser. The manufacturer shall also furnish evidence satisfactory to the purchaser that the materials to be used and proportions selected will produce concrete of the quality specified. Whatever strengths are attained the quantity of cement used shall not be less than the minimum specified.

NOTE 7—Option C can be distinctive and useful only if the designated minimum cement content is at about the same level that would ordinarily be required for the strength, aggregate size, and slump specified. At the same time, it must be an amount that will be sufficient to ensure durability under expected service conditions, as well as satisfactory surface texture and density, in the event specified strength is attained with it. Attention is directed to ACI Standard Practices 211.1 and 211.2 for additional information on mixture proportions.

6.5 The proportions arrived at by Options A, B, or C for each class of concrete and which are approved for use in a project shall be assigned a designation (7CV.PK7, etc.) to facilitate identification of each concrete mixture delivered to the project. This is the designation required in 15.1.7 and supplies information on concrete proportions when they are not given separately on each delivery ticket as outlined in 15.2. However, each delivery of concrete shall be covered by a delivery ticket showing enough information to establish that the mix conforms to the mix designs previously approved for the work.

6.6 The purchaser shall ensure that the manufacturer is provided copies of all reports of tests performed on concrete samples taken to determine compliance with specification requirements. Reports will be provided on a timely basis.

7. Measuring Materials

7.1 Cement, fine and coarse aggregates, water, and admixtures shall be measured by volume. Devices such as counters, calibrated gate openings, or flowmeters shall be available for controlling and determining the quantities of the ingredients discharged. The entire measuring and dispensing mechanism shall produce the specified proportions of each ingredient within the tolerances in 7.8.

NOTE 8—The recommendations of the equipment manufacturer in the operation of the equipment and in calibrating and using the various gages,

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TABLE 1 Recommended Total Air Content for Air-Entrained Concrete[A]

Exposure Condition[B,C]	Total Air Content, % Nominal Max Sizes of Aggregate, in. [mm]						
	⅜ [9.5]	½ [12.5]	¾ [19.0]	1 [25.0]	1½ [37.5]	2 [50.0]	3 [75.0]
Mild	4.5	4.0	3.5	3.0	2.5	2.0	1.5
Moderate	6.0	5.5	5.0	4.5	4.5	4.0	3.5
Severe	7.5	7.0	6.0	6.0	5.5	5.0	4.5

[A] For air-entrained concrete, when specified.
[B] For description of exposure conditions, refer to ACI Standard Practice 211.1, Section 6.3.3 with attention to accompanying footnotes.
[C] Unless exposure conditions dictate otherwise, it is permissible to reduce air contents recommended above by up to 1 % for concretes with specified compressive strength, f'_c, of 5000 psi [35 MPa] or above.

revolution counters, speed indicators, or other control devices should be followed.

7.2 All indicating devices that bear on the accuracy of proportioning and mixing of concrete shall be in full view and near enough to be read by the operator while concrete is being produced. The operator shall have convenient access to all controls.

7.3 The proportioning and indicating devices shall be individually checked by following the equipment manufacturer's recommendations as related to each individual concrete batching and mixing unit. Adequate standard volume measures, scales, and weights shall be made available for the checking accuracy of the proportioning mechanism.

7.4 *Yield Check*—Essentially, the volume of concrete discharged from the mixer is checked by first determining the mass of the amount of concrete discharged during some number of revolutions, or as determined by some other output indicator; this is then followed immediately by a determination of the density. The mass of concrete discharged divided by the density is equal to the number of cubic feet or cubic metres mixed and discharged during the chosen interval. The accuracy of the output indicator is thus checked by this expedient. For further guidance and a suggested calibration procedure, refer to ACI 304.6R and VMMB 100-01.

NOTE 9—It is recommended that about 2.5 to 3.0 ft^3 [0.070 to 0.085 m^3] be discharged for this purpose; this amount of concrete will weigh from 350 to 500 lb [160 to 225 kg] and can be discharged into and contained in a 35 or 55-gal [130 to 210-dm^3] drum or other suitable container which in turn can be placed on a scale of adequate capacity. The output of a batcher-mixer unit may be indicated by the number of revolutions, travel of a belt, or changes in gage readings; if so, these figures should be used as a measure of output.

7.5 *Proportioning Check*—Whenever the sources or characteristics of the ingredients are changed, or the characteristics of the mixture are noted to have changed, the purchaser is permitted to require a check of the fine aggregate content and the coarse aggregate content by use of the washout test. Essentially, in the washout test, 1 ft^3 [0.03 m^3] of concrete is washed through a No. 4 [4.75-mm] sieve and through a No. 100 [150-µm] sieve; that retained on the No. 4 sieve is normally considered coarse aggregate whereas that passing the No. 4 and retained on the No. 100 sieve is considered fine aggregate. Corrections to the quantity of aggregates (per cubic foot or cubic metre of concrete) shall be made if the original sieve analysis of each aggregate is available.

7.6 The rate of water supplied the continuous mixer shall be measured by a calibrated flowmeter coordinated with the cement and aggregate feeding mechanism, and with the mixer. The device for the measurement of water shall be capable of delivering to the batch the required quantity. The rate shall be capable of being adjusted in order to control slump at the desired levels and to determine that the water-cement (permitted or required) ratios are being met.

7.7 Liquid admixtures shall be dispensed through a controlled flowmeter.

7.8 Tolerances in proportioning the various ingredients are as follows:

Cement, mass %	0 to +4
Fine Aggregate, mass %	±2
Coarse Aggregate, mass %	±2
Admixtures, mass or volume %	±3
Water, mass or volume %	±1

The tolerances are based on a volume/mass relationship established by calibration of the measuring devices furnished as an integral part of the whole equipment.

NOTE 10—It is noted that to meet these tolerances, attention should be given to:
(*1*) Degree of compaction of the cement,
(*2*) Grading and other physical characteristics of the fine and coarse aggregates,
(*3*) Moisture content and bulking factor of the fine aggregate,
(*4*) Viscosity of the admixture, and
(*5*) Other factors of influence, for example, mechanical condition and weather.

8. Mixing Mechanism

8.1 The continuous mixer shall be an auger-type mixer or any other type suitable for mixing concrete to meet the required consistency and uniformity requirements (see 14.2.3).

8.2 Each batching or mixing unit, or both, shall carry in a prominent place a metal plate or plates on which are plainly marked the gross volume of the unit in terms of mixed concrete, discharge speed, and the mass-calibrated constant of the machine in terms of a revolution counter or other output indicator. The mixer shall produce a thoroughly mixed and uniform concrete.

NOTE 11—Slump and air content tests of samples taken in accordance with 14.2.3 can be made for a quick check of the probable degree of uniformity.

9. Mixing and Delivery

9.1 The batcher-mixer unit shall contain in separate compartments all the necessary ingredients needed for the manufacture of concrete. The unit shall be equipped with calibrated

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proportioning devices to vary the mix proportions and it shall produce concrete as required by this specification and those of the project.

9.2 *Cold Weather Concrete*—Concrete delivered in cold weather shall have the applicable minimum temperature indicated in the following table. (The purchaser shall inform the producer as to the type of construction for which the concrete is intended.)

	Minimum Concrete Temperature as Placed			
Section Size, in. [mm]	<12 [<300]	12 to 36 [300 to 900]	36 to 72 [900 to 1800]	>72 [>1800]
Temperature, min, °F (°C)	55 [13]	50 [10]	45 [7]	40 [5]

The maximum temperature of concrete produced with heated aggregates, heated water, or both, shall at no time during its production or transportation exceed 90 °F [32 °C].

NOTE 12—When hot water is used rapid stiffening may occur if hot water is brought in direct contact with the cement. Additional information on cold weather concreting is contained in ACI 306R.

9.3 The producer shall deliver the concrete during hot weather at concrete temperatures as low as practicable, subject to the approval of the purchaser.

NOTE 13—In some situations difficulty may be encountered when concrete temperatures approach 90 °F [32 °C]. Additional information may be found in the Bureau of Reclamation Concrete Manual and in ACI 305R.

10. Slump and Air Content

10.1 Slump, air-content, and temperature tests shall be made at the time of placement at the option of the inspector as often as is necessary for control checks. In addition, these tests shall be made, when specified and always when strength specimens are made (11.2).

10.2 If the measured slump, temperature, or air content falls outside the specified limits, a check test shall be made immediately on another portion of the same sample. In the event of a second failure, the concrete shall be considered to have failed the requirements of the specification.

10.3 *Tolerances in Slump*:

10.3.1 Unless other tolerances are included in the project specifications, the following shall apply:

10.3.1.1 When the project specifications for slump are written as a "maximum" or "not to exceed" requirement:

Specified Slump	Tolerance, in. (mm)
3 in. [75 mm] or less	+0–1½ [40]
More than 3 in. [75 mm]	+0–2½ [65]

This option is to be used only if one addition of water is permitted on the job provided such addition does not increase the water-cement ratio above the maximum permitted by the specifications.

10.3.1.2 When the project specifications for slump are *not* written as a "maximum" or "not to exceed" requirement:

Specified Slump	Tolerance, in. (mm)
2 in. [50 mm] and less	± ½ [15]
More than 2 in. [50 mm] through 4 in. [100 mm]	±1 [25]
More than 4 in. [100 mm]	±1½ [40]

10.4 When air-entrained concrete is desired, the purchaser shall specify the total air content of the concrete. See Table 1 for total air content (Note 4).

10.5 The air content of air-entrained concrete when sampled from the transportation unit at the point of discharge shall be within a tolerance of ±1.5 of the specified value.

11. Strength

11.1 When strength is used as a basis for acceptance of the concrete, standard specimens shall be made and cured under standard curing conditions in accordance with the applicable provisions of Practice C31/C31M. The technician performing the strength test shall be certified as an ACI Concrete Laboratory Testing Technician—Grade I or II or by an equivalent written and performance test program.

11.2 One strength test set of two cylinders and the accompanying slump, temperature, and air content tests shall be made for each 25 yd^3 [20 m^3] of concrete or fraction thereof, or whenever significant changes have been made in the proportioning controls. There shall be at least one strength test made for each class of concrete placed in 1 day.

11.3 For each strength test, two standard-size cylinders shall be made (see 14.2.2). The test result shall be the average of the strength of the two specimens except that, if any specimen shows definite evidence other than low strength, of improper sampling, molding, handling, curing, or testing, it shall be discarded and the strength of the remaining cylinder shall then be considered the test result.

11.4 The representative of the purchaser shall ascertain and record the delivery ticket number for the concrete and the exact location in the work where the concrete represented by each strength test was deposited.

11.5 To conform to the requirements of this specification, strength tests representing each class of concrete must meet the following two requirements (Note 14):

11.5.1 The average of any three consecutive strength tests shall be equal to, or greater than, the specified strength, f'_c, and

11.5.2 No individual strength test shall be more than 500 psi [3.5 MPa] below the specified strength, f'_c.

NOTE 14—Due to variations in materials, operations, and testing the average strength necessary to meet these requirements will be substantially higher than the specified strength. The amount higher depends upon the standard deviation of the test results and the accuracy with which that value can be estimated from prior data as explained in ACI 318 and ACI 301. Pertinent data is given in Table 2.

12. Failure to Meet Strength Requirements

12.1 In the event that concrete tested in accordance with the requirements of Section 11 fails to meet the strength requirements of this specification, the manufacturer of the concrete and the purchaser shall confer to determine whether agreement will be reached as to what adjustment, if any, shall be made. If an agreement on a mutually satisfactory adjustment cannot be reached by the manufacturer and the purchaser, a decision shall be made by a panel of three qualified engineers, one of whom shall be designated by the purchaser, one by the manufacturer, and the third chosen by these two members of the panel. The question of responsibility for the cost of such arbitration shall

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TABLE 2 Overdesign Necessary to Meet Strength Requirements[A]

Number of Tests[B]	Standard Deviation, psi					
	300	400	500	600	700	Unknown
15	470	620	850	1120	1390	[C]
20	430	580	760	1010	1260	[C]
30 or more	400	530	670	900	1130	[C]
	Standard Deviation, MPa					
	2.0	3.0	4.0	5.0		Unknown
15	3.1	4.7	7.3	10.0		[C]
20	2.9	4.3	6.6	9.1		[C]
30 or more	2.7	4.0	5.8	8.2		[C]

[A] Add the tabulated amounts to the specified strength to obtain the required average strengths.

[B] Number of tests of a concrete mixture used to estimate the standard deviation of a concrete production facility. The mixture used must have a strength within 1000 psi of that specified and be made with similar materials. See ACI 318.

[C] If less than 15 prior tests are available, the overdesign should be 1000 psi [7.0 MPa] for specified strength less than 3000 psi [20 MPa], 1200 psi [8.5 MPa] for specified strengths from 3000 to 5000 psi [20 to 35 MPa] and 1400 psi [10.0 MPa] for specified strengths greater than 5000 psi [35 MPa].

be determined by the panel. Its decision shall be binding, except as modified by a court decision.

13. Test Methods and Practices

13.1 Test the concrete in accordance with the following ASTM methods:

13.1.1 *Compression Test Specimens*—Use standard moist curing in accordance with the applicable provisions of Practice C31/C31M.

13.1.2 *Compression Tests*—Test Method C39/C39M.

13.1.3 *Yield, Unit Weight*—Test Method C138/C138M.

13.1.4 *Air Content*—Test Method C138/C138M, Test Method C173/C173M, or Test Method C231.

13.1.5 *Slump*—Test Method C143/C143M.

13.1.6 *Temperature*—Test Method C1064/C1064M.

13.2 The testing laboratory performing acceptance tests of concrete shall meet the requirements of Practice C1077.

14. Inspection

14.1 *Materials, Batching Facilities, and Mixing Facilities*—The manufacturer shall afford the inspector all reasonable access (without charge) for obtaining necessary samples of materials used in the concrete, and for making necessary checks of the batching and mixing facilities to determine if the concrete is being produced in accordance with this specification. All tests and inspection shall be so conducted as not to interfere unnecessarily with the batching, mixing, and discharge of the concrete to the purchaser.

14.1.1 The volume of plastic and unhardened concrete shall be checked daily on projects requiring more than 50 yd^3 [40 m^3] of concrete per day (see 7.4).

14.1.2 The manufacturer of the concrete shall conduct calibration and mixer efficiency tests at intervals not exceeding 6 months. Data on such tests using materials proposed for use in the project shall be furnished to the purchaser upon request. The amount of various ingredients (cement, fine and coarse aggregate, admixtures, and water) shall be checked as required in 7.5.

14.2 *Fresh Concrete*:

14.2.1 The contractor shall afford the inspector all reasonable access and assistance (without charge) for the procurement of samples of fresh concrete at the time of placement so as to determine conformance of the concrete to this specification.

14.2.2 At any time after at least 2 ft^3 [0.05 m^3] of concrete have been discharged, one sample of concrete shall be taken for the slump test, the air content test, if required, and the strength test. The sample shall be at least 2 ft^3 in volume. Two cylinders for each age of test shall be made. Tests for slump or air content or both shall be started within 5 min of sampling; these tests shall then be completed as expeditiously as possible. Molding of specimens for strength tests shall be started within 15 min of sampling. The time for making these tests and specimens shall be as short as possible.

14.2.3 Samples for determining the uniformity of mixing shall be taken at arbitrarily designated times. After at least 2 ft^3 [0.05 m^3] have been discharged, a sample of at least 4 ft^3 [0.10 m^3] shall be taken followed by another sample being taken no sooner than after 4 min of continuous discharge or 1 yd^3 [0.75 m^3] whichever is smaller. These samples shall be checked for conformance to the criteria set forth in Annex A1.

14.2.4 Tests of concrete required to determine compliance with this specification shall be made by a certified ACI Concrete Field Testing Technician, Grade I or equivalent. Equivalent personnel certification programs shall include both written and performance examinations as outlined in ACI CP-1.

14.3 Laboratory reports of concrete test results used to determine compliance with this specification shall include a statement that all tests performed by the laboratory or its agents were in accordance with the applicable test methods or shall note all known deviations from the prescribed procedures (Note 15). The reports shall also list any part of the test methods not performed by the laboratory.

NOTE 15—Deviation from standard test methods may adversely affect test results.

15. Batch Ticket Information

15.1 The manufacturer of the concrete shall furnish to the purchaser with each increment of discharged concrete, a delivery ticket or a statement of particulars on which is shown the following:

15.1.1 Name of concrete supplier,

15.1.2 Serial number of the delivery ticket or statement,

15.1.3 Date; starting time, and finishing time,

15.1.4 Identification number of batching or mixing equipment, or both,

15.1.5 Name of the purchaser,

15.1.6 Specific designation of the job (name and location),

15.1.7 Specific class or designation of the concrete in conformance with that employed in the job specification, and

15.1.8 Amount of concrete in cubic yards or cubic metres, and reading of the revolution counter or other device that indicates quantity of concrete.

15.2 Additional information designated by the purchaser and required by the job specifications shall be furnished when requested, such as:

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15.2.1 Type, brand, and amount of cement,

15.2.2 Type, name, and amount of each admixture,

15.2.3 Information necessary to calculate total mixing water added by the producer. Total mixing water includes free water on the aggregates and water batched by the producer from the mixing equipment or other sources,

15.2.4 Maximum size of aggregate,

15.2.5 Mass or volumes of fine and coarse aggregate,

15.2.6 Notation of calibrated settings for flow control of fine and coarse aggregate, added water, and admixtures,

15.2.7 Ingredients certified as being previously approved, and

15.2.8 Signature or initials of the person operating the batching or mixing apparatus.

16. Keywords

16.1 ready-mixed concrete; testing

ANNEX

(Mandatory Information)

A1. CONCRETE UNIFORMITY REQUIREMENTS

A1.1 Scope

A1.1.1 This annex includes test procedures and uniformity requirements for use in the evaluation of concrete produced in conformance with Specification C685/C685M by an individual batching-mixing unit, loaded to rated capacity.

A1.2 Significance and Use

A1.2.1 These tests and requirements are used to evaluate loading and operating procedures; verify the accuracy of proportioning and indicating systems; and determine if mixing uniformity has been degraded by excessive wear or by accumulations of hardened concrete, or both (Note A1.1).

NOTE A1.1—The method of loading the batching-mixing unit, proper maintenance, and other factors may have an effect on the ability of the unit to produce uniformly mixed concrete. For this reason, the use of this test method not only measures the efficiency of the mixer, but also the combined effect of the method of loading and operating the unit.

A1.2.2 This annex provides additional procedures and cautions that are necessary in the application of existing test methods and practices when used to determine the uniformity of freshly mixed concrete.

A1.3 Concrete Mixture

A1.3.1 Test a concrete mixture with proportions typical of the anticipated use (Note A1.2).

NOTE A1.2—Recommended test mix parameters are available from the Volumetric Mixer Manufacturers Bureau[7]. Normally, it is not necessary to test all mixtures produced unless they are made with greatly different slump, for instance 1 in. [25 mm] and 6 in. [150 mm]; or greatly different nominal maximum size aggregates such as ⅜ in. [9.5 mm] and 1½ in. [37.5 mm].

A1.4 Testing Apparatus and Materials

A1.4.1 The apparatus and materials shall conform to the requirements of the appropriate referenced ASTM Standards.

A1.4.2 Other special equipment as required by this annex and not specifically described in the referenced ASTM Standards is identified in the subsequent sections.

[7] Available from Volumetric Mixer Manufactures Bureau, 900 Spring St., Silver Spring, MD 20910.

A1.5 Sampling

A1.5.1 Take samples of the concrete discharge at approximately 15 and 85 % of the unit rated capacity by intercepting the full discharge stream (Note A1.3).

NOTE A1.3—Concrete with slumps over about 5 in. [125 mm] may segregate on the mixer blades or in the chute if discharge is stopped and started during the sampling process. For this reason, all samples should be taken without stopping or starting discharge during the sampling procedure.

A1.6 Slump

A1.6.1 Perform two slump tests on each sample in accordance with Test Method C143/C143M. Start testing the slump of each sample within 5 min after it was obtained.

A1.6.2 Calculate the average of the two tests performed on each sample.

A1.7 Fresh Concrete Density (Unit Weight)

A1.7.1 Determine the fresh concrete density of each sample in accordance with Test Method C138/C138M. If applicable, using a concrete sample in a ¼-ft^3 [7-L] air meter container to determine fresh concrete density; then using that same compacted sample to determine air content by Test Method C231; and then further using that sample to determine the coarse aggregate content percent is not prohibited (Note A1.4).

NOTE A1.4—Determination of fresh concrete density in a larger ½-ft^3 [14-L] container may provide a somewhat more accurate determination. The use of a separate sample of concrete for determination of coarse aggregate content may also improve accuracy, as some segregation or loss of coarse aggregate may occur when striking off the air content test sample.

A1.7.2 Calculate the fresh concrete density of the sample as follows:

$$D = (M_c - M_m)/V_m \quad \text{(A1.1)}$$

where:

D = fresh concrete density (unit weight), lb/ft^3 [kg/m^3],
M_c = mass of the measure filled with concrete, lb [kg],
M_m = mass of the measure empty, lb [kg], and
V_m = volume of the measure, ft^3 [m^3].

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A1.8 Air Content

A1.8.1 Use Test Method C231 or Test Method C173/C173M, as applicable, to determine the air content of the concrete.

A1.9 Air Free Fresh Concrete Density (Air Free Unit Weight)

A1.9.1 Calculate the air free fresh concrete density of each sample as follows:

$$AFFD = (100 * D)/(100 - A) \quad \text{(A1.2)}$$

where:

$AFFD$ = air free fresh concrete density, lb/ft^3 [kg/m^3],
D = fresh concrete density, lb/ft^3 [kg/m^3] as measured in A1.7, and
A = air content, %, as measured in A1.8.

A1.10 Coarse Aggregate Content

A1.10.1 Determine the coarse aggregate content by either the Dry or Wet Method as follows. When the coarse aggregate content is determined from a separate sample of concrete not used for other tests, use a minimum sample mass of 25 lb [10 kg] for concrete made with ¾ in. [19.0 mm] or smaller nominal maximum size coarse aggregate, or minimum mass of 50 lb [20 kg] for concrete made with larger aggregate (Note A1.5).

NOTE A1.5—As noted in A1.7.1, the fresh concrete density and air content sample can be used for determination of coarse aggregate content. When this option is chosen, the amount of coarse aggregate recovered may be as little as 14 lb [6.4 kg], and the precision of the sieve analysis determination may be somewhat less than indicated in Test Method C136.

A1.10.2 Use the mass of the sample as determined in A1.7, or take another portion of the sample in a convenient-sized container and determine the mass of concrete. When concrete contains aggregate larger than 1 in. [25.0 mm] nominal maximum size, use a concrete sample large enough to yield a sample of coarse aggregate for final sieving at least as large as that required by Test Method C136.

A1.10.3 Wash the sample over a No. 4 [4.75 mm] sieve sufficiently to remove the cement and most of the fine aggregate. Determine the coarse aggregate mass using method A1.10.3.1 or A1.10.3.2.

A1.10.3.1 *Dry Method*—Dry the sample and sieve in accordance with Test Method C136. Determine CA_{dry}, the dry mass of coarse aggregate retained on the No. 4 [4.75 mm] sieve.

A1.10.3.2 *Wet Method*—Continue to carefully sieve the washed sample over the No. 4 [4.75 mm] sieve, washing to remove the remainder of the fine aggregate. Determine the mass of the wet sample immersed in water as in Test Method C127. Determine CA_{SSD}, the saturated surface dry mass of the aggregate retained on the No. 4 [4.75 mm] sieve as follows:

$$CA_{SSD} = \frac{C}{\left(1 - \frac{1}{G_{SSD}}\right)} \quad \text{(A1.3)}$$

where:

CA_{SSD} = saturated surface dry mass of the coarse aggregate, lb [kg],
C = immersed mass of the aggregate, lb [kg], and
G_{SSD} = relative density (specific gravity) of the aggregate (SSD).

A1.10.4 Calculate the coarse aggregate content percent by mass, by expressing the mass of coarse aggregate (CA_{dry} or CA_{SSD}) as a percentage of the mass of the original concrete sample.

A1.11 Compressive Strength

A1.11.1 Make and cure a minimum of two cylinders, either 6 by 12 in. [150 by 300 mm] or 4 by 8 in. [100 by 200 mm], from each sample of concrete in accordance with Practice C31/C31M. Cure cylinders as required, except that initial curing shall be by immersion in lime water immediately after molding. Maintain the water temperature between the required 60 to 80 °F [16 to 27 °C] for the initial 24 to 48 h. Finally, cure the cylinders in accordance with Practice C31/C31M until ready for testing.

A1.11.2 Test the cylinders at 7 days in accordance with Test Method C39/C39M. Average the strength of the 7-day tests of cylinders from each sample and express that value as a percentage of the average of all cylinders made from that batch tested at the same age.

A1.11.3 Examine the results of tests of individual cylinders made from the same sample of concrete and exclude the results from that sample if the range of tests exceeds 8.0 % when two cylinders are tested and 9.5 % when three are tested (Note A1.6)

NOTE A1.6—On the average, these ranges should not be exceeded more than roughly 1 time in 20. The values for permissible ranges of individual cylinders are from the precision statement in Test Method C39/C39M. Although the d2s (difference two sigma) values in Test Method C39/C39M are for 6 by 12-in. [150 by 300-mm] cylinders, available data suggest that 4 by 8-in. [100 by 200-mm] cylinder results should be only slightly less precise.

A1.12 Required Uniformity

A1.12.1 Units are required to conform to the minimum requirements of Table A1.1.

A1.13 Report

A1.13.1 Report the following information:
A1.13.1.1 Unit identification and rated capacity.
A1.13.1.2 Description of the unit configuration.
A1.13.1.3 Description of the loading and operating procedures.

TABLE A1.1 Requirements for Within-Batch Uniformity of Concrete[A]

Test	Range of 2 Samples
Air content, %	1.0
Air free fresh concrete density, lb/ft^3[kg/m^3]	1.0 [16]
Slump, in. [mm]	
Average slump 4 in. [100 mm] or less	1.0 [25]
Average slump, greater than 4 in. [100 mm]	1.5 [40]
Coarse aggregate content, percent by mass of concrete	6.0
Seven-day compressive strength, percent of average[B]	7.5

[A] A quick test of the probable uniformity of a batch of concrete is to test for uniformity of the slump and of the air content of air entrained concrete.

[B] Calculated as a percent of the average strength for the two samples taken from the batch. Either two or three cylinders must be tested from each of the two samples from the batch tested. When other requirements are met, tentative approval should be given pending the receipt of 7-day strength test results.

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A1.13.1.4 Unit control settings.

A1.13.1.5 Identification of testing agency or agencies including:

(1) Corporate name and address,

(2) Responsible official,

(3) Indication that all testing personnel are certified as required in 14.2.4, and

(4) Indication that all tests were performed in accordance with the referenced test methods as modified herein.

A1.13.1.6 Concrete test data including:

(1) Individual test results for each slump, air content, fresh concrete density, air free fresh concrete density, coarse aggregate content (including method, wet or dry), and 7-day compressive strength (including cylinder size),

(2) Averages of duplicate tests made on the same sample,

(3) Range of results of tests on the two samples, and

(4) Comparison of that range with the maximum permitted in Table A1.1.

SUMMARY OF CHANGES

Committee C09 has identified the location of selected changes to this specification since the last issue, C685/C685M–07, that may impact the use of this specification. (Approved February 1, 2010)

(*1*) Revised 4.1 and 4.2 to match the language in C94/C94M.

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Designation: C 688 – 08

Standard Specification for Functional Additions for Use in Hydraulic Cements[1]

This standard is issued under the fixed designation C 688; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope*

1.1 This specification covers methods to investigate the effectiveness of a material to beneficially change the properties of hydraulic cements when the material is incorporated during manufacture of the cement.

1.2 The values stated in SI units are to be regarded as standard. No other units of measurement are included in this standard.

1.3 The effect of additions in cement may markedly change properties other than those they are intended to modify. This specification is designed to test for such changes. Table 1 sets forth values for those properties of cement pastes and mortars that would permit a judgment of the changes effected by an addition. Likewise, Table 2 sets forth similar criteria for concrete. Certain additions may be found effective for more than one purpose as indicated in 3.1.4 and 3.1.5.

2. Referenced Documents

2.1 *ASTM Standards:*[2]

C 39/C 39M Test Method for Compressive Strength of Cylindrical Concrete Specimens
C 78 Test Method for Flexural Strength of Concrete (Using Simple Beam with Third-Point Loading)
C 109/C 109M Test Method for Compressive Strength of Hydraulic Cement Mortars (Using 2-in. or [50-mm] Cube Specimens)
C 143/C 143M Test Method for Slump of Hydraulic-Cement Concrete
C 150 Specification for Portland Cement
C 151 Test Method for Autoclave Expansion of Hydraulic Cement
C 157/C 157M Test Method for Length Change of Hardened Hydraulic-Cement Mortar and Concrete
C 187 Test Method for Normal Consistency of Hydraulic Cement
C 219 Terminology Relating to Hydraulic Cement
C 226 Specification for Air-Entraining Additions for Use in the Manufacture of Air-Entraining Hydraulic Cement
C 232 Test Methods for Bleeding of Concrete
C 234 Test Method for Comparing Concretes on the Basis of the Bond Developed with Reinforcing Steel (Discontinued 2000)[3]
C 266 Test Method for Time of Setting of Hydraulic-Cement Paste by Gillmore Needles
C 403/C 403M Test Method for Time of Setting of Concrete Mixtures by Penetration Resistance
C 451 Test Method for Early Stiffening of Hydraulic Cement (Paste Method)
C 465 Specification for Processing Additions for Use in the Manufacture of Hydraulic Cements
C 595 Specification for Blended Hydraulic Cements
C 596 Test Method for Drying Shrinkage of Mortar Containing Hydraulic Cement
C 666/C 666M Test Method for Resistance of Concrete to Rapid Freezing and Thawing
C 845 Specification for Expansive Hydraulic Cement
C 1157 Performance Specification for Hydraulic Cement

3. Terminology

3.1 *Definitions:*

3.1.1 *accelerating addition*—a functional addition that accelerates the setting or early strength, or both, of concrete and mortar.

3.1.2 *retarding addition*—a functional addition that retards the setting of concrete and mortar.

3.1.3 *set-control addition*—a functional addition composed essentially of calcium sulfate in any hydration state from $CaSO_4$ to $CaSO_4 \cdot 2H_2O$.

3.1.4 *water-reducing addition*—a functional addition used to reduce the quantity of mixing water required to produce concrete and mortar of a given consistency.

3.1.5 *water-reducing and accelerating addition*—a functional addition that reduces the quantity of mixing water required to produce concrete of a given consistency and that accelerates the setting or early strength development, or both, of concrete and mortar.

3.1.6 *water-reducing and retarding addition*—a functional addition that reduces the quantity of mixing water required to

[1] This specification is under the jurisdiction of ASTM Committee C01 on Cement and is the direct responsibility of Subcommittee C01.20 on Additions.

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[2] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

[3] Withdrawn. The last approved version of this historical standard is referenced on www.astm.org.

***A Summary of Changes section appears at the end of this standard.**

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TABLE 1 Criteria for Evaluating Neat Cement and Mortar Containing Functional Cement Additions

Tests	Type of Addition					
	Water Reducing	Retarding	Accelerating	Water-Reducing and Retarding	Water-Reducing and Accelerating	Set-Control
Normal consistency, deviation from control, percentage points[A]	−1.0 min	+1.0 max	+1.0 max	−1.0 min	−1.0 mm	±1.0 max
Standard consistency (flow) deviation from control, percentage points[A]	−4.0 min	+2.0 max	+2.0 max	−4.0 min	−4.0 min	±2.0 max
Setting time, (Gillmore) deviation from control, h:min						
Initial						
At least	...	1:00 later[B]		1:00 later[B]		...
Not more than	1:00 earlier nor 1:30 later	3:30 later	1:30 earlier nor 1:30 later	3:30 later	1:30 earlier nor 1:30 later	1:00 earlier nor 1:30 later
Setting time, Vicat Initial[C]						
At least	...	0:50 later[B]	...		...	...
Not more than	0:50 earlier nor 1:15 later	2:50 later	1:15 earlier nor 1:15 later	0:50 later[B] 2:50 later	1:15 earlier nor 1:15 later	0:50 earlier nor 1:15 later
Final						
Not more than	1:00 earlier nor 1:30 later	3:30 later	1:00 earlier nor 1:30 later	3:30 later	1:00 earlier nor 1:30 later	1:00 earlier nor 1:30 later
Compressive strength, min, percent of control:[D]						
1 day in moist air	110	90	125[E]	90	125	[F]
1 day in moist air, 2 days in water	110	90	125[E]	100	125	
1 day in moist air, 6 days in water	110	90	100	110	110	
1 day in moist air, 27 days in water	110	95	95	110	110	
Autoclave Expansion						
max increase in % change in length compared to control	0.10	0.10	0.10	0.10	0.10	0.10
Drying Shrinkage of Mortar						
max % change in length compared to control	0.020	0.020	0.030	0.020	0.020	0.020

[A] The minus sign indicates that the percentage of water required shall be less than that of the control cement by at least the indicated percentage points.
[B] Or 50 % later, whichever is the lesser.
[C] Either Vicat or the Gillmore time of setting method shall be used at the choice of the manufacturer.
[D] The compressive strength of mortar containing the test cement shall be not less than 95 % of that attained at any previous test age. The objective of this limit is to require that the strength of mortar containing the addition under test shall not decrease with age.
[E] In cases where the accelerated set time only is required, the strength can be reduced to 100 % of the control.
[F] The grand average of the 1, 3, 7, and 28-day strengths shall be not less than 95 % of the grand average for the corresponding control cement.

produce concrete and mortar of a given consistency and simultaneously retards the setting of concrete and mortar.

NOTE 1—This section is intended to provide a specification that may be applied to calcium sulfates as defined in Terminology C 219.

NOTE 2—It should be realized that some calcium sulfates, particularly some byproduct calcium sulfates, have produced cements with undesired set behavior after storage.

4. Ordering Information

4.1 The purchaser shall specify the type of functional addition desired.

5. Materials

5.1 *Cements*—The cements used in the evaluation of the addition shall be as described in Section 4.1 of Specification C 465 with the following exceptions:

5.1.1 At least one of the Type I cements shall contain not less than 9 percent tricalcium aluminate (C_3A).

5.1.2 Disregard the last sentence of Section 3.1.6 of Specification C 465 and substitute the following: " Each control cement shall comply with all the requirements in the specification (C 150, C 595, C 845, and C 1157) applicable to that type of cement. The method shall be adequate for the qualitative and quantitative determination of the addition in the finished cement, and shall be fully described in the report of the tests on the addition."

5.2 *Aggregates*—The aggregates used in the evaluation of the addition shall be in accordance with the Aggregates portion of the Materials section of Specification C 465, using proportions specified in Concrete Mixtures section of that specification.

6. *General Requirements* General Requirements

6.1 The cement, mortar, and concrete in which each of the additions is used shall conform to the respective requirements prescribed in Table 1 and Table 2, except that if the test cement fails to meet the requirements of Table 1, but possesses all the requirements listed in Table 2, then the requirements of Table 2 shall govern approval of the addition.

6.2 The trade name, source, and character of the material shall be specified and the means for the quantitative determination of the proposed addition in the finished cement, shall be furnished by the manufacturer or seller of the addition, and the results of such pertinent quantitative analysis shall form a part of the record of tests of the addition.

6.3 At the request of the purchaser of an addition for a specific functional purpose, the manufacturer shall state in writing the content of any substance which is known to or believed to impair other desirable properties of the cement or concrete.

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TABLE 2 Criteria for Evaluating Concrete Containing Functional Cement Additions[A]

Tests	Type of Addition				
	Water Reducing	Retarding	Accelerating	Water-Reducing and Retarding	Water-Reducing and Accelerating
Water content, max, percent of control	95	...	...	95	95
Time of setting, (penetration) deviation from control, h:min:					
Initial					
At least	...	1:00 later[B]		1:00 later[B]	
Not more than	1:00 earlier nor	3:30 later	3:30 earlier	3:30 later	3:30 earlier
Final	1:00 later				
Not more than	1:00 earlier nor 1:30 later	3:30 later	...	3:30 later	...
Compressive strength, min, percent of control:[C]					
1 day[D]	110	85	125[E]	100	125
3 days	110	85	125[E]	100	125
7 days	110	90	100	110	110
28 days	110	90	95	110	110
3 months	100	90	95	100	100
1 year	100	90	95	100	100
Flexural strength, min, percent of control:[C]					
1 day[D]	100	85	110	90	110
3 days	100	85	110	100	110
7 days	100	90	100	100	100
28 days	100	90	90	100	100
3 months	100	90	90	100	100
1 year	100	90	90	100	100
Bond strength, percent of control:					
28 days	100	90	100	100	100
Volume change, expressed as change in length, max, increase over control, percentage points:					
28 days	0.010	0.010	0.030	0.010	0.010
3 months	0.010	0.010	0.030	0.010	0.010
1 year	0.010	0.010	0.030	0.010	0.010
Durability factor, min, percent of control[F]	80	80	80	80	80

[A] The values in the table are intended to allow for normal variation in test results. For example, the object of the 90 % compressive strength requirement for a retarding addition is to require a level of performance comparable to that of the reference concrete.

[B] Or 50 % later, whichever is the lesser.

[C] The compressive and flexural strength of the concrete containing the addition under test at any test age shall be not less than 90 % of that attained at any previous test age. The objective of this limit is to require that the compressive or flexural strength of the concrete containing the addition under test shall not decrease with age.

[D] One-day strengths applicable only to Type III cement. One-year strength tests shall be made; however, the addition may be approved after completion of the 3-month strength results, at the discretion of the purchaser.

[E] In cases where the accelerated set time only is required, the strength can be reduced to 100 % of the control.

[F] This requirement is applicable only when the addition is to be used in air-entrained concrete.

6.4 The additions shall be evaluated by comparing cements containing the "test addition" to cements ground from similar clinkers from the same source. Those cements without test additions are referred to in this specification as "control cements."

6.4.1 *Special Provisions for Set-Control Additions Conforming to* 3.1.3:

6.4.1.1 The additions shall be evaluated by comparing cements containing the "test addition" to control cements ground from similar clinkers from the same source and under the same grinding conditions with the mill temperatures being within ± 3 °C (5 °F) of the same value. The control cements shall be produced with calcium sulfate at any hydration state having a past record of satisfactory usage as an addition for portland cement.

6.4.1.2 Each test cement shall contain sufficient test addition $CaSO_4$ to produce a sulfur trioxide (SO_3) content that differs by no more than 0.24 percentage points from that of the control cement. The SO_3 shall be expressed as a percentage of the mass of the cement and reported to the nearest 0.01 %.

6.4.1.3 The test cements containing the additions shall conform to the requirements of 8.1 and Table 1. The cements need not be tested in concrete according to the requirements of 8.2 and Table 2.

6.5 The amount of addition that is incorporated into the cement for evaluation purposes shall be such as to produce the desired effects as listed in Table 1. When these tests show compliance with the requirements of this specification, the addition shall be used only in amounts up to the maximum amount tested in any one of the five cements used in the evaluation. For a cement requiring more than the established amount, a separate compliance test on this one cement can be made which will then establish the new maximum amount which can be used.

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6.6 The cement produced with the functional additions shown in Section 3 shall comply with the specification for the respective cement and the ordinarily determined properties of cement paste, mortar, or concrete made with the cement containing the test addition shall not differ from these same properties of the cement paste, mortar, or concrete made with the control cement as indicated by the standard tests, except as provided in Table 1 and Table 2.

6.7 Generally, the addition rates required for functional purposes are several times greater than those needed for processing purposes and the resultant increase in flowability, or lubricity, from these increased addition rates may cause sufficient reduction in mill retention time to affect significantly the particle size distribution of the treated cement. The test addition may, in instances where the full-scale tests have shown reduced mill retention time to be significant, be determined for acceptance purposes by making supplementary laboratory or pilot batch mill grinds.

6.8 Furthermore, the effect of the addition on the properties of the cement, mortar, or concrete shall be within the limits of Section 8 and Table 1 and Table 2. In the event tests are conducted by making laboratory or pilot batch mill tests, this fact shall be entered in the report as specified in Section 9, and the specific tests shall be indicated.

6.9 After it has been documented once by the test results that a specific trade name and source of an addition have met the requirements of this specification, further tests shall be waived for subsequent shipments of the same product. Each shipment, however, shall be identified as to trade name, source, and date of shipment, and shall be essentially identical to nature and composition to that same trade name product which initially met the requirements of this specification.

7. Sampling

7.1 Sample the cements in accordance with the Sampling Cement section of Specification C 465. The quantity of sample shall be sufficient to make all the evaluation tests prescribed by this method. (A minimum of 300 kg (650 lb) per lot of cement is usually satisfactory.)

8. Test Methods

8.1 *Cements and Mortars*—Test the cements and mortars in accordance with the following ASTM test methods (see Table 1):

8.1.1 *Autoclave Expansion*—Test Method C 151.

8.1.2 *Drying Shrinkage of Mortar*—The length change of air-stored mortar bars made with the test cement shall not be more than 0.020 percentage points greater than that of similar mortar bars made with the control cement cured and tested according to Test Method C 596, except that for accelerators, an increased shrinkage of 0.03 percentage points will be allowed.

8.1.3 *Normal Consistency*—Test Method C 187.

8.1.4 *Standard Consistency (Flow)*—Test Method C 109/C 109M.

8.1.5 *Setting Time*—Test Method C 266.

8.1.5.1 For set-control additions conforming to 3.1.3 repeat the setting time tests 3 months after grinding. Keep cement samples for these tests in sealed metal containers with minimum air contact.

8.1.6 *Compressive Strength*—For functional additions having no water-reducing effects, use Test Method C 109/C 109M. For functional additions having some water-reducing effects, use Test Method C 109/C 109M except that mortars for both the test and the control specimens shall be made to a flow of 110 ± 5. In either case, there shall be six specimens for each condition of test.

8.1.6.1 It is required that cubes for companion cements be made and tested on the same days with storage of specimens side by side in the same section of the moist cabinet during the 24-h curing period. However, in water storage, store control and test specimens in separate tanks. If less than four specimens are left for each period, after discarding faulty cubes, make a retest.

NOTE 3—It is suggested that three batches of nine cubes each be made for each cement, then six cubes be picked at random for each age of test and the three excess cubes held to replace any faulty cubes found.

8.1.7 *False Set*—For set-control additions conforming to 3.1.3, perform false set tests initially and 3 months after grinding in accordance with Test Method C 451. The final penetration in percent shall be no less than 75 % as great as that with the control cement.

8.2 *Concretes*—Test the plastic and hardened concretes in accordance with the following ASTM methods (see Table 2):

8.2.1 *Consistency*—The consistency (slump) of the concrete produced with the test cement shall not differ from that of the control concrete by more than ± 13 mm (± ½ in.), when tested in accordance with Test Method C 143/C 143M, and each shall have a slump of 64 ± 13 mm (2½ ± ½ in.).

8.2.2 *Water Content*—The maximum water content of the test concrete shall be as shown in Table 2 when compared with the control concrete of similar consistency tested as in 8.2.1.

8.2.3 *Time of Setting*—Test Method C 403/C 403M.

8.2.4 *Compressive Strength*—Test Method C 39/C 39M.

8.2.5 *Flexural Strength*—Test Method C 78.

8.2.6 *Bond to Steel*—Test Method C 234.

8.2.7 *Volume Change*—Test Method C 157/C 157M.

8.2.8 *Resistance to Freezing and Thawing (Durability Factor)*—Test Method C 666/C 666M. The air content of both the control and test concrete shall be 6 ± 0.5 % obtained by admixing appropriate quantities of any of the reference air entraining agents listed in the General Requirements of Specification C 226.

8.2.9 *Bleeding*—At the request of the purchaser, test the bleeding characteristics in accordance with Test Method C 232.

9. Report

9.1 The report shall conform to the Report section of Specification C 465, except that comparison of test results shall be made to the requirements prescribed in this specification instead of to the requirements of Specification C 465.

10. Keywords

10.1 additions; functional; hydraulic cement

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SUMMARY OF CHANGES

Committee C01 has identified the location of selected changes to this specification since the last issue, C 688 – 00(2005), that may impact the use of this specification. (Approved December 1, 2008)

(*1*) Revised 1.1 and 6.5.

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Designation: C 702 – 98 (Reapproved 2003)

American Association State Highway and Transportation Officials Standard: T 248

Standard Practice for Reducing Samples of Aggregate to Testing Size[1]

This standard is issued under the fixed designation C 702; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope

1.1 This practice covers three methods for the reduction of large samples of aggregate to the appropriate size for testing employing techniques that are intended to minimize variations in measured characteristics between the test samples so selected and the large sample.

1.2 The values stated in SI units are to be regarded as the standard.

1.3 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

2. Referenced Documents

2.1 *ASTM Standards:*

C 125 Terminology Relating to Concrete and Concrete Aggregates[2]

C 128 Test Method for Density, Relative Density (Specific Gravity), and Absorption of Fine Aggregate[2]

D 75 Practice for Sampling Aggregates[3]

3. Terminology

3.1 *Definitions*—The terms used in this practice are defined in Terminology C 125.

4. Significance and Use

4.1 Specifications for aggregates require sampling portions of the material for testing. Other factors being equal, larger samples will tend to be more representative of the total supply. This practice provides procedures for reducing the large sample obtained in the field or produced in the laboratory to a convenient size for conducting a number of tests to describe the material and measure its quality in a manner that the smaller test sample portion is most likely to be a representation of the larger sample, and thus of the total supply. Failure to carefully follow the procedures in this practice could result in providing a nonrepresentative sample to be used in subsequent testing. The individual test methods provide for minimum amount of material to be tested.

4.2 Under certain circumstances, reduction in size of the large sample prior to testing is not recommended. Substantial differences between the selected test samples sometimes cannot be avoided, as for example, in the case of an aggregate having relatively few large size particles in the sample. The laws of chance dictate that these few particles may be unequally distributed among the reduced size test samples. Similarly, if the test sample is being examined for certain contaminants occurring as a few discrete fragments in only small percentages, caution should be used in interpreting results from the reduced size test sample. Chance inclusion or exclusion of only one or two particles in the selected test sample may importantly influence interpretation of the characteristics of the original sample. In these cases, the entire original sample should be tested.

5. Selection of Method

5.1 *Fine Aggregate*—Reduce the size of samples of fine aggregate that are drier than the saturated-surface-dry condition (Note 1) using a mechanical splitter according to Method A. Reduce the size of samples having free moisture on the particle surfaces by quartering according to Method B, or by treating as a miniature stockpile as described in Method C.

5.1.1 If the use of Method B or Method C is desired, and the sample does not have free moisture on the particle surfaces, moisten the sample to obtain free moisture on the particle surfaces, mix thoroughly, and then reduce the sample size.

5.1.2 If use of Method A is desired and the sample has free moisture on the particle surfaces, dry the entire sample to at least the saturated-surface-dry condition, using temperatures that do not exceed those specified for any of the tests contemplated, and then reduce the sample size. Alternatively, if the moist sample is very large, make a preliminary split using a mechanical splitter having chute openings of 38 mm (1½ in.) or more in width to reduce the sample to not less than 5000 g. Dry the portion so obtained, and reduce it to test sample size using Method A.

NOTE 1—The method of determining the saturated-surface-dry condition is described in Test Method C 128. As a quick approximation, if the

[1] This practice is under the jurisdiction of ASTM Committee C09 on Concrete and Concrete Aggregates and is the direct responsibility of Subcommittee C09.20 on Normal Weight Aggregates.

Current edition approved May 10, 1998. Published December 1998. Originally approved in 1971. Last previous edition approved in 1993 as C 702 – 93.

[2] *Annual Book of ASTM Standards,* Vol 04.02.

[3] *Annual Book of ASTM Standards,* Vol 04.03.

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fine aggregate will retain its shape when molded in the hand, it may be considered to be wetter than saturated-surface-dry.

5.2 *Coarse Aggregates and Mixtures of Coarse and Fine Aggregates*—Reduce the sample using a mechanical splitter in accordance with Method A (preferred method) or by quartering in accordance with Method B. The miniature stockpile Method C is not permitted for coarse aggregates or mixtures of coarse and fine aggregates.

6. Sampling

6.1 Obtain samples of aggregate in the field in accordance with Practice D 75, or as required by individual test methods. When tests for sieve analysis only are contemplated, the size of the field sample listed in Practice D 75 is usually adequate. When additional tests are to be conducted, the user shall be satisfied that the initial size of the field sample is adequate to accomplish all intended tests. Use similar procedures for aggregate produced in the laboratory.

METHOD A—MECHANICAL SPLITTER

7. Apparatus

7.1 *Sample Splitter*—Sample splitters shall have an even number of equal width chutes, but not less than a total of eight for coarse aggregate, or twelve for fine aggregate, which discharge alternately to each side of the splitter. For coarse aggregate and mixed aggregate, the minimum width of the individual chutes shall be approximately 50 % larger than the largest particles in the sample to be split (Note 2). For dry fine aggregate in which the entire sample will pass the 9.5-mm (⅜-in.) seive, a splitter having chutes 12.5 to 20 mm (½ to ¾ in.) wide shall be used. The splitter shall be equipped with two receptacles to hold the two halves of the sample following splitting. It shall also be equipped with a hopper or straight-edged pan which has a width equal to or slightly less than the over-all width of the assembly of chutes, by which the sample may be fed at a controlled rate to the chutes. The splitter and accessory equipment shall be so designed that the sample will flow smoothly without restriction or loss of material (see Fig. 1 and Fig. 2).

NOTE 2—Mechanical splitters are commonly available in sizes adequate for coarse aggregate having the largest particle not over 37.5 mm (1½ in.).

8. Procedure

8.1 Place the original sample in the hopper or pan and uniformly distribute it from edge to edge, so that when it is introduced into the chutes, approximately equal amounts will flow through each chute. Introduce the sample at a rate so as to allow it to flow freely through the chutes and into the receptacles below. Reintroduce the portion of the sample in one of the receptacles into the splitter as many times as necessary to reduce the sample to the size specified for the intended test. Reserve the portion of material collected in the other receptacle for reduction in size for other tests, when required.

METHOD B—QUARTERING

9. Apparatus

9.1 Apparatus shall consist of a straight-edged scoop, shovel, or trowel; a broom or brush; and a canvas blanket approximately 2 by 2.5 m (6 by 8 ft).

10. Procedure

10.1 Use either the procedure described in 10.1.1 or 10.1.2 or a combination of both.

10.1.1 Place the original sample on a hard, clean, level surface where there will be neither loss of material nor the accidental addition of foreign material. Mix the material thoroughly by turning the entire sample over three times. With the last turning, shovel the entire sample into a conical pile by depositing each shovelful on top of the preceding one. Carefully flatten the conical pile to a uniform thickness and diameter by pressing down the apex with a shovel so that each

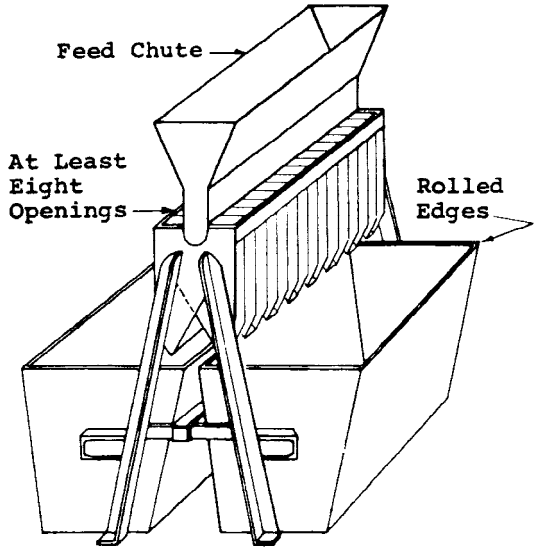

FIG. 1 Large Sample Splitter for Coarse Aggregate

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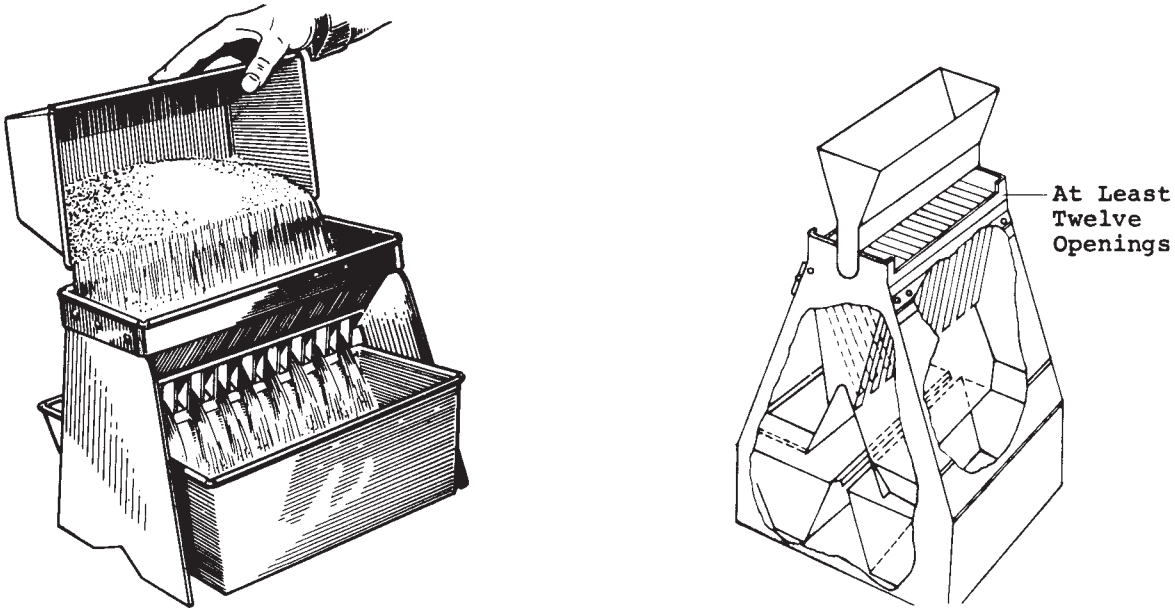

NOTE— Small Sample Splitters for Fine Aggregate. May be constructed as either closed or open type. Closed type is preferred.

FIG. 2 Sample Splitters (Riffles)

quarter sector of the resulting pile will contain the material originally in it. The diameter should be approximately four to eight times the thickness. Divide the flattened mass into four equal quarters with a shovel or trowel and remove two diagonally opposite quarters, including all fine material, and brush the cleared spaces clean. Successively mix and quarter the remaining material until the sample is reduced to the desired size (Fig. 3).

10.1.2 As an alternative to the procedure described in 10.1.1, when the floor surface is uneven, place the field sample on a canvas blanket and mix with a shovel as described in 10.1.1, or by alternately lifting each corner of the canvas and pulling it over the sample toward the diagonally opposite corner causing the material to be rolled. Flatten the pile as described in 10.1.1. Divide the sample as described in 10.1.1, or if the surface beneath the blanket is uneven, insert a stick or pipe beneath the blanket and under the center of the pile, then lift both ends of the stick, dividing the sample into two equal parts. Remove the stick leaving a fold of the blanket between the divided portions. Insert the stick under the center of the pile at right angles to the first division and again lift both ends of the stick, dividing the sample into four equal parts. Remove two diagonally opposite quarters, being careful to clean the fines from the blanket. Successively mix and quarter the remaining material until the sample is reduced to the desired size (Fig. 4).

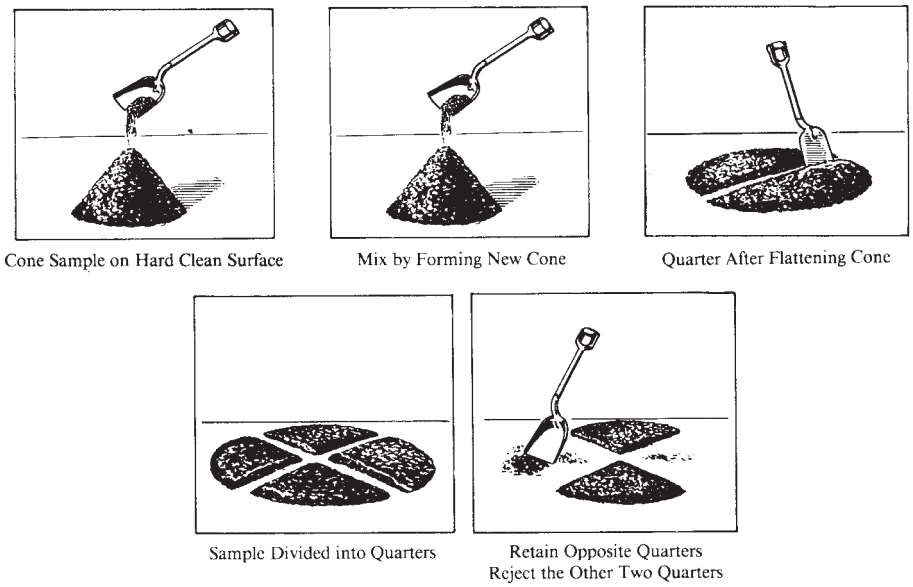

FIG. 3 Quartering on a Hard, Clean Level Surface

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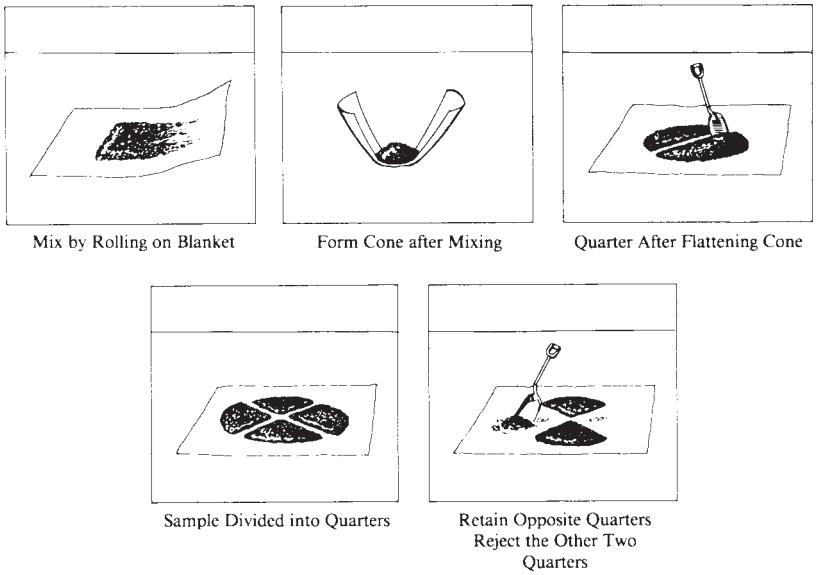

FIG. 4 Quartering on a Canvas Blanket

METHOD C—MINIATURE STOCKPILE SAMPLING (DAMP FINE AGGREGATE ONLY)

11. Apparatus

11.1 Apparatus shall consist of a straight-edged scoop, shovel, or trowel for mixing the aggregate, and either a small sampling thief, small scoop, or spoon for sampling.

12. Procedure

12.1 Place the original sample of damp fine aggregate on a hard clean, level surface where there will be neither loss of material nor the accidental addition of foreign material. Mix the material thoroughly by turning the entire sample over three times. With the last turning, shovel the entire sample into a conical pile by depositing each shovelful on top of the preceding one. If desired, flatten the conical pile to a uniform thickness and diameter by pressing down the apex with a shovel so that each quarter sector of the resulting pile will contain the material originally in it. Obtain a sample for each test by selecting at least five increments of material at random locations from the miniature stockpile, using any of the sampling devices described in 11.1.

13. Keywords

13.1 aggregate; aggregate—coarse; aggregate—fine; field testing—aggregate; sampling—aggregates; sample reduction; specimen preparation

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Designation: C 706 – 02 (Reapproved 2008)ε1

Standard Specification for Limestone for Animal Feed Use[1]

This standard is issued under the fixed designation C 706; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

ε[1] NOTE—A units statement was added editorially as paragraph 1.2 and subsequent paragraphs were renumbered in December 2008.

1. Scope

1.1 This specification covers limestone supplied for use as a mineral supplement in animal feeds.

NOTE 1—The calcium needed for animal nutrition is customarily supplied by limestone. Such limestone must be sufficiently fine to blend with mixed feeds and yet be free from excessive dusting.

1.2 The values stated in SI units are to be regarded as standard. No other units of measurement are included in this standard.

1.3 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

2. Referenced Documents

2.1 *ASTM Standards:*[2]

C 25 Test Methods for Chemical Analysis of Limestone, Quicklime, and Hydrated Lime

C 50 Practice for Sampling, Sample Preparation, Packaging, and Marking of Lime and Limestone Products

C 51 Terminology Relating to Lime and Limestone (as used by the Industry)

C 110 Test Methods for Physical Testing of Quicklime, Hydrated Lime, and Limestone

E 11 Specification for Wire Cloth and Sieves for Testing Purposes

3. Terminology

3.1 Definitions of terms applying to this specification appear in Terminology C 51.

4. General Requirements

4.1 The product must be suitable for animal feeding.

5. Chemical Requirements

5.1 Limestone, as identified on feed labels, shall conform to the chemical requirements given in Table 1.

6. Physical Requirements

6.1 Sieve analysis and other physical requirements shall be specified by the purchaser.

7. Test Methods

7.1 *Chemical Analysis*—Unless otherwise agreed upon between the purchaser and the manufacturer, the chemical analysis of the limestone shall be conducted in accordance with Test Methods C 25.

7.2 *Particle Size*—Unless otherwise agreed upon between the purchaser and the manufacturer, the sieve analysis of the material shall be determined in accordance with Test Methods C 110.

7.2.1 *Procedure*—If the entire sample is not to be dried, obtain lesser portions by riffling or quartering. Dry at between 115 to 120 °C to a constant mass and cool to room temperature. Obtain a 90 to 120-g dry sample by riffling or quartering. If the material tends to cake, break up the agglomerates with a soft rubber pestle. Quantitatively transfer the weighed sample to an 8-in. diameter standard sieve or set of sieves (for example, Nos. 10, 20, 40, 60, 80, and 100 or other appropriate combination conforming to Specification E 11). Conduct the sieve analysis in accordance with Test Methods C 110.

8. Sampling, Inspection, etc.

8.1 The sampling, inspection, rejection, retesting, packaging, and marking shall be conducted in accordance with Methods C 50.

9. Keywords

9.1 animal; feed; limestone; mineral; supplement

[1] This specification is under the jurisdiction of ASTM Committee C07 on Lime and is the direct responsibility of Subcommittee C07.02 on Specifications and Guidelines.

Current edition approved Dec. 1, 2008. Published February 2009. Originally approved in 1972. Last previous edition approved in 2002 as C 706 – 02.

[2] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

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TABLE 1 Chemical Requirements

Limestone Classes (See C 51)	Calcium, min, percent (as $CaCO_3$)	Magnesium, max, percent (as $MgCO_3$)	Magnesium, min, percent (as $MgCO_3$)	Moisture, max, percent
High Calcium	95	5	...	0.5
Magnesian	60	35[A]	5	0.5
Dolomitic	49	46[A]	35	0.5
Ground Limestone	82	[B]	[B]	0.5

[A] The high magnesium content of these materials usually limits their use to special-purpose feeds.
[B] As specified by the purchaser.

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Designation: C 737 – 08

Standard Specification for Limestone for Dusting of Coal Mines[1]

This standard is issued under the fixed designation C 737; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope*

1.1 This specification covers limestone suitable for use as dust in coal mines to prevent coal dust explosions.

NOTE 1—Limestone can serve as a source of incombustible material in coal mine operations. Limestone is dusted onto coal exposures in sufficient amount so that not less than 65 % of all loose dust shall be limestone incombustible material. In return air courses the concentration of incombustible materials should be not less than 80 % of the total dust (MSHA 30 CFR 75.403). With such a concentration of limestone incombustible material, dust explosions cannot initiate or be propagated from nearby gas explosions. The limestone must be substantially dry in order to dust satisfactorily.

1.2 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

1.3 The values stated in inch-pound units are to be regarded as standard. No other units of measurement are included in this standard.

2. Referenced Documents

2.1 *ASTM Standards:*[2]

C 25 Test Methods for Chemical Analysis of Limestone, Quicklime, and Hydrated Lime

C 50 Practice for Sampling, Sample Preparation, Packaging, and Marking of Lime and Limestone Products

C 110 Test Methods for Physical Testing of Quicklime, Hydrated Lime, and Limestone

3. Chemical Composition

3.1 Limestone shall conform to the following as to chemical composition:

Moisture (at point of manufacture), max, %	0.5
Silica, free and combined, max, %	4.0

4. Physical Properties

4.1 Limestone for this application shall have the following particle size:

Passing a No. 20 (850-μm) sieve, min, %	100
Passing a No. 200 (75-μm) sieve, min, %	70

5. Test Methods

5.1 *Chemical Analysis*—The chemical analysis of the limestone shall be conducted in accordance with Test Methods C 25.

5.2 *Particle Size*—The sieve analysis of limestone shall be conducted in accordance with Test Methods C 110.

6. General Requirements

6.1 Either high calcium or dolomitic limestone may be furnished for this application.

7. Sampling, Inspection, etc.

7.1 The sampling, inspection, rejection, retesting, packaging, and marking shall be conducted in accordance with Methods C 50.

8. Keywords

8.1 coal mines; dolomitic limestone; high calcium limestone; limestone; limestone dust; mine explosions; moisture content; silica content

[1] This specification is under the jurisdiction of ASTM Committee C07 on Lime and is the direct responsibility of Subcommittee C07.02 on Specifications and Guidelines.

Current edition approved Dec. 1, 2008. Published January 2009. Originally approved in 1973. Last previous edition approved in 2002 as C 737 – 02.

[2] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

***A Summary of Changes section appears at the end of this standard.**

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SUMMARY OF CHANGES

Committee C07 has identified the location of selected changes to this specification since the last issue, C 737 – 02, that may impact the use of this specification. (Approved December 1, 2008)

(*1*) Revised Note 1.

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Designation: C754 – 09a

Standard Specification for Installation of Steel Framing Members to Receive Screw-Attached Gypsum Panel Products[1]

This standard is issued under the fixed designation C754; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

This standard has been approved for use by agencies of the Department of Defense.

1. Scope*

1.1 This specification covers the minimum requirements for the installation of interior nonstructural steel framing and furring members designed to receive screw-attached gypsum panel products. The steel framing and furring members covered in this specification are limited to those complying with Specification C645.

1.2 Details of construction for a specific assembly to achieve the required fire resistance, sound or acoustic rating shall be obtained from reports of fire-resistance tests, engineering evaluations, or listings from recognized fire testing, sound or acoustic laboratories.

1.3 The values stated in inch-pound units are to be regarded as standard. The values given in parentheses are mathematical conversions to SI units that are provided for information only and are not considered standard.

2. Referenced Documents

2.1 *ASTM Standards:*[2]

A641/A641M Specification for Zinc–Coated (Galvanized) Carbon Steel Wire

A653/A653M Specification for Steel Sheet, Zinc-Coated (Galvanized) or Zinc-Iron Alloy-Coated (Galvannealed) by the Hot-Dip Process

A1008/A1008M Specification for Steel, Sheet, Cold-Rolled, Carbon, Structural, High-Strength Low-Alloy, High-Strength Low-Alloy with Improved Formability, Solution Hardened, and Bake Hardenable

C11 Terminology Relating to Gypsum and Related Building Materials and Systems

C645 Specification for Nonstructural Steel Framing Members

C840 Specification for Application and Finishing of Gypsum Board

2.2 *ICC-ES Document*[3]

ICC-ES-AC86 Acceptance Criteria for Steel Studs and Gypsum-Board Interior Nonload-Bearing Walls—Complete Construction—AC86—Approved July 1995 (Editorially revised September 2005) (Formerly ICBO AC86 dated July 1995)

3. Terminology

3.1 *Definitions*—Terms shall be as defined in Terminology C11.

3.2 *Descriptions of Terms Specific to This Standard:*

3.2.1 *channel*, *n*—the material described in 4.3 to which furring members are attached.

3.2.2 *cross furring*, *n*—furring member attached perpendicular to main runners or framing members.

3.2.3 *cross furring member*, *n*—a member installed perpendicularly to the main beams designed to receive screw attached gypsum panel products.

3.2.4 *direct furring*, *n*—furring members attached directly to the structural members of the building.

3.2.5 *framing member*, *n*—metal studs, runners (track), and rigid furring channels designed to receive screw attached gypsum panel products.

3.2.6 *furred ceiling*, *n*—a ceiling in which the rigid furring channels and studs are attached directly to the structural members of the building.

3.2.7 *furring*, *v*—preparing a wall or ceiling with framing or furring members to provide a level surface or airspace.

3.2.8 *furring member*, *n*—metal studs, rigid furring channels, or channels used either as direct furring or as cross furring.

3.2.9 *grid suspension system*, *n*—a ceiling system composed of modular interlocking steel components designed to receive screw-attached gypsum panel products.

[1] This specification is under the jurisdiction of ASTM Committee C11 on Gypsum and Related Building Materials and Systems and is the direct responsibility of Subcommittee C11.03 on Specifications for the Application of Gypsum and Other Products in Assemblies.

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[2] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

[3] Available from ICC Evaluation Services, Inc., 5360 Workman Mill Road, Whittier, CA 90601, www.icc-es.org.

***A Summary of Changes section appears at the end of this standard.**

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3.2.10 *main beam*, *n*—the main support member of a grid suspension system that receives cross furring members.

3.2.11 *main runner*, *n*—the channel or stud that is attached to or suspended from the structural members of the building.

3.2.12 *runner (track)*, *n*—a member designed to receive the ends of metal studs, attached directly to the structural members of the building.

3.2.13 *suspended ceiling*, *n*—a ceiling in which the main runners and cross furring are suspended below the structural members of the building.

4. Materials and Manufacture

4.1 *Studs, Runners, Rigid Furring Channels, and Grid Suspension Systems*—see Specification C645.

4.2 *Tie Wire and Hanger Wire*—Zinc-coated (galvanized) soft-annealed steel, or of a material and size having equivalent corrosion resistance and strength. Wire diameters (uncoated) specified herein correspond with United States steel wire gauge numbers as follows:

Diameter[A]		Wire Gauge
in.	mm	(U.S. Steel Wire Gauge)
0.0348	0.88	No. 20
0.0410	1.04	No. 19
0.0475	1.21	No. 18
0.0540	1.37	No. 17
0.0625	1.59	No. 16
0.0800	2.03	No. 14
0.0915	2.32	No. 13
0.1055	2.68	No. 12
0.1205	3.06	No. 11
0.1350	3.43	No. 10
0.1483	3.77	No. 9
0.1620	4.12	No. 8

[A] Allowable variations in diameter shall be in accordance with tolerances as established in Specification A641/A641M.

4.3 *Channels*—Channels shall be cold-formed from steel with a minimum 33 000 psi (228 MPa) yield strength and 0.0538 in. (1.37 mm) minimum bare steel thickness. Channels shall have a protective coating conforming to Specification A653/A653M–G40 or shall have a protective coating with an equivalent corrosion resistance, and shall have the following minimum weights in lb per 1000 linear ft (kg/m):

Size		Weight		Flange Width	
in.	(mm)	lb/1000 ft	(kg/m)	in.	(mm)
¾	(19)	277	(0.412)	½	(13)
1½	(38)	414	(0.616)	½	(13)
2	(51)	506	(0.753)	½	(13)
2½	(64)	597	(0.888)	½	(13)

4.4 *Grid Suspension System*:

4.4.1 *Main Beam*—Formed from cold-rolled steel "T" sections, indexed with slots to receive ends of cross furring members, and with stamped couplings at each end for the purpose of splicing.

4.4.2 *Cross Furring Members*—Formed from cold-rolled steel, designed to permit screw attachment of gypsum panel products, and formed with an end configuration that permits mechanical interlock with the indexed slots of the main beam.

4.5 *Rod and Flat Hangers*—Formed from steel conforming to Specification A1008/A1008M. When specified, rod and flat hangers shall be protected with zinc coating or another equally rust-inhibiting coating.

5. Installation of Metal Framing

5.1 *Tolerances*:

5.1.1 Spacing of studs and furring members shall be not more than ±⅛ in. (3 mm) from the spacing shown in Tables 1 and 2. Any cumulative error shall be not more than ±⅛ in.

5.2 *Runner (Track) Installation*:

5.2.1 *General*—Runners shall be aligned accurately at the floor and ceiling and securely anchored approximately 2 in. (50 mm) from the runner ends, not more than 24 in. (610 mm) on center. Runners shall be secured with fasteners at partition corners. One runner shall extend to the end of the corner and the other runner shall butt to it and be gapped to allow clearance for the gypsum panel product thickness. Runners shall not be mitered.

5.2.2 *Runners to Concrete Slabs*—Shall be fastened with concrete stub nails, expansion anchors, shielded screws, or power-driven fasteners not exceeding 24 in. (610 mm) on center.

5.2.3 *Runners to Wood*—Shall be fastened with screws providing not less than 1 in. (25 mm) penetration or nails providing 1½ in. (38 mm) penetration into the wood.

5.2.4 *Runners to Suspended Ceilings*—Shall be fastened with "Molly"-type expandable fasteners, toggle bolts, clamps, or screws into channels, splines, "T" runners, or other members.

5.3 *Stud Installation*:

5.3.1 *Stud Height and Spacing Limitations*:

5.3.1.1 Maximum framing spacing determined by gypsum panel product thickness shall be in accordance with Table 1.

5.3.1.2 Stud heights shall be not greater than those shown in Tables 3-5.

5.3.1.3 Studs shall engage both the floor and ceiling runners. The gap between the end of a stud and the web of the top and bottom runner shall be not more than ¼ in. (6 mm).

5.3.1.4 Where conditions require that a partition be constructed with compensation for vertical structural movement, the gap between the end of a stud and the adjacent runner shall be designed by an architect or engineer.

5.3.2 *Location*:

5.3.2.1 Studs shall be positioned vertically and shall be spaced not more than the maximum framing spacing allowed for the finish specified. Studs located adjacent to door and window frames, partition intersections, and corners shall be anchored to runner flanges by screws, or by crimping at each stud and runner flange.

5.3.2.2 At the junction of through and abutting partitions, a stud shall be located not more than 2 in. (50 mm) away from the intersection in the abutting partition from the through partition (see Fig. 1), and not more than 2 in. (50 mm) from partition corners and other construction. A stud shall be located adjacent to all door and borrowed light frames. Studs shall be securely anchored to the jamb anchor clips on each door frame or borrowed light frame by bolt or screw attachment. A header shall be formed over metal door and borrowed light frames with a cut-to-length section of runner placed horizontally with the flanges cut and web bent vertically at each end, and securely attached to the adjacent vertical studs. A cut-to-length stud shall be positioned at the location of vertical joints over

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TABLE 1 Maximum Framing Spacing

NOTE 1—Where a conflict exists in spacing between base and face layers, the closer spacing shall govern.

Gypsum Panel Product Thickness		Location	Application	Maximum Spacing, oc		
					Two Layers	
Base Layer, in. (mm)	Face Layer, in. (mm)			One Layer Only, in. (mm)	Fasteners Only, in. (mm)	Adhesive Between Layers, in. (mm)
⅜ (9.5)	. . .	ceilings	perpendicular	16 (406)[A]	16 (406)[A]	16 (406)[A]
	⅜ (9.5)	ceilings	perpendicular	NA	16 (406)	16 (406)
	⅜ (9.5)	ceilings	parallel	NA	NR	16 (406)
½ (12.7)	. . .	ceilings	perpendicular	24 (610)[A]	24 (610)[A]	24 (610)[A]
	. . .	ceilings	parallel	16 (406)[A]	16 (406)[A]	16 (406)[A]
	⅜ (9.5)	ceilings	perpendicular	NA	16 (406)	24 (610)
	⅜ (9.5)	ceilings	parallel	NA	NR	24 (610)
	½ (12.7)	ceilings	perpendicular	NA	24 (610)	24 (610)
	½ (12.7)	ceilings	parallel	NA	16 (406)	24 (610)
⅝ (15.9)	. . .	ceilings	perpendicular	24 (610)[A]	24 (610)[A]	24 (610)[A]
	. . .	ceilings	parallel	16 (406)[A]	16 (406)[A]	16 (406)[A]
	⅜ (9.5)	ceilings	perpendicular	NA	16 (406)	24 (406)
	⅜ (9.5)	ceilings	parallel	NA	NR	24 (610)
	½ or ⅝ (12.7 or 15.9)	ceilings	perpendicular	NA	24 (610)	24 (610)
	½ or ⅝ (12.7 or 15.9)	ceilings	parallel	NA	16 (406)	24 (406)
¼ (6.4)	. . .	walls	parallel	NR	16 (406)[A]	16 (406)[A]
	⅜ (9.5)	walls	NR	NR	NR	NR
	½ or ⅝ (12.7 or 15.9)	walls	perpendicular or parallel	NA	16 (406)	16 (406)
⅜ (9.5)	. . .	walls	perpendicular or parallel	16 (406)[A]	16 (406)[A]	24 (610)[A]
	⅜ or ½ or ⅝ (9.5 or 12.7 or 15.9)	walls	perpendicular or parallel	NA	16 (406)	24 (610)
½ or ⅝ (12.7 or 15.9)	. . .	walls	perpendicular or parallel	24 (610)[A]	24 (610)[A]	24 (610)[A]
	⅜ or ½ or ⅝ (9.5 or 12.7 or 15.9)	walls	perpendicular or parallel	NA	24 (610)	24 (610)

Perpendicular—perpendicular to framing members
Parallel—parallel to framing members
NA—not applicable
NR—not recommended
oc—on center

[A] Denotes framing spacing for base layer in two-layer application.

TABLE 2 Spans and Spacings of Horizontal Furring Members

Type of Furring	Maximum[A] Spacing c to c,[B] in. (mm)	Maximum Span, ft (mm)
Rigid Furring Channel	24 (610)	4 (1220)
1⅝ in. (41 mm) stud (erected with open side up and against support)	24 (610)	5 (1520)
2½ in. (64 mm) stud (erected with web vertical to support)[C]	24 (610)	6 (1830)
3⅝ in. (92 mm) stud (erected with web vertical to support)[C]	24 (610)	8 (2440)

[A] Consult Table 1 for maximum spacing as determined by gypsum panel product thickness.
[B] c to c—center to center
[C] A6 in. (150 mm) length of same size stud or track shall be nested to form a "box" at each saddle tie.

the header extending to the ceiling runner. Additional cut to length studs required to comply with framing spacing in accordance with Table 1 shall also be added over the header, extending to the ceiling runner.

5.3.2.3 At partition corners, a stud shall be installed so that it forms the outside corner. Following application of a single layer of gypsum panel product to this stud, a second stud shall be installed in the abutting runner and the web shall be screw attached through the gypsum panel product into the flange of the first stud (see Fig. 2). A three-stud conventional corner shall be permitted (see Fig. 3).

5.4 *Chase Wall Partitions*:

5.4.1 A double row of runners and studs as specified in 5.2 and 5.3 shall be installed. Height shall be in accordance with 5.3.1.2.

5.4.2 Where a gypsum panel product is used as bracing between chase walls, a gap of not more than 20 in. (508 mm) between rows of studs shall be permitted.

5.4.3 Horizontal cross braces to opposite studs shall be installed not more than 4 ft (1220 mm) on center vertically. Horizontal cross braces shall be either of the following:

5.4.3.1 Gypsum panel product gussets 12 in. (305 mm) deep attached to the stud webs with three screws.

5.4.3.2 A stud or runner with the web screw attached to the wall stud web with not less than two screws.

5.5 *Rigid Furring Channel Installation, Direct Attachment to Masonry or Concrete*—The furring member shall be attached to masonry or concrete surfaces, either vertically or horizontally. Spacing shall be determined by gypsum panel product thickness in accordance with Table 1. For furring positioned horizontally, the center line of the furring members closest to the floor and ceiling shall be attached not more than 3 in. (76 mm) from the floor and ceiling lines. The furring member shall be secured with fasteners occurring on alternated flanges and spaced 24 in. (610 mm) on center.

5.6 *Resilient Furring Channel Installation to Steel and Wood Members*:

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TABLE 3 Maximum Stud Height,[A] ft-in. (mm), Single Layer ½-in. (12.7-mm) Thick Gypsum Board,[B] Vertical Application,[C] on Each Side of Minimum 0.0179-in. (0.455-mm) Base Metal Thickness Steel Studs Spaced 12-in. (305-mm), 16-in. (406-mm), and 24-in. (610-mm) o.c.[D,E,F]

Stud Depth, in. (mm), *Industry Designator*[G]	Deflection Limit	Maximum Stud Height ft-in. (mm)								
		Framing Spaced 12 in. (305 mm) o.c. Lateral Pressure			Framing Spaced 16 in. (406 mm) o.c. Lateral Pressure			Framing Spaced 24 in. (610 mm) o.c. Lateral Pressure		
		5 psf (240 Pa)	7.5 psf (360 Pa)	10 psf (480 Pa)	5 psf (240 Pa)	7.5 psf (360 Pa)	10 psf (480 Pa)	5 psf (240 Pa)	7.5 psf (360 Pa)	10 psf (480 Pa)
1-⅝ (41.3) *162S125-18*	L/120	11-2 (3400)	9-9 (2970)	8-10 (2690)	10-7 (3230)	8-10 (2690)	8-4 (2540)	9-9 (2970)	8-0 (2440)	H
	L/240	8-10 (2690)	H	H	8-4 (2540)	H	H	7-11 (2410)	H	H
	L/360	H	H	H	H	H	H	H	H	H
2-½ (63.5) *250S125-18*	L/120	15-1 (4600)	12-4 (3760)	10-9 (3280)	13-3 (4040)	10-10 (3300)	9-5 (2870)	11-10 (3610)	9-8 (2950)	8-5 (2570)
	L/240	11-11 (3630)	10-5 (3180)	9-6 (2900)	11-3 (3430)	9-10 (3000)	8-11 (2720)	10-7 (3230)	9-3 (2820)	8-5 (2570)
	L/360	10-5 (3180)	9-1 (2770)	H	9-10 (3000)	8-7 (2620)	H	9-3 (2820)	8-1 (2460)	H
3-½ (88.9)[I] *350S125-18*	L/120	17-8 (5380)	14-3 (4340)	12-5 (3780)	15-4 (4670)	12-5 (3780)	10-9 (3280)	13-9 (4190)	11-0 (3350)	9-5 (2870)
	L/240	15-4 (4670)	13-3 (4040)	12-0 (3660)	14-4 (4370)	12-5 (3780)	10-9 (3280)	13-5 (4090)	11-0 (3350)	9-5 (2870)
	L/360	13-3 (4040)	11-7 (3530)	10-5 (3180)	12-4 (3760)	10-10 (3300)	9-9 (2970)	11-7 (3530)	10-1 (3070)	9-1 (2770)
4 (101.6) *400S125-18*	L/120	19-6 (5940)	15-9 (4800)	13-8 (4170)	17-2 (5230)	13-10 (4220)	11-11 (3630)	15-1 (4600)	12-1 (3680)	10-5 (3180)
	L/240	16-5 (5000)	14-4 (4370)	13-0 (3960)	15-4 (4670)	13-4 (4060)	11-11 (3630)	14-2 (4320)	12-1 (3680)	10-5 (3180)
	L/360	14-4 (4370)	12-6 (3810)	11-4 (3450)	13-4 (4060)	11-8 (3560)	10-6 (3200)	12-4 (3760)	10-9 (3280)	9-9 (2970)
6 (152.4) *600S125-18*	L/120	22-10 (6960)	18-7 (5660)	16-2 (4930)	19-9 (6020)	16-2 (4930)	14-0 (4270)	16-9 (5110)	13-5 (4090)	11-5 (3480)
	L/240	22-1 (6730)	18-7 (5660)	16-2 (4930)	19-9 (6020)	16-2 (4930)	14-0 (4270)	16-9 (5110)	13-5 (4090)	11-5 (3480)
	L/360	19-4 (5890)	16-9 (5110)	15-0 (4570)	17-11 (5460)	15-7 (4750)	13-10 (4220)	16-9 (5110)	13-5 (4090)	11-5 (3480)

[A] Based on tests conducted with gypsum board attached with screws spaced 12 in. (305 mm) o.c. to framing members.
[B] Maximum stud heights are also applicable to walls sheathed with gypsum board greater than ½ in. (12.7 mm) thick and multiple layers of gypsum board.
[C] Application per Specification C840.
[D] Limiting heights based on ICC-ES "Acceptance Criteria for Steel Studs and Gypsum-Board Interior Nonload-Bearing Walls—Complete Construction—AC86—Approved July 1995 (Editorially revised September 2005)."
[E] Runner flanges need not be fastened to studs except as required by 5.3.2.1.
[F] ICC-ES-AC86 utilized a 0.75 load reduction factor (for strength determination only) to determine the heights as shown in the table.
[G] The *Industry Designator* defines the cold formed steel framing member.
Example: *350S125-18:*
350 designates the member web depth in 100ths of an in., 350 = 3.50 in. (88.9 mm).
S designates the type of member, *S* = stud.
125 designates the member flange width in 100ths of an in., 125 = 1.25 in. (32 mm).
18 designates the member base metal thickness in mils, 18 = .0179 in. (0.455 mm).
[H] Data not available.
[I] Also applicable to 3-⅝ in. (92.1 mm) stud depth, *362S125-18*.

5.6.1 Resilient furring channel shall be installed to wall framing members with the mounting flange of the resilient furring channel down, except at the floor where the attachment flange shall be permitted to be installed with the flange up to accommodate fastening to the framing members (See Fig. 4). In the case of two-legged resilient furring channel only the lower attachment flange shall be attached the the wall framing members.

5.6.2 For wall framing members, the first (lowest) row of resilient furring channel shall be not more than 2 in. (50 mm) off of the floor (as measured from the floor to the center of the face of the resilient channel) and the highest row of resilient furring channel shall be not more than 6 in. (150 mm) from the ceiling (as measured from the ceiling to the center of the face of the resilient channel). For ceiling framing members the first row and the last row of resilient furring channel shall be located not more than 6 in. (150 mm) from the adjacent wall.

5.6.3 The resilient furring channel shall be positioned with the slotted hole(s) directly over the framing member (See Fig. 4). The resilient furring channel shall be attached to the framing member with Type-S × ⅜ in. (10 mm) pan head framing screws using the screw hole provided in the mounting flange.

NOTE 1—If no screw hole is provided or located at the framing member, drill through the mounting flange to attach the resilient furring channel to the member.

5.6.4 Resilient furring channel members shall be spliced either by "nesting" the ends of the resilient furring channel members directly over the framing member and screwing through the mounting flange into the framing members or by butting the resilient furring channel members over the framing member and screwing through the mounting flange into the stud members. A gap of not less than 1/16 in. (2 mm) shall be left between the members. When nesting the ends of the members, an additional screw attaching the mounting flanges of the resilient furring channels to each other at the ends of each of the nested resilient furring channels shall be installed.

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TABLE 4 Maximum Stud Height,[A] ft-in. (mm), Single Layer ½-in. (12.7-mm) Thick Gypsum Board,[B] Vertical Application,[C] on Each Side of Minimum 0.0296-in. (0.752-mm) Base Metal Thickness Steel Studs Spaced 12-in. (305-mm), 16-in. (406-mm), and 24-in. (610-mm) o.c.[D,E,F]

Stud Depth, in. (mm), *Industry Designator*[G]	Deflection Limit	Maximum Stud Height ft-in. (mm)								
		Framing Spaced 12 in. (305 mm) o.c. Lateral Pressure			Framing Spaced 16 in. (406 mm) o.c. Lateral Pressure			Framing Spaced 24 in. (610 mm) o.c. Lateral Pressure		
		5 psf (240 Pa)	7.5 psf (360 Pa)	10 psf (480 Pa)	5 psf (240 Pa)	7.5 psf (360 Pa)	10 psf (480 Pa)	5 psf (240 Pa)	7.5 psf (360 Pa)	10 psf (480 Pa)
1-⅝ (41.3) *162S125-30*	L/120	12-5 (3780)	10-10 (3300)	9-11 (3020))	11-6 (3510)	10-1 (3070)	9-2 (2790)	10-5 (3180)	9-2 (2790)	8-3 (2520)
	L/240	9-11 (3020)	*H*	*H*	9-2 (2790)	*H*	*H*	8-3 (2520)	*H*	*H*
	L/360	*H*	*H*	*H*	*H*	*H*	*H*	*H*	*H*	*H*
2-½ (63.5) *250S125-30*	L/120	16-8 (5080)	14-7 (4450)	13-2 (4010)	15-4 (4670)	13-4 (4060)	12-1 (3680)	13-9 (4190)	11-11 (3630)	10-9 (3280)
	L/240	13-2 (4010)	11-6 (3510)	10-5 (3180)	12-1 (3680)	10-6 (3000)	9-6 (2900)	10-9 (3280)	9-4 (1930)	8-6 (2590)
	L/360	11-6 (3510)	10-0 (3050)	9-1 (2770)	10-6 (3000)	9-2 (2790)	8-4 (2540)	9-4 (1930)	8-1 (260)	7-4 (2240)
3-½ (88.9)[I] *350S125-30*	L/120	21-8 (6610)	18-1 (5770)	17-1 (5210)	19-11 (6070)	17-5 (5310)	15-8 (4780)	17-9 (5410)	15-6 (4720)	14-0 (4270)
	L/240	17-1 (5210)	14-10 (4520)	13-5 (4090)	15-8 (4780)	13-7 (4140)	12-3 (3730)	14-0 (4270)	12-0 (3660)	10-10 (3300)
	L/360	14-10 (4520)	12-20 (3910)	1-8 (3560)	13-7 (4140)	11-9 (3580)	10-7 (3230)	12-0 (3660)	10-5 (3180)	9-4 (1930)
4 (101.6) *400S125-30*	L/120	24-0 (7320)	20-11 (6380)	19-0 (5790)	22-0 (6710)	19-3 (5870)	17-6 (5330)	19-8 (6000)	17-1 (5250)	14-9 (4500)
	L/240	19-0 (5790)	16-6 (5030)	14-11 (4550)	17-6 (5330)	15-2 (4620)	13-8 (4170)	15-7 (4750)	13-5 (4090)	12-1 (3680)
	L/360	16-6 (5030)	14-4 (4370)	12-11 (2940)	15-2 (4620)	13-1 (3990)	11-10 (3610)	13-5 (4090)	11-7 (3530)	10-5 (3180)
6 (152.4) *600S125-30*	L/120	32-1 (9780)	28-0 (8530)	24-7 (7490)	29-2 (8890)	24-9 (7540)	21-5 (6530)	25-1 (7650)	20-6 (6250)	17-9 (5410)
	L/240	25-6 (7770)	22-3 (6780)	20-3 (6170)	23-2 (7060)	20-3 (6170)	18-4 (5590)	20-3 (6170)	17-8 (5380)	16-0 (4880)
	L/360	22-3 (6780)	19-5 (5910)	17-6 (5330)	20-3 (6170)	17-8 (5380)	15-10 (4830)	17-8 (5380)	15-5 (4700)	13-8 (4170)

[A] Based on tests conducted with gypsum board attached with screws spaced 12 in. (305 mm) o.c. to framing members.
[B] Maximum stud heights are also applicable to walls sheathed with gypsum board greater than ½ in. (12.7 mm) thick and multiple layers of gypsum board.
[C] Application per Specification C840.
[D] Limiting heights based on ICC-ES "Acceptance Criteria for Steel Studs and Gypsum-Board Interior Nonload-Bearing Walls—Complete Construction—AC86—Approved July 1995 (Editorially revised September 2005)."
[E] Runner flanges need not be fastened to studs except as required by 5.3.2.1.
[F] ICC-ES-AC86 utilized a 0.75 load reduction factor (for strength determination only) to determine the heights as shown in the table.
[G] The *Industry Designator* defines the cold formed steel framing member.
Example: *350S125-30:*
350 designates the member web depth in 100ths of an in., 350 = 3.50 in. (88.9 mm).
S designates the type of member, *S* = stud.
125 designates the member flange width in 100ths of an in., 125 = 1.25 in. (32 mm).
30 designates the member base metal thickness in mils, 30 = .0296 in. (0.752 mm).
[H] Data not available.
[I] Also applicable to 3-⅝ in. (92.1 mm) stud depth, *362S125-30*.

5.6.5 Gypsum panel products shall be attached to the resilient furring channel using a screw length to ensure that the screw point does not make contact with the framing member.

5.7 *Resilient Furring Channel Installation to Wood Members*:

5.7.1 Resilient furring channel shall be installed to wall framing members with the mounting flange of the resilient furring channel down, except at the floor where the mounting flange shall be permitted to be installed with the flange up to accommodate fastening to the framing members (See Fig. 4). In the case of two-legged resilient furring channel only the lower mounting flange shall be attached to the wall framing members.

5.7.2 For wall framing members, the first (lowest) row of resilient furring channel shall be not more than 2 in. (50 mm) off of the floor (as measured from the floor to the center of the face of the resilient channel) and the last (highest) row of resilient furring channel shall be not more than 6 in (150 mm) from the ceiling (as measured from the ceiling to the center of the face of the resilient channel). For ceiling framing members the first row and the last row of resilient furring channel shall be located not more than 6 in. (150 mm) from the adjacent wall.

5.7.3 The resilient furring channel shall be positioned with the slotted hole(s) directly over the framing member (See Fig. 4). The resilient furring channel shall be attached to the framing member with Type-W or Type-S screws (minimum 1¼ (32 mm) long) screws using the screw hole provided in the mounting flange.

NOTE 2—If no screw hole is provided or located at the framing member, drill through the mounting flange to attach the resilient furring channel to the member.

5.7.4 Resilient furring channel members shall be spliced either by "nesting" the ends of the resilient furring channel members directly over the framing member and screwing through the mounting flange into the framing members or by butting the resilient furring channel members over the framing member and screwing through the mounting flange into the stud members. A gap of not less than 1/16 in. (2 mm) shall be left between the members. When nesting the ends of the members, an additional screw attaching the mounting flanges of the

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TABLE 5 Maximum Stud Height[A], ft-in. (mm), Single Layer ½-in. (12.7-mm) Thick Gypsum Board,[B] Vertical Application,[C] on Each Side of Minimum 0.0329-in. (0.836-mm) Base Metal Thickness Steel Studs Spaced 12-in. (305-mm), 16-in. (406-mm), and 24-in. (610-mm) o.c.[D,E,F]

Stud Depth, in. (mm), *Industry Designator*[G]	Deflection Limit	Maximum Stud Height ft-in. (mm)								
		Framing Spaced 12 in. (305 mm) o.c. Lateral Pressure			Framing Spaced 16 in. (406 mm) o.c. Lateral Pressure			Framing Spaced 24 in. (610 mm) o.c. Lateral Pressure		
		5 psf (240 Pa)	7.5 psf (360 Pa)	10 psf (480 Pa)	5 psf (240 Pa)	7.5 psf (360 Pa)	10 psf (480 Pa)	5 psf (240 Pa)	7.5 psf (360 Pa)	10 psf (480 Pa)
1-⅝ (41.3) *162S125-33*	L/120	13-0 (3960)	11-4 (3450)	10-4 (3150)	12-1 (3680)	10-7 (3230)	9-8 (2950)	11-0 (3350)	9-7 (2920)	8-9 (2670)
	L/240	10-4 (3150)	9-0 (2740)	H	9-8 (2950)	8-5 (2570)	H	8-9 (2670)	7-8 (2340)	H
	L/360	9-0 (2740)	H	H	8-5 (2570)	H	H	7-8 (2340)	H	H
2-½ (63.5) *250S125-33*	L/120	17-9 (5410)	15-6 (4720)	13-11 (4240)	16-5 (5000)	14-4 (4370)	12-10 (3910)	14-10 (4520)	13-0 (3960)	11-7 (3530)
	L/240	13-11 (4240)	12-1 (3680)	10-11 (3330)	12-10 (3910)	11-2 (3400)	10-0 (3050)	11-7 (3530)	10-0 (3050)	8-11 (2720)
	L/360	12-1 (3680)	10-6 (3200)	9-5 (2870)	11-2 (3400)	9-8 (2950)	8-8 (2640)	10-0 (3050)	8-7 (2620)	7-8 (2340)
3-½ (88.9)[I] *350S125-33*	L/120	22-6 (6860)	19-8 (5990)	17-10 (5440)	20-8 (6300)	18-1 (5510)	16-5 (5000)	18-6 (5640)	16-2 (5840)	14-9 (4500)
	L/240	17-10 (5440)	15-6 (4720)	14-1 (4290)	16-5 (5000)	14-3 (4340)	12-11 (3940)	14-9 (4500)	12-9 (3890)	11-7 (3530)
	L/360	15-6 (4720)	13-7 (4140)	12-4 (3760)	14-3 (4340)	12-6 (3810)	11-4 (3450)	12-9 (3890)	11-2 (3400)	10-1 (3070)
4 (101.6) *400S125-33*	L/120	25-1 (7650)	21-11 (6680)	19-11 (6070)	23-1 (7040)	20-2 (6150)	18-4 (5590)	20-9 (6320)	18-1 (5510)	16-5 (5000)
	L/240	19-11 (6070)	17-4 (5280)	15-8 (4780)	18-4 (5590)	15-11 (4850)	14-5 (4390)	16-5 (5000)	14-3 (4340)	12-10 (3910)
	L/360	17-4 (5280)	15-0 (4570)	13-7 (4140)	15-11 (4850)	13-9 (4190)	12-6 (3810)	14-3 (4340)	12-4 (3760)	11-2 (3400)
6 (152.4) *600S125-33*	L/120	33-9 (10290)	29-6 (8990)	26-9 (8150)	30-10 (9400)	27-0 (8230)	24-6 (7470)	27-2 (8280)	23-10 (7260)	19-1 (5820)
	L/240	26-9 (8150)	23-5 (7140)	21-3 (6480)	24-6 (7470)	21-4 (6500)	19-5 (5920)	21-7 (6580)	18-10 (5740)	17-3 (5260)
	L/360	23-5 (7140)	20-6 (6250)	18-7 (5660)	21-4 (6500)	18-9 (5720)	17-0 (5180)	18-10 (5740)	16-7 (5050)	15-0 (4570)

[A] Based on tests conducted with gypsum board attached with screws spaced 12 in. (305 mm) o.c. to framing members.
[B] Maximum stud heights are also applicable to walls sheathed with gypsum board greater than ½ in. (12.7 mm) thick and multiple layers of gypsum board.
[C] Application per Specification C840.
[D] Limiting heights based on ICC-ES "Acceptance Criteria for Steel Studs and Gypsum-Board Interior Nonload-Bearing Walls—Complete Construction—AC86—Approved July 1995 (Editorially revised September 2005)."
[E] Runner flanges need not be fastened to studs except as required by 5.3.2.1.
[F] ICC-ES-AC86 utilized a 0.75 load reduction factor (for strength determination only) to determine the heights as shown in the table.
[G] The *Industry Designator* defines the cold formed steel framing member.
Example: *350S125-33:*
350 designates the member web depth in 100ths of an in., 350 = 3.50 in. (88.9 mm).
S designates the type of member, *S* = stud.
125 designates the member flange width in 100ths of an in., 125 = 1.25 in. (32 mm).
33 designates the member base metal thickness in mils, 33 = .0329 in. (0.836 mm).
[H] Data not available.
[I] Also applicable to 3-⅝ in. (92.1 mm) stud depth, *362S125-33*.

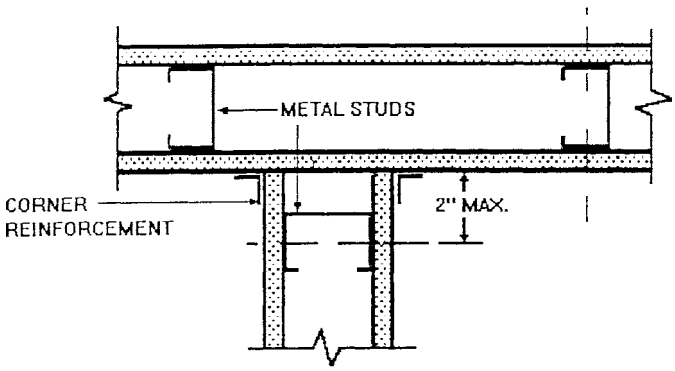

FIG. 1 Abutting Partition Detail

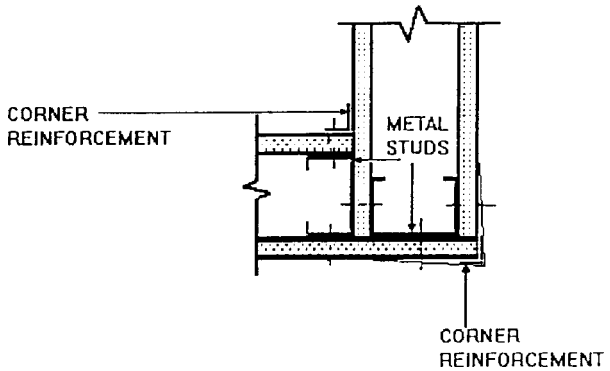

FIG. 2 Partition Corner Detail

resilient furring channels to each other at the ends of the nested resilient furring channels shall be installed.

5.7.5 Gypsum panel products shall be attached to the resilient furring channel using a screw length to ensure that the screw point does not make contact with the framing member.

5.8 *Wall Furring-Bracket System*:

5.8.1 Adjustable wall furring brackets with serrated edges facing upward shall be attached to masonry or concrete walls in the following spacing pattern: 48 in. (1220 mm) on center vertically, 6 in. (152 mm) maximum from floor and ceiling, 36 in. (910 mm) on center horizontally, 4 in. (100 mm) maximum from columns or other abutting construction, and as required above and below windows. Each bracket shall be fastened through the hole nearest to the serrated edges.

5.8.2 Channels ¾ in. (19 mm) shall be laid horizontally on the furring brackets so that the channel flanges engage the

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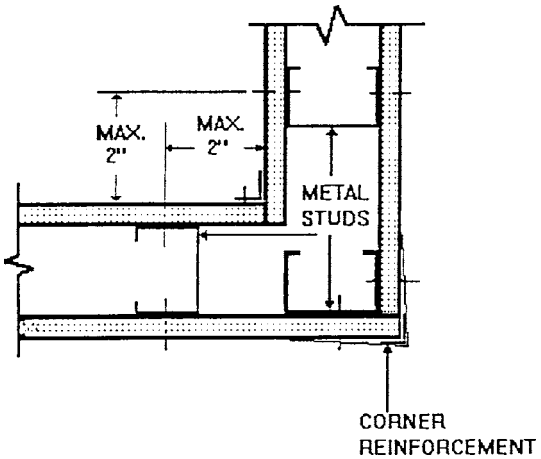

FIG. 3 Partition Corner Detail

serrated edges of the bracket. Each channel shall be plumbed to align with ceiling and base channels. Channels shall be wire-tied to each bracket with a double strand of 16 gauge or a triple strand of 18-gauge tie wire. Each excess bracket length shall be bent down and inward toward the wall.

5.8.3 Rigid furring channels shall be positioned vertically with wing flanges against the channels with spacing determined by gypsum panel product thickness in accordance with Table 1. Each furring channel intersection shall be wire-tied with a double strand of 16-gauge or a triple strand of 18-gauge tie wire.

5.9 *Soffits*—Soffits shall be framed by attaching runners to ceilings and walls as specified in 5.2.1. Runners shall be used for backing of all outside corners. Hangers or spacers (cut-to-length pieces of stud), shall be provided from ceiling runner to outside corner and from outside corner to vertical surface. Where the hanger or spacer length is not more than the maximum framing spacing allowed in Table 1 for the gypsum panel product thickness specified, hangers or spacers shall be located not more than 4 ft (1220 mm) on centers. Where the hanger or spacer length is more than the maximum framing spacing allowed, they become the attachment means and shall be spaced in accordance with Table 1.

6. Suspended and Furred Ceilings

6.1 *Hangers and Inserts for Suspended Ceilings*:

6.1.1 Minimum No. 12-gauge (2.9 mm) galvanized, soft annealed, mild steel wire per Specification A641/A641M shall be used for ceiling areas not more than 16 ft^2 (1.5 m^2) and not more than 6 lb/ft^2 (2.7 kg/m^2).

6.1.2 For ceiling weights greater than 6 lb/ft^2 (2.7 kg/m^2) but not more than 10 lb/ft^2 (4.6 kg/m^2), use Table 6.

6.1.3 Wire hangers shall be saddle-tied around main runners and furring members so as to prevent turning or twisting of the member and to develop the full strength of the hanger with a minimum of three complete wraps around itself within 3 in. (75 mm) (see Fig. 5 and Fig. 6).

6.1.4 Wire for attaching main runners and rigid furring channels directly to concrete beams and joists, to steel beams and joists, and to wood beams and joists shall be per 6.1.1 or 6.1.2.

6.1.5 *Flat Channel Beam Hanger*—For attaching indirect hung grid suspension ceiling systems to 1.5 in. (38 mm) or 2.0 in. (51 mm) cold rolled channel. Flat channel beam hanger shall be formed from steel conforming to Specification A653/A653M and having a minimum width of 1.5 in. (38 mm) and a minimum thickness of 0.048 in. (1.21 mm) (See Fig. 7)

6.2 *Wood Construction*—Hangers for suspended ceilings under wood construction shall be per 6.1.1 or 6.1.2, and shall be attached to supports by any of the following methods.

6.2.1 A hole shall be drilled through the wood member not less than 3 in. (76 mm) above the bottom with the upper end of the wire hanger passed through the hole and twisted three times around itself (see Fig. 8).

6.2.2 Three 12-penny nails shall be driven, on a downward slant, into the sides of the wood member with not less than 1¼ in. (32 mm) penetration and not less than 5 in. (130 mm) from the bottom edges, and not more than 36 in. (910 mm) on center with the upper end of the wire hanger wrapped around the nails and twisted three times around itself (see Fig. 9).

6.2.3 A loop shall be formed on the upper end of the wire hanger and secured to the wood member by not less than four 1½ in. (38 mm), 9-gauge diameter wire staples driven horizontally or on a downward slant into the sides of the wood members, three near the upper end of the loop, and the fourth to fasten the loose end (see Fig. 10).

6.2.4 Where supports for flooring are thicker than 1½ in. (38 mm) and are spaced more than 4 ft (1220 mm) on center, 1½ in. (38 mm) No. 1/0 (0.3065 in.) (7.78 mm) eye screws, or equivalent, spaced not greater than 3 ft (910 mm) on centers shall be screwed into the flooring with the upper end of the hanger inserted through the eye screws and twisted three times around itself.

6.2.5 *Flat Hangers*—Two holes shall be drilled in the upper end of the flat hangers and nailed to the sides of the wood members with 12d penny nails driven through holes and clinched. Nails shall be not less than 3 in. (76 mm) above the bottom edge of the framing member (see Fig. 11).

6.3 *Rigid Furring Channels*—Rigid furring channels applied directly to wood framing shall be applied with screws providing 1-in. (25.4 mm) penetration or as otherwise specified by the manufacturer of the furring channels.

6.4 *Flat Hangers and Inserts*:

6.4.1 *Inserts*—Where 1 by 3⁄16-in. (25 by 4.7-mm) inserts are used, 7⁄16-in. (11-mm) diameter holes shall be punched on the center line at the lower ends of the insert to permit flat hangers to be bolted tightly to the inserts with 3⁄8-in. (10-mm) diameter bolts.

6.4.2 *Hangers*—Lower ends of the flat hangers shall be bolted to the main runners or shall be bent tightly around the members and bolted tightly to the main part of the hanger with 3⁄8-in. (9.5-mm) diameter bolts in a 7⁄16-in. (11-mm) diameter hole (see Fig. 12), or machine screws.

6.4.3 *General*—Holes in both inserts and hangers shall not be nearer to the ends than 3⁄8 in. (10 mm).

6.5 *Main Runners for Suspended Ceilings*—Channels for the various spacings of hangers shall be as specified in Table 7.

6.5.1 Ends and sides of main runners and cross furring shall not come in contact with abutting masonry or reinforced

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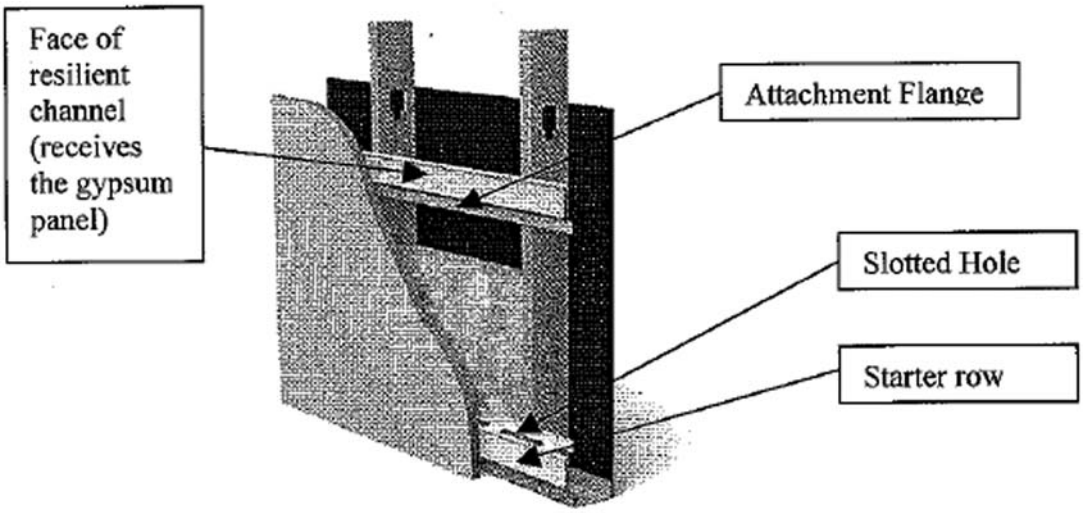

FIG. 4 Resilient Furring Channel

concrete walls or partitions. Clearance of not less than 1 in. (25 mm) from ends and ⅛ in. (3 mm) from sides shall be provided. A channel shall be located within 6 in. (150 mm) of the paralleling walls to support the ends of the cross furring. The ends at walls shall be supported by hangers located not more than 6 in. (150 mm) from such ends.

6.5.2 When main runners and cross furring are spliced, the ends shall be overlapped not less than 12 in. (305 mm) with flanges interlocked and securely fastened near each end of the splice with double loops of No. 16-gauge tie wire, minimum, or with screws.

6.6 *Furring Members for Suspended or Furred Ceilings*:

6.6.1 Furring members shall be spaced in accordance with Table 2 and Table 7.

6.6.2 Furring members shall be securely fastened to main runners and structural supports with special clips, screws, or equivalent attachments. Where required, rigid furring channels shall be saddle-tied to main runners with No. 16-gauge tie wire, a double strand of 18-gauge tie wire, or with screws (see Fig. 13).

6.6.3 When furring members are spliced, the ends shall be overlapped not less than 8 in. (203 mm) and securely fastened near each end of the splice with double loops of No. 16-gauge tie wire or with screws.

6.6.4 Flanges of rigid furring channels shall be interlocked. Ends and sides of furring members shall not come in contact with abutting masonry or reinforced concrete walls or partitions.

6.7 *Grid Suspension System*—Main beams shall be suspended in parallel rows spliced together at their ends.

6.7.1 Hangers for supporting the main beams shall be per 6.1.1 or 6.1.2.

6.7.2 Cross furring members of grid suspension systems shall interlock to the main beams in rows running perpendicular and spaced not to exceed maximums specified in Table 1. Cross furring members along the ceiling perimeter shall be supported by angle or channels attached to the wall.

7. Product Delivery, Identification, and Marking

7.1 All materials shall be delivered in original packages, containers, or bundles bearing the brand name and the name of the manufacturer or the supplier for whom the product is manufactured.

8. Product Storage

8.1 All materials shall be kept dry, preferably by being stored inside a building under a roof. Where necessary to store material outside, it shall be stacked off the ground, properly supported on a level platform, and fully protected from the weather.

9. Keywords

9.1 channel; framing; framing member; furring; grid suspension system; gypsum panel product; hangers; hanger wire; main runners; rigid furring channel; runner; stud; suspended ceiling; tie wire

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TABLE 6 Suspended and Furred Ceilings, Minimum Sizes for Hangers for Ceilings Greater Than 6 lb/ft² (2.7 kg/m²) But Not More Than 10 lb/ft² (4.6 kg/m²)

Type of Hanger			Maximum Ceiling Area Supported, ft² (m²)	Minimum Size, in. (mm) [gauge]
Hangers for Suspended Ceilings			14 (1.3)	0.1350 (3.43) [10] hanger wire
			16 (1.5)	0.1483 (3.77) [9] hanger wire
			18 (1.7)	0.1620 (4.12) [8] hanger wire
			20 (1.9)	3/16 (4.76) diameter mild steel rod
			22.5 (2.1)	7/32 (5.56) diameter mild steel rod
			25 (2.3)	1/4 (6.35) diameter mild steel rod
			28 (2.6)	1 by 3/16 (25.4 by 4.76) mild steel flat
Hangers for attaching main runners and furring directly to structural members	For supporting main runners	Hangers between structural members[A]	9 (0.8)	0.1055 (2.68) [12] hanger wire
			14 (1.3)	0.1350 (3.43) [10] hanger wire
			18 (1.7)	0.1620 (4.12) [8] hanger wire
		Double-wire loops at structural member[A]	9 (0.8)	0.0800 (2.03) [14] hanger wire
			14 (1.3)	0.1055 (2.68) [12] hanger wire
			18 (1.7)	0.1350 (3.43) [10] hanger wire
	For supporting furring without a runner (wire loops at supports)	Types of support:		
		Concrete	9 (0.8)	0.0800 (2.03) [14] hanger wire
		Steel or Wood	9 (0.8)	0.0625 (1.59) [16] hanger wire (two loops)[B]

[A] Inserts, special clips or screws, or other devices of equal strength shall be permitted.

[B] Two loops of 0.0475 in. (1.21 mm), No. 18-gauge galvanized wire shall be permitted to be substituted for each loop of 0.0625 in. (1.59 mm), No. 16-gauge wire for attaching steel furring to steel or wood joists.

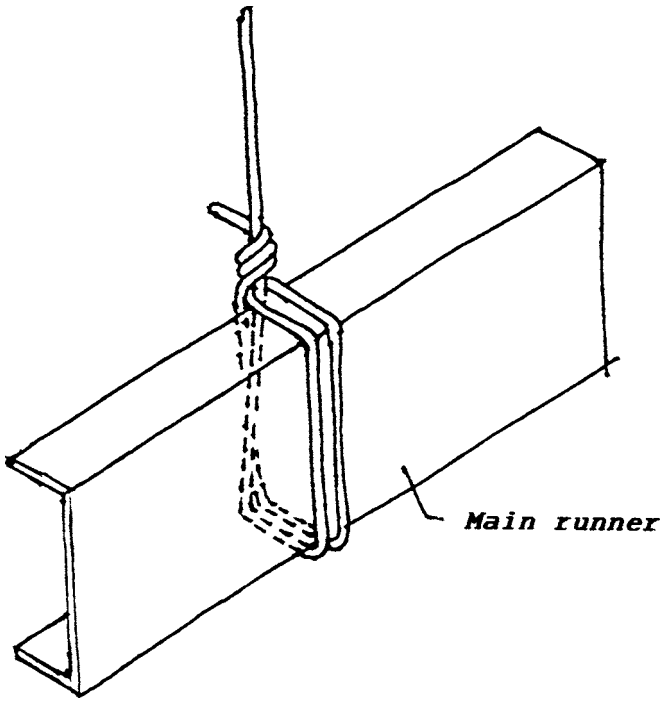

FIG. 5 Saddle Tie

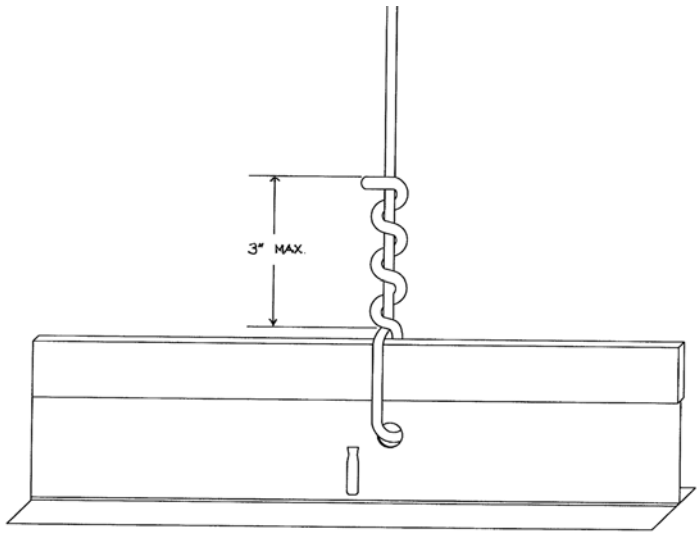

FIG. 6 Hanger Wire Tie Detail

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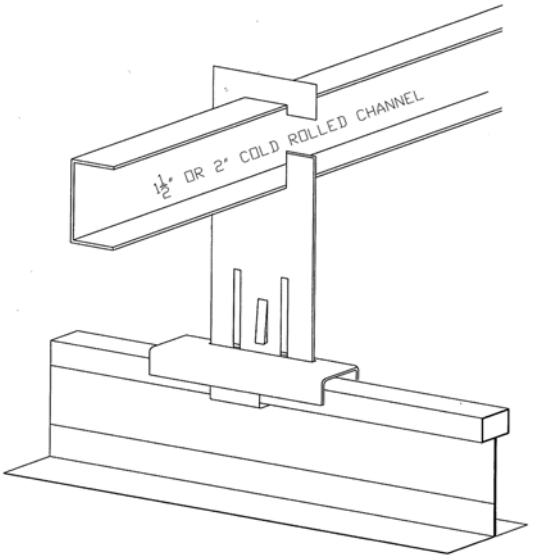

FIG. 7 Flat Channel Beam Hanger Supporting Suspended Ceiling Main Runner

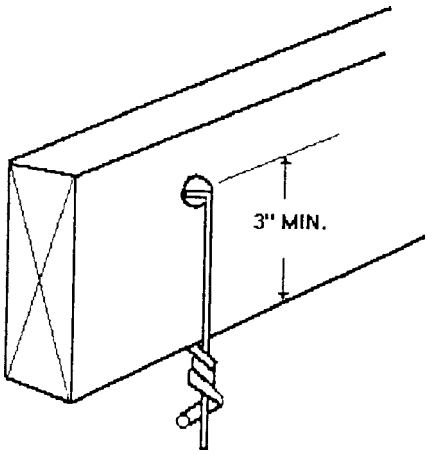

FIG. 8 Wire Hanger Attached to Wood Member Through a Drilled Hole

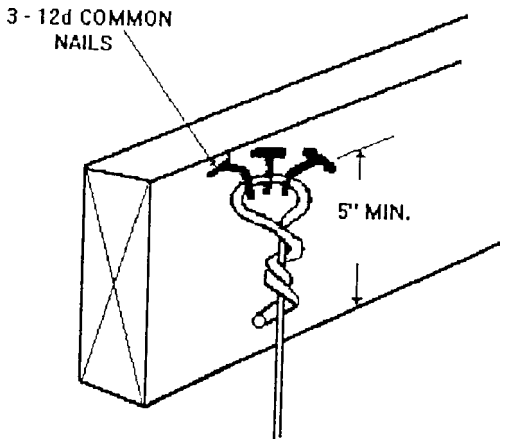

FIG. 9 Wire Hanger Attached to Wood Member Using Nails

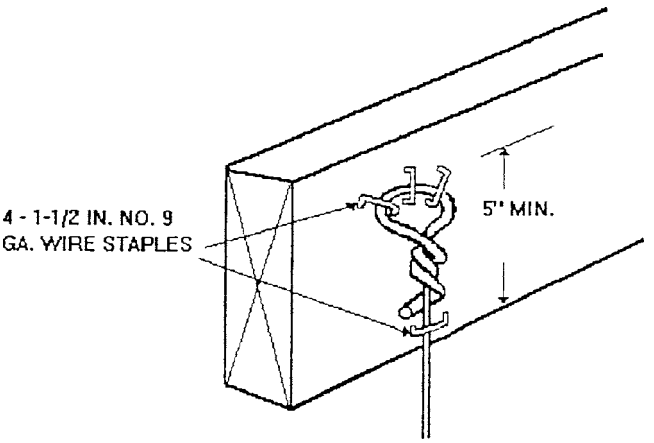

FIG. 10 Wire Hanger Attached to Wood Member Using Staples

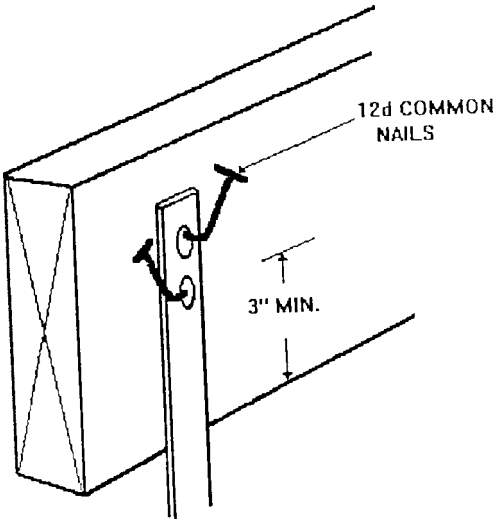

FIG. 11 Flat Hanger Attached to Wood Member Using Nails

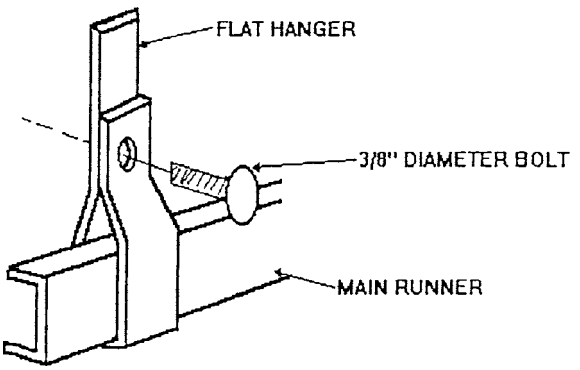

FIG. 12 Flat Hanger Attached to Main Runner Using Bolt

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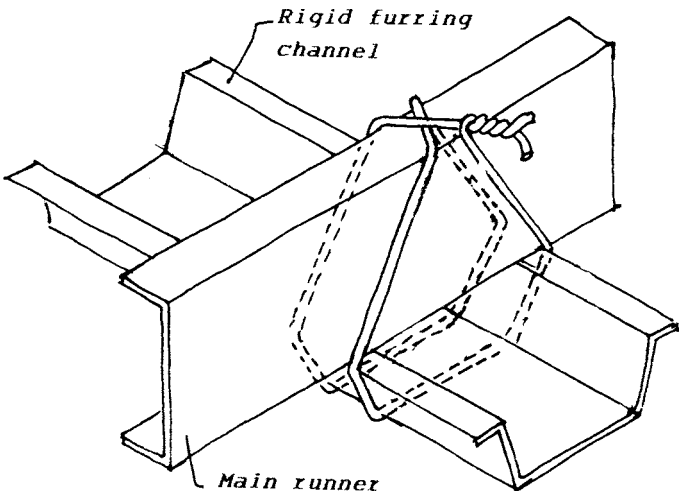

FIG. 13 Saddle Tie

TABLE 7 Allowable Spans, ft-in. (mm)
Cold-Rolled Channel Main Runners[A,B,C,D,E,F]

Member Size, In (mm)	Member Weight lb/1000 ft (kg/m)	Span Condition[G,H]	Total Uniform Load = 4 psf (0.19 kPa) Member Spacing, in. (mm)				
			24 (610)	36 (914)	48 (1220)	60 (1520)	72 (1830)
¾ (19)	277 (0.412)	Simple	3–3 (990)	2–10 (860)	2–7 (790)	2–5 (740)	2–3 (690)
		2 or More	4–1 (1240)	3–6 (1070)	3–3 (990)	3–0 (910)	2–10 (860)
1½ (38)	414 (0.616)	Simple	5–1 (1550)	4–5 (1350)	4–0 (1220)	3–9 (1140)	3–6 (1070)
		2 or More	7–1 (2160)	6–2 (1880)	5–8 (173)	5–2 (1570)	4–10 (1470)
2 (51)	506 (0.753)	Simple	5–4 (1630)	4–8 (1420)	4–3 (1300)	4–0 (1220)	3–9 (1140)
		2 or More	7–5 (2260)	6–6 (1980)	5–11 (1800)	5–6 (1680)	5–2 (1570)
2½ (64)	597 (0.888)	Simple	5–7 (1700)	4–11 (1500)	4–5 (1350)	4–2 (1270)	3–11 (1190)
		2 or More	7–9 (2360)	6–9 (2060)	6–2 (1880)	5–9 (1750)	5–5 (1650)
Total Uniform Load = 6 psf (0.29 kPa)							
Member Size, In (mm)	Member Weight lb/1000 ft (kg/m)	Span Condition[G,H]	Member Spacing, in. (mm)				
			24 (610)	36 (914)	48 (1220)	60 (1520)	72 (1830)
¾ (19)	277 (0.412)	Simple	2–10 (860)	2–6 (780)	2–3 (690)	2–1 (630)	2–0 (610)
		2 or More	3–6 (1070)	3–1 (490)	2–10 (860)	2–7 (790)	2–5 (740)
1½ (38)	414 (0.616)	Simple	4–5 (1350)	3–11 (1190)	3–6 (1070)	3–3 (990)	3–1 (940)
		2 or More	6–2 (1880)	5–5 (1650)	4–10 (1470)	4–6 (1370)	4–2 (1270)
2 (51)	506 (0.753)	Simple	4–8 (1420)	4–1 (1240)	3–9 (1140)	3–6 (1070)	3–3 (990)
		2 or More	6–6 (1980)	5–8 (1730)	5–2 (1570)	4–10 (1470)	4–7 (1400)
2½ (64)	597 (0.888)	Simple	4–11 (1500)	4–3 (1300)	3–11 (1190)	3–8 (1120)	3–5 (1040)
		2 or More	6–9 (2060)	5–11 (1800)	5–5 (1650)	5–0 (1520)	4–9 (1450)

[A] Bare metal thickness of cold-rolled main runners shall be not less than 0.0538 in. (1.367 mm).
[B] Inside corner radii shall not be greater than ⅛ in. (3.19 mm).
[C] Spans based on upper flange of main runners laterally unbraced.
[D] Maximum deflection limited to 1/360 th of the span length.
[E] Steel yield stress, *Fy*, shall be not less than 33 000 psi (228 MPa).
[F] Tabulated spans apply only to main runners with webs oriented vertically.
[G] "2 or More" spans refers to two or more continuous, equal spans.
[H] For the "2 or More" span condition, listed spans represent the center-to-center distance between adjacent supports.

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SUMMARY OF CHANGES

Committee C11 has identified the location of selected changes to this specification since the last issue, C754 – 08, that may impact the use of this specification. (Approved November 15, 2009)

(*1*) Revised 1.2.

(*2*) Added new 5.6, 5.7, and Fig. 4 and renumbered subsequent paragraphs, notes, and figures.

Committee C11 has identified the location of selected changes to this specification since the last issue, C754 – 08, that may impact the use of this specification. (Approved May 15, 2009)

(*1*) Revised Fig. 1.

Committee C11 has identified the location of selected changes to this specification since the last issue, C754 – 07, that may impact the use of this specification. (Approved November 1, 2008)

(*1*) Revised 4.5, 6.1.1, 6.1.2, 6.1.3, 6.1.4, 6.2, and 6.7.1.
(*2*) Added new 6.1.5.
(*3*) Revised the title of Table 6.
(*4*) Added new Fig. 6 and Fig. 7 and renumbered subsequent figures.

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Designation: C 778 – 06

Standard Specification for Standard Sand[1]

This standard is issued under the fixed designation C 778; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

This standard has been approved for use by agencies of the Department of Defense.

1. Scope*

1.1 This specification covers standard sand for use in the testing of hydraulic cements.

1.2 The values stated in SI units are to be regarded as the standard.

1.3 Values in SI units shall be obtained by measurement in SI units or by appropriate conversion, using the Rules for Conversion and Rounding given in IEEE/ASTM SI 10, of measurements made in other units.

1.4 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

2. Referenced Documents

2.1 *ASTM Standards:* [2]

C 109/C 109M Test Method for Compressive Strength of Hydraulic Cement Mortars(Using 2-in. or [50-mm] Cube Specimens)

C 127 Test Method for Density, Relative Density (Specific Gravity), and Absorption of Coarse Aggregate

C 136 Test Method for Sieve Analysis of Fine and Coarse Aggregates

C 150 Specification for Portland Cement

C 185 Test Method for Air Content of Hydraulic Cement Mortar

C 595 Specification for Blended Hydraulic Cements

C 702 Practice for Reducing Samples of Aggregate to Testing Size

C 1005 Specification for Reference Masses and Devices for Determining Mass and Volume for Use in the Physical Testing of Hydraulic Cements

E 11 Specification for Wire Cloth and Sieves for Testing Purposes

IEEE/ASTM SI 10 Standard for Use of the International System of Units (SI): The Modern Metric System

3. Terminology

3.1 *Definitions of Terms Specific to This Standard:*

3.1.1 *20–30 sand*, *n*—standard sand, predominantly graded to pass a 850-µm (No. 20) sieve and be retained on a 600-µm (No. 30) sieve.

3.1.2 *graded sand*, *n*—standard sand, predominantly graded between the 600-µm (No. 30) sieve and the 150-µm (No. 100) sieve.

3.1.3 *standard sand*, *n*—silica sand, composed almost entirely of naturally rounded grains of nearly pure quartz, used for preparing mortars in the testing of hydraulic cements.

4. Requirements

4.1 Sand shall meet the requirements of Table 1 with respect to grading, source of sand, and absence of undesirable air entraining characteristics.

METHODS OF SAMPLING AND TESTING STANDARD SANDS

5. Apparatus

5.1 *Sieves*—The sieves shall be standard 203-mm (8-in.) diameter, full-height, wire-cloth sieves, conforming to the requirements of Specification E 11, and of the following sizes:

1.18-mm (No. 16)	425-µm (No. 40)
850-µm (No. 20)	300-µm (No. 50)
600-µm (No. 30)	150-µm (No. 100)

5.2 *Sample Splitter*—The sample splitter, receptacles, and feeder pan or hopper shall conform to the general design requirements listed in Method A, apparatus section of Practice C 702, except that the device shall have no fewer than eight chutes having a maximum opening no greater than 13 mm, and

[1] This specification is under the jurisdiction of ASTM Committee C01 on Cement and is the direct responsibility of Subcommittee C01.95 on Coordination of Standards.

Current edition approved May 15, 2006. Published May 2006. Originally approved in 1974. Last previous edition approved in 2002 as C 778 – 02.

[2] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

***A Summary of Changes section appears at the end of this standard.**

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TABLE 1 Standard Sand Requirements

Characteristics	20-30 Sand	Graded Sand
Grading, percent passing sieve:		
1.18 mm (No. 16)	100	100
850 µm (No. 20)	85 to 100	
600 µm (No. 30)	0 to 5	96 to 100
425 µm (No. 40)		65 to 75
300 µm (No. 50)		20 to 30
150 µm (No. 100)		0 to 4
Difference in air content of mortars made with washed and unwashed sand, max, % air[A]	2.0	1.5[B]
Source of sand	Ottawa, IL or LeSuer, MN	Ottawa, IL

[A] This determination is needed when contamination of sand is suspected as discussed in 8.1.

[B] Compressive strength of Test Method C 109/C 109M mortar made with Specification C 150 or C 595 cement will be reduced approximately 4 % for each percent of air in the compacted cube. However, as many as three batches of washed and three of unwashed sand may be needed to reliably detect a difference in strength of 7 % between washed and unwashed sand mortars.

a minimum opening at least three times the diameter of the largest particle of sand in a sample to be split.

5.3 *Reference Masses and Devices for Determining Mass*—Reference masses and devices for determining mass shall conform to the requirements of Specification C 1005 as appropriate for the size of the sample the mass of which is to be determined.

6. Sampling

6.1 Sample each lot or shipment and test for the grading requirements in Table 1. Determine air entraining characteristics only when contamination of sand is suspected. Sample the shipment in accordance to the procedure listed in 9.1.

6.2 *Procedure*—Using *Method A–Mechanical Splitter* procedure described in Practice C 702, reduce the entire contents of a bag of standard sand to a testing size of approximately 100 g.

7. Sieve Analysis

7.1 *Sieving*—Sieve the sand by hand or mechanically as described in Test Method C 136.

7.2 *Reporting*—Report the results of the sieve analysis as total percentage passing each sieve.

8. Tests for Air-Entraining Potential of Sand

8.1 Small amounts of some surfactants or other contaminants will produce air voids in mortars made with 20–30 sand, graded sands or both. When contamination is suspected, test the sands in accordance with the procedures described in this section to determine the effect on air content or strength (see Note 1).

NOTE 1—It may be desirable to wash these sands routinely to avoid potential problems. Additionally, the washing procedure outlined in 8.1.1 will tend to minimize segregation of sand that may occur when the sand is handled in a dry state.

8.1.1 Obtain a sample of at least 2800 g from a full bag of sand. Place the remainder of the sand from the bag in a concrete mixer of the drum type. Add sufficient water to cover the sand and mix for 2 min. Decant the water over a 75 µm sieve and drain for 2 min. Repeat the washing and decanting procedure four times. Tilt the mixer and drain the sand for 20 min or longer. Determine the mass of damp sand and place it in approximately batch-sized quantities in separate containers. Dry the sand to constant mass in an oven at 110 °C. Cool and adjust the quantity of dry sand to the amount required for a test. Prepare two batches of each of "washed" and as "as received" sand for test following the procedures in Test Method C 185 for 20–30 sand or Test Method C 109/C 109M for graded sand.

8.1.2 Tests for air-entraining potential of a standard sand shall be made on a single day by a single operator.

8.2 *20–30 Sand*—Prepare two batches of mortar with washed sand and two with "as received" sand in accordance with Test Method C 185. Compare the average air content for washed and unwashed sand mortars for compliance with limit in Table 1.

8.3 *Graded Sand*—Prepare two batches of mortar with washed sand and two with "as received" sand in accordance with Test Method C 109/C 109M. When Test Method C 109/C 109M mortar cubes are removed from the molds, determine the density of a group of at least three cubes from each batch by determining the mass of the cubes both in air and immersed in water. Follow procedures outlined in Test Method C 127 for bulk specific gravity (SSD). Determine the mass of the cubes to at least the nearest gram. Calculate the apparent air content as follows:

$$\text{apparent air content} = ((D_t - D_m)/D_t) \times 100 \quad (1)$$

where:

D_m = the measured density (bulk specific gravity (SSD)), and

D_t = the theoretical density of air-free mortar, g/cm^3.

Note that D_t is calculated as the total mass of the ingredients in a batch of mortar divided by the sum of the absolute volumes of the cement, sand, and water used in the batch. Average the apparent air content of the two batches made with washed sand and compare that average with the similar average for "as received" sand mortar to determine compliance with the limit in Table 1.

9. Rejection

9.1 *Standard Sand*—Reject a bag of standard sand if the contents fail to meet one or more of the requirements of this specification. Sample a shipment of standard sand by selecting every 15th bag by consecutive number beginning with the 5th bag of the shipment. Count bags missing from the sequence as if they were there. Accept a shipment of standard sand if the contents of the selected bags meet the requirements of this specification. If any of the selected bags fail to meet one or more of the requirements of this specification, resample the shipment by selecting every 15th bag by consecutive number beginning with the 10th bag of the shipment. Accept a shipment of standard sand if the contents of the selected bags on the resampling meet the requirements of this specification. If any of the selected bags in the resampling fail to meet one or more of the requirements of this specification, and the rejected bag is within a 15-bag sequence of a bag rejected in the first selection of bags, reject the entire sequence of bags between accepted tests. Reject the entire shipment if half of the number

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of bags tested fail to meet the requirements of this specification, or if the shipment consists of five bags or less if one randomly selected bag fails the specification.

9.2 Table 2 shows for both sampling and resampling in Column 2 the number of bags to be tested based on the total number of consecutive bags in the shipment. Column 3 shows the identification of the bag to be selected for test based on the consecutive number of the bags.

TABLE 2 Sampling and Resampling of Standard Sand

Total No. of Consecutive Bags in Shipment	No. of Bags to Test	Test in Consecutive No., the Following Bags
Sampling:		
less than 5	1	random
5 to 19	1	5th
20 to 34	2	5th and 20th
35 to 49	3	5th, 20th, and 35th
50 to 64	4	5th, 20th, 35th, and 50th
Resampling:		
less than 5	none	reject shipment
5 to 19	1	10th
20 to 34	2	10th and 25th
35 to 49	3	10th, 25th, and 40th
50 to 64	4	10th, 25th, 40th, and 55th

NOTE 2—For example, if, in a shipment of 30 bags, on first sampling, the 20th bag fails the specification, and on resampling, the 25th bag fails the specification, the entire shipment is rejected. If the shipment were 100 bags and on first sampling only the 20th bag fails, and on resampling only the 25th bag fails, only bags Nos. 11 to 34 would be rejected.

10. Packaging and Package Marking

10.1 *Packaging*—Standard sands shall be delivered in bags with impervious liners made of material that will not contaminate the sand.

10.2 *Marking*—Each bag shall be plainly marked as follows: ASTM C 778 20-30 Sand or ASTM C 778 Graded Sand as the case may be. The source of the sand and the mass of the sand contained therein shall be plainly indicated on each bag.

11. Keywords

11.1 20-30 sand; graded sand; hydraulic cement testing sand; standard sand

SUMMARY OF CHANGES

Committee C01 has identified the location of selected changes to this specification since the last issue, C 778 – 02, that may impact the use of this specification. (Approved May 15, 2006)

(*1*) Revised 5.2.
(*2*) Added new 6.1.
(*3*) Revised 9.1 and Note 2.

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Designation: C 779/C 779M – 05

Standard Test Method for Abrasion Resistance of Horizontal Concrete Surfaces[1]

This standard is issued under the fixed designation C 779/C 779M; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope

1.1 This test method covers three procedures for determining the relative abrasion resistance of horizontal concrete surfaces. The procedures differ in the type and degree of abrasive force they impart, and are intended for use in determining variations in surface properties of concrete affected by mixture proportions, finishing, and surface treatment. They are not intended to provide a quantitative measurement of the length of service that may be expected from a specific surface.

1.2 The values stated in SI units or inch-pound units are to be regarded separately as standard. Within the text, the inch-pound units are shown in brackets. The values stated in each system are not exact equivalents; therefore, each system shall be used independently of each other.

1.3 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.* (**Warning**—Fresh hydraulic cementitious mixtures are caustic and may cause chemical burns to skin and tissue upon prolonged exposure.)[2]

NOTE 1—Other procedures are available for measuring the abrasion resistance of concrete surfaces in addition to the three procedures contained in this test method. Consideration should be given to Test Methods C 944 and C 418. The test method most closely representing service conditions should be used.

2. Referenced Documents

2.1 *ASTM Standards:* [3]

C 418 Test Method for Abrasion Resistance of Concrete by Sandblasting

C 670 Practice for Preparing Precision and Bias Statements for Test Methods for Construction Materials

C 944 Test Method for Abrasion Resistance of Concrete or Mortar Surfaces by the Rotating-Cutter Method

3. Significance and Use

3.1 The three test methods provide simulated abrasion conditions, which can be used to evaluate the effects on abrasion resistance of concrete, concrete materials, and curing or finishing procedures. They may also be used for quality acceptance of products and surface exposed to wear. They are not intended to provide a quantitative measurement of length of service.

3.2 The equipment used by each of these procedures is portable and thus suitable for either laboratory or field testing. The three procedures determine the relative wear of concrete surfaces as follows:

3.2.1 *Procedure A*—The revolving-disk machine operates by sliding and scuffing of steel disks in conjunction with abrasive grit.

3.2.2 *Procedure B*—The dressing-wheel machine operates by impact and sliding friction of steel dressing wheels.

3.2.3 *Procedure C*—The ball-bearing machine operates by high-contact stresses, impact, and sliding friction from steel balls.

NOTE 2—Diagrams of three machines meeting these specifications are shown in Fig. 1, Fig. 2, and Fig. 3.[4]

PROCEDURE A—REVOLVING DISKS

4. Apparatus

4.1 The function of the apparatus is dependent upon the abrasive action of the flat faces of three 60-mm (2⅜-in.) diameter, cold-rolled steel revolving disks, each attached to motor-driven vertical shafts which also revolve about a vertical axis. The inside diameter of the resulting circular and abraded track shall be approximately 150 mm (6 in.) and the outside diameter 275 mm (11 in.). Crossed slots 90° to each other and cut 5 mm (3⁄16 in.) deep and 6 mm (¼ in.) wide are located symmetrically in the abrasive flat faces.

[1] This test method is under the jurisdiction of ASTM Committee C09 on Concrete and Concrete Aggregates and is the direct responsibility of Subcommittee C09.62 on Abrasion Testing of Concrete.

Current edition approved Dec. 15, 2005. Published January 2006. Originally approved in 1974. Last previous edition approved in 2000 as C 779 – 00.

[2] Section on Safety Precautions, *Manual of Aggregate and Concrete Testing*, *Annual Book of ASTM Standards*, Vol. 04.02.

[3] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

[4] The sole source of supply of these machines known to the committee at this time is White Machine Co., 9591 York Alpha Dr., North Royalton, OH 44133; Spirit Fabricating, Ltd., 9260 Valley View Rd., Macedonia, OH 44056. If you are aware of alternative suppliers, please provide this information to ASTM International Headquarters. Your comments will receive careful consideration at a meeting of the responsible technical committee,[1] which you may attend.

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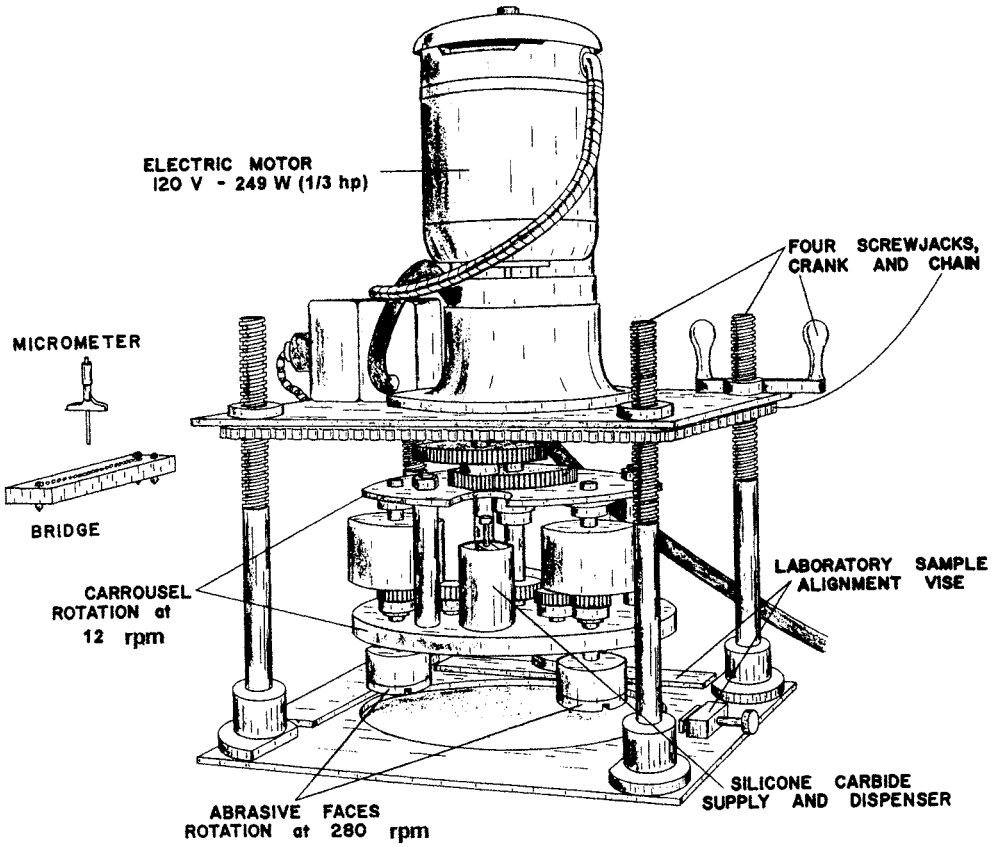

FIG. 1 Revolving Disks Abrasion Test Machine

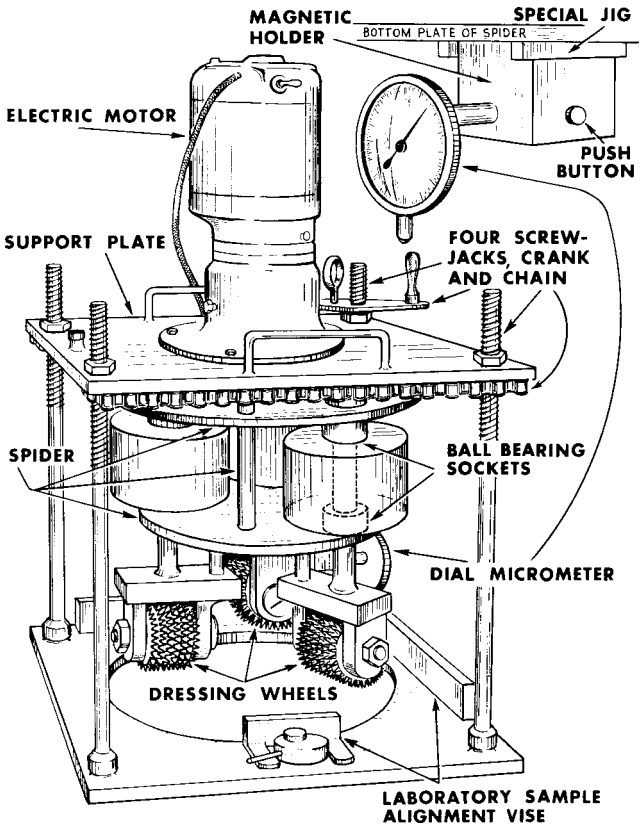

FIG. 2 Dressing Wheel Abrasion Test Machine

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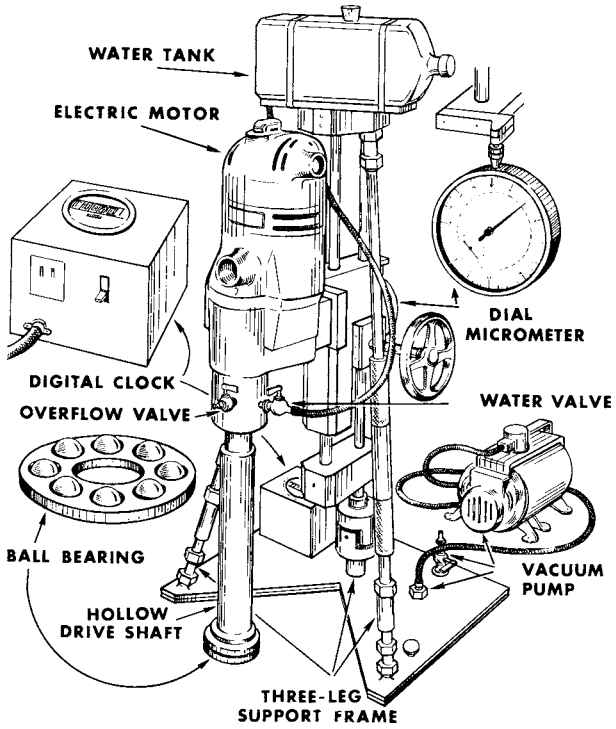

FIG. 3 Ball Bearing Abrasion Test Machine

4.2 The disks are free floating inasmuch as they are self-supporting and are driven transversely along a circular path at 12 rev/min (12 rpm) while being individually turned on their own axis at 280 rev/min (280 rpm). Cups attached at the top of the shaft of each disk shall be loaded with lead shot to produce a uniform total load of 22 N (5 lbf) on each abrading disk face.

4.3 The abrasive grit shall consist of 250 µ [No. 60] silicon carbide. This is fed from a storage cup mounted on the revolving circular plate through a 3-mm (⅛-in.) orifice passing through the plate. The flow of abrasive shall be controlled to a rate of 4 to 6 g/min by an adjusting needle located in the orifice. The abrasive falls at the midwidth of the circular abraded track, and midway between two of the disks.

4.4 The micrometer bridge consists of a machine-finished 25-mm (1-in.) rectangular steel bar of at least 300-mm (12-in.), clear span supported by a tripod and drilled along its centerline with ten 3-mm (⅛-in.) diameter holes spaced 6-mm (¼ in.) on center. The measuring instrument is a depth micrometre with a needle having an effective depth range of 25 to 50 mm (1 to 2 in.) and graduated to an accuracy of at least 0.025 mm (0.001 in.).

5. Test Specimen

5.1 For laboratory test purposes, the machine is designed to accommodate approximately 300 by 300-mm (12 by 12-in.) test specimens. The apparatus is equipped with an adjusting handle linked by a sprocket and chain-drive assembly to the four 25-mm (1-in.) diameter posts which support the entire rotating abrasion element. This feature permits the abrasion of test panels up to approximately 100-mm (4-in.) in thickness. A zero adjustment in the height of the abrasion assembly also permits the use of the apparatus as a portable device for measuring the abrasion resistance on the surfaces in place as well as on test specimens.

6. Procedure

6.1 Prior to the test period, precondition the sample to remove curing compound and surface irregularities by running the abrasion machine for 5 min, after which the initial measurements shall be taken. Obtain initial measurements to an accuracy of at least 0.025 mm (0.001 in.) of the test area by taking two series of 20 measurements each. Place the micrometer bridge so that the line of the second series of readings bisects at right angles to the first series of measurements. In making measurements subsequent to the abrasion period, take care that the micrometer bridge is placed in precisely the same position in which the reference measurements were obtained. To ensure this, outline the ends of the positioned micrometer bridge on the surface prior to making the initial measurements.

6.2 A test period of 30 min generally produces significant wear on most concrete surfaces, but it is recommended to extend the test period to 60 min, if information on the longtime abrasion resistance is desired.

6.3 In using the device as a portable apparatus, take care in the selection of the areas to be tested. Although the base of the apparatus is equipped with rubber pads, not only to prevent the apparatus from creeping during the abrasion operation but also to minimize the effect of slight variations in the level of the test areas. Select test areas with a minimum of variation in level so as to eliminate the creeping effect.

6.4 Take measurements of depth wear with a micrometer bridge as described in 4.4 to an accuracy of at least 0.025 mm (0.001 in.). Prior to each set of measurements, clean the specimen surface carefully by removing loose particles.

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6.5 Make three tests on surfaces representative of the concrete to be evaluated. When wear of the disks reduces the depth of the slots to less than 1.5 mm (1/16 in.), they shall be replaced. New disk faces shall be subjected to a break-in period of at least 15 min.

7. Interpretation of Results

7.1 The comparison of measurements of average depth of wear of representative surfaces at 30 and 60-min exposure to abrasion will indicate the relative abrasion resistance of these surfaces.

8. Report

8.1 Report the depth of wear of each surface tested as well as the average obtained on replicate surfaces.

8.2 Record mixture proportions (including cement content and water-cement ratio), specific gravities, grading of fine and coarse aggregates, Los Angeles abrasion test results, type and amount of material added to freshly placed concrete surface, type and extent of troweling, curing details, and age of concrete when tested.

PROCEDURE B—DRESSING WHEELS

9. Apparatus

9.1 The function of the apparatus is dependent upon the abrasive action of three sets of steel dressing wheels riding in a circular path over a horizontal concrete surface. The dressing wheels in each of the three sets of wheels turn freely on a horizontal axle at the bottom of a free-floating, weighted, vertical steel shaft.

9.2 Each of the three sets of seven dressing wheels are spaced so that each set cuts approximately a 40-mm (1½-in.) wide path. The machine produces a circular abrasion path of about 140-mm (5½-in.) inside diameter and 220-mm (8½-in.) outside diameter.

9.3 The apparatus shall consist of a motor-driven spider arrangement turning at 56 rev/min (56 rpm). The motor shall be mounted on a horizontal plate supported by four screw jacks allowing the motor to be raised and lowered. The spider shall be hung from the vertical motor shaft. The three vertical shafts shall be mounted in the spider arrangement so that they rotate with the spider and are free to move up and down in independent thrust-bearing sockets.

9.4 The three shafts shall be fitted with a yoke inside, upon which a series of seven dressing wheels are placed on a horizontal axle. The mass of each complete dressing wheel assembly as it bears on the concrete surface shall be 7.5 kg (16.5 lb).

9.5 The dressing wheels shall have an outside diameter of 60 mm (2⅜ in.) and a thickness of 3 mm (⅛ in.) and shall be provided with 18 flattened points, each having dimensions of 3.0 by 2.0-mm (0.125 by 0.075 in.). The dressing wheels shall be assembled on the shaft alternated with steel washers. The total width of seven dressing wheels and eight washers shall be approximately 40 mm (1½ in.). The dressing wheels must be loose enough to turn freely and independently.

9.6 The measuring instrument shall be a dial micrometer, reading to an accuracy of at least 0.025 mm (0.001 in.) with a range of at least 10 mm (0.4 in.). The contact end of the micrometer spindle shall have a spherical surface of 9.5-mm (⅜-in.) diameter. A jig located on the underside of the spider holds the micrometre magnetically in the approximate center of the path of the dressing wheels.

10. Test Specimen

10.1 Place a sample approximately 300 by 300 by 100-mm (12 by 12 by 4-in.) thick into the machine and lock it in place with vises provided. Do not remove the sample until the test is completed. Test three identical samples.

11. Procedure

11.1 Position the abrasion apparatus over surface to be tested. Rubber pads on the bottom of machine will hold the machine in place. Turn the screw crank until the full weight of each dressing-wheel shaft is resting on the concrete surface. Lower the spider as far as possible without exerting any pressure from the spider itself onto these three shafts. Allow a spacing of 15 mm (0.5 in.) for vertical travel of the dressing wheels. Lock the screw crank to prevent any change in vertical movement of the spider during testing.

11.2 Take an initial measurement to the nearest 0.025 mm (0.001 in.) on the test area with the dial micrometer in place while revolving the spider two revolutions by hand. Record this initial reading as a reference reading and then remove the micrometer. Start the machine and let it run for 30 min, brush off the loose material, insert the dial micrometer, and record the average reading again. If the readings are not reasonably uniform, record several readings taken around the circumference of the abraded surface from which the average reading may be computed. The difference between the reference reading and the 30-min reading is indicative of the depth of wear.

11.3 Make three tests on surfaces representative of the concrete to be evaluated. After every third test, install new dressing wheels.

11.4 A test period of 30 min generally produces significant wear on most concrete surfaces, but it is recommended to extend the period to 60 min, if simulation of more severe abrasion is desired. Take depth-of-wear readings at 15-min intervals to the nearest 0.025 mm (0.001 in.) to obtain a time versus wear curve.

12. Interpretation of Results

12.1 The comparison of measurements of average depth of wear of representative surfaces at 30 and 60-min exposure to abrasion will indicate the relative abrasion resistance of these surfaces.

12.2 A comparison of curves will indicate whether the resistance to abrasion is primarily at the surface or at a greater depth.

13. Report

13.1 Plot the time versus depth of wear of tests performed for 30 and 60-min durations on three representative surface locations or specimens and determine the average line.

13.2 Record the mixture proportions including cement content and water-cement ratio, specific gravities, grading of fine

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and coarse aggregates, Los Angeles abrasion test results, type and amount of material added to freshly placed concrete surface, type and extent of troweling, curing details, and age of concrete when tested.

PROCEDURE C—BALL BEARINGS

14. Apparatus

14.1 The function of the apparatus is dependent upon the abrasive action of a rapidly rotating ball bearing under load on a wet concrete test surface. Water is used to flush out loose particles from the test path, bringing the ball bearing in contact with sand and stone particles still bonded to the concrete surface, thus providing impact as well as sliding friction.

14.2 The apparatus shall consist of a motordriven, hollow, vertical shaft resting on and turning ball bearings which rest on the concrete surface. As the ball bearings cut into the concrete surface, depth-of-wear readings can be taken continuously without stopping the test.

14.3 A digital clock shall be electrically connected to the drive motor so that both the drive motor and the clock can be started simultaneously. The clock shall read in seconds up to 9999 s.

14.4 The abrasion tool shall be composed of eight 18-mm ($^{23}/_{32}$-in.) diameter steel balls equally spaced in a retainer ring. The diameter of the ball circle shall be 60 mm (2½ in.). The abrasion tool shall be given a breaking-in period of 300 s. The abrasion tool shall be discarded when the diameter of the steel ball has been reduced to 17.8 mm (0.7 in.).

NOTE 3—During this period the steel balls will become slightly textured, leaving an apparent larger diameter.

14.5 The hollow vertical drive shaft shall be provided with a flanged bearing plate at its lower end, grooved to match the ball circle of the abrasion tool, and a centered 3-mm (⅛-in.) diameter orifice to permit a constant flow of water. The drive shaft shall be further provided with an adjustment of plumbness to the test surface. The total load on the ball bearing shall be 120 N (27 lbf) including the weight of drive motor, hollow drive shaft, and contained water. The motor shall be capable of revolving the drive shaft at 1000 rpm/min (1000 rpm) under load.

14.6 The dial indicator shall have a travel of 15 mm (½ in.) and to an accuracy of at least 0.025 mm (0.001 in.).

14.7 A 4-L (1-gal) plastic tank mounted on the motor base supplies water which flows by gravity through the hollow drive shaft and orifice in the flange plate onto the concrete surface.

14.8 The machine base shall be provided with a vacuum hold-down device having three support points.

15. Test Specimen

15.1 When tests are run on concrete specimens rather than on a concrete slab in place, mount the samples securely so as to have a rigidity approximating that of a slab in place. This can be achieved by using bonding agents or a vacuum to hold the test sample to the horizontal surface upon which the machine is mounted.

15.2 Use test samples 300 by 300 by 100-mm (12 by 12 by 4-in.) thick. The rate of wear on this size sample has been found to be about 90 % of the rate of wear of a concrete slab in place. The size of the test specimen will affect the rate of wear measured by this test method.

16. Procedure

16.1 Mount the machine firmly and securely on a concrete surface by use of a vacuum hold-down device.

16.2 Place a sheet of paper between the test surface and the ball bearings under the load of the motor. Revolve the drive shaft several times by hand. A complete circular mark formed on the paper indicates the drive shaft is normal to the surface. If a crescent is formed, adjust the plumbness of the drive shaft and repeat the procedure until a circle is obtained.

16.3 Open the two valves at the base of the drive motor; one to allow water to fill the hollow drive shaft, the other to determine that the hollow shaft is filled. Then close the overflow valve. Fill the water tank to the prescribed mark to assure a standard initial head.

16.4 Bring the dial gage clamped to the supporting shaft to bear on the sliding bracket of the motor and drive shaft. Reset the digital clock to zero.

16.5 Take the reference dial micrometer reading immediately following the slight jump of the dial, just after the motor is started.

16.6 Take dial micrometer readings to an accuracy of at least 0.025 mm (0.001 in.) of the depth of abrasion at least every 50 s for a total period of 1200 s, or until a maximum depth of 3.0 mm (0.1225 in.) is reached. Take an average reading of the pulsating micrometer dial.

16.7 Take three tests on surfaces representative of the concrete to be evaluated.

17. Interpretation of Results

17.1 Determine the depth of wear for each interval of the test. The comparison of curves showing a plot of depth of wear versus time for each series of concrete surfaces tested will indicate the relative abrasion resistance of these surfaces.

17.2 A material that is uniform in abrasion resistance will have a curve approximating a half-parabola inclined toward the time axis. A comparison of curves will indicate whether the resistance to abrasion is primarily at the surface or at greater depth.

17.3 When comparing test results of concrete surfaces of a wide range in abrasion resistance, establish the time required to reach a particular depth.

18. Report

18.1 Plot the time versus depth of wear of tests performed on three representative concrete surfaces and determine the average line.

18.2 Record mixture proportions including cement factor and water-cement ratio, specific gravities, and grading of fine and coarse aggregates, Los Angeles abrasion test results, type and amount of material added to freshly placed concrete surface, type and extent of troweling, curing details, and age of concrete when tested.

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TABLE 1 Within-Laboratory Precision for Single Operator

Procedure	Coefficient of Variation, Percent of Mean[A]	Acceptable Range of Two Results, Percent of Mean[A]
A Revolving disk	5.51	15.6
B Dressing wheel	11.69	33.1
C Ball bearing	17.74	50.2

[A] These numbers represent respectively the 1s % and d2s % limits as described in Practice C 670, in the section on Alternative Form of the Precision Statement.

19. Precision and Bias

19.1 *Precision*[5]—Criteria for judging the acceptability of abrasion resistance test results obtained by this method[6] are given as follows:

NOTE 4—The figures given in Table 1 column 2 are the coefficients of variation that have been found to be appropriate for the materials and conditions of test as determined with inch-pound units and equipment as described in column 1.

19.2 *Bias*—Since there is no acceptable reference material suitable for determining bias for the procedure in this test method, no statement on bias is being made.

20. Keywords

20.1 abrasion; concrete; impact; surface treatments; wear

[5] Supporting data have been filed at ASTM International Headquarters and may be obtained by requesting Research Report RR: C09-1015 .

[6] The precision of this test method has been found to depend primarily on the procedure used and not on the depth and period of abrasion and the age of concrete after casting.

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Designation: C786/C786M – 10

Standard Test Method for Fineness of Hydraulic Cement and Raw Materials by the 300-µm (No. 50), 150-µm (No. 100), and 75-µm (No. 200) Sieves by Wet Methods[1]

This standard is issued under the fixed designation C786/C786M; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope*

1.1 This test method covers wet sieving techniques for determination of fineness of hydraulic cement and raw materials by means of the 300-µm (No. 50), the 150-µm (No. 100), and the 75-µm (No. 200) sieves.

1.2 The values stated in either SI units or inch-pound units are to be regarded separately as standard. The values stated in each system may not be exact equivalents; therefore, each system shall be used independently of the other. Combining values from the two systems may result in non-conformance with the standard. Values in SI units [or inch-pound units] shall be obtained by measurement in SI units [or inch-pound units] or by appropriate conversion, using the Rules for Conversion and Rounding given in IEEE/ASTM SI 10 of measurements made in other units. Values are stated in SI units when inch-pound units are not used in practice.

1.3 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

2. Referenced Documents

2.1 *ASTM Standards:*[2]

C114 Test Methods for Chemical Analysis of Hydraulic Cement

C184 Test Method for Fineness of Hydraulic Cement by the 150-µm (No. 100) and 75-µm (No. 200) Sieves[3]

C430 Test Method for Fineness of Hydraulic Cement by the 45-µm (No. 325) Sieve

E11 Specification for Woven Wire Test Sieve Cloth and Test Sieves

IEEE/ASTM SI 10 American National Standard for Use of the International System of Units (SI): The Modern Metric System

3. Apparatus

3.1 *Wet Test Sieves*—Standard 300-µm (No. 50), 150-µm (No. 100), or 75-µm (No. 200) sieve cloth conforming to the requirements of Specification E11, for standard sieves shall be woven from AISI Type 304 wire. The cloth shall be mounted in the frame without distortion, looseness, or wrinkling. Sieve frames are designated as 76.2 or 101.6-mm [3 or 4-in.] diameter type, as follows:

	Sieves	
	76 mm [3-in.] mm [in.]	102 mm [4-in.] mm [in.]
Diameter of frame	76 ± 6 [3.0 ± 0.25]	102 ± 6 [4.0 ± 0.25]
Depth of sieve from top of frame	83 ± 6 [3.25 ± 0.25]	108 ± 6 [4.25 ± 0.25]
Overall height	102 ± 6 [4.0 ± 0.25]	127 ± 6 [5.0 ± 0.25]

3.1.1 For a sieve fabricated by soldering the cloth to the frame, the joint shall be made smooth to prevent material from lodging in the joints between the sieve cloth and the frame. Two-piece sieves shall clamp tightly on the cloth to prevent particles from lodging in the joints between the sieve cloth and the frame, and shall have legs of sufficient length, 19-mm [0.75-in.] minimum, to allow air circulation beneath the sieve cloth.

3.2 *Spray Nozzle*—conforming to the requirements of Test Method C430. Nozzles having an alternative design are acceptable if the sieve test results agree with those performed using a nozzle conforming to Test Method C430.

3.3 *Pressure Gage*—conforming to the requirements of Test Method C430.

3.4 *Balance*—analytical, accurate to within 0.005 g.

3.5 *Weights*—The weights used in fineness determinations shall conform to the requirements of Test Methods C114.

3.6 *Brush*—A nylon or pure bristle brush will be required for use in cleaning the sieves. A 13-mm [0.5-in.] diameter round-style brush with a 229-mm [9-in.] handle is a convenient

[1] This test method is under the jurisdiction of ASTM Committee C01 on Cement and is the direct responsibility of Subcommittee C01.25 on Fineness.

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[2] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

[3] Withdrawn. The last approved version of this historical standard is referenced on www.astm.org.

***A Summary of Changes section appears at the end of this standard.**

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size. (**Warning—**Do not use brass or steel-bristle brushes for cleaning sieves due to the possibility that the stiff bristle will part the wire weave, thereby altering the size of the openings and rendering the sieve useless. A 13-mm [½-in.] hog bristle stencil brush is also satisfactory for brushing sieves.)

3.7 *Dry Test Sieves*—The standard samples for calibrating the wet test sieves must be standardized on 203-mm [8-in.] diameter sieves meeting the requirements of Test Method C184. The 300-µm (No. 50) sieve shall meet the same requirements.

3.8 *NBS SRM No. 1004*—Glass Bead Standard.

4. Dry Sieve Standardization

4.1 *Correction Factors*:

4.1.1 Correction of the residues obtained on the 203-mm [8-in.] diameter 300-µm (No. 50) and 150-µm (No. 100) dry testing sieves is not required.

4.1.2 Where applicable, a correction factor for a 75-µm (No. 200) sieve shall be determined using the instructions given in Annex A1. A correction factor should be determined when accuracy is desired in order to compare results between laboratories.

4.2 *Standard Samples*—Each laboratory must prepare its own standard samples for wet-sieve tests for each of the sieve sizes used. Select standard samples at a level of fineness in the same range as that used in routine work. After the selected material is reserved, uniformly mix the gross sample by placing it on a sheet of rubber, oil cloth, or heavy wrapping paper, depending on the sample size, and raising first one corner of the sheet and then the other so as to roll the sample over and over at least 100 times. Temporarily seal the prepared standard material in airtight containers during the standardization procedure prior to sealing small portions as standard samples in vials. Using the 203-mm [8-in.] diameter sieves from 3.7, perform the dry sieving tests, following the procedure of Test Method C184. Repeat the test three times and use the average of the amounts passing, expressed as percent, as the standard value of the sample. Use this standard sample to calibrate the wet sieves. Place the entire sample in airtight vials as soon as possible to prevent changes due to humidity. Vials shall be prepared in denominations such as to contain approximately 50 g for standardizing the 300-µm (No. 50); 25 g for the 150-µm (No. 100); or 10 g for the 75-µm (No. 200) sieve.

5. Wet Sieve Calibration

5.1 Weigh the contents of the applicable size standard sample vial for the desired sieve determination on a balance of appropriate sensitivity to the nearest 0.01 g. Record the weight and transfer the sample quantitatively to a clean dry wet test 300-µm (No. 50), 150-µm (No. 100), or 75-µm (No. 200) sieve and proceed as directed in Section 6. The sieve correction factor is the difference between the test residue obtained and the residue value indicated by the standardization tests of Section 4, expressed as a percentage of the test residue. This factor is expressed as follows:

$$C = \frac{(Rs \times Wt/100) - Rt}{Rt} \times 100 \quad (1)$$

where:

C = sieve correction factor (which may be either plus or minus), %,
R_t = test residue from sample retained on sieve, g,
R_s = standard residue retained on sieve, %, and
W_t = weight of test sample, g.

5.1.1 Example of Determination of Wet Sieve Calibration:

% Residue on 150-µm (No. 100) sieve for standard sample, R_s = 5.40%
Residue from test sample, R_t = 1.25 g
Weight of sample, W_t = 25.5 g

$$\text{Correction factor, } C, \% = \frac{(5.40 \times 25.5/100) - 1.25}{1.25} \times 100 = \pm 10.2 \quad (2)$$

NOTE 1—The sieve correction is specified as a factor to be multiplied by the residue obtained, and therefore the amount to be added to or subtracted from the test residue in any given instance is proportional to the amount of the residue.

6. Procedure for Wet Sieving

6.1 Weigh the sample to the nearest 0.01 g using approximately 50 g for a 300-µm (No. 50), 25 g for a 150-µm (No. 100), or 10 g for a 75-µm (No. 200) determination. Record the weight and transfer the sample quantitatively to a clean dry sieve. Wet the sample thoroughly with a gentle stream of water. Remove the sieve from under the nozzle and adjust the pressure on the spray nozzle to 69 ± 4 kPa [10 ± 0.5 psi]. Return the sieve to its position under the nozzle and wash for 1½ min, moving the sieve in the spray with a circular motion in a horizontal plane at the rate of one motion per second. Every portion of the screen should be sprayed during each circular motion of the sieve. Hold the sieve so that the bottom of the spray nozzle extends 13 mm [0.5 in.] below the top of the sieve frame. Immediately after removing the sieve from the spray, rinse once with about 50 cm^3 of distilled or deionized water using caution not to lose any of the residue. Gently blot the lower surface of the screen cloth with a damp, clean cloth. Dry the sieve and residue in an oven or over a hot plate (see Note 2), supporting the sieve in such a manner that air may pass freely beneath it. Cool the sieve; then brush the residue from the sieve, and weigh on a balance to the nearest 0.01 g (see Note 3).

NOTE 2—Care should be taken when heating the sieve, so that any solder that may have been used in assembling the sieve does not soften.

NOTE 3—Prior to each use, dip the sieve in dilute acetic acid (1+6) or dilute HCl (1+10) and immediately rinse it with distilled or deionized water to remove particles lodged in the meshes. Recalibrate the sieve after 25 determinations.

7. Calculation

7.1 Calculate the fineness of the material as follows:

$$R_c = (R_t/W) \times (100 + C) \quad (3)$$

$$F = 100 - R_c \quad (4)$$

where:

F = fineness expressed as the corrected percentage of sample passing the sieve,
R_c = corrected residue, %,
W = weight of sample used for test, g,

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R_t = residue from the sample retained on the sieve, g, and
C = sieve correction factor (determined in accordance with Section 5, which may be either plus or minus), %.

7.1.1 Example for 150-µm (No. 100) Sieve Determination:

Sieve correction factor, C	= ±10.2 %
Exact weight of sample used for test, W	= 25.10 g
Residue from sample retained on sieve, R_t	= 1.42 g
Corrected residue,	
$R_c = (1.42/25.10) \times (100 + 10.2)$	= 6.2 %
$F = 100 - 6.2$	= 93.8 %

8. Precision and Bias

8.1 No precision data are available due to the limited use of this method. Therefore, users are advised to develop their own laboratory precision.

8.2 Since there is no accepted reference material suitable for determining any bias that may be associated with this test method, no statement on bias is being made.

9. Keywords

9.1 fineness; hydraulic cement and raw materials; sieve

ANNEX

(Mandatory Information)

A1. DRY SIEVE CORRECTION FACTORS

A1.1 300-µm (No. 50) and 150-µm (No. 100) 203-mm [8-in.] Diameter Sieves

A1.1.1 The particle size distribution curve of cement at the 300-µm (No. 50) and 150-µm (No. 100) is level in this region, and therefore it is felt that no sieve correction is necessary.

A1.2 75-µm (No. 200) 203-mm [8-in.] Diameter Sieve

A1.2.1 A75-µm (No. 200) sieve may or may not need to be standardized, depending on the accuracy required. For internal laboratory use where changes in fineness are of more importance than the absolute value, it is not necessary to standardize the dry sieve. The sieve cloth, as a minimum, should conform to Specification E11. A correction factor should be established where accuracy is desired in order to compare results between laboratories.

A1.2.2 To determine the percentage of test material passing through a nominal 75-µm (No. 200) sieve, two additional sieves are needed: a 90-µm (No. 170) and a 63-µm (No. 230) sieve. Using NBS SRM No 1004 (No. 140-No. 400 sieve), Glass Bead Standard, determine the effective openings of each of the three sieves.

NOTE A1.1—NBS SRM No. 1004 tends to blind the screen during use and the beads lodged in the meshes are difficult to remove. Tapping the frame of the sieve and gentle brushing of the cloth from the underside will aid in recovering all the beads and keep the bead loss down to approximately 50 mg.

A1.2.3 Select a test material. It is important that the sample for calibration be of the same typical fineness as the range in which the sieve is to be used. The use of the same test material selected for the 75-µm (No. 200) dry sieve calibration is encouraged (see 4.2). Determine the percent residue of the test material on each of the three sieves, following the procedure of Test Method C184. Plot the average percent residues *versus* the effective opening. The percent residue at the nominal opening of the No. 200 sieve can be read off the plot and the difference between the actual obtained residue and the nominal residue at 75 µm may be used algebraically as a sieve correction factor for that sieve, only in the same general fineness area.

A1.3 Example—Determination Of Sieve Correction factor for 75-µm (No. 200) Sieve

A1.3.1 Using the SRM 1004, the following was determined:

(*a*) Effective opening of nominal sieves being corrected:

75-µm (No. 200)	72 µm
90-µm (No. 170)	90 µm
63-µm (No. 230)	65 µm

(*b*) Test sample residue, % (to be plotted on graph paper):

at 90 µm	1.1 %
at 72 µm	2.3 %
at 65 µm	2.8 %

(*c*) From the above plot:

$$\text{Residue at } 75-\mu\text{m} = 2.1\% \qquad \text{(A1.1)}$$

A1.3.2 Since the sieve is woven too tightly and retains more than it should if it were a 75-µm opening, the correction, C, to be applied to the residue in percent is –0.2%.

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SUMMARY OF CHANGES

Committee C01 has identified the location of selected changes to this test method since the last issue, C786 – 96(2003), that may impact the use of this test method. (Approved February 1, 2010)

(*1*) Revised the standard as a dual-units test method.

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Designation: C 796 – 04

Standard Test Method for Foaming Agents for Use in Producing Cellular Concrete Using Preformed Foam[1]

This standard is issued under the fixed designation C 796; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

This standard has been approved for use by agencies of the Department of Defense.

1. Scope

1.1 This test method furnishes a way of measuring, in the laboratory, the performance of a foaming chemical to be used in producing foam (air cells) for making cellular concrete.

1.2 This test method includes the following:

1.2.1 Manufacture of laboratory quantities of cellular concrete.

1.2.2 Determination of the air content of the freshly prepared cellular concrete and of the hardened concrete after handling in conventional machinery.

1.2.3 Determination of the following properties of the hardened concrete: compressive strength, tensile splitting strength, density, and water absorption. It may not be necessary to study all of the above properties in all cases, depending on the proposed use of the material.

1.3 The values stated in inch-pound units are to be regarded as the standard.

1.4 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

1.5 The text of this standard references notes and footnotes which provide explanatory material. These notes and footnotes (excluding those in tables and figures) shall not be considered as requirements of the standard.

2. Referenced Documents

2.1 *ASTM Standards:* [2]

C 88 Test Method for Soundness of Aggregates by Use of Sodium Sulfate or Magnesium Sulfate

C 150 Specification for Portland Cement

C 192/C 192M Practice for Making and Curing Concrete Test Specimens in the Laboratory

C 495 Test Method for Compressive Strength of Lightweight Insulating Concrete

C 496/C 496M Test Method for Splitting Tensile Strength of Cylindrical Concrete Specimens

C 511 Specification for Mixing Rooms, Moist Cabinets, Moist Rooms, and Water Storage Tanks Used in the Testing of Hydraulic Cements and Concretes

C 802 Practice for Conducting an Interlaboratory Test Program to Determine the Precision of Test Methods for Construction Materials

C 869 Specification for Foaming Agents Used in Making Preformed Foam for Cellular Concrete

3. Terminology

3.1 *Definitions:*

3.1.1 *cellular concrete*—a lightweight product consisting of portland cement, cement-silica, cement-pozzolan, lime-pozzolan, or lime-silica pastes, or pastes containing blends of these ingredients and having a homogeneous void or cell structure, attained with gas-forming chemicals or foaming agents (for cellular concretes containing binder ingredients other than, or in addition to portland cement, autoclave curing is usually employed).[3] In cellular concrete the density control is achieved by substituting macroscopic air cells for all or part of the fine aggregate. Normal-weight coarse aggregate is usually not used but lightweight aggregates, both fine and coarse, are often utilized in cellular concrete.

3.2 *Symbols:*

D_{ex1} = experimental density of the concrete before pumping, lb/ft^3(kg/m^3)

D_{ex2} = experimental density of the concrete after pumping, lb/ft^3(kg/m^3)

D_{th} = theoretical density of the plastic mix based on absolute volume, lb/ft^3(kg/m ^{3})

D_d = design density of the text mixture, lb/ft^3(kg/m^3)

SGC = specific gravity of cement = 3.15

[1] This test method is under the jurisdiction of ASTM Committee C09 on Concrete and Concrete Aggregates and is the direct responsibility of Subcommittee C09.23 on Chemical Admixtures.

Current edition approved Nov. 1, 2004. Published November 2004. Originally approved in 1974. Last previous edition approved in 1997 as C 796 – 97.

[2] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

[3] ACI Committee 116, "Cement and Concrete Terminology," American Concrete Institute, Publication SP-19, 1967, p. 144.

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T = time required to overfill the container, min
T_1 = time required to generate 1 ft^3(1 m^3) of foam, min
V = volume of foam container, ft^3(m^3)
V_a = volume of air required in the test batch, ft^3(m^3)
V_c = volume of test specimen (cylinder), ft^3(m^3)
V_f = volume of foam in the test batch, ft^3(m^3)
V_w = volume of water absorbed by test specimen in 24 h, ft^3(m^3)
W_1 = net weight of foam in overfilled container before striking off, lb (kg)
W_2 = net weight of foam in container after striking off, lb (kg)
W_c = weight of cement in the test batch, lb (kg)
W_f = weight of foam in the test batch, lb (kg)
W_{TW} = total weight of water in the test batch, including weight of foam, lb (kg)
W_{uf} = density of foam, lb/ft^3(kg/m^3)
W_w = weight of water added to test batch at mixer, lb (kg)

4. Summary of Test Method

4.1 This test method includes the following:

4.1.1 Manufacture of laboratory quantities of cellular concrete.

4.1.2 Determination of the air content of freshly prepared cellular concrete and of hardened concrete after handling in conventional machinery.

4.1.3 Determination of the following properties of hardened concrete: compressive strength, tensile splitting strength, density, and water absorption. It may not be necessary to study all of the above properties in all cases, depending on the proposed use of the material.

5. Significance and Use

5.1 This test method is used to develop data for comparison or compliance with the requirements of Specification C 869.

6. Apparatus

6.1 *Mixer*—The mixer shall be a power-driven paddle-type mixer with a capacity of at least 4 ft^3(0.12 m^3), an operating speed of 40 to 50 r/min (4.2 to 5.2 rad/s), and equipped with rubber wiper blades.

6.2 *Foam Generator*—The foam generator shall be a laboratory-sized generator approved by the manufacturer of the foam being used and shall be similar to the type used in the field.

6.3 *Pump*—The pump shall be an open or closed throat-type pump and shall be run at 260 to 630 r/min (27.2 to 66.0 rad/s). The pump shall be equipped with a 4.5-ft^3(0.13-m^3)" feed" reservoir and 50 ft (15 m) of open-end 1-in. (25-mm) inside diameter rubber hose on the pump discharge, the exit end of the hose being at the same height as the pump.

6.4 *Curing Cabinet*—The curing cabinet shall be as described in Specification C 511.

6.5 *Molds*—The cylindrical molds for compression test specimens shall be as described in the Apparatus section of Test Method C 495. The molds for all other test specimens shall conform to the cylinder molds in the Apparatus section of Practice C 192/C 192M.

6.6 *Strike-Off Plate for Molds*—A ¼-in. (6-mm) thick, flat steel plate at least 8 in. (200 mm) longer and 2 in. (50 mm) wider than the diameter of the mold.

6.7 *Scales*—Scales and weights shall be accurate to within 0.1 % of the weight of the material being measured.

6.8 *Compression Machines*—Compression testing machines used for compressive strength tests and tensile-splitting strength tests shall conform to the requirements of Test Methods C 495 and C 496/C 496M, respectively.

6.9 *Drying Oven*—The drying oven shall be as described in Test Method C 88.

6.10 *Compressed Air*—A source of compressed air capable of maintaining pressures in the range of 60 to 100 psi (0.4 to 0.7 MPa) to ±1 psi (±0.007 MPa).

6.11 *Weighing Container for Concrete*— A machined-steel container of 0.5 ft^3(0.014 m^3) volume with a flat smooth rim.

6.12 *Strike-Off Plate for Weighing Container*—A ¼-in. (6-mm) thick, flat steel plate, at least 8 in. (200 mm) longer and 2 in. (50 mm) wider than the diameter of the rim of the weighing container.

6.13 *Stop Watch*—A stop watch graduated in seconds and minutes.

6.14 *Calipers*—Calipers to span 3, 6, and 12 in. (76, 152, and 305 mm).

6.15 *Foam Weighing Container*—A lightweight vessel of approximately 2 ft^3(0.06 m^3) capacity, with a smooth rim for striking off.

6.16 *Strike-Off Plate for Foam Weighing Container*—A ¼-in. (6-mm) thick, flat steel plate at least 8 in. (200 mm) longer and 2 in. (50 mm) wider than the diameter of the rim of the container.

6.17 *Small Tools*—Small tools such as a rubber-headed hammer and a trowel shall be provided.

7. Materials and Proportions

7.1 *Cement*—The cement used shall be Type I or Type III portland cement meeting the requirements of Specification C 150.

7.2 *Water-Cement Ratio*—The water requirement will vary with the type and source of cement. For the purpose of these tests, w/c = 0.58 for Type I cement and w/c = 0.64 for Type III cement shall be used. However, if a particular cement or foaming agent used with these values of w/c does not produce a satisfactory mix, a trial mix or mixes may be made using a different water-cement ratio.

7.3 *Batch Quantities*—The cement quantity shall be sufficient to allow molding all the test specimens from one test batch. The mixture water-cement ratio determined from 7.2 shall be used to make the test batch.

7.3.1 The foaming solution in the foam shall be considered as part of the total mixing water. Foam volume shall be adjusted for the batch to produce a density after pumping of 40 ± 3 lb/ft^3(641 ± 48 kg/m^3).

8. Procedure

8.1 Make an aqueous solution of the foaming agent in the dilution specified by the manufacturer. If the dilution is not specified, preliminary tests are necessary to determine the

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required dilution. A suggested starting point for such tests is 40 parts water to 1 part foaming agent, by volume.

8.2 Charge the foam generator with the amount of foaming solution suggested by the manufacturer of the generator.

8.3 Connect the generator with the source of compressed air, adjusting the pressure to that recommended by the manufacturer of the foaming agent being tested.

8.4 Using the stop watch, calibrate the generator as follows. Weigh the empty foam container and determine its volume. Overfill the container with foam, measuring the time required using a stop watch then weigh. Strike off the excess foam, holding the strike-off plate in a horizontal position (plane of the plate horizontal) and moving it across the top of the container with a sawing action. Again weigh. Calculate the time required per cubic foot (or cubic metre) of foam using the following equation:

$$T_1 = (T \times W_2)/(W_1 \times V) \quad (1)$$

8.4.1 Calculate also the unit weight of the foam as follows:

$$W_{uf} = W_2/V \quad (2)$$

8.4.2 Calculate the length of time required to generate the required volume of foam, $V_f\ T_1$, as follows:

$$V_fT_1 = 62.4\ V_aT_1/(62.4 - W_{uf})\ (V_fT_1 = 1000\ V_aT_1/(1000 - W_{uf})) \quad (3)$$

8.4.3 Calculate the weight, W_f, of the required volume of foam, V_fW_{uf}.

NOTE 1—The weight of the foam will usually range from 2 to 4 lb/ft^3 (32 to 64 kg/m^3) depending on the foam chemical used. Adjust the unit weight of foam, W_{uf}, to the manufacturer's recommendation if the foam generator is adjustable.

8.4.3.1 If Type I cement is used, weigh out 58.0 – W_f lb (26.31 – W_f kg) of water, W_w, and 100.0 lb (45.36 kg) of Type I cement.

8.4.3.2 If Type III cement is used, weigh out 64.0 – W_f lb (29.03 – W_f kg) of water, W_w, and 100.0 lb (45.36 kg) of Type III cement.

8.5 Wet the mixer with water and drain. Add the water, W_w, and start the mixer. Gradually add the cement (over a period of ½ min). With a trowel, break up any lumps of undispersed cement. Mix for 5 min.

8.6 While still mixing, add V_f ft^3(m^3) of foam. The required foam time is V_fT_1. Mix for 2 min after all the foam has been added. Discharge the mixer into the pump feed reservoir. Immediately, proceed to 8.7.

8.7 *Weighing*—Fill a tared weighing container with a representative sample of the concrete in the reservoir. Before taking the sample, carefully mix the concrete in the reservoir to assure better uniformity without entrapping large air bubbles in the mix. Use a paddle of proper size to reach the bottom of the reservoir. Use a scoop to transfer the concrete to the container and tap the sides of the container briskly with the rubber hammer during the filling operation. Overfill the container and strike off the excess concrete, holding the strike-off plate in a horizontal position (plane of plate horizontal) and moving it across the top of the container with a sawing motion. Wipe the surface of the container free of spilled concrete with a cloth. Weigh the full container. Calculate the density of the concrete and record as the density before pumping (D_{ex1}).

8.7.1 Pump the batch of concrete through the 50-ft (15-m) hose, discharging it into a sampling basin. From the sampling basin, take a second density sample as in 8.7, weigh, and record as the density after pumping ($D_{ex\ 2}$).

8.8 *Molding*—Immediately, fill the cylinder molds with concrete from the sampling basin. Tap the sides of the mold with the rubber hammer while the mold is being filled. The minimum number of specimens required is four cylinders, 3 by 6 in. (76 by 152 mm) and ten cylinders 6 by 12 in. (152 by 305 mm).

8.8.1 As soon as possible after casting, strike off the top surface of each specimen and cover the specimen with a plastic bag to prevent evaporation, without marring the surface.

8.9 *Removal from Molds and Curing*— Follow the applicable requirements of the Test Specimen section of Test Method C 495 with the following exception: continue air drying from day 25 to day 28 in place of oven drying the specimens. Do not oven dry specimens that are to be load-tested.

8.10 *Compressive Strength*—Test four 3 by 6-in. (76 by 152-mm) cylinders for compressive strength in accordance with Test Method C 495.

8.11 *Tensile Splitting Strength*—Test four 6 by 12-in. (152 by 305-mm) cylinders for tensile splitting strength at age 28 days in accordance with Test Method C 496/C 496M, for lightweight concrete.

8.12 *Oven-Dry Weight*—Determine the oven-dry density in accordance with the section on Oven-Dry Weight of Test Method C 495. Use three 6 by 12-in. (152 by 305-mm) cylinders from 7.9 at age 28 days.

8.13 *Water Absorption*:

8.13.1 Take three 6 by 12-in. (152 by 305-mm) specimens from 8.9 at age 28 days. Take the dimensions with calipers as described in the Test Specimen Section of Test Method C 495.

8.13.2 Submerge the specimens 6 in. (150 mm) below the water surface. Maintain the water temperature at 73.5 ± 3.5 °F (23.0 ± 2.0 °C). Remove from water, allow excess water to run off (30 s) and weigh. This is the wet weight of the specimen.

9. Calculation

9.1 *Air Content*:

9.1.1 Determine the experimental density of the freshly mixed concrete at the mixer, D_{ex1}, and at the pump discharge (end of hose), D_{ex2}, by dividing the net weights of the samples from 8.7 and 8.7.1 by the volume of the container. Record to the nearest 0.5 lb/ft^3(8 kg/m ^{3}).

9.1.2 Determine the experimental density of the specimens from 8.12 before and after drying from the weights and volumes of the specimens. Use three 6 by 12-in. (152 by 305-mm) cylinders. Record to the nearest 0.5 lb/ft^3(8 kg/m^3).

9.1.3 Determine the air content of the freshly mixed concrete from the experimental densities, before and after pumping, and the theoretical density, D_{th}, based on the absolute volume. Record the air content to the nearest 1 %. Calculate the theoretical density in lb/ft^3(kg/m^3) as follows:

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Inch-Pound Units:

$$D_{th} = (W_w + W_c + W_f)/[(W_w/62.4) + (W_c/(SGC \times 62.4)) + (W_f/62.4)] \quad (4)$$

SI Equivalents:

$$D_{th} = (W_w + W_c + W_f)/[(W_w/1000) + (W_c/(SGC \times 1000)) + (W_f/1000)] \quad (5)$$

9.1.3.1 Calculate the air content before pumping or the percent of air at the mixer as follows:

$$\text{Air content before pumping} = 100\,[1 - (D_{ex1}/D_{th})] \quad (6)$$

9.1.3.2 Calculate the air content after pumping, or the percent of air at end of hose as follows:

$$\text{Air content after pumping} = 100\,[1 - (D_{ex2}/D_{th})] \quad (7)$$

NOTE 2—Using the prescribed procedure and assuming the specific gravity of cement is 3.15 and that the total water used is 58.0 lb (26.31 kg) for Type I cement, the theoretical density is 109.9 lb/ft^3(1761 kg/m ^{3}). Similarly, for Type III cement the total water is 64.0 lb (29.03 kg) and the theoretical density is 106.9 lb/ft^3(1712 kg/m ^{3}).

9.1.4 Calculate the loss of air during pumping as the difference between the air content before and after pumping. Record to the nearest 1 %.

$$\text{Loss of air, \% by volume} = 100\,[(D_{ex2} - D_{ex1})/D_{th}] \quad (8)$$

9.1.5 Calculate the design density (D_d) of the test mixture in lb/ft^3(kg/m ^{3}) as follows:

Inch-Pound Units:

$$D_d = (W_w + W_c + W_f)/[(W_w/62.4) + (W_c/SGC \times 62.4) + V_f] \quad (9)$$

SI Equivalents:

$$D_d = (W_w + W_c + W_f)/[(W_w/1000) + (W_c/SGC \times 1000) + V_f] \quad (10)$$

9.2 *Water Absorption*:

9.2.1 Find the average weight of water absorbed by the cylinders by subtracting the average dry weight of cylinders (see 8.12) from the average wet weight of cylinders (see 8.13). Record to the nearest 0.1 lb (or 0.05 kg).

9.2.2 Find the average volume of water absorbed by dividing the average weight of water absorbed by the density of water in lb/ft ^{3}(kg/m^3). Determine the water absorption using the following equation:

$$\text{absorption, \% by volume} = (V_w/V_c) \times 100 \quad (11)$$

Record absorption to the nearest 0.5 %.

10. Report

10.1 Using the degrees of precision specified in Section 9, report the following:

10.1.1 Identification of chemical tested, including manufacturer's name, brand, and lot number,

10.1.2 Water to cement ratio and type of cement used,

10.1.3 Air content before and after pumping,

10.1.4 Oven-dry density,

10.1.5 Water absorption, % by volume,

10.1.6 Compressive strength,

10.1.7 Loss of air during pumping, %,

10.1.8 Tensile splitting strength, and

10.1.9 Difference between design density and experimental densities before and after pumping.

11. Precision and Bias

11.1 *Precision*[4]

11.1.1 Data used to develop the precision statement were obtained using the inch-pound version of this test method. The precision indices shown in parenthesis are exact conversions of the values in inch-pound units. Data were obtained from three laboratories for one material.

11.1.2 *Single-Operator Precision*—The single-operator standard deviations are listed in the third column of Table 1.

TABLE 1 Single Operator Precision

Test	Avg. of Laboratory Averages	Standard Deviation (1s)	Acceptable Range of Two Results (d2s)
Compressive Strength, psi (MPa)	427 (2.9)	61 (0.4)	171 (1.2)
Splitting Tensile Strength, psi (MPa)	46 (0.3)	9 (0.06)	24 (0.2)
Density, lb/ft^3 (kg/m^3)	31.3 (501)	1.7 (27)	4.8 (77)
Absorption, %	17.8	0.6	1.8

Therefore, results of two properly conducted tests by the same operator are not expected to differ by more than the values shown in the fourth column of Table 1.

11.1.3 *Multilaboratory Precision*—The multilaboratory standard deviations are listed in the third column of Table 2. Therefore, results of two properly conducted tests on the same material by two different laboratories are not expected to differ by more than the values shown in the fourth column of Table 2.

11.1.4 The numbers of laboratories and materials used in the interlaboratory study do not meet the minimum requirements for determining precision prescribed in Practice C 802. This precision statement is provisional. Within five years, additional data that meets the requirements of Practice C 802 will be obtained and processed.

11.2 *Bias*

11.2.1 Since there is no accepted reference material for determining the bias of this test method, no statement on bias is made.

[4] Supporting data have been filed at ASTM International Headquarters and may be obtained by requesting Research Report RR:C09–1027.

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TABLE 2 Multilaboratory Precision

Test	Avg. of Laboratory Averages	Standard Deviation (1s)	Acceptable Range of Two Results (d2s)
Compressive Strength, psi (MPa)	427 (2.9)	68 (0.5)	190 (1.3)
Splitting Tensile Strength, psi (MPa)	46 (0.3)	8.6 (0.06)	24 (0.2)
Density, lb/ft^3 (kg/m^3)	31.3 (501)	2.0 (32)	5.6 (90)
Absorption, %	17.8	0.6	1.8

APPENDIX

(Nonmandatory Information)

X1. DERIVATION OF FORMULA FOR FOAM VOLUME

X1.1 The formula for foam volume required for the test batch may be derived as follows:

X1.1.1 Knowing the wet density, 40 lb/ft^3 (641 kg/m^3), calculate the volume of air required as follows:

Inch-Pound Units:

$$\text{Wet density, } 40 \text{ lb/ft}^3 = (W_{TW} + W_c)/[(W_{TW}/62.4) + (W_c/(3.15 \times 62.4)) + V_a] \quad \text{(X1.1)}$$

SI Equivalents:

$$\text{Wet density, } 641 \text{ kg/m}^3 = (W_{TW} + W_c)/[(W_{TW}/1000) + (W_c/(3.15 \times 1000)) + V_a] \quad \text{(X1.2)}$$

X1.1.2 Solving for the volume of air required in cubic feet (or cubic metres):

Inch-Pound Units:

$$V_a = (0.359\ W_{TW} + 0.7965\ W_c)/40 \text{ ft}^3 \quad \text{(X1.3)}$$

SI Equivalents:

$$V_a = (0.359\ W_{TW} + 0.7965\ W_c)/641 \text{ m}^3 \quad \text{(X1.4)}$$

X1.2 The air volumes required for the test batches are as follows:

Type of Cement	V_a, ft^3(m^3)
Type I	2.51 (0.071)
Type III	2.57 (0.073)

X1.3 Treating the diluted foam chemical as water (sp gr = 1) the following relationships between air volume and foam volume may be stated:

$$V_f = V_a + (W_f/62.4)/\text{ft}^3 \quad \text{or} \quad V_f = V_a + (W_f/1000)/\text{m}^3 \quad \text{(X1.5)}$$

X1.4 If W_{uf} is the unit weight of foam, then $W_f = W_{u\,f} \times V_f$ and the equation in X1.3 may be stated in the following manner:

$$V_f - (W_{uf}V_f/62.4) = V_a \text{ ft}^3 \quad \text{or} \quad V_f - (W_{uf}V_f/1000) = V_a\text{m}^3 \quad \text{(X1.6)}$$

$$V_f = V_a/[1 - (W_{uf}/62.4)]/\text{ft}^3 \quad \text{or}$$
$$V_f = V_a/[1 - (W_{uf}/1000)]/\text{m}^3, \quad \text{and} \quad \text{(X1.7)}$$

$$V_f = 62.4\ V_a/(62.4 - W_{uf})/\text{ft}^3 \quad \text{or} \quad V_f = 1000\ V_a/(1000 - W_{uf})/\text{m}^3 \quad \text{(X1.8)}$$

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Designation: C802 – 09a

Standard Practice for Conducting an Interlaboratory Test Program to Determine the Precision of Test Methods for Construction Materials[1]

This standard is issued under the fixed designation C802; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope*

1.1 This practice describes techniques for planning, conducting, and analyzing the results of an interlaboratory study of a test method. It is designed to be used in conjunction with Practice C670. Thus, the procedures recommended in this practice have the limited purpose of providing reliable information on which precision statements of the type described in Practice C670 can be based. It is not appropriate for use in programs whose purpose is to develop a test method or to assess the relative merits of two or more test methods.

1.2 The values stated in inch-pound units are to be regarded as standard. The values given in parentheses are mathematical conversions to SI units that are provided for information only and are not considered standard.

2. Referenced Documents

2.1 *ASTM Standards:*[2]

C109/C109M Test Method for Compressive Strength of Hydraulic Cement Mortars (Using 2-in. or [50-mm] Cube Specimens)

C136 Test Method for Sieve Analysis of Fine and Coarse Aggregates

C670 Practice for Preparing Precision and Bias Statements for Test Methods for Construction Materials

C1067 Practice for Conducting A Ruggedness or Screening Program for Test Methods for Construction Materials

E105 Practice for Probability Sampling Of Materials

E177 Practice for Use of the Terms Precision and Bias in ASTM Test Methods

E178 Practice for Dealing With Outlying Observations

3. Significance and Use

3.1 Certain criteria need to be met before undertaking an interlaboratory study to determine the precision of a test method. It is not necessary that all of the following conditions described be completely fulfilled in every case; however, if some conditions are not met or are met incompletely, the program will become more complicated and require more work and expense, or may result in impaired information. The recommendations outlined in this section are intended to ensure that the test method is free of technical difficulties to the greatest extent possible before an expensive and time-consuming interlaboratory study is undertaken.

3.1.1 The first requirement is the existence of a valid and well-written test method that has been developed in one competent laboratory (or by cooperative work in a small number of laboratories), and has been subjected to a screening procedure, or to ruggedness testing as described in Practice C1067. As a result of the screening procedure and some experience with the test method in the sponsoring laboratory and one or two others, a written version of the test method has been developed (but not necessarily published as a standard method) that describes the test procedure in terms that can easily be followed in any properly equipped laboratory. Conditions that affect the test results should be identified and the proper degree of control of those conditions should be specified in the description of the test procedure (see Note 1).

NOTE 1—The desired degree of control of conditions that affect test results may not always be practically achievable, and tolerances in the test method should recognize this fact. Variations in test results due to variations in such conditions contribute to the total variation which determines the precision of the test method. If the resulting variation is so great that uncertainties in average values obtained by the test method are unacceptably high, then the test method itself is at fault, and efforts should be made to improve it or to replace it by a better one. An expensive and time-consuming interlaboratory study should not be undertaken on such a test method.

3.1.2 Any apparatus required for performing the test should be appropriately designed and available at reasonable cost.

3.1.3 Personnel in participating laboratories should have enough experience with the test method so that they are competent to run the test. The importance of this requirement will vary with the complexity of the method and the degree to which it departs from familiar procedures.

3.1.4 Preliminary knowledge should exist about how changes in materials and conditions affect the test results. There should be a reasonable degree of certainty that the

[1] This practice is under the jurisdiction of ASTM Committee C09 on Concrete and Concrete Aggregates . This practice was developed jointly by ASTM Committee C01, C09, D04, and D18, and is endorsed by all four committees.

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[2] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

***A Summary of Changes section appears at the end of this standard.**

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within-laboratory variances are the same in different laboratories, and that troublesome interactions do not exist. These conditions are investigated in the analysis of the data of an interlaboratory study, and are discussed further in 8.2.2, 8.2.3, and Appendix X1.

3.1.5 Facilities and procedures for procurement, preparation, and distribution of samples must be available and should be as simple and free of difficulties as practicable.

3.1.6 Selection of samples must be done by a randomization process, and one person who is familiar with randomization procedures should be responsible for seeing that the procedure is carried out. Refer to Recommended Practice E105.

3.1.7 Adequate numbers of participating laboratories, operators, and materials must be available. Requirements in these areas are specified in Sections 4 and 5.

3.1.8 The entire interlaboratory test program should be developed from the beginning with the help and advice of persons familiar with statistical procedures and with the materials involved (see Note 2). The same persons who design the experiment should also carry out, or at least have control over, the process of analysis of the data.

NOTE 2—It may not always be possible to obtain people who are familiar with the materials involved who have a sufficient knowledge of the proper statistical techniques and their proper use. In this case, the committee should obtain the services of a competent statistician who has experience in practical work with data from materials testing, and provide him with an opportunity for learning something about the particular materials and test method involved. Planners of an interlaboratory study should also be warned to avoid the pitfall of assuming that the use of statistical analysis software programs necessarily results in special expertise in the handling of data or the interpretation of results.

3.2 It is important to bear in mind that estimates of the precision of a test method are always based on a particular set of data obtained at a particular time and they need to be kept up-to-date. As materials, apparatus, and conditions change, and operators change or gain more experience, the characteristic precision of the results obtained may change, especially if the test method is new. In some cases, it may even be desirable to conduct more tests at a later date (though not necessarily a repetition of the complete interlaboratory study) in order to provide a check on estimates previously obtained and either verify them or introduce revisions.

4. Laboratories

4.1 The problem of obtaining competent participating laboratories for an interlaboratory study is often one of the most difficult ones connected with the process. The number of laboratories available is seldom as extensive as one would like, and if the test method is new, complicated, or expensive and time-consuming to run, the problem is further complicated. The problem usually becomes one of finding and obtaining the cooperation of enough qualified laboratories to obtain meaningful estimates of precision, rather than that of selection among a group of available laboratories. If there is great difficulty in obtaining a sufficient number of competent and willing laboratories, then the possibility exists that the test method should not be subjected to a formal interlaboratory study.

4.2 For the purposes of programs using this recommended practice, it is recommended that at least ten participating laboratories be included **(1, 2).**[3] In cases where it is impossible to obtain ten laboratories, the effect of an increased number may be obtained by repeating the program with the same group of laboratories six months later. Usually, results obtained from the same laboratory after a time lapse of approximately six months display most of the characteristics of results from a different laboratory, especially if a different operator and apparatus can be used. If this procedure is followed, it is necessary to be sure that the same materials are used, and that their characteristics have not changed in the interim.

4.3 In general, it is recommended that any laboratory that is considered qualified to run the test in routine testing situations should be permitted and encouraged to participate. "Qualified" implies proper laboratory facilities and testing equipment, competent operators familiar with the test method, a reputation for reliable testing work, and sufficient time and interest to do a good job. It does not mean, however, that only a select group of laboratories that are considered to be those best qualified for the interlaboratory study should be picked. Precision estimates for inclusion in a test method must be obtained under conditions and through the efforts of laboratories and personnel that are representative of the situations in which the test method will be used in practice **(3).** If a laboratory has all the other requirements, but its personnel has had insufficient experience with the method, the operators in that laboratory should be given an opportunity to familiarize themselves with the method and to practice its application before the interlaboratory study starts.

5. Materials

5.1 The number and type of materials to be included in an interlaboratory study will depend on the following:

5.1.1 The range of the values of the property being measured on a given material and how the precision varies over that range,

5.1.2 The number of different materials to which the test method is to be applied,

5.1.3 The difficulty and expense involved in obtaining, processing, and distributing samples,

5.1.4 The difficulty of, length of time required for, and expense of performing the tests, and

5.1.5 The uncertainty of prior information on any of these points. For example, if it is already known that the precision is relatively constant or proportional to the average level over the range of values of interest, a smaller number of materials will be needed than if it is known that the precision changes erratically at different levels. A preliminary pilot or screening program may help to settle some of these questions, and may often result in the saving of considerable time and expense in the full interlaboratory study **(4).**

5.2 In general, a minimum of three materials should be considered acceptable.

[3] The boldface numbers in parentheses refer to the list of references at the end of this practice.

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6. Estimates of Precision

6.1 In accordance with Recommended Practice C670, the procedure described in this practice is designed to provide two basic estimates of the precision of a test method: (*a*) single-operator precision, and (*b*) multilaboratory precision. If other estimates of precision are desired, other references should be consulted (see Practice E177) **(5).**

6.2 *Single-operator precision* provides an estimate of the difference that may be expected between duplicate measurements made on the same material in the same laboratory by the same operator using the same apparatus within a time span of a few days.

6.3 *Multilaboratory precision* provides an estimate of the difference that may be expected between measurements made on the same material in two different laboratories.

7. Collection of Data

7.1 In order to minimize the problems concerned with analysis of data, a definite form and instructions for obtaining and recording the data should be developed and distributed to all participating laboratories.

7.2 *Directions to Laboratories*—The directions to the laboratories should deal mainly with reporting of data. No special instructions for performing the tests that differ from those given in the description of the test method should be included. The laboratories should be cautioned to conduct tests and report results exactly as specified in the test method, with the one exception as noted in 7.2.2.

7.2.1 *Averaging Test Results*—Laboratories should particularly be cautioned against practices such as running a number of tests and selecting the "best" ones or reporting the average of several determinations, except as such averaging is specified in the test method. For example, Test Method C109/C109M specifies three or more test specimens, and requires that the strength of all acceptable test specimens made from the same sample and tested at the same period shall be averaged and reported. In this case, the directions for the interlaboratory test should specify the number of determinations to be obtained and reported. Whenever a test result is defined, either in the test method or in the instructions to laboratories participating in an interlaboratory test program, as the average of a particular number of determinations, the individual determinations should be reported, in addition to the averages. When two or more measurements are averaged to obtain a test result, the data from the interlaboratory test program may be used to develop an estimate of the precision of these individual measurements. See 3.3.3 of Practice C670.

7.2.2 *Rounding of Data*:

7.2.2.1 Generally, laboratories should be required to report all figures obtained in making the measurements, rather than rounding the results before recording them. In some cases, this may result in recording of more digits than is customary or even more than the test method calls for in the section on Reporting (see X1.3.1). This is necessary because the variation from which information about the precision of the test method comes is contained in the least significant digits, which are often discarded in reporting the results of routine testing **(6).** For example, Method C136 calls for reporting of percentages to the nearest whole number. This is adequate for the usual reporting purposes, but for purposes of determining precision, at least one decimal place is needed. It is better to require the reporting of too many decimal places than too few, since a decision about rounding all data can be made when the analysis is done. If too few places are reported, however, valuable information may be irretrievably lost, and the result might well be the impairment of the entire program.

7.2.2.2 In cases where a test result is the result of a calculation based on two or more measured quantities, the basic measurements should be used in the calculations without any rounding. The planners of the interlaboratory program will then have to determine how many places need to be reported in order to retain the essential information for determining variability. Sometimes it is advisable to ask the laboratories to report the basic quantities measured instead of, or in addition to, the final calculated result. This enables the final result to be checked, or changes in decisions about the test results to be made, when the data are analyzed. This procedure is especially appropriate if the results are to be analyzed by computer, and the program can be utilized to perform the basic calculations and analyze the calculated results.

7.3 *The Data Sheet*—This practice is based on the following assumptions: p laboratories each have made n replicate measurements on each of q materials (see Ref **7**). Table 1 and Table 2 are sample data sheets for an individual laboratory and for a summary of data for the entire program for a program with: p = ten laboratories, n = four replicates, (test results on each material in each laboratory), and, q = five materials. These data sheets suggest the forms to be used when an individual measurement constitutes the basic test result. In cases where individual measurements are averaged or otherwise subjected to calculation to produce a test result, the form of the individual laboratory sheet may be altered or a secondary sheet provided to permit recording of the fundamental measurements and the test results.

7.4 *Number of Replicates*:

7.4.1 The number of replicate determinations to be made on each material in each laboratory depends largely on the number of laboratories participating, on the homogeneity of the material, and on the expense, difficulty, and time involved in

TABLE 1 Data Sheet for an Interlaboratory Test Program for an ASTM Test Method

Laboratory:

Replicate	Material				
	A	B	C	D	E
a	_____	_____	_____	_____	_____
b	_____	_____	_____	_____	_____
c	_____	_____	_____	_____	_____
d	_____	_____	_____	_____	_____

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TABLE 2 Summary Data Sheet for an Interlaboratory Test Program for an ASTM Test Method

Laboratory	Replicate	Material				
		A	B	C	D	E
1	a					
	b					
	c					
	d					
2	a					
	b					
	c					
	d					
3	a					
	b					
	c					
	d					
4	a					
	b					
	c					
	d					
5	a					
	b					
	c					
	d					
6	a					
	b					
	c					
	d					
7	a					
	b					
	c					
	d					
8	a					
	b					
	c					
	d					
9	a					
	b					
	c					
	d					
10	a					
	b					
	c					
	d					

increasing the number of determinations. It should be recognized that in order to obtain the necessary information to write a meaningful precision statement, it is often necessary to use more replicates in the interlaboratory study than is required for routine use of the test method. An increase in the number of replicates improves the estimates of within-laboratory precision but has no effect on between-laboratory precision (**8**)**.** It is recommended that, for 10 to 15 participating laboratories, at least three replicates should be required. In cases where it is not possible to obtain 10 participating laboratories, the number of replicates, n, should be equal to or greater than $(30/p) + 1$. For more than 15 laboratories, the number of replicates may be reduced to two. (If 30 is not a multiple of p, $30/p$ is rounded to the next higher integer.) This will give an adequate estimate of within-laboratory precision, but information about between-laboratory precision is not as good as desired with fewer than 10 laboratories.

7.4.2 The variation among replicate measurements is supposed to be representative of the irreducible error variance characteristic of the test method. In some cases, it is possible to take supposedly replicate measurements in such a manner that there is little or no opportunity for chance variation, and the measurements are in effect simply repetitions of the same measurement. For example, in making a chemical analysis by atomic absorption or some other kind of automatic measuring device, laboratories have been known to take three readings of the meter on the same sample in quick succession. The three readings so taken were almost identical, but were still reported as replicate readings. In cases such as this, three separate readings with different portions of the sample should be tested possibly on different days, with the same operator and apparatus in order to provide meaningful replicate measurements.

7.5 *Outliers*—In general, the practice of discarding individual test results that appear to differ by suspiciously large

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amounts from the others, should be avoided unless there is clear evidence that there was some physical reason to consider the result faulty. It is recommended that no purely statistical criterion be used for the purpose. In particular, laboratories should be asked to report all results in their proper place and include notes describing the conditions surrounding those results that are suspected of being faulty. Sometimes if a test really went wrong, a laboratory should discard the results and repeat the test. Tests should not be repeated, however, just because the results don't look good. Further discussion of the problems of outliers is given in Appendix X2, Practice E178, and in Refs (**9** and **10**).

7.6 *Missing Data*—Sometimes individual items of data are missing from the summary because they were discarded, failed to be supplied by a laboratory, or for other reasons. In general, if the number of missing data items from all laboratories constitutes no more than 1 % of the total number of items, the analysis may be conducted as though the missing items were present. For example, if one result out of four replicates on a given material from a given laboratory is missing, the three remaining results should be added and then divided by 3 to get the average, $\bar{x}_i$. The within-laboratory variance, s_i^2, should also be calculated using 3 for the number of results. From then on, both results should be used as though they were based on four measurements. If the number of missing results exceeds 1 % of the total, some of the tests should be repeated in order to obtain proper measurements for the missing values. Missing values handled in this way must be individual values distributed throughout the mass of data, and should not be concentrated as a group in one laboratory-material cell. If the latter occurs, the laboratory should provide another group of measurements on the material in question. Analysis-of-variance procedures exist for the analysis of such unbalanced sets of data. The advice of a statistical consultant should be obtained when such practices are used.

8. Analysis of Data

8.1 The procedure described herein is simplified, and statistical terms are avoided to the greatest extent possible in order to make the recommended practice easily usable by persons with little statistical background. This exposes the recommended practice to the danger that, although the technique recommended is widely applicable to many situations using many kinds of data, it may be used mechanically in situations in which it is not applicable by persons who are not familiar with the statistical background of the recommended procedures. For this reason, it is recommended to seek the advice of a person who is familiar with the statistical procedures before undertaking analysis of an interlaboratory study by this or any other published procedure. An example of the procedure is given in Appendix X1. For further description of the method, see Ref (**5**).

8.2 *Between-Laboratory and Within-Laboratory Analysis for Each Material*—The first step in the analysis is to obtain estimates of between-laboratory and within-laboratory variances for each material. This may be done by using the form shown in Table 3. Table 3 is set up as an example, using material A in ten laboratories with four replicate test results per laboratory to correspond with the sample summary data sheet in Table 2. Similar tables should be set up for each material in the study. The subscript i is used to designate a particular laboratory in the analysis and goes from 1 to p, the total number of laboratories. Capital letter subscripts, A, B, etc., are used to designate quantities calculated for the different materials. The averages, $\bar{x}_i$, and variances, s_i^2, in the last two columns are the within-laboratory averages and variances for the given material, and are calculated from the n replicate test results for each of the p laboratories as follows:

$\bar{x}_i$ = $\Sigma\, x_i/n$ = sum of n replicate test results for laboratory i divided by n.

s_i^2 = $(\Sigma\, x_i^2 - n\,\bar{x}_i^2)/(n-1)$ = sum of squares of n replicate test results for laboratory i less n times the square of the average for laboratory i, divided by one less than the number of replicate test results.

NOTE 3—The results of the calculations described here may be subject to a rounding error if the numbers involved are large. See Appendix X1 and Note X1.1 for an example of this and a discussion of how to deal with this problem.

TABLE 3 Between and Within Analysis for Material A[A]

Laboratory	Data				Average $\bar{x}_1$	Within-Laboratory Variance s_1^2
	a	b	c	d		
1	_____	_____	_____	_____	$\bar{x}_1$	s_1^2
2	_____	_____	_____	_____	$\bar{x}_2$	s_2^2
3	_____	_____	_____	_____	$\bar{x}_3$	s_3^2
4	_____	_____	_____	_____	$\bar{x}_4$	s_4^2
5	_____	_____	_____	_____	$\bar{x}_5$	s_5^2
6	_____	_____	_____	_____	$\bar{x}_6$	s_6^2
7	_____	_____	_____	_____	$\bar{x}_7$	s_7^2
8	_____	_____	_____	_____	$\bar{x}_8$	s_8^2
9	_____	_____	_____	_____	$\bar{x}_9$	s_9^2
10	_____	_____	_____	_____	$\bar{x}_{10}$	s_{10}^2

[A] p = 10 laboratories.
n = 4 replicate test results on each material in each laboratory.
Overall average $\bar{x}_A$ =
Pooled within-laboratory variance s_A^2 (pooled) =
Variance of laboratory averages $s_{\bar{x}_A}^2$ =
Between-laboratory component of variance $s_{L_A}^2$ =

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From the p individual within-laboratory averages and variances, four quantities for the given material; namely, the overall average, pooled within-laboratory variance, variance of laboratory averages, and between-laboratory component of variance, are calculated and entered on Table 3 as follows:

$\bar{x}_A$ = $\Sigma\, \bar{x}_i/p$ = sum of p averages for the laboratories divided by p

s_A^2 (pooled) = $\Sigma s_i^2/p$ = average of within-laboratory variances (see Note 4).

$s_{\bar{x}_A}^2$ = $[\Sigma\, \bar{x}_i^2 - p\,(\bar{x}_A)^2]/(p - 1)$ = sum of squares of p within-laboratory averages less p times the overall average squared, divided by $p - 1$.

$s_{L_A}^2$ = $s_{\bar{x}_A}^2 - [s_A^2\,(\text{pooled})/n]$ = the variance of laboratory averages less $1/n$ times the pooled variance.

A sample work sheet showing exactly how these calculations are made appears in Appendix X1.

NOTE 4—The method of pooling variances used here applied only when all the individual variances being pooled are based on the same number of measurements. In general, a pooled estimate of a variance is not obtained by averaging individual variances.

8.2.1 Before proceeding with the analysis, it is necessary to investigate agreement of the data with the following two assumptions: (*a*) the variances are the same in different laboratories (homogeneity of variance), and (*b*) the results show the same pattern of change from one material to another in different laboratories (lack of interactions). These two aspects of the analysis are discussed in 8.2.2 and 8.2.3.

8.2.2 *Investigation of Agreement of Variances*—This method is based on the assumption that the within-laboratory variances in different laboratories (of which the s_i^2 in Table 3 and its variations, are estimates) are the same. This does not mean that the s_i^2 have to be very close together, since an individual variance can be about four times the average variance (for $p = 10$ and $n = 4$) when all the calculated variances are really estimates of the same variance. In order to check for agreement among variances, it is helpful to plot the individual variances against the laboratories, draw a horizontal line across the plot at the level of the average variance, and examine the lowest and highest individual variances. A variance that is very low compared to the others may indicate that the laboratory is not permitting the normal causes for variation between results to show up, while a high variance indicates the lack of proper control of the testing process.

8.2.2.1 Table 4 gives approximate values (upper 5 % level) for the ratio of the largest variance to the sum of the variances that should not be exceeded (**11**).

8.2.2.2 The case of a small variance is not usually as troublesome as that of a variance that is too large. However, when one laboratory performs its tests in such a way that the normal causes of variation do not affect the results, an unrealistically low variance may occur. If no significantly high variance is present, as judged by the criterion given above, the following method may be used to examine a suspiciously low variance. The statistic used is the ratio of highest to lowest variance in the group. Table 5 gives the approximate values (upper 5 % level) for this ratio that should not be exceeded (**12**).

TABLE 4 Approximate Values (Upper 5 % Level) for the Ratio of the Largest Variance to the Sum of the Variances

No. of Laboratories	No. of Replicates				
	2	3	4	5	6
5	0.8412	0.6838	0.5981	0.5441	0.5065
6	0.7808	0.6161	0.5321	0.4803	0.4447
7	0.7271	0.5612	0.4800	0.4307	0.3974
8	0.6798	0.5157	0.4377	0.3910	0.3595
9	0.6385	0.4775	0.4027	0.3584	0.3286
10	0.6020	0.4450	0.3733	0.3311	0.3029
11	0.5700[A]	0.4140[A]	0.3480[A]	0.3070[A]	0.2810[A]
12	0.5410	0.3924	0.3264	0.2880	0.2624
13	0.5140[A]	0.3630[A]	0.3080[A]	0.2690[A]	0.2470[A]
14	0.4920[A]	0.3450[A]	0.2910[A]	0.2530[A]	0.2320[A]
15	0.4709	0.3346	0.2758	0.2419	0.2195
20	0.3894	0.2705	0.2205	0.1921	0.1735
30	0.2929	0.1980	0.1593	0.1377	0.1237

[A] Values obtained by graphic interpolation.

8.2.2.3 Often the data from one laboratory may indicate a high or low variance compared to the others, and elimination of that laboratory from the analysis results in a set of data with similar variances for the remaining laboratories (see Appendix X1). If all the variances are erratic, however, the test method is in trouble. Efforts to develop precision statements from the data should be suspended and further study of the test method should be undertaken to determine the causes for such erratic behavior. The advice of a statistical consultant should be obtained whenever there is doubt about eliminating a high or low variance.

8.2.3 *Interactions*—A common problem with test results obtained from an interlaboratory study is the presence of interactions between laboratories and materials. This means that the pattern of change of the results obtained on a given group of materials in one laboratory differs from the pattern obtained in another laboratory. In extreme cases, different laboratories may even fail to rate materials in the same order. The accepted statistical technique for finding significant interactions is an analysis of variance. A reasonably reliable method for checking to see if troublesome interactions may exist, however, is to make a plot of the averages obtained on the

TABLE 5 Approximate Values (Upper 5 % Level) for the Ratio of Highest to Lowest Variance

No. of Laboratories	No. of Replicates				
	2	3	4	5	6
5	[A]	202	51	25	16
6	[A]	266	62	30	19
7	[A]	333	73	34	21
8	[A]	403	84	38	23
9	[A]	475	94	41	25
10	[A]	550	104	45	26
11	[A]	626	114	48	28
12	[A]	704	124	51	30
13	[A]	790[B]	135[B]	54[B]	31[B]
14	[A]	885[B]	145[B]	57[B]	32[B]
15	[A]	995[B]	155[B]	59[B]	33[B]

[A] Although it may be possible to calculate this value, it is suggested that all values be included in the analysis when only 2 replicates are used.

[B] Value obtained by graphic extrapolation.

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materials by each laboratory (see X1.3.5). These plots should show similar patterns of change from material to material for all laboratories. One laboratory may show a noticeably different pattern from the others and may be eliminated. However, if the patterns vary for more than one or two of the laboratories, the test method needs to be reinvestigated, and the causes of the interactions discovered and eliminated. The advice of a statistical consultant should be obtained.

8.3 *Within-Laboratory and Between-Laboratory Variances*—After the analysis described in 8.2 has been completed for all materials and investigations for homogeneity of variance and for interactions have been completed, the quantities indicated are assembled in Table 6. The averages in Column 2 are the overall averages for each material, which are arranged in increasing order of the magnitude of the average. The components of variance in Columns 3 and 4 are the pooled within-laboratory variance and the component of between-laboratory variance, respectively, for each material. The variances in Columns 5 and 6 are the pooled within-laboratory variances (same as Column 3) and the sum of the two components of variance (Column 3 plus Column 4), respectively (see Note 5).

NOTE 5—These within-laboratory and between-laboratory variances apply to single determinations in a laboratory, even though the data from which they are derived involve replicate measurements in a laboratory. Thus, precision statements based on these variances will apply to comparisons between two single measurements within a laboratory or between laboratories, respectively.

8.4 *Estimates of Precision*—The reason for listing the materials in increasing order of magnitude in Table 6 is to permit examination of the precision and how it varies with the level of the property measured, and thus to make a decision about the proper form of the precision statement. For this purpose, the quantities listed in Table 7 are calculated and entered as shown, still in increasing order of magnitude of the average. Column 2 in Table 7 is the same as Column 2 in Table 6. Columns 3 and 4 contain the square roots of the numbers in Columns 5 and 6 of Table 6. Columns 5 and 6 of Table 7 contain the corresponding coefficients of variation, expressed as percents, that is, the within-laboratory or between-laboratory standard deviation, respectively, divided by the corresponding average and multiplied by 100.

8.4.1 *Determination of Form of Precision Statement*—The appropriate form of a precision statement depends on the relationship between the average level of the property measured for the different materials and the within-laboratory and between-laboratory standard deviations. There are three main forms of the relationship that cover most of the cases which are pertinent to ASTM test methods: (*a*) cases in which the standard deviation is relatively constant over the range of materials; (*b*) cases in which the standard deviation has an approximately linear relationship with the average level and the coefficient of variation is relatively constant; and (*c*) cases where the materials fall into two or more distinct groups within which condition (*a*) or (*b*) holds approximately, and for each of which a characteristic precision can be determined. In most cases, the determination of which of these alternatives applies, or whether some more complicated situation exists can be determined for practical purposes by plotting the standard deviations and coefficients of variation against the average level. Two separate graphs, one for the two standard deviations and one for the two coefficients of variation, are usually adequate (see Note 6). If more sophisticated techniques are desired, they may be found in other references **(5, 13).** The appropriate measures of precision described in 8.4.2-8.4.5 become the indexes of precision as described in Practice C670.

NOTE 6—Usually, the same case should be applicable to both between-laboratory and within-laboratory precision. Sometimes, however, one of the two types of measures of precision is dependent on the level and the other is not. In situations like this, it may be possible to select a suitable compromise in order to have the two precision statements in the same form. The advice of a statistical consultant should be obtained.

8.4.2 *Constant Standard Deviation*—In this case the pooled within-laboratory standard deviation over all materials becomes the single-operator standard deviation or one-sigma limit (1s) and the pooled between-laboratory standard deviation becomes the multilaboratory standard deviation or one-sigma limit (1s) as described in Sections 3 and 4 of Practice C670. The pooled standard deviations are derived by adding Columns 5 and 6 of Table 6 for within-laboratory and between-laboratory estimates, respectively, dividing each of the two totals by q, and taking the square roots.

8.4.3 *Constant Coefficient of Variation*—In this case the average within-laboratory coefficient of variation becomes the single-operator, one-sigma limit in percent (1s %) and the average between-laboratory coefficient of variation becomes the multilaboratory one-sigma limit in percent (1s %) as described in 3.1.3 of Practice C670. Since it is not possible to pool coefficients of variation in the same manner as variances and standard deviations, the simple arithmetic averages of Columns 5 and 6 in Table 7 are used.

8.4.4 *Separate Groups with Constant Standard Deviation or Coefficient of Variation (see Note 7)*—In this case the single-operator and multilaboratory one-sigma limits or one-sigma limits in percent are calculated separately for each group in the same manner as described in 8.4.2 or 8.4.3 above. For each

TABLE 6 Averages, Components of Variance, and Variances for All Materials

Material	Average[A]	Components of Variance		Variance	
		Within-Laboratory	Between-Laboratory	Within-Laboratory	Between-Laboratory
A					
B					
C					
D					
E					

[A] Listed in increasing order of magnitude

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TABLE 7 Averages, Standard Deviations, and Coefficients of Variation for All Materials

Material	Average[A]	Standard Deviations		Coefficient of Variation	
		Within-Laboratory	Between-Laboratory	Within-Laboratory	Between-Laboratory
A					
B					
C					
D					
E					

[A] Listed in increasing order of magnitude

group, the range of average values over which the index of precision applies is supplied with the estimates. Refer to 6.2.2.2 and 6.2.2.3 of Practice C670.

NOTE 7—Situations of the type described in 8.4.4 and 8.4.5 are often indications that something is wrong with the experimental situation or the test method. If the standard deviation and coefficient of variation are so erratic that it is difficult to write an applicable precision statement without giving separate indexes of precision for each material tested in the interlaboratory program, this is very possibly an indication that the test method itself may be subject to erratic variations and may need to be restudied and revised. Also interactions or non-normal distributions may exist in the data. See X1.3.4 and X1.3.5 and Ref. **(8).** In cases of erratic precision, a precision statement in the test method may really be more misleading than helpful to persons trying to use or interpret the results of the test method. It may actually provide invalid information about what should be expected when the test method is used.

8.4.5 *Irregular or Nonlinear Relationship Between Standard Deviation, Coefficient of Variation, and Average Level (see* Note 7*)*—One way of dealing with situations that do not apply to 8.4.2-8.4.4 is to use the largest estimate of the standard deviation or coefficient of variation (whichever comes closest to being constant) and to use the abbreviation" max" after the indexes of precision (see section 6.2.2.1 of Practice C670). This practice should be discouraged because the resulting indexes of precision are certain to be more lenient than they should be. The maximum limit applies strictly to the level at which the maximum standard deviation or coefficient of variation occurred. Tests done at other levels, for which lower precision limits apply, will be judged on the basis of a wider tolerance than they should be. Also, as pointed out in 8.2.2, individual estimates of variance can vary widely from each other yet still be estimates of the same underlying variance, and it may often be that the pooled or averaged estimates are still the most appropriate ones to use, even if upon superficial examination, the individual variances appear to scatter rather wildly. It is again emphasized that the advice of a statistical consultant is needed here.

8.4.5.1 Cases where the standard deviation or coefficient of variation is a nonlinear function of the average level are dealt with in Ref. **(5).** Very often the amount of data, especially the number of laboratories and materials, is insufficient to establish the form of such a relationship beyond question, and estimates of precision based on one of the cases already described will serve. In addition, the difficulty of writing a precision statement based on a nonlinear relation, that can be easily understood and applied by the user of a test method indicates that such statements should be avoided if possible.

APPENDIXES

(Nonmandatory Information)

X1. EXAMPLE OF ANALYSIS OF DATA FROM AN INTERLABORATORY STUDY

X1.1 *Introduction*—The following example is based on data from an interlaboratory study of tests of expansive cements conducted by ASTM Subcommittee C01.12 on Blended Cements.

X1.2 *Characteristics of the Study and Data*—The major test program was preceded by preliminary tests in three of the participating laboratories, each using a different kind of cement and the test procedures to be used in the major test program. The purpose of the preliminary tests was to determine whether there were any glaring deficiencies connected with the test procedures, and to alter the procedures, if necessary, before undertaking the major test program. This is the screening procedure referred to in 3.1.1 (see Note X1.1).

X1.2.1 In the main test program, eleven laboratories tested five cements for several properties, including restrained and unrestrained expansion of mortar, compressive strength at several ages of unrestrained and restrained modified 2-in. (50.8-mm) cubes, time of setting, false set, and restrained expansion and compressive strength of concrete.

X1.2.2 The data used in this analysis are the 3-day unrestrained compressive strengths of the 2-in. (50.8-mm) mortar cubes. In each laboratory, three rounds of mortar specimens were made with four of the cements, with three cube specimens per round. Four rounds were made with the fifth cement, but in this analysis only the data from the first three rounds reported were used. The average of the three cubes from a single round was used as an individual test result. Thus, the data used

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constitute a study with p = 11 laboratories; q = five materials; and n = three replicates (each an average of three specimens). Certain minor adjustments were made in the data in order to present a better illustration of the technique of analyzing the results of an interlaboratory study, but the data are essentially as reported by the laboratories.

X1.3 *Analysis of Data:*

NOTE X1.1—Since the discussion and tables following constitute directions for manipulating the numbers only, and what is of interest is the process of analysis itself, rather than the analyzed data, it is not deemed appropriate to include metric equivalents, and in the tables, no units at all are given. Units in both systems, however, are given in the finished precision statements, which are examples of what would be published as a result of the analysis. For those who are interested in converting the numbers, however, the following information is given:

(*1*) All the numbers given are in psi or $(psi)^2$.

(*2*) For individual values, averages, and sums of individual values,

$$psi \times 6.9 = kPa \text{ and}$$

$$psi \times 0.0069 = MPa.$$

(*3*) For sums of squares, variances, etc.

$$(psi)^2 \times 47.54 = (kPa)^2$$

X1.3.1 *Step 1: Assembling the Data*—Table X1.1 shows the data sheet for one laboratory for all the tests. The individual cube values and averages for each round are given. In this laboratory, the individual results are given to the nearest 25 psi, which is the case with most of the compressive strength data from the study. Some of the laboratories, however, gave results of individual cube strengths to the nearest 1 psi. The testing machines used in testing 2-in. cubes generally are graduated to 50-lb intervals and can be estimated to half a graduation. The total load is divided by four to get pounds per square inch. Some laboratories give individual results to the nearest 25 psi and some to the nearest 50 psi. Others round the result of the division to the nearest 1 psi, which gives different results in the final digit depending on whether or not half divisions on the dial are estimated and how the results of the division are rounded. In addition, different methods were used in averaging the three individual cube measurements to get a test result.

TABLE X1.1 Data Sheet for Interlaboratory Test for Compressive Strength of 2 by 2-in. (50.8 by 50.8-mm) Mortar Cubes at 3 Days

Laboratory: ABC Testing Agency, Washington, DC						
Round	Specimen	Material				
		A	B	C	D	E
1	1	2950	3750	2750	1775	2025
	2	2800	3575	2825	1875	2075
	3	2825	3825	2800	1900	2100
	Avg.	2858	3717	2792	1850	2067
2	1	2875	3800	2775	2025	2225
	2	2875	4050	2900	2025	2275
	3	2850	3925	2725	2025	2225
	Avg.	2867	3925	2800	2020	2242
3	1	2875	3925	2625	1975	2075
	2	2875	3925	2775	1975	2100
	3	2975	4000	2650	1975	2125
	Avg.	2908	3950	2683	1980	2100

X1.3.1.1 In setting up the instructions for an interlaboratory study, directions for handling details such as this should be spelled out, so that the laboratories use the same procedure. In the analysis presented here, the individual cube results were used as reported, and the averages of the three were recalculated and rounded to the nearest 1 psi in cases where the averages given by the laboratories had been rounded to the nearest 10 psi.

X1.3.1.2 Table X1.2 is a Summary Data Sheet for all laboratories and all materials. The individual entries are the averages of the three cubes per round. The arithmetic labor of an analysis such as this can often be reduced by coding the data, that is, by subtracting a constant from all the numbers. This treatment has no effect on the variances and standard deviations that form the essential parts of the estimates of precision. Averages are reduced by the amount of the constant subtracted and can be restored by merely adding it again. The practice is helpful in avoiding difficulties that sometimes arise from squaring and summing the squares of large numbers when

TABLE X1.2 Summary Data Sheet for Interlaboratory Test Program for Compressive Strength of 2 by 2-in. (50.8 by 50.8-mm) Mortar Cubes at 3 Days

Laboratory		Material				
		A	B	C	D	E
1	a	2858	3717	2792	1850	2067
	b	2867	3925	2800	2025	2242
	c	2908	3950	2683	1975	2100
2	a	1813	2382	1737	1784	1314
	b	2388	3588	2475	1992	2113
	c	2625	3396	2321	1825	1650
3	a	3083	3750	2867	1757	2100
	b	3033	3600	2908	1758	2058
	c	3158	3667	2825	1803	1937
4	a	2783	3783	2608	1925	2175
	b	2692	3867	2800	1925	2125
	c	2817	3800	2600	1808	2042
5	a	3098	3742	2575	1675	2000
	b	3133	3617	2958	1983	2125
	c	3058	3392	2817	1875	2092
6	a	3263	4117	2850	2204	2529
	b	3259	4325	2917	2171	2596
	c	3300	4004	3025	2163	2525
7	a	3225	3983	2717	1867	2250
	b	3125	3817	2533	1875	2242
	c	2850	3550	2775	1925	2300
8	a	3267	4075	2950	2166	2358
	b	3525	4425	3317	2383	2442
	c	3158	4025	3075	2217	2200
9	a	3177	3920	2747	1978	2203
	b	3230	3933	2800	1983	2200
	c	3303	4000	2797	1973	2215
10	a	2840	3907	2425	1767	1942
	b	2858	3858	2158	1817	2000
	c	2667	3967	2600	1883	2067
11	a	2967	3775	2658	1850	1900
	b	2900	3842	2600	1865	1992
	c	3033	3758	2675	1867	2025

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a calculator that carries a limited number of digits is used. The data were not coded for the analysis given in this example, but they could have been. For Material A, with Laboratory 2 excluded (see X1.3.3.1), the subtraction of 2550 (or any number in the range 2526 to 2567) would have reduced all the data to three-digit numbers. The most appropriate number would have been different for the different materials.

X1.3.2 *Step 2: Processing for Outliers*—The criterion given by Dixon and Massey **(10)** was used to examine the sets of three cubes per round and of three rounds per material in a laboratory for outliers. The only cases that exceeded the critical value of 0.988 were cases in which two of the figures were identical, in which case any difference of the third measurement, however small, results in a calculated statistic of 1.00, and the method breaks down. Thus, no outliers were eliminated.

X1.3.3 *Step 3: Between and Within Analysis for All Materials*—Tables X1.3-X1.7 (see Table 3) show the results of the between and within analysis for the various materials tested. The data given under headings a, b, and c are the replicate measurements for the given material for each laboratory, taken from the Summary Data Sheet. The $\bar{x}_i$ and s_i^2 are obtained as described in 8.2.

X1.3.3.1 These tables show two values of $\bar{x}$ and s^2(pooled) for each material, one pair calculated with Laboratory 2 included, and one without Laboratory 2. This is done because it quickly became evident, as discussed further below, that the results of Laboratory 2 differed radically from those of the other ten laboratories. Laboratory 2 had a variance from 4 to 10 times as large as the second highest variance for four of the five materials. It also had the lowest average in four out of the five cases, by quite a large margin. The components of variance used in the analysis, therefore, were those calculated with Laboratory 2 excluded. The final analysis, thus, was based on p = 10 laboratories, q = five materials, and n = three replicates.

TABLE X1.3 Between and Within Analysis for Material A[A,B]

Laboratory	Data			Average $\bar{x}_i$	Within-Laboratory Variance s_i^2
	a	b	c		
1	2858	2867	2908	2878	718
2	1813	2388	2625	2275	174 356
3	3083	3033	3158	3091	3958
4	2783	2692	2817	2764	4177
5	3098	3133	3058	3096	1408
6	3263	3259	3300	3274	511
7	3225	3125	2850	3067	37 708
8	3267	3525	3158	3317	35 522
9	3177	3230	3303	3237	4002
10	2840	2858	2667	2788	11 122
11	2967	2900	3033	2967	4422

[A] p = 11 laboratories
n = 3 replicate test results
$\bar{x}$ (with Lab. 2) = 2978
s_A^2 (pooled, with Lab. 2) = 25 263
$\bar{x}_A$ (without Lab. 2) = 3048
s_A^2 (pooled, without Lab. 2) = 10 355
$s_{\bar{x}_A}^2$ = 38 566
$s_{L_A}^2$ = 35 114
[B] The ratio of high variance to the sum of the variances = 0.6274, the ratio of the high variance to the low variance (with Lab. 2) = 341, and the ratio of the high variance to the low variance (without Lab. 2) = 74.

TABLE X1.4 Between and Within Analysis for Material B[A]

Laboratory	Data			Average $\bar{x}_i$	Within-Laboratory Variance s_i^2
	a	b	c		
1	3717	3925	3950	3864	16 412
2	2383	3588	3396	3122	419 176
3	3750	3600	3667	3672	5646
4	3783	3867	3800	3817	1972
5	3742	3617	3392	3584	31 458
6	4117	4325	4004	4149	26 512
7	3983	3817	3550	3783	47 722
8	4075	4425	4025	4175	47 500
9	3920	3933	4000	3951	1843
10	3907	3858	3967	3911	2980
11	3775	3842	3758	3792	1972

[A] p = 11 laboratories
n = 3 replicate test results
$\bar{x}_B$ (with Lab. 2) = 3802
s_B^2 (pooled, with Lab. 2) = 54 831
$\bar{x}_B$ (without Lab. 2) = 3870
s_B^2 (pooled, without Lab. 2) = 18 402
$s_{\bar{x}_B}^2$ = 35 165
$s_{L_B}^2$ = 29 031
The ratio of the high variance to the sum of the variances = 0.6950, the ratio of the high variance to the low variance (with Lab. 2) = 227, and the ratio of the high variance to the low variance (without Lab. 2) = 26.

TABLE X1.5 Between and Within Analysis for Material C[A]

Laboratory	Data			Average $\bar{x}_i$	Within-Laboratory Variance s_i^2
	a	b	c		
1	2792	2800	2683	2758	4236
2	1737	2475	2321	2178	151 569
3	2867	2908	2825	2867	1722
4	2608	2800	2600	2669	12 821
5	2575	2958	2817	2783	37 522
6	2850	2917	3025	2931	7796
7	2717	2533	2775	2675	15 964
8	2950	3317	3075	3114	34 813
9	2747	2800	2797	2781	886
10	2425	2158	2600	2394	49 546
11	2658	2600	2675	2644	1546

[A] p = 11 laboratories
n = 3 replicate test results
$\bar{x}_C$ (with Lab. 2) = 2709
s_C^2 (pooled, with Lab. 2) = 28 951
$\bar{x}_C$ (without Lab. 2) = 2762
s_C^2 (pooled, without Lab. 2) = 16 685
$s_{\bar{x}_C}^2$ = 36 592
$s_{L_C}^2$ = 31 031
The ratio of the high variance to the sum of variances = 0.4759, the ratio of the high variance to the low variance (with Lab. 2) = 171, and the ratio of the high variance to the low variance (without Lab. 2) = 56.

X1.3.3.2 Table X1.10 is a work sheet showing in detail how the calculations were done for Material A, with Laboratory 2 excluded. Rows 1 through 3 are the individual measurements from the columns headed a, b, and c in Table 3. Row 4 contains the sums of the three replicate measurements, and Row 5 contains the individual averages entered under $\bar{x}_i$ in Table 3. Row 6 contains the sums of the squares of the three replicate measurements for each laboratory. Row 7 contains the quantities obtained by squaring the averages in Row 5 and multiplying by 3 (the number of replicates) (see Note X1.2). Row 8 gives the differences between the values in Rows 6 and 7 and corresponds to the numerator in the equation for s_i^2 (see 8.2). Row 9 contains the s_i^2 obtained by dividing Row 8 by $n - 1$, in this case, 2. The column headed Sum contains the sums of the $\bar{x}_i$ and the s_i^2 in Rows 5 and 9, respectively. The column

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TABLE X1.6 Between and Within Analysis for Material D[A]

Laboratory	Data			Average $\bar{x}_i^2$	Within-Laboratory Variance s_i^2
	a	b	c		
1	1850	2025	1975	1950	8125
2	1784	1992	1825	1867	12 139
3	1757	1758	1803	1773	700
4	1925	1925	1808	1886	4563
5	1675	1983	1875	1844	24 421
6	2204	2171	2163	2179	472
7	1867	1875	1925	1889	988
8	2166	2383	2217	2255	12 874
9	1978	1983	1973	1973	25
10	1767	1817	1883	1822	3385
11	1850	1865	1867	1861	86

[A] p = 11 laboratories
n = 3 replicate test results
$\bar{x}_D$ (with Lab. 9) = 1937
s_D^2 (pooled, with Lab. 9) = 6162
$\bar{x}_D$ (without Lab. 9) = 1933
s_D^2 (pooled, without Lab. 9) = 6776
$s_{\bar{x}_D}^2$ = 24 931
$s_{L_D}^2$ = 22 672
The ratio of the high variance to the sum of the variance = 0.3604, the ratio of the high variance to the low variance (with Lab. 9) = 977, and the ratio of the high variance to the low variance (without Lab. 9) = 284.

TABLE X1.7 Between and Within Analysis for Material E[A]

Laboratory	Data			Average $\bar{x}_i^2$	Within-Laboratory Variance s_i^2
	a	b	c		
1	2067	2242	2100	2136	8634
2	1314	2113	1650	1692	160 944
3	2100	2058	1937	2032	7162
4	2175	2125	2042	2114	4513
5	2000	2125	2092	2072	4196
6	2529	2596	2525	2550	1591
7	2250	2242	2300	2264	988
8	2358	2442	2200	2333	15 097
9	2203	2200	2215	2206	63
10	1942	2000	2067	2003	3913
11	1900	1992	2025	1972	4196

[A] p = 11 laboratories
n = 3 replicate test results
$\bar{x}_E$ (with Lab. 2) = 2125
s_E^2 (pooled, with Lab. 2) = 19 210
$\bar{x}_E$ (without Lab. 2) = 2168
s_E^2 (pooled, without Lab. 2) = 5035
$s_{\bar{x}_E}^2$ = 31 233
$s_{L_E}^2$ = 29 555
The ratio of the high variance to the sum of the variances = 0.7616, the ratio of the high variance to the low variance (with Lab. 2) = 2555, and the ratio of the high variance to the low variance (without Lab. 2) = 240.

TABLE X1.8 Averages, Components of Variance, and Variances for All Materials

Material	Average	Components of Variance		Variances[A]	
		W/L	B/L	W/L	B/L
D	1932.68	6775.5	22 672.5	6775.5	29 448.0
E	2168.28	5035.5	29 554.8	5035.5	34 590.3
C	2761.73	16 685.4	31 030.6	16 685.4	47 716.0
A	3047.84	10 355.0	35 114.0	10 355.0	45 469.0
B	3869.69	18 401.9	29 030.6	18 401.9	47 432.5

[A] Based on one measurement on each material in each laboratory.

headed Average contains the two sums divided by 10, the number of laboratories. These two figures are x_A and s_A^2, respectively. The four figures in the last column headed Sum of Squares are (*a*) the sum of the squares of the values in Row 5; (*b*) 10 times the square of the average x_i, 3048; (*c*) the difference between (*a*) and (*b*); and (*d*) the number (*c*) divided by 9, or one less than the number of laboratories.

TABLE X1.9 Averages, Standard Deviations, and Coefficients of Variation for All Materials

Material	Average	Standard Deviations		Coefficients of Variation	
		W/L	B/L	W/L	B/L
D	1932.68	82.314	171.604	4.3	8.9
E	2168.28	70.961	185.985	3.3	8.6
C	2761.73	129.172	218.440	4.7	7.9
A	3047.84	101.759	213.235	3.3	7.0
B	3869.69	135.654	217.790	3.5	5.6

NOTE X1.2—It will be noted that the quantities obtained by squaring the $\bar{x}_i$'s in Row 5 and multiplying by 3 do not agree in all cases with those given in Row 7. This is due to the rounding error involved in calculating the averages. All the $\bar{x}_i$'s are given to the nearest unit. In the two cases (Laboratories 4 and 6) where Σx_i is an exact multiple of 3 and there is no rounding error, 3 $\bar{x}_i^2$ in Row 7 agrees with the quantity obtained by using the $\bar{x}_i$ from Row 5. The quantities in Row 5 in Table X1.10 were obtained by retaining all 10 digits that resulted from the division of Σx_i by 3 and squaring this result, not by squaring the rounded $\bar{x}_i$'s. This will usually take care of the rounding error. Another method of avoiding the effects of rounding error is to use the formula $(\Sigma x_i)^2/n$ in place of $n\bar{x}_i^2$. In the example, square the Σx_i in Row 4 and divide by 3 to get the quantities for Row 7.

The sum and average in the two columns to the right of column 11 were obtained by summing the rounded $\bar{x}_i$'s, but in this case the rounding error tends to be averaged out over the ten laboratories. Rounding error could be avoided entirely here also, by (*a*) using the full ten or more digits provided by the calculator to get the sum of the $\bar{x}_i$'s or (*b*) by summing the 10 Σ $\bar{x}_i$'s and then dividing by 30 (which is pn) to get $\bar{x}_A$, the average $\bar{x}$.

X1.3.4 *Step 4: Investigation for Homogeneity of Variance*—Figs. X1.1-X1.5 are plots of the individual within-laboratory variances for each laboratory for the five different materials. The drastic departure of the variances of Laboratory 2 is clearly demonstrated by these plots. The average within-laboratory variances, s_x^2 (pooled), both with and without Laboratory 2 are also shown on the plots, except for Material B, for which the average variance with Laboratory 2 included was off the diagram. Use of the criterion for the highest variance given in 8.2 confirmed that the variances for Laboratory 2 were too extreme in four of the five cases and, therefore, Laboratory 2 was eliminated in those four cases. Since more than one half of the cases for Laboratory 2 were involved, an alternative judgement could have been to eliminate Laboratory 2 from the analysis in all five cases. Use of the criterion for the lowest variance revealed one out of five cases for Laboratory 9 where the elimination of a low variance was indicated. In that case, Laboratory 9 was eliminated from the analysis. Since less than one-half of the cases for Laboratory 9 were involved, an alternative judgement could have been to allow Laboratory 9 in all five cases to remain in the analysis.

X1.3.5 *Step 5: Investigation for Interactions*—Average strength was plotted against material designation arranged in increasing order of average strength for the materials for each of the laboratories. These plots for the first three laboratories are shown on Fig. X1.6. Laboratories 1 and 3 show very similar patterns, but the plot for Laboratory 2 again indicates that the results from this laboratory really do not fit the pattern. The drop in strength between Materials D and E was the only

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TABLE X1.10 Worksheet for Material A

Row	Laboratory Numbers										Sum	Average	Sum of Squares
	1	3	4	5	6	7	8	9	10	11			
1 x_a	2858	3083	2783	3098	3263	3225	3267	3177	2840	2967			
2 x_b	2867	3033	2692	3133	3259	3125	3525	3230	2858	2900			
3 x_c	2908	3158	2817	3058	3300	2850	3158	3303	2667	3033			
4 Σx_i	8633	9274	8292	9289	9822	9200	9950	9710	8365	8900			
5 $\bar{x}_i$	2878	3091	2764	3096	3274	3067	3317	3237	2788	2967	30 478	3048	93 240 646
6 Σx_i^2	24 846 250	28 676 942	22 927 442	28 764 657	32 158 250	28 288 750	33 071 878	31 436 038	23 346 653	26 412 178			92 893 555
7[A] $3\bar{x}_i^2$	24 844 815	28 669 025	22 919 088	28 761 840	32 157 228	28 213 333	33 000 833	31 428 033	23 324 408	26 403 333			347 091
8 6 to 7	1435	7917	8354	2817	1022	75 417	71 045	8005	22 245	8845			38 566
9 s_i^2	718	3958	4177	1408	511	37 708	35 522	4002	11 122	4422	103 550	10 355	
10 s_i	27	63	65	38	23	194	188	63	105	67			
11 $\bar{x}_A$ = 30 478/10 = 3048													
12 s_A^2 (pooled) = 103 550/10 = 10 355													
13 $s_{\bar{x}_A}^2$ = 347 091/9 = 38 566													
14 $s_{L_A}^2$ = 38 566 – (10 355/3) = 35 114													

[A] See Note X1.2.

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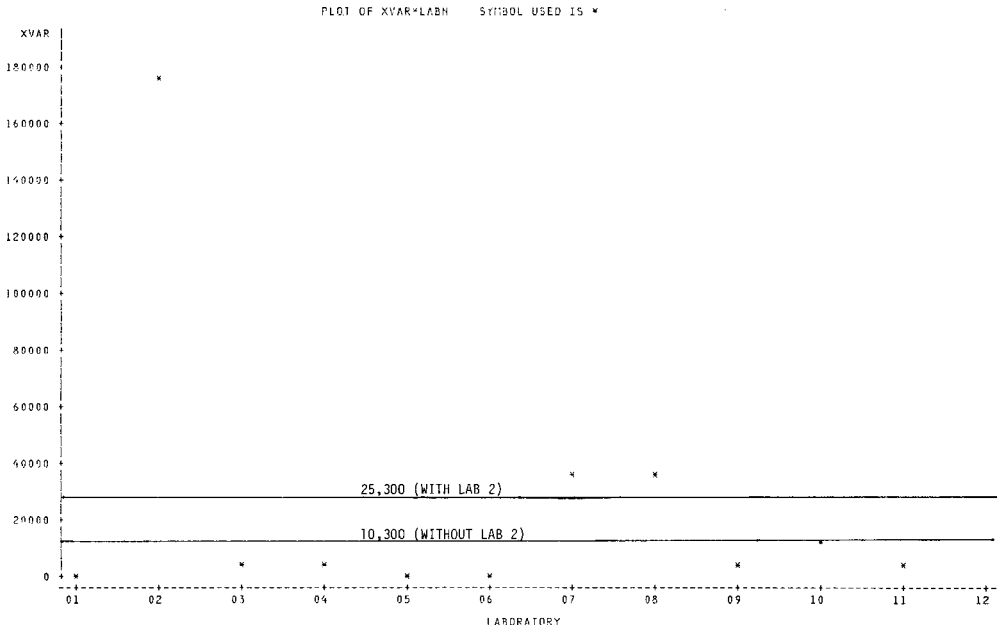

FIG. X1.1 Variance Versus Laboratory For Material A

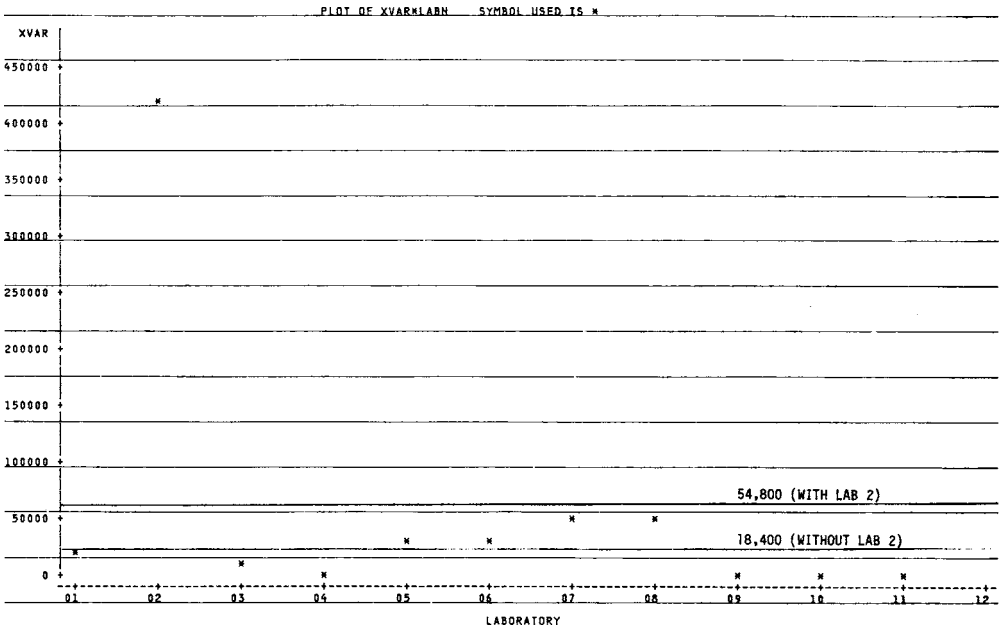

FIG. X1.2 Variance Versus Laboratory for Material B

case where a reversal of the order of two materials occurred. All of the other eight laboratories showed results with a similar pattern to those of Laboratories 1 and 3. It was, therefore concluded that, with partial (or total) the elimination of Laboratory 2, no serious interactions remained.

X1.3.6 *Step 6: Development of the Estimates of Precision*—Table X1.8 and Table X1.9, show the components of variance, variances, standard deviations, and coefficients of variation, developed in accordance with Practice C670. The variances given in Table X1.8 are for individual determinations in each laboratory, even though three replicates were used in the analysis.

X1.3.7 *Step 7: Determination of the Form of the Precision Statements*—Fig. X1.7 and Fig. X1.8, respectively, show plots of the standard deviation versus average and coefficient of variation versus average. Each plot shows between-laboratory and within-laboratory results separately. Fig. X1.7 indicates that the standard deviation tends to increase with increasing level of strength, both within and between laboratories. Examination of the curves also indicates the possibility that two levels of standard deviation might exist, one for the two lower strength cements, D and E, and another for the three higher ones. With only the information from the five materials given, it is difficult to determine which one of these situations really

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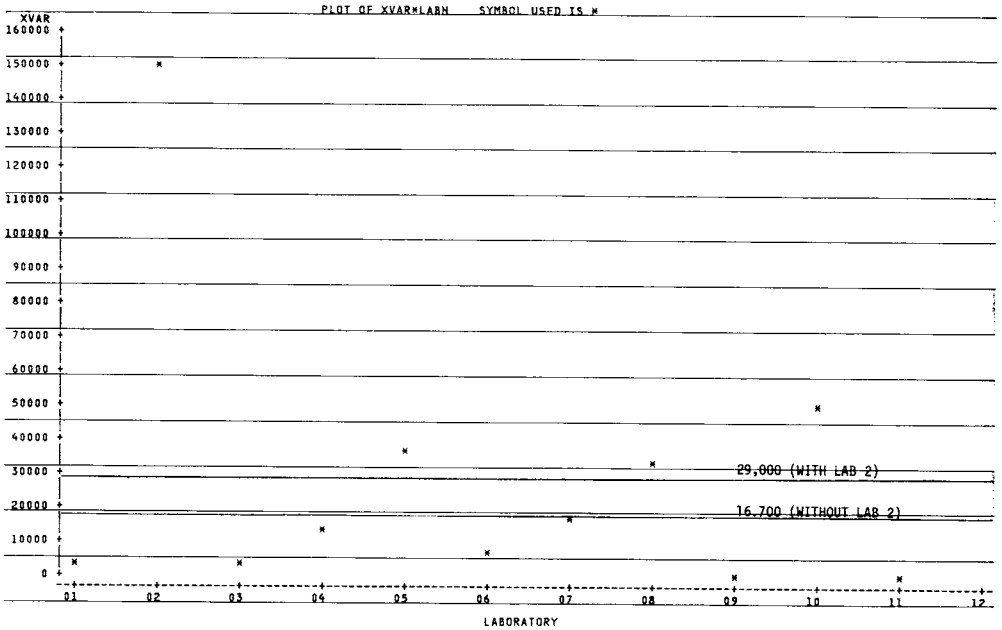

FIG. X1.3 Variance Versus Laboratory for Material C

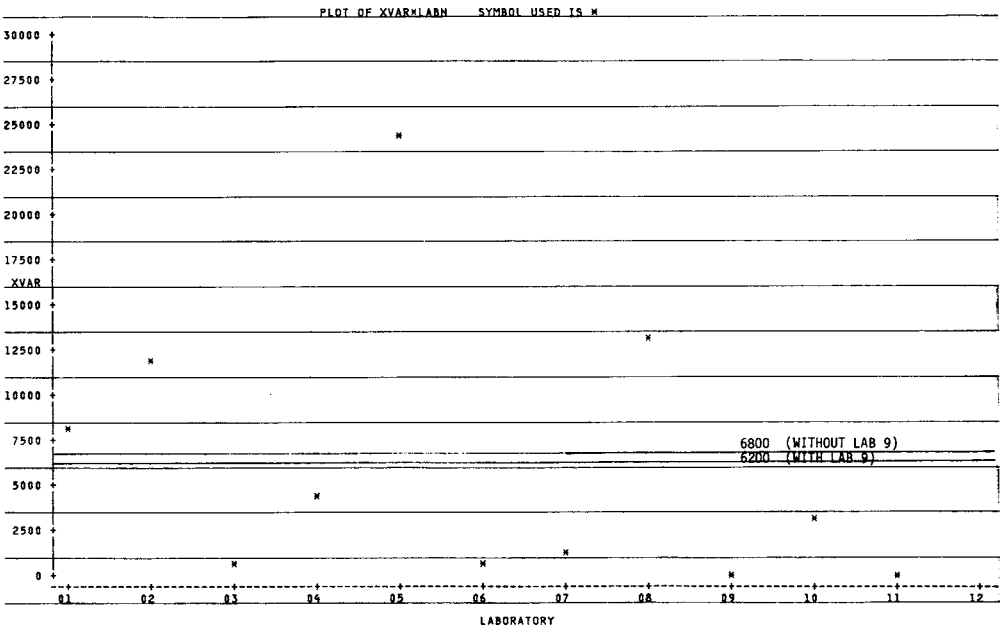

FIG. X1.4 Variance Versus Laboratory for Material D

exists. Fig. X1.8 indicates that the between-laboratory coefficient of variation tends to decrease with increasing level, although the coefficients for the two lower materials were the same. The within laboratory coefficients appear to be about the same for all levels.

X1.3.7.1 References (**14-18**) give information on the relationship between the variability and strength of concrete. References (**15-17**) report that standard deviation is relatively constant above 3000 psi (20.7 MPa) and coefficient of variation is constant below that level. The results of this analysis are compatible with this conclusion if the transition is lower, say about 2500 psi (17.2 MPa). Note that these results are on small mortar cubes instead of large concrete specimens, and are tested at 3 days instead of 28 days as is usual in concrete testing. The precision statements that follow are thus based on the assumption of constant coefficients of variation of 3.8 and 8.8 %, respectively, for within-laboratory and between-laboratory results for average strengths below 2500 psi (17.2 MPa), and on constant standard deviations of 125 and 215 psi (0.862 and 1.48 MPa), respectively, for within-laboratory and between-laboratory results for average strengths above 2500 psi. Maximum allowable ranges for three cubes from the same batch, for three test results, each consisting of an average of three cubes and for the difference between averages of three test results in different laboratories are also given (see Practice C670).

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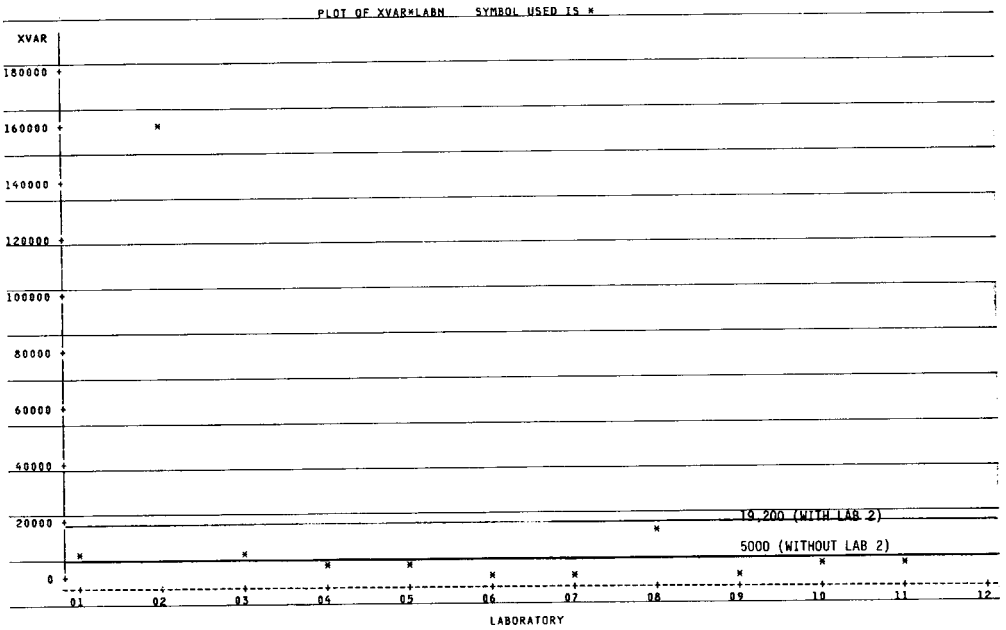

FIG. X1.5 Variance Versus Laboratory for Material E

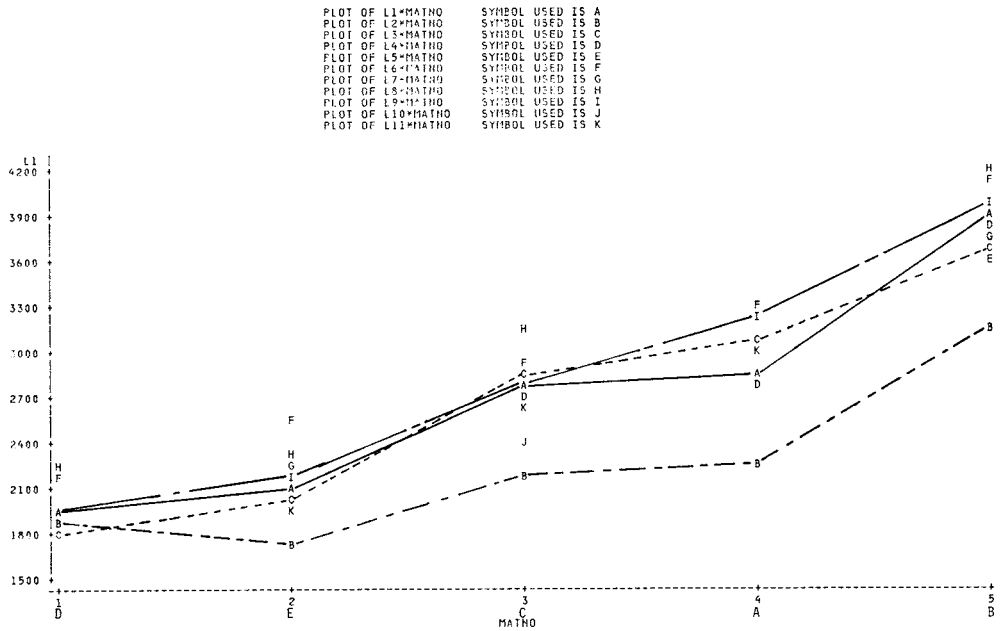

FIG. X1.6 Average Strength Versus Material

X1.3.8 *Step 8: Writing the Precision Statements*—The precision statements based on the data as described in X1.3.7.1 are as follows:

Single-Operator Precision (Average Strength Below 2500 psi (17.2 MPa))—The single-operator coefficient of variation of a single test result for average strengths below 2500 psi (a test result is defined in this method as the average of three separate measurements) has been found to be 3.8 %.[A] Therefore, results of two properly conducted tests by the same operator (each consisting of the average of three cubes from the same batch of mortar) should not differ by more than 10.8 %[A] of the average of the two results. The range of three test results obtained by the same operator should not exceed 12.5 % of the average of the three.[B]

Multilaboratory Precision (Average Strength Below 2500 psi (17.2 MPa))—The multilaboratory coefficient of variation of a single test result for average strengths below 2500 psi (a test result is defined in this method, as the average of three separate measurements) has been found to be 8.8 %.[A] Therefore, results of two properly conducted tests in different laboratories on the same cement should not differ by more than 24.9 % of their average.[A]

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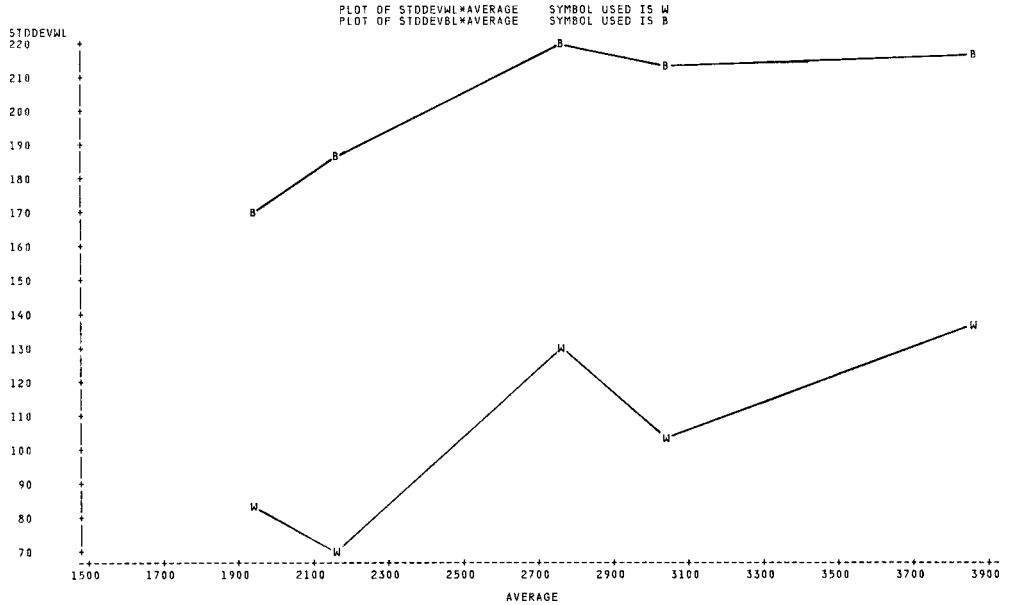

FIG. X1.7 Standard Deviation Versus Average

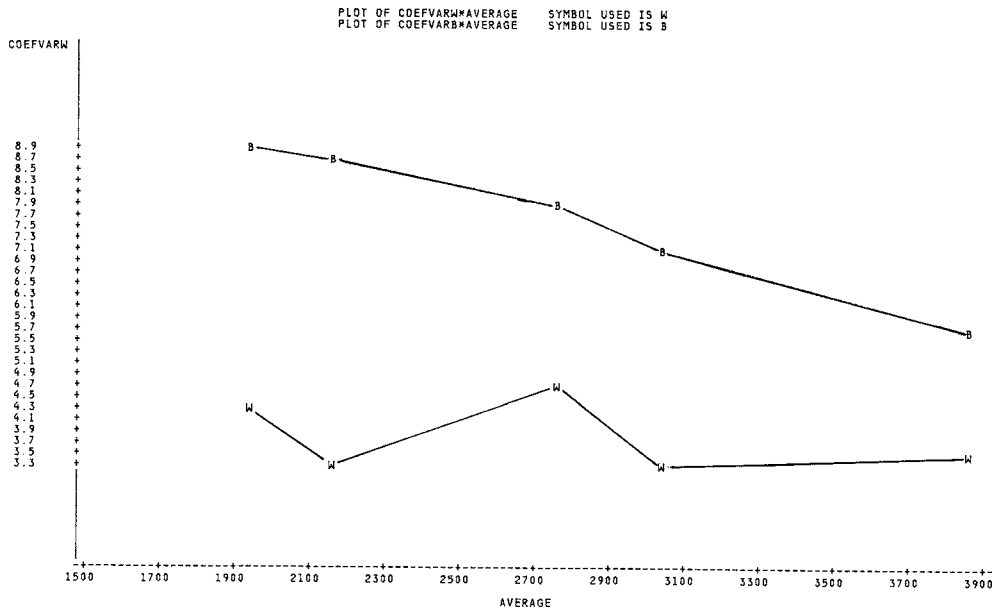

FIG. X1.8 Coefficient of Variation Versus Average

Single-Operator Precision (Average Strength Above 2500 psi (17.2 MPa))—The single-operator standard deviation of a single test result for average strengths above 2500 psi (a test result is in this method, as the average of three separate measurements) has been found to be 125 psi (0.862 MPa). Therefore, results of two properly conducted tests by the same operator (each consisting of the average of three cubes from the same batch of mortar) should not differ by more than 355 psi (2.45 MPa).[A] The range of the three test results obtained by the same operator should not exceed 410 psi (2.83 MPa).[B]

Multilaboratory Precision (Average Strength Above 2500 psi (17.2 MPa))—The multilaboratory standard deviation of a single test result for average strengths above 2500 psi (a test result is defined in this method, as the average of three separate measurements) has been found to be 215 psi (1.48 MPa).[A] Therefore, results of two properly conducted tests in different laboratories on the same cement should not differ by more than 610 psi (4.21 MPa).[A]

[A] These numbers represent, respectively, the (1s %) and (d2s %) limits as described in Practice C670.

[B] Calculated as described in Practice C670.

X1.3.8.1 The figures in the above example are obtained as follows:

(1) The (1s) and (1s %) figures are the standard deviations and coefficients of variation, respectively, as given in X1.3.7.

(2) The (d2s) and (d2s %) figures are the (1s) and (1s %) figures multiplied by 2.83 (that is, $2\sqrt{2}$).

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(3) The maximum allowable ranges for three test results are the (1s) and (1s %) figures for single-operator precision multiplied by 3.3, the multiplier for ranges of 3 as described in Practice C670.

X2. OUTLIERS

X2.1 The objective of the process of screening for outliers is to retain all data that legitimately belong in the population of results characteristic of the test method, and to eliminate only those that differ so drastically that their inclusion distorts the realistic picture of that population (**9**). The procedure used should be a conservative one. The error of discarding results that should not be discarded tends to be more common than that of retaining results that should not be retained. For example, criteria that call for discarding results that would be expected 5 % of the time are often used. An interlaboratory program that includes ten laboratories, five materials and four replicates produces 200 measurements. On the average, such programs should produce ten results in the 5 % rejection range. Rejection of these results as outliers could cause the final estimates of precision to be much smaller than they ought to be.

X2.2 If it is considered desirable to apply statistical techniques for the rejection of outliers, the criteria and technique to be used should be selected and applied by the organizing committee on the advice of the statistical consultant, and not by the individual laboratories. Also the significance level of the test used should be no greater than 1.0 %. Approved methods are described in Refs (**10** and **13**).

REFERENCES

(**1**) *ASTM Manual for Conducting an Interlaboratory Study of a Test Method, STP. 335*, ASTM, Philadelphia, PA 1963, p. 4.
(**2**) Youden, W. J., Statistical Techniques for Collaborative Tests, Association of Official Analytical Chemists, Washington, DC, 1967, pp. 7–9.
(**3**) *Ibid*, p. 9.
(**4**) *ASTM STP 335*, pp. 3–4, 9.
(**5**) *ASTM STP 335.*
(**6**) *ASTM Manual on Quality Control of Materials, STP 15C*, ASTM, Philadelphia, PA, 1951, pp. 47–49.
(**7**) Mandel, John," Repeatability and Reproducibility," *Materials Research and Standards*, ASTM, Vol. 11, No. 8, August 1971, p. 8.
(**8**) Youden, 1967, p. 18.
(**9**) *Ibid*, pp. 26–27.
(**10**) Dixon, W. J., and Massey, F. J., *Introduction to Statistical Analysis*, 2nd Ed., McGraw-Hill, New York, NY, 1957, Table 8e.
(**11**) This table was adapted from *Techniques of Statistical Analysis*, Chapter 15 on "Significance of the Largest of a Set of Sample Estimate of Variance," Eisenhart, Churchill, Solomon, and Herbert.
(**12**) This table was adapted from Biometrika Tables for Statisticians, Pearson, B. S., and Hartley, H. O., Vol I (2nd ed.), Cambridge, MA, 1958.
(**13**) Mandel, *op cit.*
(**14**) Neville, A. M., "The Relation Between Standard Deviation and Mean Strength of Concrete Test Cubes," *Magazine of Concrete Research*, Vol II, No. 32, July 1959.
(**15**) Metcalf, J. B., "The Specification of Concrete Strength, Part II, The Distribution of Strength of Concrete for Structures in Current Practice," *RRL Report LR 3000*, Road Research Laboratory, Crawthorne, Berkshire, U. K., 1970.
(**16**) Murdock, C. J., "The Control of Concrete Quality," *Proceedings of Institute of Civil Engineers*, Part I, Vol 2, No. 4, July 1953.
(**17**) Erntroy, H. C., "The Variation of Works Test Cubes," *Research Report 10*, Cement and Concrete Assn., London, November 1960.
(**18**) Rüsch, H., "Statistical Quality Control of Concrete," *Materialprüfung*, Vol 6, No. 11, 1964, pp. 387–394.

SUMMARY OF CHANGES

Committee C09 has identified the location of selected changes to this practice since the last issue, C802–09, that may impact the use of this practice. (Approved December 15, 2009)

(*1*) Revised a reference in 8.2 from Note 5 to Note 4.

Committee C09 has identified the location of selected changes to this practice since the last issue, C802–96(2008)$^{\varepsilon 1}$, that may impact the use of this practice. (Approved November 1, 2009)

(*1*) Revised Note 2.

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Designation: C 803/C 803M – 03

Standard Test Method for Penetration Resistance of Hardened Concrete[1]

This standard is issued under the fixed designation C 803/C 803M; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope *

1.1 This test method covers the determination of the resistance of hardened concrete to penetration by either a steel probe or pin.

1.2 The values stated in either SI units or inch-pound units are to be regarded separately as standard. The values stated in each system may not be exact equivalents; therefore, each system shall be used independently of the other. Combining values from the two systems may result in nonconformance with the standard.

1.3 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.* For specific hazard statements, see Section 7.

2. Referenced Documents

2.1 *ASTM Standards:*

C 670 Practice for Preparing Precision and Bias Statements for Test Methods for Construction Materials[2]

C 125 Terminology Relating to Concrete and Concrete Aggregates[2]

2.2 *ANSI Standard:*

A10.3 Safety Requirements for Powder Actuated Fastening Systems[3]

3. Terminology

3.1 *Definitions:*

3.2 For definitions of terms used in this test method, refer to Terminology C 125.

4. Summary of Test Method

4.1 A driver delivers a known amount of energy to either a steel probe or pin. The penetration resistance of the concrete is determined by measuring either the exposed lengths of probes that have been driven into the concrete or by measuring the depth of the holes created by the penetration of the pins into the concrete.

5. Significance and Use

5.1 This test method is applicable to assess the uniformity of concrete and to delineate zones of poor quality or deteriorated concrete in structures.

5.2 This test method is applicable to estimate in-place strength, provided that a relationship has been experimentally established between penetration resistance and concrete strength. Such a relationship must be established for a given test apparatus (see also 9.1.5), using similar concrete materials and mixture proportions as in the structure. Use the procedures and statistical methods in ACI 228.1R for developing and using the strength relationship.[4]

NOTE 1— Since penetration results may be affected by the nature of the formed surfaces (for example, wooden forms versus steel forms), correlation testing should be performed on specimens with formed surfaces similar to those to be used during construction. Additional information on the factors affecting penetration test results and summaries of past research are available.[4,5]

5.3 Steel probes are driven with a high-energy, powder-actuated driver, and probes may penetrate some aggregate particles. Probe penetration resistance is affected by concrete strength as well as the nature of the coarse aggregate. Steel pins are smaller in size than probes and are driven by a low energy, spring-actuated driver. Pins are intended to penetrate the mortar fraction only; therefore, a test in which a pin strikes a coarse aggregate particle is disregarded.

5.4 This test method results in surface damage to the concrete, which may require repair in exposed architectural finishes.

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[1] This test method is under the jurisdiction of ASTM Committee C09 on Concrete and Concrete Aggregates and is the direct responsibility of Subcommittee C09.64 on Nondestructive and In-Place Testing.

Current edition approved Jan. 10, 2003. Published April 2003. Originally approved in 1975. Last previous edition approved in 1997 as C 803/C 803M-97ε1.

[2] *Annual Book of ASTM Standards*, Vol 04.02.

[3] Available from American National Standards Institute (ANSI), 25 W. 43rd St., 4th Floor, New York, NY 10036.

[4] ACI 228.1R-95, "In-Place Methods to Estimate Concrete Strength," Report of ACI Committee 228 on Nondestructive Testing, American Concrete Institute, Farmington Hills, MI.

[5] Malhotra, V. M., and Carette, G. G., "Penetration Resistance Methods," Chapter 2 in *Handbook on Nondestructive Testing of Concrete*, Malhotra, V. M., and Carino, N. J., eds., CRC Press, Boca Raton, FL, 1991, pp. 19–38.

***A Summary of Changes section appears at the end of this standard.**

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6. Apparatus [6]

6.1 *Resistance Testing With Probes*:

6.1.1 *Driver Unit*—The driver unit shall be capable of driving the probe into the concrete with an accurately controlled amount of energy so that the probe will remain firmly embedded. The driver unit shall incorporate features to prevent firing when not properly placed in the positioning device on the concrete surface.

NOTE 2—A powder-actuated device conforming to ANSI A10.3 has been used successfully.

6.1.1.1 For a specified energy loading, the variation of the velocity of standard probes propelled by the standard driving unit shall not have a coefficient of variation greater than 3 % for any ten tests made by accepted ballistic methods.

NOTE 3—A conventional counter chronograph and appropriate ballistic screens may be used to measure velocity at 2 m [6.5 ft] from the end of the driving unit.

6.1.2 *Probe*— The probe shall be a hardened alloy-steel rod plated for corrosion protection, with a blunt conical end that can be inserted into the driver unit and driven into the concrete surface so that it remains firmly embedded and the length of the projecting portion can be measured. The hardness shall be between Rockwell 44 HRC and 48 HRC. The exposed end of the probe shall be threaded to accommodate accessories designed to facilitate measurement and withdrawal.

NOTE 4—If probes are to be removed from the concrete, a device, consisting of a nut that can be screwed onto the end of the probe by a wrench and spacers that can be slipped over the probe for the nut to bear against, will serve to withdraw the probes.

6.1.2.1 The length of probes shall be uniform within ± 0.5 %.

6.1.3 *Measurement Equipment*:

6.1.3.1 *Measuring Instrument*—A measuring instrument, such as a caliper, depth gage, or other measuring device, and associated equipment, shall be used to measure the exposed length of a probe to the nearest 0.5 mm [0.025 in.].

6.1.3.2 The measuring equipment shall include a reference base plate or other device that is supported on the concrete surface at three equally spaced points at least 50 mm [2 in.] from the probe to be measured.

NOTE 5—In order to hold the reference base plate against the surface of the concrete when measurements in the horizontal direction or in the bottom of an overhead concrete surface are being made, a plate retainer consisting of a spring and a nut that can be screwed onto the threaded end of the probe may be used.

NOTE 6—A probe-measuring cap that can be screwed onto the threaded end of the probe has been used to facilitate measuring exposed length and to compensate for the height of the reference base plate.

6.1.4 *Positioning Device*—A device to be placed on the surface of the concrete for positioning and guiding the probe and driver unit during firing will be used.

NOTE 7—This may be a single-positioning device or a triangular device with holes at the three corners that permits the firing of three probes in a triangular pattern in accordance with 7.1.1.

6.2 *Resistance Testing with Pins*:

6.2.1 *Driver Unit*—The driver shall be a device capable of driving a pin into the concrete with an accurately controlled amount of energy. The pin will be forced into the concrete, creating a hole so that the depth of penetration can be measured.

NOTE 8—A spring-actuated driver unit with a spring stiffness of 49.7 kN/m [284 lb/in.] has been successfully used to test concrete with strength in the range of 3 to 28 MPa [450 to 4000 psi].

6.2.2 The spring-actuated driver requires regular verification of the amount of energy transferred to the pin. Servicing is required whenever there is reason to question its proper operation.

NOTE 9—The amount of energy transferred to the pin can be verified using calibration blocks supplied by the manufacturer. Pins are driven into the blocks using the spring-actuated driver, and the measured penetration is compared to manufacturer's specifications. If the penetration does not meet the manufacturer's specification, the driver unit should be serviced.

6.2.3 *Pin*—The pin shall be a hardened alloy-steel drill rod, heat treated to Rockwell hardness 62 to 66 HRC, with one end sharpened and the other end blunt. The dimensions of the pins shall be uniform within ±2.0 %. Each pin shall be used only once and then discarded.

NOTE 10—A pin with approximate length of 30 mm [1.2 in.], a diameter of 3.6 mm [0.14 in.] and a tip machined at an angle of 22.5 degrees with its longitudinal axis, has been used successfully in the driver unit described in Note 8.

6.2.4 *Measuring Equipment*:

6.2.4.1 *Measuring Instrument*—A depth gage with a reference plate shall be used to measure the depth of penetration of the pin tip into the concrete to the nearest 0.001 in. [0.025 mm].

6.2.4.2 The measuring rod of the depth gage shall have a diameter and a tip angle that are less than that of the pin.

6.2.4.3 The test equipment shall include an air blower to clean the small hole created by a pin before measurement of the depth of penetration.

7. Hazards

7.1 *Resistance Testing With Probes*:

7.1.1 Exercise care in the operation of the driver unit to prevent unexpected or inadvertent discharge of a probe.

7.1.2 Wear safety goggles, hearing protection, and other appropriate protective equipment when driving probes into concrete.

7.1.3 The driving unit, if powder actuated, shall conform to the applicable requirements of ANSI A10.3.

7.1.4 If reinforcing bars or other metal embedments in the concrete are suspected to have cover depths shallower than the anticipated probe penetration, select test positions so that probes will not strike such embedded items (Note 11).

NOTE 11—The location of reinforcement may be established using reinforcement locators or metal detectors. Follow the manufacturer's instructions for proper operation of such devices.

7.2 *Resistance Testing with Pins*:

7.2.1 Use care in the operation of the spring actuated driver to prevent injury from the inadvertent firing of the pin.

[6] Apparatus to conduct these tests is available commercially.

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7.2.2 Personnel should wear safety goggles and other appropriate protective equipment when performing the test.

8. Sampling

8.1 *Resistance Testing With Probes*:

8.1.1 The concrete to be tested must have reached a sufficient degree of resistance to penetration so that the probe will not penetrate more than one half the thickness of the concrete member and will remain firmly embedded. No probe shall be located less than 175 mm [7 in.] from any other probe, nor less than 100 mm [4 in.] from the edge of a concrete surface.

8.1.2 A minimum of three firmly embedded test probes in a given test area shall constitute one test. If the range of three valid probe penetration measurements exceeds the value in the third column of Table 1, make a fourth measurement and discard the measurement with the greatest deviation from the average. If the three remaining measurements still do not meet the limit given in Table 1, select a different test area and obtain three new measurements.

NOTE 12—The number of tests to be taken depends on the intended use of the results. Refer to ACI 228.1R[4] for recommendations.

8.2 *Resistance Testing with Pins*:

8.2.1 The concrete to be tested must have reached a sufficient degree of resistance to penetration so that the pin does not penetrate to a depth greater than the exposed length of the pin when inserted into the hammer of the driver.

NOTE 13—For the driver unit described in Note 8, the exposed length is 7.6 mm [0.30 in.].

8.2.2 No pin penetration shall be located less than 50 mm [2 in.] or more than 150 mm [6 in.] from any other pin penetration, nor less than 50 mm [2 in.] from the edge of a concrete surface.

8.2.3 The average depth of penetration measured for six pins driven into the concrete in a given test area shall constitute one test. See Note 12.

8.2.4 Discard a reading when the pin obviously hit a coarse aggregate or an entrapped air void, and perform a new test. If the range of six valid pin penetration measurements exceeds the value in the third column of Table 2, make a seventh measurement and discard the measurement with the greatest deviation from the average. If the six remaining measurements still do not meet the limit given in Table 2, select a different test area and obtain six new measurements.

9. Procedure

9.1 *Resistance Testing With Probes*:

9.1.1 Concrete surfaces to be tested that are coarser than burlap dragged finishes shall be ground over an area larger than that covered by the positioning device and reference base plate.

9.1.2 Place the positioning device on the surface of the concrete at the location to be tested. Mount a probe in the driver unit, position the driver in the positioning device, and fire the probe into the concrete. Follow the safety directions supplied with the apparatus.

9.1.3 Remove the positioning device and tap the probe on the exposed end with a small hammer to ensure that it has not rebounded and to confirm that it is firmly embedded. Reject loose probes.

9.1.4 Place the reference base plate over the probe and position it so that it bears firmly on the surface of the concrete without rocking or other movement. If the surface of the concrete has been raised around the base of the probe, remove the crushed concrete to allow the reference base plate to lie flat. If necessary, install plate retainers and probe-measuring caps. Measure the distance from the reference base plate to the end of the probe, or to the upper surface of the measuring cap, to the nearest 0.5 mm [0.025 in.]. Verify that requirements of 8.1.2 are met. If a probe is more than 10 degrees from perpendicular with respect to the surface of the concrete, discard that probe and embed another. Determine the average exposed probe length.

NOTE 14—Mechanical and electronic devices are available to facilitate determining the average exposed length of the probes.

9.1.5 When tests are to be made on concrete having a density of approximately 2000 kg/m^3 [125 lb/ft^3] or less, and on all concrete with strengths less than 17 MPa [2500 psi], decrease the amount of energy delivered to the probe by the driver or use a larger-diameter probe, or both. Decrease the

TABLE 1 Precision[A] for Resistance Testing with Probes

Maximum Size of Aggregate	(1s) Limit[B], mm [in.]	Maximum Range of Three Individual[C] Measurements, mm [in.]	(d2s) Limit[D] Maximum Difference Between Two Tests (Each test calculated as the average of three measurements), mm [in.]
No. 4 (Mortar)	2.0 [0.08]	6.6 [0.26]	3.3 [0.13]
25 mm [1-in.]	2.5 [0.10]	8.4 [0.33]	4.1 [0.16]
50 mm [2 in.]	3.6 [0.14]	11.7 [0.46]	5.6 [0.22]

[A] These values represent indexes of precision as described in Practice C 670.
[B] These values are the single-operator standard deviations for tests made on concrete with the maximum size aggregate shown in Column 1.
[C] These values are the maximum allowable ranges for groups of three individual measurements made close together, either as individual measurements or by using the triangular positioning device.
[D] A difference larger than the values given indicates a high probability that there is a statistically significant difference in the concrete in the two areas represented by the two groups of three measurements each.

TABLE 2 Precision[A] for Resistance Testing with Pins

Material	(1s) Limit[B], mm [in.]	Maximum Range of Six Individual[C] Measurements, mm [in.]	(d2s) Limit[D] Maximum Difference Between Two Tests (Each test calculated as the average of six measurements), mm [in.]
Concrete 3–28 MPa [450–4000 psi]	0.4 [0.016]	1.6 [0.064]	0.5 [0.018]

[A] These values represent indexes of precision as described in Practice C 670.
[B] These values are the single-operator standard deviations for tests on concrete shown in Column 1.
[C] This value is the maximum allowable range for groups of six individual measurements made in a 300 mm [12 in.] diameter region.
[D] A difference larger than the values given indicates a high probability that there is a statistically significant difference in the concrete in the two areas represented by the two groups of six measurements each.

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delivered energy by positioning the probe further down the barrel of the driver unit, as recommended by the manufacturer. Do not use the low-power setting if the probes are not firmly embedded in the concrete. Separate strength relationships must be developed for different probe sizes and power level settings.

NOTE 15—Probes of 79.4-mm [3.125-in.] overall length and 7.9-mm [0.312-in.] diameter, with the penetrating end diameter reduced to 6.4 mm [0.250 in.] for approximately 14.3 mm [0.562 in.] in length, have been found satisfactory for testing concrete having a density of 2000 kg/m^3 [125 lb/ft ^{3}] or greater. A7.9-mm [0.312-in.] diameter and 79.4-mm [3.125-in.] length probe should be used with concrete having a density of less than 2000 kg/m^3 [125 lb/ft^3]. A change in section or shoulder has been found to be helpful in preventing rebound after setting.

9.2 *Resistance Testing with Pins*:

9.2.1 Concrete surfaces to be tested which are heavily textured, soft, or consist of loose mortar shall be ground flat with an abrasive stone consisting of medium grain texture silicon carbide or equivalent material. The area to be ground for each pin penetration measurement shall be at least as large as the bearing area of the driver. The area shall be sufficiently flat if there is no visible gap between the surface and a pin laid sideways on the surface.

9.2.2 Insert a new pin into the spring-actuated driver unit.

9.2.3 Load the spring-actuated driver unit by compressing the spring until the trigger mechanism engages.

9.2.4 Place the driver unit firmly against the perpendicular to the surface of the concrete to be tested. Pull the trigger to release the spring and drive the pin into the concrete surface. Remove the unit including the pin.

9.2.5 Clean the pin hole using the air blower device.

9.2.6 Insert the depth gage into the pin hole and measure the depth of penetration to the nearest 0.02 mm [0.001 in.].

10. Report

10.1 For probe or pin tests, report the following information:

10.1.1 Identification of the location tested in the concrete construction and the type of concrete member tested,

10.1.2 Description of concrete mixture including type of coarse aggregate,

10.1.3 Description of surface finish and, if required, the surface preparation used prior to testing.

10.1.4 Approximate locations of test areas, and

10.1.5 Date and time of testing.

10.2 For probe tests, report the following information:

10.2.1 Driver unit identification number and energy level used in testing,

10.2.2 Dimensions of probes,

10.2.3 Approximate thickness of member tested,

10.2.4 The exposed lengths of the probes and the average exposed length in each test area, and

10.2.5 Description of unusual conditions, including tests rejected for data analysis.

10.3 For pin tests, report the following information:

10.3.1 Driver unit identification number,

10.3.2 Approximate thickness of member tested,

10.3.3 The penetration depths of the pins and the average penetration depth in each test area, and

10.3.4 Description of unusual conditions, including tests rejected for data analysis.

11. Precision and Bias

11.1 *Precision*—The data used to develop the precision statements were obtained using apparatus and measurements in inch-pound units. The precision indexes given in Table 1 and Table 2 are conversions of the inch-pound values given in parentheses.

11.2 *Resistance Testing With Probes*:

11.2.1 The indexes of precision given in Table 1 apply to measurements obtained by a single operator using the same instrument on the same concrete, that is, concrete made with the same materials, procedures, equipment, and curing conditions.

11.3 *Resistance Testing with Pins*:

11.3.1 The single-specimen, single-operator, driver, day precision is 0.4 mm [0.016 in.] (1s) as defined in Practice C 670.

11.3.2 The indexes of precision given in Table 2 apply to measurements obtained by a single operator using the same instrument on the same concrete, that is, concrete made with the same materials, procedures, equipment, and curing conditions.

11.4 *Bias*—This test method has no bias because penetration resistance is defined in terms of this test method.

12. Keywords

12.1 concrete strength; concrete uniformity; in-place strength; in-place test; penetration resistance

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C 803/C 803M – 03

SUMMARY OF CHANGES

Committee C09 has identified that the following changes to this test method have been incorporated since the last issue (C 803/C 803M-97$^{\epsilon 1}$):

(1) Nonmandatory language in various sections has been replaced with mandatory language.
(2) A Terminology section has been added.
(3) The procedure in 9.1.4 has been clarified and a new requirement was added to deal with probes that are not driven perpendicular to the concrete surface.
(4) In 9.2.1, the area to be ground is revised to accommodate different bearing areas of the driver.
(5) Various editorial improvements.

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Designation: C 805/C 805M – 08

Standard Test Method for Rebound Number of Hardened Concrete[1]

This standard is issued under the fixed designation C 805/C 805M; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

This standard has been approved for use by agencies of the Department of Defense.

1. Scope*

1.1 This test method covers the determination of a rebound number of hardened concrete using a spring-driven steel hammer.

1.2 The values stated in either SI units or inch-pound units are to be regarded separately as standard. The values stated in each system may not be exact equivalents; therefore, each system shall be used independently of the other. Combining values from the two systems may result in non-conformance with the standard.

1.3 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

2. Referenced Documents

2.1 *ASTM Standards:* [2]

C 42/C 42M Test Method for Obtaining and Testing Drilled Cores and Sawed Beams of Concrete

C 125 Terminology Relating to Concrete and Concrete Aggregates

C 670 Practice for Preparing Precision and Bias Statements for Test Methods for Construction Materials

E 18 Test Methods for Rockwell Hardness of Metallic Materials

3. Terminology

3.1 *Definitions:*

3.1.1 For definitions of terms used in this test method, refer to Terminology C 125.

4. Summary of Test Method

4.1 A steel hammer impacts, with a predetermined amount of energy, a steel plunger in contact with a surface of concrete, and the distance that the hammer rebounds is measured.

5. Significance and Use

5.1 This test method is applicable to assess the in-place uniformity of concrete, to delineate regions in a structure of poorer quality or deteriorated concrete, and to estimate in-place strength.

5.2 Relationships between rebound number and concrete strength that are provided by instrument manufacturers shall be used only to provide indications of relative concrete strength at different locations in a structure. To use this test method to estimate strength, it is necessary to establish a relationship between strength and rebound number for a given concrete mixture and given apparatus. Establish the relationship by correlating rebound numbers measured on the structure with the strengths of cores taken from corresponding locations. At least two replicate cores shall be taken from at least six locations with different rebound numbers. Select test locations so that a wide range of rebound numbers in the structure is obtained. Obtain, moisture condition, and test cores in accordance with Test Method C 42/C 42M.

NOTE 1—See ACI 228.1R[3] for additional information on developing the relationship and on using the relationship to estimate in-place strength.

5.3 For a given concrete mixture, the rebound number is affected by factors such as moisture content of the test surface, the method used to obtain the test surface (type of form material or type of finishing), vertical distance from the bottom of a concrete placement, and the depth of carbonation. These factors need to be considered in interpreting rebound numbers.

5.4 Different hammers of the same nominal design may give rebound numbers differing from 1 to 3 units. Therefore, tests should be made with the same hammer in order to compare results. If more than one hammer is to be used, perform tests on

[1] This test method is under the jurisdiction of ASTM Committee C09 on Concrete and Concrete Aggregates and is the direct responsibility of Subcommittee C09.64 on Nondestructive and In-Place Testing.

Current edition approved Aug. 1, 2008. Published September 2008. Originally approved in 1975. Last previous edition approved in 2002 as C 805 – 02.

[2] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

[3] ACI 228.1R-95, "In-Place Methods to Estimate Concrete Strength," American Concrete Institute (ACI), P.O. Box 9094, Farmington Hills, MI 48333-9094, http://www.concrete.org.

***A Summary of Changes section appears at the end of this standard.**

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a range of typical concrete surfaces so as to determine the magnitude of the differences to be expected.

5.5 This test method is not suitable as the basis for acceptance or rejection of concrete.

6. Apparatus

6.1 *Rebound Hammer*, consisting of a spring-loaded steel hammer that when released strikes a steel plunger in contact with the concrete surface. The spring-loaded hammer must travel with a consistent and reproducible velocity. The rebound distance of the steel hammer from the steel plunger is measured on a linear scale attached to the frame of the instrument.

NOTE 2—Several types and sizes of rebound hammers are commercially available to accommodate testing of various sizes and types of concrete construction.

6.2 *Abrasive Stone*, consisting of medium-grain texture silicon carbide or equivalent material.

6.3 *Test Anvil*, approximately 150-mm [6-in.] diameter by 150-mm [6-in.] high cylinder made of tool steel with an impact area hardened to 66 ± 2 HRC as measured by Test Methods E 18. An instrument guide is provided to center the rebound hammer over the impact area and keep the instrument perpendicular to the surface.

6.4 *Verification*—Rebound hammers shall be serviced and verified annually and whenever there is reason to question their proper operation. Verify the functional operation of a rebound hammer using the test anvil described in 6.3. During verification, support the test anvil on a bare concrete floor or slab. The manufacturer shall report the rebound number to be obtained by a properly operating instrument when tested on an anvil of specified hardness.

NOTE 3—Typically, a rebound hammer will result in a rebound number of 80 ± 2 when tested on the anvil described in 6.3. The test anvil needs to be supported on a rigid base to obtain reliable rebound numbers. Verification on the test anvil does not guarantee that the hammer will yield repeatable data at other points on the scale. The hammer can be verified at lower rebound numbers by using blocks of polished stone having uniform hardness. Some users compare several hammers on concrete or stone surfaces encompassing the usual range of rebound numbers encountered in the field.

7. Test Area and Interferences

7.1 *Selection of Test Surface*—Concrete members to be tested shall be at least 100 mm [4 in.] thick and fixed within a structure. Smaller specimens must be rigidly supported. Avoid areas exhibiting honeycombing, scaling, or high porosity. Do not compare test results if the form material against which the concrete was placed is not similar (see Note 4). Troweled surfaces generally exhibit higher rebound numbers than screeded or formed finishes. If possible, test structural slabs from the underside to avoid finished surfaces.

7.2 *Preparation of Test Surface*—A test area shall be at least 150 mm [6 in.] in diameter. Heavily textured, soft, or surfaces with loose mortar shall be ground flat with the abrasive stone described in 6.2. Smooth-formed or troweled surfaces do not have to be ground prior to testing (see Note 4). Do not compare results from ground and unground surfaces. Remove free surface water, if present, before testing.

NOTE 4—Where formed surfaces were ground, increases in rebound number of 2.1 for plywood formed surfaces and 0.4 for high-density plywood formed surfaces have been noted.[4] Dry concrete surfaces give higher rebound numbers than wet surfaces. The presence of surface carbonation can also result in higher rebound numbers.[5] In cases of a thick layer of carbonated concrete, it may be necessary to remove the carbonated layer in the test area, using a power grinder, to obtain rebound numbers that are representative of the interior concrete. Data are not available on the relationship between rebound number and thickness of carbonated concrete. The user should exercise professional judgment when testing carbonated concrete.

7.3 Do not test frozen concrete.

NOTE 5—Moist concrete at 0 °C [32 °F] or less may exhibit high rebound values. Concrete should be tested only after it has thawed. The temperatures of the rebound hammer itself may affect the rebound number. Rebound hammers at -18 °C [0 °F] may exhibit rebound numbers reduced by as much as 2 or 3 units[6].

7.4 For readings to be compared, the direction of impact, horizontal, downward, upward, or at another angle, must be the same or established correction factors shall be applied to the readings.

7.5 Do not conduct tests directly over reinforcing bars with cover less than 20 mm [0.75 in.].

NOTE 6—The location of reinforcement may be established using reinforcement locators or metal detectors. Follow the manufacturer's instructions for proper operation of such devices.

8. Procedure

8.1 Hold the instrument firmly so that the plunger is perpendicular to the test surface. Gradually push the instrument toward the test surface until the hammer impacts. After impact, maintain pressure on the instrument and, if necessary, depress the button on the side of the instrument to lock the plunger in its retracted position. Read the rebound number on the scale to the nearest whole number and record the rebound number. Take ten readings from each test area. No two impact tests shall be closer together than 25 mm [1 in.]. Examine the impression made on the surface after impact, and if the impact crushes or breaks through a near-surface air void disregard the reading and take another reading.

9. Calculation

9.1 Discard readings differing from the average of 10 readings by more than 6 units and determine the average of the remaining readings. If more than 2 readings differ from the average by 6 units, discard the entire set of readings and determine rebound numbers at 10 new locations within the test area.

10. Report

10.1 Report the following information, if known, for each test area.

10.1.1 General information:

10.1.1.1 Date of testing,

[4] Gaynor, R. D., "In-Place Strength of Concrete—A Comparison of Two Test Systems," and "Appendix to Series 193," National Ready Mixed Concrete Assn., TIL No. 272, November 1969.

[5] Zoldners, N. G., "Calibration and Use of Impact Test Hammer," *Proceedings* , American Concrete Institute, Vol 54, August 1957, pp. 161–165.

[6] National Ready Mixed Concrete Assn., TIL No. 260, April 1968.

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10.1.1.2 Air temperature and time of testing,
10.1.1.3 Age of concrete, and
10.1.1.4 Identification of test location in the concrete construction and the size of member tested.
10.1.2 Information about the concrete:
10.1.2.1 Mixture identification and type of coarse aggregate, and
10.1.2.2 Specified strength of concrete.
10.1.3 Description of test area:
10.1.3.1 Surface characteristics (trowelled, screeded. formed),
10.1.3.2 If applicable, type of form material used for test area,
10.1.3.3 If surface was ground and depth of grinding,
10.1.3.4 If applicable, curing conditions, and
10.1.3.5 Surface moisture condition (wet or dry).
10.1.4 Hammer information:
10.1.4.1 Hammer identification or serial number, and
10.1.4.2 Date of hammer verification.
10.1.5 Rebound number data:
10.1.5.1 Orientation of hammer during test,
10.1.5.2 On vertical surfaces (walls, columns, deep beams), relative elevation of test region,
10.1.5.3 Individual rebound numbers,
10.1.5.4 Remarks regarding discarded readings,
10.1.5.5 Average rebound number, and
10.1.5.6 If applicable, description of unusual conditions that may affect test readings.

11. Precision and Bias

11.1 *Precision*—The single-specimen, single-operator, machine, day standard deviation is 2.5 units (1s) as defined in Practice C 670. Therefore, the range of ten readings should not exceed 12.

11.2 *Bias*—The bias of this test method cannot be evaluated since the rebound number can only be determined in terms of this test method.

12. Keywords

12.1 concrete; in-place strength; nondestructive testing; rebound hammer; rebound number

SUMMARY OF CHANGES

Committee C09 has identified the location of selected changes to this test method since the last issue, C 805 – 02, that may impact the use of this test method. (Approved August 1, 2008)

(*1*) The standard was revised as a combined units designation.
(*2*) Revised 5.2 by requiring a correlation to be developed only by using cores.
(*3*) Revised 5.3 by adding information on the effect of elevation in a concrete placement.
(*4*) Revised 5.5 to clarify that the method is not suitable to accept or reject concrete.
(*5*) Revised 7.2 by adding a provision to remove free water before testing. Revised Note 4 by deleting the sentence referring to wetting of the surface.
(*6*) Revised Section 10 Report to provide more logical groupings of the information to be reported and to acknowledge that all the information may not be known.

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Designation: C 806 – 04

Standard Test Method for Restrained Expansion of Expansive Cement Mortar[1]

This standard is issued under the fixed designation C 806; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope

1.1 This test method covers the determination of length changes of expansive cement mortar, while under restraint, due to the development of internal forces resulting from hydration of the cement.

1.2 The values stated in non-SI units are to be regarded as the standard. When both the inch-pound units and the SI units are present, the non-SI units are to be regarded as the standard. The values in SI units are approximate, are listed for information only, and will likely provide different values than the inch-pound units.

1.3 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.* (**Warning**—Fresh hydraulic cement mixtures are caustic and may cause burns to skin and tissue upon prolonged exposure.[2])

2. Referenced Documents

2.1 *ASTM Standards:* [3]

A 307 Specification for Carbon Steel Bolts and Studs, 60 000 PSI Tensile Strength

C 157 Test Method for Length Change of Hardened-Hydraulic-Cement, Mortar, and Concrete

C 219 Terminology Relating to Hydraulic Cement

C 305 Practice for Mechanical Mixing of Hydraulic Cement Pastes and Mortars of Plastic Consistency

C 490 Practice for Use of Apparatus for the Determination of Length Change of Hardened Cement Paste, Mortar, and Concrete

C 670 Practice for Preparing Precision and Bias Statements for Test Methods for Construction Materials

C 778 Specification for Standard Sand

C 1005 Specification for Reference Masses and Devices for Determining Mass and Volume for Use in the Physical Testing of Hydraulic Cements

F 606 Test Methods for Determining the Mechanical Properties of Externally and Internally Threaded Fasteners, Washers, and Rivets

3. Terminology

3.1 Definitions of terms used in this test method are given in Terminology C 219.

4. Apparatus

4.1 *Molds*—The molds for casting test specimens, when used in conjunction with the restraining cage described in 4.2, shall provide for forming either 2 by 2 by 10-in. prisms having a 10-in. gage length, or 50 by 50 by 250-mm prisms having a 250-mm gage length. The molds shall otherwise conform to the requirements of Practice C 490, except that the gage stud holder, gage studs, and spacer screws described in that specification will not be used.

4.2 *Restraining Cage*, consisting of a threaded steel rod with steel end plates held in place by nuts as shown in Fig. 1. The rod shall be provided with cap nuts for prevention of corrosion. The rod shall conform to Specification A 307 Grade A except, it shall support 1180-lbf (5249 N) proof load when tested in accordance with Method 1 of Test Methods F 606.

4.3 *Length Comparator*—The length comparator for measuring length shall conform to and be used in accordance with the requirements of Practice C 490. If the terminals of the comparator are fitted with collars, they shall be such that the cap nuts on the ends of the threaded rod of the specimen do not rest on the collar during measuring.

4.4 *Tamper*—The tamper shall be made of nonabsorptive, nonabrasive material such as medium-hard rubber or seasoned oak wood, rendered nonabsorptive by immersion for 15 min in paraffin at approximately 392 °F (200 °C), and shall have a cross section of about ½ by 1 in. (13 by 25 mm) and convenient length of about 6 in. (150 mm). The tamping face of the tamper shall be flat and at right angles to the length of the tamper.

4.5 *Apparatus for Demolding Specimens*—Apparatus similar to that described in the Apparatus section of Test Method C 157, may be found useful for demolding specimens.

[1] This test method is under the jurisdiction of ASTM Committee C01 on Cement and is the direct responsibility of Subcommittee C01.13 on Special Cements.

Current edition approved July 1, 2004. Published July 2004. Originally approved in 1975. Last previous edition approved in 1995 as C 806 – 95.

[2] Section of Safety, Manual of Cement Testing, *Annual Book of ASTM Standards*, Vol 04.01.

[3] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

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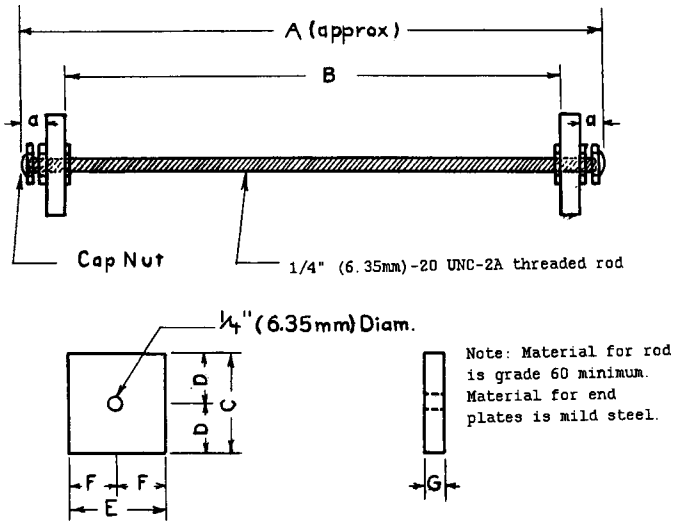

	Dimension, in. (mm)	Tolerance, in. (mm)
A	11¾ (300)	...
B	10 (250)	⅛ (3)
C	2 (50)	...
D	1 (25)	...
E	1 31/32 (49)	1/32 (1)
F	63/64 (24.5)	...
G	⅜ (10)	...

FIG. 1 Restraining Cage

4.6 *Weights and Weighing Devices*—Scales used shall comply with Specification C 1005.

NOTE 1—Generally defined, the sensibility reciprocal is the change in load required to change the position of rest of the indicating element or elements of a nonautomatic-indicating scale a definite amount at any load.

4.7 *Glass Graduates*, of suitable capacities (preferably large enough to measure the mixing water in a single operation) shall be made to deliver the indicated volume at 68 °F (20 °C). The permissible variation shall be ±2 mL. These graduates shall be subdivided to at least 5 mL, except that the graduation lines may be omitted for the lowest 10 mL for a 250-mL graduate and the lowest 25 mL for a 500-mL graduate. The main graduation lines shall be circles and shall be numbered. The least graduations shall extend at least one seventh of the way around, and intermediate graduations shall extend at least one fifth of the way around.

4.8 *Mixer, Bowl, and Paddle*—The mixer shall be an electrically driven mechanical mixer of the type equipped with paddle and mixing bowl, as specified in the Apparatus section of Practice C 305.

4.9 *Trowel*—The trowel shall have a steel blade 4 to 6 in. (102 to 152 mm) in length, with straight edges.

5. Temperature and Humidity

5.1 The temperature of the air in the vicinity of the mixing operation, the dry materials, mixing water, molds, base plates, mixing bowl, moist closet or moist room, and storage water shall not vary from 73.4 °F (23 °C) by more than ±3 °F (±1.7 °C).

5.2 The relative humidity of the laboratory shall be not less than 50 %. The moist closet or moist room shall provide a relative humidity of not less that 95 %.

6. Graded Standard Sand

6.1 Sand used shall comply with the graded sand requirement of Specification C 778.

Passing Sieve	Percentage Retained
No. 100 (150-µm)	98 ± 2
No. 50 (300-µm)	72 ± 5
No. 30 (600-µm)	2 ± 2
No. 16 (1.18-mm)	none

NOTE 2—*Segregation of Graded Sand*—The graded standard sand should be handled in such a manner as to prevent segregation, since variations in the grading of the sand cause variations in the consistency of the mortar. In emptying sacks of sand into bins or in scooping sand out of bins or sacks, care should be exercised to prevent the formation of mounds of sand or craters in the sand, down the slopes of which the coarser particles will roll. Bins should be of sufficient size to permit these precautions. Devices for drawing the sand from bins by gravity should not be used.

7. Test Specimen

7.1 The test specimen shall be a 2 by 2 by 10-in. prism having a 10-in. gage length, or a 50 by 50 by 250-mm prism

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having a 250-mm gage length. At least two specimens shall be prepared for each test.

8. Preparation and Assembly of Specimen Molds and Restraining Cage

8.1 Install the cap nuts firmly in place on the ends of the restraining rods and measure the restraining rods for length while they are at a temperature of 73.4 ± 1 °F (23.0 ± 0.5 °C).

8.2 The edges of the end plates of the restraining cage that contact the sides and bottom of the mold shall be thinly covered with a heavy mineral oil or light cup grease such as petrolatum. After assembly of the molds, place a restraining cage in each compartment. Seal the contact lines between the outer sides and base plate of the molds with paraffin or micro-crystalline wax. Thinly cover the interior faces of the molds with mineral oil and remove any oil or grease from the restraining cage rod and end plates.

9. Proportioning and Mixing of Mortars

9.1 Proportion the standard mortar by using one part of cement to 2.75 parts of graded standard sand by mass. Mix 800 g of cement, 2200 g of graded standard sand, and 400 mL of water to produce a batch sufficient for two test specimens.

9.2 Mix in accordance with the procedure for mixing mortars given in Practice C 305. Upon completion of mixing, shake the mixing paddle into the mixing bowl to remove excess mortar.

10. Molding Specimens

10.1 Start molding specimens immediately after completion of mixing. Place the mortar in the mold in two layers with the first layer just covering the restraining rod and the second layer slightly overfilling the mold. Compact each layer by tamping. Work the mortar into the corners, around the restraining rod, without striking the rod, and along the surfaces of the mold with the tamper until a homogeneous specimen is obtained. After the top layer has been compacted, strike-off the mortar flush with the top of the mold, and smooth the surface with a few strokes of the trowel.

11. Curing of Specimens

11.1 Immediately after completion of molding, cover the specimens with a polyethylene sheet, or other suitable material for preventing loss or gain of moisture, at the surface of the specimens. The cover should make contact with the surface of the mortar. Place the specimens in the moist room or moist cabinet.

11.2 Remove the specimens from the molds at an age of 6 ± ¼ h after the addition of water to the cement during the mixing operation (Note 3). Particular care must be exercised in this operation in order not to damage the specimens because of their low strength at this age. It is preferable to use the demolding devices referred to in 4.5 for freeing specimens from the base and side plates.

NOTE 3—At this time comparator readings may be made. Although these readings may differ slightly from the initial reading made on the restraining rod prior to molding the specimen, it can serve as a check on the initial reading which should be used as the basis for calculating the length change.

11.3 Cure the specimens in lime-saturated water at 73.4± 3.0 °F (23.0 ± 1.7 °C) until they have reached an age of 7 days ± 1 h, including the period in the molds, except that the temperature of the curing water shall be 73.4 ± 1 °F (23.0 ± 0.5 °C) for at least the last 15 min. At the end of this period, remove the specimens from the water one at a time, wipe with a damp cloth, and immediately make comparator readings with the cap nuts in place.

11.4 Return the specimens to curing in lime-saturated water at 73.4 ± 3.0 °F (23.0 ± 1.7 °C) until they have reached an age of 28 days including the period in the molds. At the end of the curing period, make comparator readings immediately after the specimens have been subjected to about 15 min of storage in water at 73.4 ± 1.0 °F (23.0± 0.5 °C) and in the same manner as described in 11.3.

12. Calculation

12.1 Calculate the expansion or shrinkage at any age as follows:

$$E_x = \frac{L_x - L_i}{10\,(250)} \times 100 \qquad (1)$$

where:

E_x = expansion at x age, %,
L_x = comparator reading of specimen at x age – reference bar comparator reading, in. (mm), and
L_i = initial comparator reading of restraining rod – reference bar comparator reading, in. (mm).

13. Report

13.1 Report the following information:

13.1.1 Number of specimens for each condition and date molded,

13.1.2 Source and identification of cement.

13.1.3 Age of specimen for each observation for length change,

13.1.4 Length-change data, expressed as linear expansion or contraction based on the length of the specimen at time of molding shall be reported as percent change dimension to the nearest 0.001 %, and

13.1.5 Any other pertinent information.

14. Precision and Bias [4]

14.1 *Precision*:

14.1.1 *Within Batch Precision*—The standard deviation of two bars made from the same batch and tested together was found to be 0.00276 %. Therefore two bars made from the same batch should not differ from each other by more than 0.008 % length change.[5]

14.1.2 *Single Operator Precision*—The single operator standard deviation has been found to be 0.0038 at seven and twenty eight days age, based on the average of two bars. Therefore the results of two properly conducted tests by the

[4] Supporting data have been filed at ASTM International Headquarters and may be obtained by requesting Research Report RR: C01-1001.

[5] These numbers represent, respectively, the (1s) and (d2s) limits as described in Practice C 670.

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same operator on the same material should not differ by more than 0.011 % length change.[5]

14.1.3 *Multilaboratory Precision*—The multilaboratory standard deviation has been found to be 0.0093 at seven and twenty eight days age, based on the average of two bars. Therefore the results of two properly conducted tests on the same material in two different laboratories should not differ by more than 0.026 % length change.[5]

14.2 *Bias*—A bias statement cannot be prepared due to the fact that absolute standards are not available.

15. Keywords

15.1 cement mortar; expansive cement; restrained expansion

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Designation: C 806 – 04

Standard Test Method for Restrained Expansion of Expansive Cement Mortar[1]

This standard is issued under the fixed designation C 806; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope

1.1 This test method covers the determination of length changes of expansive cement mortar, while under restraint, due to the development of internal forces resulting from hydration of the cement.

1.2 The values stated in non-SI units are to be regarded as the standard. When both the inch-pound units and the SI units are present, the non-SI units are to be regarded as the standard. The values in SI units are approximate, are listed for information only, and will likely provide different values than the inch-pound units.

1.3 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.* (**Warning**—Fresh hydraulic cement mixtures are caustic and may cause burns to skin and tissue upon prolonged exposure.[2])

2. Referenced Documents

2.1 *ASTM Standards:* [3]

A 307 Specification for Carbon Steel Bolts and Studs, 60 000 PSI Tensile Strength

C 157 Test Method for Length Change of Hardened-Hydraulic-Cement, Mortar, and Concrete

C 219 Terminology Relating to Hydraulic Cement

C 305 Practice for Mechanical Mixing of Hydraulic Cement Pastes and Mortars of Plastic Consistency

C 490 Practice for Use of Apparatus for the Determination of Length Change of Hardened Cement Paste, Mortar, and Concrete

C 670 Practice for Preparing Precision and Bias Statements for Test Methods for Construction Materials

C 778 Specification for Standard Sand

C 1005 Specification for Reference Masses and Devices for Determining Mass and Volume for Use in the Physical Testing of Hydraulic Cements

F 606 Test Methods for Determining the Mechanical Properties of Externally and Internally Threaded Fasteners, Washers, and Rivets

3. Terminology

3.1 Definitions of terms used in this test method are given in Terminology C 219.

4. Apparatus

4.1 *Molds*—The molds for casting test specimens, when used in conjunction with the restraining cage described in 4.2, shall provide for forming either 2 by 2 by 10-in. prisms having a 10-in. gage length, or 50 by 50 by 250-mm prisms having a 250-mm gage length. The molds shall otherwise conform to the requirements of Practice C 490, except that the gage stud holder, gage studs, and spacer screws described in that specification will not be used.

4.2 *Restraining Cage*, consisting of a threaded steel rod with steel end plates held in place by nuts as shown in Fig. 1. The rod shall be provided with cap nuts for prevention of corrosion. The rod shall conform to Specification A 307 Grade A except, it shall support 1180-lbf (5249 N) proof load when tested in accordance with Method 1 of Test Methods F 606.

4.3 *Length Comparator*—The length comparator for measuring length shall conform to and be used in accordance with the requirements of Practice C 490. If the terminals of the comparator are fitted with collars, they shall be such that the cap nuts on the ends of the threaded rod of the specimen do not rest on the collar during measuring.

4.4 *Tamper*—The tamper shall be made of nonabsorptive, nonabrasive material such as medium-hard rubber or seasoned oak wood, rendered nonabsorptive by immersion for 15 min in paraffin at approximately 392 °F (200 °C), and shall have a cross section of about ½ by 1 in. (13 by 25 mm) and convenient length of about 6 in. (150 mm). The tamping face of the tamper shall be flat and at right angles to the length of the tamper.

4.5 *Apparatus for Demolding Specimens*—Apparatus similar to that described in the Apparatus section of Test Method C 157, may be found useful for demolding specimens.

[1] This test method is under the jurisdiction of ASTM Committee C01 on Cement and is the direct responsibility of Subcommittee C01.13 on Special Cements.

Current edition approved July 1, 2004. Published July 2004. Originally approved in 1975. Last previous edition approved in 1995 as C 806 – 95.

[2] Section of Safety, Manual of Cement Testing, *Annual Book of ASTM Standards*, Vol 04.01.

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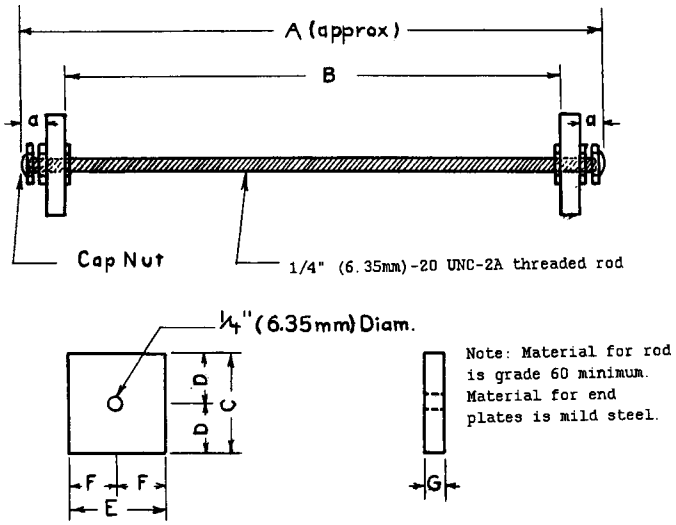

	Dimension, in. (mm)	Tolerance, in. (mm)
A	11¾ (300)	...
B	10 (250)	⅛ (3)
C	2 (50)	...
D	1 (25)	...
E	1 31/32 (49)	1/32 (1)
F	63/64 (24.5)	...
G	⅜ (10)	...

FIG. 1 Restraining Cage

4.6 *Weights and Weighing Devices*—Scales used shall comply with Specification C 1005.

NOTE 1—Generally defined, the sensibility reciprocal is the change in load required to change the position of rest of the indicating element or elements of a nonautomatic-indicating scale a definite amount at any load.

4.7 *Glass Graduates*, of suitable capacities (preferably large enough to measure the mixing water in a single operation) shall be made to deliver the indicated volume at 68 °F (20 °C). The permissible variation shall be ±2 mL. These graduates shall be subdivided to at least 5 mL, except that the graduation lines may be omitted for the lowest 10 mL for a 250-mL graduate and the lowest 25 mL for a 500-mL graduate. The main graduation lines shall be circles and shall be numbered. The least graduations shall extend at least one seventh of the way around, and intermediate graduations shall extend at least one fifth of the way around.

4.8 *Mixer, Bowl, and Paddle*—The mixer shall be an electrically driven mechanical mixer of the type equipped with paddle and mixing bowl, as specified in the Apparatus section of Practice C 305.

4.9 *Trowel*—The trowel shall have a steel blade 4 to 6 in. (102 to 152 mm) in length, with straight edges.

5. Temperature and Humidity

5.1 The temperature of the air in the vicinity of the mixing operation, the dry materials, mixing water, molds, base plates, mixing bowl, moist closet or moist room, and storage water shall not vary from 73.4 °F (23 °C) by more than ±3 °F (±1.7 °C).

5.2 The relative humidity of the laboratory shall be not less than 50 %. The moist closet or moist room shall provide a relative humidity of not less that 95 %.

6. Graded Standard Sand

6.1 Sand used shall comply with the graded sand requirement of Specification C 778.

Passing Sieve	Percentage Retained
No. 100 (150-µm)	98 ± 2
No. 50 (300-µm)	72 ± 5
No. 30 (600-µm)	2 ± 2
No. 16 (1.18-mm)	none

NOTE 2—*Segregation of Graded Sand*—The graded standard sand should be handled in such a manner as to prevent segregation, since variations in the grading of the sand cause variations in the consistency of the mortar. In emptying sacks of sand into bins or in scooping sand out of bins or sacks, care should be exercised to prevent the formation of mounds of sand or craters in the sand, down the slopes of which the coarser particles will roll. Bins should be of sufficient size to permit these precautions. Devices for drawing the sand from bins by gravity should not be used.

7. Test Specimen

7.1 The test specimen shall be a 2 by 2 by 10-in. prism having a 10-in. gage length, or a 50 by 50 by 250-mm prism

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having a 250-mm gage length. At least two specimens shall be prepared for each test.

8. Preparation and Assembly of Specimen Molds and Restraining Cage

8.1 Install the cap nuts firmly in place on the ends of the restraining rods and measure the restraining rods for length while they are at a temperature of 73.4 ± 1 °F (23.0 ± 0.5 °C).

8.2 The edges of the end plates of the restraining cage that contact the sides and bottom of the mold shall be thinly covered with a heavy mineral oil or light cup grease such as petrolatum. After assembly of the molds, place a restraining cage in each compartment. Seal the contact lines between the outer sides and base plate of the molds with paraffin or micro-crystalline wax. Thinly cover the interior faces of the molds with mineral oil and remove any oil or grease from the restraining cage rod and end plates.

9. Proportioning and Mixing of Mortars

9.1 Proportion the standard mortar by using one part of cement to 2.75 parts of graded standard sand by mass. Mix 800 g of cement, 2200 g of graded standard sand, and 400 mL of water to produce a batch sufficient for two test specimens.

9.2 Mix in accordance with the procedure for mixing mortars given in Practice C 305. Upon completion of mixing, shake the mixing paddle into the mixing bowl to remove excess mortar.

10. Molding Specimens

10.1 Start molding specimens immediately after completion of mixing. Place the mortar in the mold in two layers with the first layer just covering the restraining rod and the second layer slightly overfilling the mold. Compact each layer by tamping. Work the mortar into the corners, around the restraining rod, without striking the rod, and along the surfaces of the mold with the tamper until a homogeneous specimen is obtained. After the top layer has been compacted, strike-off the mortar flush with the top of the mold, and smooth the surface with a few strokes of the trowel.

11. Curing of Specimens

11.1 Immediately after completion of molding, cover the specimens with a polyethylene sheet, or other suitable material for preventing loss or gain of moisture, at the surface of the specimens. The cover should make contact with the surface of the mortar. Place the specimens in the moist room or moist cabinet.

11.2 Remove the specimens from the molds at an age of 6 ± ¼ h after the addition of water to the cement during the mixing operation (Note 3). Particular care must be exercised in this operation in order not to damage the specimens because of their low strength at this age. It is preferable to use the demolding devices referred to in 4.5 for freeing specimens from the base and side plates.

NOTE 3—At this time comparator readings may be made. Although these readings may differ slightly from the initial reading made on the restraining rod prior to molding the specimen, it can serve as a check on the initial reading which should be used as the basis for calculating the length change.

11.3 Cure the specimens in lime-saturated water at 73.4± 3.0 °F (23.0 ± 1.7 °C) until they have reached an age of 7 days ± 1 h, including the period in the molds, except that the temperature of the curing water shall be 73.4 ± 1 °F (23.0 ± 0.5 °C) for at least the last 15 min. At the end of this period, remove the specimens from the water one at a time, wipe with a damp cloth, and immediately make comparator readings with the cap nuts in place.

11.4 Return the specimens to curing in lime-saturated water at 73.4 ± 3.0 °F (23.0 ± 1.7 °C) until they have reached an age of 28 days including the period in the molds. At the end of the curing period, make comparator readings immediately after the specimens have been subjected to about 15 min of storage in water at 73.4 ± 1.0 °F (23.0± 0.5 °C) and in the same manner as described in 11.3.

12. Calculation

12.1 Calculate the expansion or shrinkage at any age as follows:

$$E_x = \frac{L_x - L_i}{10\,(250)} \times 100 \qquad (1)$$

where:

E_x = expansion at x age, %,
L_x = comparator reading of specimen at x age – reference bar comparator reading, in. (mm), and
L_i = initial comparator reading of restraining rod – reference bar comparator reading, in. (mm).

13. Report

13.1 Report the following information:

13.1.1 Number of specimens for each condition and date molded,

13.1.2 Source and identification of cement.

13.1.3 Age of specimen for each observation for length change,

13.1.4 Length-change data, expressed as linear expansion or contraction based on the length of the specimen at time of molding shall be reported as percent change dimension to the nearest 0.001 %, and

13.1.5 Any other pertinent information.

14. Precision and Bias [4]

14.1 *Precision*:

14.1.1 *Within Batch Precision*—The standard deviation of two bars made from the same batch and tested together was found to be 0.00276 %. Therefore two bars made from the same batch should not differ from each other by more than 0.008 % length change.[5]

14.1.2 *Single Operator Precision*—The single operator standard deviation has been found to be 0.0038 at seven and twenty eight days age, based on the average of two bars. Therefore the results of two properly conducted tests by the

[4] Supporting data have been filed at ASTM International Headquarters and may be obtained by requesting Research Report RR: C01-1001.

[5] These numbers represent, respectively, the (1s) and (d2s) limits as described in Practice C 670.

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same operator on the same material should not differ by more than 0.011 % length change.[5]

14.1.3 *Multilaboratory Precision*—The multilaboratory standard deviation has been found to be 0.0093 at seven and twenty eight days age, based on the average of two bars. Therefore the results of two properly conducted tests on the same material in two different laboratories should not differ by more than 0.026 % length change.[5]

14.2 *Bias*—A bias statement cannot be prepared due to the fact that absolute standards are not available.

15. Keywords

15.1 cement mortar; expansive cement; restrained expansion

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Designation: C 807 – 08

Standard Test Method for Time of Setting of Hydraulic Cement Mortar by Modified Vicat Needle[1]

This standard is issued under the fixed designation C 807; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope*

1.1 This test method covers the determination of the time of setting of hydraulic cement mortar by means of the modified Vicat needle.

1.2 The values stated in SI units are to be regarded as standard. No other units of measurement are included in this standard.

1.3 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.* (**Warning**—Fresh hydraulic cementitious mixtures are caustic and may cause chemical burns to skin and tissue upon prolonged exposure. The use of gloves, protective clothing, and eye protection is recommended. Wash contact area with copious amounts of water after contact. Wash eyes for a minimum of 15 min. Avoid exposure of the body to clothing saturated with the liquid phase of the unhardened material. Remove contaminated clothing immediately after exposure.)

1.4 The text of this standard references notes and footnotes which provide explanatory material. These notes and footnotes (excluding those in tables and figures) shall not be considered as requirements of the standard.

2. Referenced Documents

2.1 *ASTM Standards:* [2]

C 109/C 109M Test Method for Compressive Strength of Hydraulic Cement Mortars (Using 2-in. or [50-mm] Cube Specimens)

C 183 Practice for Sampling and the Amount of Testing of Hydraulic Cement

C 187 Test Method for Normal Consistency of Hydraulic Cement

C 219 Terminology Relating to Hydraulic Cement

C 305 Practice for Mechanical Mixing of Hydraulic Cement Pastes and Mortars of Plastic Consistency

C 511 Specification for Mixing Rooms, Moist Cabinets, Moist Rooms, and Water Storage Tanks Used in the Testing of Hydraulic Cements and Concretes

C 670 Practice for Preparing Precision and Bias Statements for Test Methods for Construction Materials

C 778 Specification for Standard Sand

C 845 Specification for Expansive Hydraulic Cement

C 1005 Specification for Reference Masses and Devices for Determining Mass and Volume for Use in the Physical Testing of Hydraulic Cements

D 1193 Specification for Reagent Water

3. Terminology

3.1 Terms used in this standard are defined in Terminology C 219.

4. Summary of Test Method

4.1 A mortar is prepared with the cement to be tested, using stipulated quantities of cement and water, and sufficient standard sand to produce a required consistency as determined by a stipulated penetration using the plunger of the modified Vicat apparatus. Mortar of the proper consistency is then tested for time of setting, using the needle of the modified Vicat apparatus for the determination of a stipulated penetration. The time required to obtain the stipulated penetration of the modified Vicat needle is the time of setting.

5. Significance and Use

5.1 The purpose of this test method is to establish whether or not a cement complies with a specification limit on time of setting. It has been found to be particularly applicable for the determination of the setting time of expansive cements (see Specification C 845).

6. Apparatus

6.1 *Tamper and Trowel*, conforming to the requirements of Test Method C 109/C 109M. In addition, the edges of the trowel when placed on a plane surface shall not depart from straightness by more than 1 mm.

[1] This test method is under the jurisdiction of ASTM Committee C01 on Cement and is the direct responsibility of Subcommittee C01.30 on Time of Set.

Current edition approved June 1, 2008. Published July 2008. Originally approved in 1975. Last previous edition approved in 2005 as C 807 – 05.

[2] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

***A Summary of Changes section appears at the end of this standard.**

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6.2 *Vicat Apparatus*, conforming to the requirements of Test Method C 187, with the following modifications:

6.2.1 For consistency determination, the plunger end of the movable rod shall be 17.5 ± 0.5 mm in diameter instead of 10 mm, and the total mass of the movable rod (including the 17.5-mm plunger) shall be 400 ± 0.5 g.

6.2.2 For time of setting determination, a 2 ± 0.05-mm stainless steel needle shall be substituted for the 1-mm needle. The total mass of the movable rod with the 2-mm needle shall be 300 ± 0.5 g.

6.3 *Mold for Consistency and Setting Time*—A smooth cylindrical brass ring 76 ± 0.5 mm inside diameter (3-in. brass tubing) by 40 ± 1 mm deep, cemented to a plane, non-absorptive plate, or smooth cylindrical brass cups having the above dimensions.

6.4 *Mixer, Bowl, Paddle, and Scraper*, conforming to the requirements of Practice C 305.

6.5 *Glass Graduates*, conforming to the requirements of Specification C 1005.

6.6 *Masses and Mass Determining Devices*, conforming to the requirements of Specification C 1005. The devices for determining mass shall be evaluated for precision and accuracy at a total load of 1000 g.

7. Reagents and Materials

7.1 *Graded Standard Sand*, conforming to the requirements of Specification C 778.

7.2 *Mixing Water*—Potable water is satisfactory for routine tests. For all referee and cooperative tests, reagent water conforming to the requirements of Specification D 1193 for Type III or Type IV grade of reagent water shall be used.

8. Sampling

8.1 When the test is part of acceptance testing, sample the cement in accordance with Practice C 183.

9. Conditioning

9.1 Maintain the temperature of the room, dry materials, paddle, bowl, and molds at 23.0 ± 3.0 °C.

9.2 Maintain the temperature of the mixing water at 23.0 ± 2.0 °C

9.3 The relative humidity of the mixing room shall not be less than 50 %.

9.4 The moist closet or moist room shall be in accordance with Specification C 511.

10. Procedure

10.1 *Preparation of Mortar*:

10.1.1 Mix 750 g of cement, 375 mL of water, and the quantity of graded standard sand required to give the consistency specified below under "Test for Consistency" in accordance with the mortar mixing procedure described in Practice C 305.

10.1.2 Upon completion of mixing, place a layer of mortar about 20 mm in thickness in the mold and puddle with the tamper. Hold the tamper with the 25-mm side parallel to the radius of the mold for 14 strokes spaced equally around the outside of the mold. Apply an additional four strokes to the center of the specimen with the longitudinal axis of the tamper at the center of the mold and rotate the tamper 45° between each stroke. Then fill the mold to overflowing with mortar and puddle as specified for the first layer. Cut off the mortar to a plane surface flush with the top of the mold in two operations. First, with the trowel held at about a 20° angle, start at one side of the mold, 10 mm above the mold, and finish the stroke by cutting the mortar off the top of the mold at the opposite side. Second, starting from the opposite direction, cut the mortar flush with the top of the mold by drawing the straight edge of the trowel (held nearly perpendicular to the mold) with a sawing motion across the top of the mold.

10.2 *Test for Consistency*—Center the mortar confined in the mold under the movable rod of the modified Vicat apparatus described above. Bring the plunger in contact with the surface of the mortar and tighten the setscrew. Then set the movable indicator to the upper zero mark on the scale, or take an initial reading, and release the rod 35 to 50 s after starting to fill the mold. The mortar shall have the desired consistency when the rod settles to a point 20 ± 4 mm below the original surface 30 s after being released. Cover the bowl containing the remainder of the mortar with the lid while the consistency test is being made. Make trial mortars with varying percentages of standard sand until the desired consistency is obtained.

10.3 *Test for Time of Setting*—Mix the mortar remaining in the bowl at medium speed (285 ± 10 rpm) for 30 s after it has been found that the mortar has the proper consistency. Following the completion of the mixing, mold the test specimen as specified above. Immediately after molding, place the test specimen in the moist closet or moist room where it shall remain except when penetration tests are being made. Allow the time of setting specimen to remain in the moist closet or moist room for 30 min without being disturbed. Then, using the modified Vicat apparatus described above, bring the needle in contact with the surface of the mortar and tighten the setscrew. Set the movable indicator to the upper zero mark on the scale, or take an initial reading. Release the rod quickly by releasing the setscrew, and allow the needle to settle for 30 s. Determine the penetration of the needle at this time and every 30 min thereafter until the needle fails to penetrate to the bottom of the mold. Then, take penetration tests every 10 min until a penetration of 10 mm or less is obtained. Perform no penetration test closer than 10 mm from any previous penetration test or from the inside edge of the mold. Record the results of all penetration tests, and, by interpolation, determine the time when a penetration of 10 mm is obtained. The difference, in minutes, between the time of contact of cement and water in the mortar mixing procedure and the time a penetration of 10 mm is obtained is the time of setting.

10.4 *Precautions*—Maintain testing apparatus on a rigid surface, free of vibration during the penetration test. Do not oil the plunger of the Vicat apparatus at any time, but keep the plunger and guide bearing clean at all times.

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11. Calculation

11.1 Calculate the time of setting to the nearest one minute as follows:

$$\left(\left(\frac{(H-E)}{(C-D)}\right) \times (C-10)\right) + E \quad (1)$$

where:

E = time in minutes of last penetration greater than 10 mm,
H = time in minutes of first penetration less than 10 mm,
C = penetration reading at Time E, and
D = penetration reading at Time H.

12. Report

12.1 Report the time of setting in minutes, to the nearest one minute.

13. Precision and Bias

13.1 The multilaboratory standard deviation has been found to be 15.2 min. Therefore, the results of two properly conducted tests from two different laboratories on samples of the same cement should not differ by more than 43 min. (See Note 1)

13.2 No information can be presented on the bias of the procedure in this test method for measuring time of setting because no material having an accepted reference value is available.

NOTE 1—These numbers represent, respectively, the 1s and d2s limits as defined in Practice C 670.

14. Keywords

14.1 hydraulic-cement mortar; time of setting; Vicat needle, expansive

SUMMARY OF CHANGES

Committee C01 has identified the location of selected changes to this test method since the last issue, C 807 – 05, that may impact the use of this test method. (Approved June 1, 2008)

(*1*) Editorially revised the units statement in 1.2 to conform to ASTM Form and Style.

(*2*) Revised 6.1, 6.6, and 9.3.

(*3*) Editorially revised 11.1 and 12.1.

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Designation: C 807 – 08

Standard Test Method for Time of Setting of Hydraulic Cement Mortar by Modified Vicat Needle[1]

This standard is issued under the fixed designation C 807; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope*

1.1 This test method covers the determination of the time of setting of hydraulic cement mortar by means of the modified Vicat needle.

1.2 The values stated in SI units are to be regarded as standard. No other units of measurement are included in this standard.

1.3 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.* (**Warning**—Fresh hydraulic cementitious mixtures are caustic and may cause chemical burns to skin and tissue upon prolonged exposure. The use of gloves, protective clothing, and eye protection is recommended. Wash contact area with copious amounts of water after contact. Wash eyes for a minimum of 15 min. Avoid exposure of the body to clothing saturated with the liquid phase of the unhardened material. Remove contaminated clothing immediately after exposure.)

1.4 The text of this standard references notes and footnotes which provide explanatory material. These notes and footnotes (excluding those in tables and figures) shall not be considered as requirements of the standard.

2. Referenced Documents

2.1 *ASTM Standards:* [2]

C 109/C 109M Test Method for Compressive Strength of Hydraulic Cement Mortars (Using 2-in. or [50-mm] Cube Specimens)

C 183 Practice for Sampling and the Amount of Testing of Hydraulic Cement

C 187 Test Method for Normal Consistency of Hydraulic Cement

C 219 Terminology Relating to Hydraulic Cement

C 305 Practice for Mechanical Mixing of Hydraulic Cement Pastes and Mortars of Plastic Consistency

C 511 Specification for Mixing Rooms, Moist Cabinets, Moist Rooms, and Water Storage Tanks Used in the Testing of Hydraulic Cements and Concretes

C 670 Practice for Preparing Precision and Bias Statements for Test Methods for Construction Materials

C 778 Specification for Standard Sand

C 845 Specification for Expansive Hydraulic Cement

C 1005 Specification for Reference Masses and Devices for Determining Mass and Volume for Use in the Physical Testing of Hydraulic Cements

D 1193 Specification for Reagent Water

3. Terminology

3.1 Terms used in this standard are defined in Terminology C 219.

4. Summary of Test Method

4.1 A mortar is prepared with the cement to be tested, using stipulated quantities of cement and water, and sufficient standard sand to produce a required consistency as determined by a stipulated penetration using the plunger of the modified Vicat apparatus. Mortar of the proper consistency is then tested for time of setting, using the needle of the modified Vicat apparatus for the determination of a stipulated penetration. The time required to obtain the stipulated penetration of the modified Vicat needle is the time of setting.

5. Significance and Use

5.1 The purpose of this test method is to establish whether or not a cement complies with a specification limit on time of setting. It has been found to be particularly applicable for the determination of the setting time of expansive cements (see Specification C 845).

6. Apparatus

6.1 *Tamper and Trowel*, conforming to the requirements of Test Method C 109/C 109M. In addition, the edges of the trowel when placed on a plane surface shall not depart from straightness by more than 1 mm.

[1] This test method is under the jurisdiction of ASTM Committee C01 on Cement and is the direct responsibility of Subcommittee C01.30 on Time of Set.

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6.2 *Vicat Apparatus*, conforming to the requirements of Test Method C 187, with the following modifications:

6.2.1 For consistency determination, the plunger end of the movable rod shall be 17.5 ± 0.5 mm in diameter instead of 10 mm, and the total mass of the movable rod (including the 17.5-mm plunger) shall be 400 ± 0.5 g.

6.2.2 For time of setting determination, a 2 ± 0.05-mm stainless steel needle shall be substituted for the 1-mm needle. The total mass of the movable rod with the 2-mm needle shall be 300 ± 0.5 g.

6.3 *Mold for Consistency and Setting Time*—A smooth cylindrical brass ring 76 ± 0.5 mm inside diameter (3-in. brass tubing) by 40 ± 1 mm deep, cemented to a plane, non-absorptive plate, or smooth cylindrical brass cups having the above dimensions.

6.4 *Mixer, Bowl, Paddle, and Scraper*, conforming to the requirements of Practice C 305.

6.5 *Glass Graduates*, conforming to the requirements of Specification C 1005.

6.6 *Masses and Mass Determining Devices*, conforming to the requirements of Specification C 1005. The devices for determining mass shall be evaluated for precision and accuracy at a total load of 1000 g.

7. Reagents and Materials

7.1 *Graded Standard Sand*, conforming to the requirements of Specification C 778.

7.2 *Mixing Water*—Potable water is satisfactory for routine tests. For all referee and cooperative tests, reagent water conforming to the requirements of Specification D 1193 for Type III or Type IV grade of reagent water shall be used.

8. Sampling

8.1 When the test is part of acceptance testing, sample the cement in accordance with Practice C 183.

9. Conditioning

9.1 Maintain the temperature of the room, dry materials, paddle, bowl, and molds at 23.0 ± 3.0 °C.

9.2 Maintain the temperature of the mixing water at 23.0 ± 2.0 °C

9.3 The relative humidity of the mixing room shall not be less than 50 %.

9.4 The moist closet or moist room shall be in accordance with Specification C 511.

10. Procedure

10.1 *Preparation of Mortar*:

10.1.1 Mix 750 g of cement, 375 mL of water, and the quantity of graded standard sand required to give the consistency specified below under "Test for Consistency" in accordance with the mortar mixing procedure described in Practice C 305.

10.1.2 Upon completion of mixing, place a layer of mortar about 20 mm in thickness in the mold and puddle with the tamper. Hold the tamper with the 25-mm side parallel to the radius of the mold for 14 strokes spaced equally around the outside of the mold. Apply an additional four strokes to the center of the specimen with the longitudinal axis of the tamper at the center of the mold and rotate the tamper 45° between each stroke. Then fill the mold to overflowing with mortar and puddle as specified for the first layer. Cut off the mortar to a plane surface flush with the top of the mold in two operations. First, with the trowel held at about a 20° angle, start at one side of the mold, 10 mm above the mold, and finish the stroke by cutting the mortar off the top of the mold at the opposite side. Second, starting from the opposite direction, cut the mortar flush with the top of the mold by drawing the straight edge of the trowel (held nearly perpendicular to the mold) with a sawing motion across the top of the mold.

10.2 *Test for Consistency*—Center the mortar confined in the mold under the movable rod of the modified Vicat apparatus described above. Bring the plunger in contact with the surface of the mortar and tighten the setscrew. Then set the movable indicator to the upper zero mark on the scale, or take an initial reading, and release the rod 35 to 50 s after starting to fill the mold. The mortar shall have the desired consistency when the rod settles to a point 20 ± 4 mm below the original surface 30 s after being released. Cover the bowl containing the remainder of the mortar with the lid while the consistency test is being made. Make trial mortars with varying percentages of standard sand until the desired consistency is obtained.

10.3 *Test for Time of Setting*—Mix the mortar remaining in the bowl at medium speed (285 ± 10 rpm) for 30 s after it has been found that the mortar has the proper consistency. Following the completion of the mixing, mold the test specimen as specified above. Immediately after molding, place the test specimen in the moist closet or moist room where it shall remain except when penetration tests are being made. Allow the time of setting specimen to remain in the moist closet or moist room for 30 min without being disturbed. Then, using the modified Vicat apparatus described above, bring the needle in contact with the surface of the mortar and tighten the setscrew. Set the movable indicator to the upper zero mark on the scale, or take an initial reading. Release the rod quickly by releasing the setscrew, and allow the needle to settle for 30 s. Determine the penetration of the needle at this time and every 30 min thereafter until the needle fails to penetrate to the bottom of the mold. Then, take penetration tests every 10 min until a penetration of 10 mm or less is obtained. Perform no penetration test closer than 10 mm from any previous penetration test or from the inside edge of the mold. Record the results of all penetration tests, and, by interpolation, determine the time when a penetration of 10 mm is obtained. The difference, in minutes, between the time of contact of cement and water in the mortar mixing procedure and the time a penetration of 10 mm is obtained is the time of setting.

10.4 *Precautions*—Maintain testing apparatus on a rigid surface, free of vibration during the penetration test. Do not oil the plunger of the Vicat apparatus at any time, but keep the plunger and guide bearing clean at all times.

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11. Calculation

11.1 Calculate the time of setting to the nearest one minute as follows:

$$\left(\left(\frac{(H-E)}{(C-D)}\right) \times (C-10)\right) + E \quad (1)$$

where:

E = time in minutes of last penetration greater than 10 mm,
H = time in minutes of first penetration less than 10 mm,
C = penetration reading at Time E, and
D = penetration reading at Time H.

12. Report

12.1 Report the time of setting in minutes, to the nearest one minute.

13. Precision and Bias

13.1 The multilaboratory standard deviation has been found to be 15.2 min. Therefore, the results of two properly conducted tests from two different laboratories on samples of the same cement should not differ by more than 43 min. (See Note 1)

13.2 No information can be presented on the bias of the procedure in this test method for measuring time of setting because no material having an accepted reference value is available.

NOTE 1—These numbers represent, respectively, the 1s and d2s limits as defined in Practice C 670.

14. Keywords

14.1 hydraulic-cement mortar; time of setting; Vicat needle, expansive

SUMMARY OF CHANGES

Committee C01 has identified the location of selected changes to this test method since the last issue, C 807 – 05, that may impact the use of this test method. (Approved June 1, 2008)

(*1*) Editorially revised the units statement in 1.2 to conform to ASTM Form and Style.

(*2*) Revised 6.1, 6.6, and 9.3.

(*3*) Editorially revised 11.1 and 12.1.

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Designation: C 821 – 09

Standard Specification for Lime for Use with Pozzolans[1]

This standard is issued under the fixed designation C 821; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope*

1.1 This specification covers all types of commercial hydrated lime such as: high-calcium, magnesium, or dolomitic-hydrated lime. By-product limes and slaked quick limes in dry, wet, or slurried form are also included.

1.2 The values stated in inch-pound units are to be regarded as standard. The values given in parentheses are mathematical conversions to SI units that are provided for information only and are not considered standard.

1.3 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

2. Referenced Documents

2.1 *ASTM Standards:*[2]

C 25 Test Methods for Chemical Analysis of Limestone, Quicklime, and Hydrated Lime

C 50 Practice for Sampling, Sample Preparation, Packaging, and Marking of Lime and Limestone Products

C 51 Terminology Relating to Lime and Limestone (as used by the Industry)

C 204 Test Methods for Fineness of Hydraulic Cement by Air-Permeability Apparatus

C 593 Specification for Fly Ash and Other Pozzolans for Use With Lime for Soil Stabilization

3. Terminology

3.1 *Definitions*:

3.1.1 For definitions of terms used in this specification, refer to Terminology C 51.

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *chemical factor*, *n*—a numerical value of the active constituents in the hydrated lime that react chemically with a pozzolan. The value is based on the combined calcium oxide equivalents of free calcium oxide, calcium hydroxide, and magnesium oxide. Calcium carbonate and magnesium hydroxide are excluded, since these compounds have been found to be nonreactive.

3.2.2 *pozzolanic receptivity index*, *n*—a performance factor incorporating both chemical quality and fineness, determined by Eq 3.

4. Chemical and Physical Requirements

4.1 The lime shall conform to the requirements listed in Table 1, except as noted in Section 5.

5. Performance Requirements

5.1 If the chemical factor, Blaine fineness, or pozzolanic receptivity index is below the limits given in Table 1, the lime shall be required to meet the applicable performance requirements listed in Table 2. Where such lime complies with the limits listed in Table 2, it shall be considered acceptable for use with pozzolans. However, it may be necessary to increase the lime content in the lime-pozzolan mixtures in order to meet minimum design criteria.

6. Test Methods

6.1 *Chemical Factor*:

6.1.1 Determine calcium oxide (CaO), magnesium oxide (MgO), and carbon dioxide (CO_2) contents in accordance with Test Methods C 25. When the magnesium oxide content is greater than 5 %, determine the peak height of magnesium oxide and magnesium hydroxide using standard X-ray diffraction procedures and calculate the ratio (*r*) of magnesium oxide to hydroxide using Eq 1. When the magnesium oxide is less than 5 %, the value of *r* shall be 0.30.

$$r = \frac{\text{cps MgO}}{\text{cps MgO} + 2.0\ (\text{cps Mg}(\text{OH})_2)} \quad (1)$$

where:

cps = counts per second of principal peaks corresponding to an interplanar spacing for MgO of 2.106 Å and for $Mg(OH)_2$ of 2.365 Å.

6.1.2 *Calculation of Chemical Factor*—Using the test results provided by 6.1.1 the chemical factor (C.F.) is determined by Eq 2:

$$\text{C.F.} = (\text{CaO}) - 1.27\ (\text{CO}_2) + 1.4\ r\ (\text{MgO}) \quad (2)$$

[1] This specification is under the jurisdiction of ASTM Committee C07 on Lime and is the direct responsibility of Subcommittee C07.02 on Specifications and Guidelines.

Current edition approved June 1, 2009. Published July 2009. Originally approved in 1975. Last previous edition approved in 2000 as C 821 – 78(2000).

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TABLE 1 Chemical and Physical Requirements

Chemical factor, min	50
Blaine fineness, min, cm^2/g	10 000
Pozzolanic receptivity index, min	100

TABLE 2 Performance Requirements

Plastic Compositions:		
Lime-pozzolan strength, min, psi (MPa)	600	(4.13)
Nonplastic Compositions:		
Lime-pozzolan-aggregate strength, min, psi (MPa)	400	(2.76)
Vacuum saturation strength, min, psi (MPa)	400	(2.8)

6.2 *Blaine Fineness*—Calculate in accordance with Method C 204, except use the specific gravity of the lime in calculating the trial weight of the sample, and the weight finally chosen must result in a firm bed as described in Test Method C 204. Use the specific gravity of the lime and finally chosen weight to determine the porosity of the bed in accordance with Eq 2 of Test Method C 204, and use this porosity (as well as specific gravity) in calculating the surface area.

6.3 *Pozzolanic Receptivity Index (PRI)*:

$$\text{PRI} = \frac{\text{chemical factor} \times \text{Blaine fineness}}{10\ 000} \quad (3)$$

6.4 *Lime-Pozzolan Strength*—See Specification C 593, Section 7. The pozzolan used shall pass the requirements of Specification C 593 when tested with a lime having a pozzolanic receptivity index of 80 or higher.

6.5 *Lime-Pozzolan-Aggregate Strength, Freeze-Thaw Resistance*—See Specification C 593, Section 8. The pozzolan used shall pass the requirements of Specification C 593 when tested with a lime having a pozzolanic receptivity index of 80 or higher.

7. Sampling, Inspection, Packing, and Marking

7.1 The sampling, inspection, rejection, retesting, packing, and marking shall be conducted in accordance with Methods C 50.

8. Keywords

8.1 hydrated; lime; pozzolans

SUMMARY OF CHANGES

Committee C07 has identified the location of selected changes to this specification since the last issue, C 821 – 78(2000), that may impact the use of this specification. (Approved June 1, 2009)

(*1*) This specification was reinstated with revision. A units statement was added in new 1.2 and subsequent paragraphs were renumbered. Reference to Terminology C 51 was added to Section 3 and Referenced Documents.

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Designation: C 823/C 823M – 07

Standard Practice for Examination and Sampling of Hardened Concrete in Constructions[1]

This standard is issued under the fixed designation C 823/C 823M; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

This standard has been approved for use by agencies of the Department of Defense.

1. Scope*

1.1 This practice outlines procedures for visual examination and sampling of hardened concrete in constructions. Reference is made to the examination and sampling of concrete in prefabricated building units, precast products, and laboratory specimens.

1.2 The values stated in either inch-pound units or SI units shall be regarded separately as standard. Inch-pound units are shown in parentheses. The values stated in each system may not be exact equivalents; therefore, each system must be used independently of the other. Combining values from the two systems may result in nonconformance with the standard.

1.3 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

2. Referenced Documents

2.1 *ASTM Standards:* [2]

C 42/C 42M Test Method for Obtaining and Testing Drilled Cores and Sawed Beams of Concrete

C 125 Terminology Relating to Concrete and Concrete Aggregates

C 215 Test Method for Fundamental Transverse, Longitudinal, and Torsional Resonant Frequencies of Concrete Specimens

C 295 Guide for Petrographic Examination of Aggregates for Concrete

C 457 Test Method for Microscopical Determination of Parameters of the Air-Void System in Hardened Concrete

C 597 Test Method for Pulse Velocity Through Concrete

C 670 Practice for Preparing Precision and Bias Statements for Test Methods for Construction Materials

C 856 Practice for Petrographic Examination of Hardened Concrete

E 105 Practice for Probability Sampling Of Materials

E 122 Practice for Calculating Sample Size to Estimate, With a Specified Tolerable Error, the Average for a Characteristic of a Lot or Process

E 141 Practice for Acceptance of Evidence Based on the Results of Probability Sampling

3. Terminology

3.1 *Definitions*—For definitions of terms used in this practice, refer to Terminology C 125.

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *concrete constructions*, *n*—any object, unit, or structure that has been built of hydraulic cement concrete.

3.2.2 *category of concrete*, *n*—a specified level of quality in concrete that is observed to be in a definable range of condition as a result of service or test exposure, as distinguished from concrete in the same or related constructions that is either of differing specified quality or of the same specified quality but in observably different condition at the time of examination. It is also used to refer to concrete having a certain attribute or attributes. (see the Sampling Plan Section).

4. Significance and Use

4.1 The examination may provide a basis for laying out in situ testing of the concrete.

4.2 The sampling can provide materials for petrographic examination, in accordance with Practice C 856, chemical or physical analytical procedures, or any of a wide variety of

[1] This practice is under the jurisdiction of ASTM Committee C09 on Concrete and Concrete Aggregates , and is the direct responsibility of Subcommittee C09.65 on Petrography.

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[2] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

***A Summary of Changes section appears at the end of this standard.**

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destructive or nondestructive tests to determine physical, mechanical, or structural properties of the concrete.

4.3 The results of examination and sampling carried out in accordance with this practice may be used for a variety of purposes and to serve a variety of objectives, some of which are discussed in the Procedural Plan Section.

5. Qualifications and Instruction of Personnel

5.1 *Qualifications*—The examination, formulation of sampling plan, and the sampling procedures shall be performed by persons qualified by education and experience to carry out such work, to operate equipment employed, to record and interpret observations, and to report upon the sampling plan and its execution. Technicians and workmen may be required to assist in the operations but appropriate training and supervision are mandatory.

5.2 *Instruction of Personnel*—This practice may be used by personnel employed directly by those for whom the examination and sampling program are conducted. The employer should tell the personnel in as much detail as necessary, the purposes and objectives of the examination, the kind of information sought, and the extent of examination and sampling desired. Pertinent background information should be made available. If the person to perform the work is highly experienced, the employer should seek his or her advice in delineating the investigation. The nature, extent, and objectives of the examination and sampling plan should be recorded, and the record may appropriately include the items under Agreements with Consultants.

5.3 *Agreements with Consultants*—This practice may be the basis for establishing arrangements between a purchaser of a consulting service and the consultant. The purchaser and consultant should jointly determine the nature, extent, and objectives of the examination and sampling program to be made, and should record their agreement in writing. The agreement may stipulate specific determinations to be made, observations to be reported, numbers and kinds of samples to be taken, level of reliability required for results of tests, portions of the constructions to be sampled, funds to be obligated, a time schedule for the investigation, or a combination of these and other conditions.

EXAMINATION OF CONCRETE IN CONSTRUCTIONS

6. Procedural Plan

6.1 *Objective*—The objective of the examination of concrete is to provide information that can be used to evaluate the condition of the concrete and the constructions, and to corroborate observed satisfactory performance, or to document and explain distress or failure. The examination of concrete in service or under test should be undertaken in accordance with a scope, an objective, and systematic procedures, all agreed upon between the responsible parties. The extent of the investigation and the procedures that are most appropriate for the examination depend upon a decision as to the objectives of the investigation and the level of reliability required of resulting test data. This decision may stipulate an authorized budget and a time schedule for completion of various stages of the investigation. The budget and time schedule can be modified following preliminary investigations and adjusted periodically as information accumulates.

6.2 *Purpose*—Investigations of the condition of concrete in service are usually undertaken for the following reasons: (*a*) to determine the ability of the concrete to perform satisfactorily under anticipated conditions of future service; (*b*) to identify the processes or materials causing distress or failure; (*c*) to discover conditions in the concrete that caused or contributed to satisfactory performance or to failure; (*d*) to establish methods for repair or replacement without hazard of recurrence of the distress; *(e)* to determine conformance with construction specification requirements; (*f*) to develop data to aid in fixing financial and legal responsibility for cases involving failure or unsatisfactory service; and (*g*) to evaluate the performance of the components used in the concrete. It is assumed that the manager of the investigation will begin with one or more working hypotheses, derived from information received or gathered, that are intended to explain the reasons for the condition or conditions of the concrete, and that will be continuously revised and refined as more information is received. It is intended that at the end of the investigation, an explanation will have been produced which is the best obtainable from the investigation of the available evidence concerning the mechanisms that operated to produce the condition or conditions of the constructions.

6.3 *Scope of Investigation*—The scope of an investigation of concrete in service may be limited to only isolated areas displaying deterioration. Or the investigation may be concerned with general distress, such as excessive deflection or collapse of structural members. It may involve study of the dislocation of entire structures or large portions of structures. The investigation may be confined chiefly to the study of the concrete, or it may require substantial research into other circumstances, such as foundation conditions, conditions of service, construction practices, and comparisons with other structures.

7. Preliminary Investigations

7.1 *Purpose*—The purpose of preliminary investigations is to establish the general condition of the concrete and the existence of any unsatisfactory condition, to describe its nature, and to estimate its extent and possible effect upon the performance, service life, and safety of the structure. An investigation of failure or inadequate performance of concrete in constructions is predicated upon a conclusion, usually by the owner or his representatives, that an unsatisfactory condition exists or is imminent. Such a conclusion may be in error, either because the observed condition is insignificant, or because the full extent of the actual distress or inadequacy has not been detected.

7.2 *Test Methods*—The preliminary investigation may include, as appropriate, visual inspection of the structure, review of plans and specifications for the work, and examination of available reports of project engineers and inspectors, compilation of available data on service conditions, petrographic examination in accordance with Practice C 856, and testing of a few selected samples of concrete and secondary chemical deposits in or on the concrete or both. Deflection or expansion

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(or shrinkage) of typical portions of the structure might appropriately be measured. The condition of the concrete in place can be estimated using nondestructive testing procedures, such as impact devices and ultrasonic methods (see Test Method C 597). Selected critical portions of structures may be probed and sampled by drilling (Method C 42/C 42M). The cores may be tested in accordance with Test Method C 215. Borehole cameras and viewing devices have been found to be helpful in specific instances **(1, 2, 3)**.[3]

7.3 *Conclusions*—The findings of the preliminary investigation may allay all concern with respect to the condition of the concrete. In certain cases, the findings are adequate for a final conclusion on the significance of observed distress. Otherwise, care should be taken to assure that the preliminary investigation provides the information necessary to delineate a plan for the further investigations covered in Sections 8-14.

8. Assembly of Records

8.1 *Reports and Legal Documents*—The investigation of concrete performance should be preceded or accompanied by the assembly and critical review of records pertaining to the project specifications, construction contract, construction operations, concrete-making materials, weather conditions during and after construction, and the actual conditions of service. Such records should establish the specified requirements for the materials and the completed work, and may reveal circumstances or conditions that caused or contributed to the distress of the concrete. Records of operation and maintenance may describe the beginning and progress of unsatisfactory performance.

8.2 *Interviews*—Interviews with contractors, engineers, inspectors, tradesmen, and suppliers should be conducted to obtain pertinent information that is not included in the written record. Owners, occupants, and users of the constructions should be queried concerning the onset and progress of evident distress, especially with respect to possible relationship to any change of the conditions of use and service.

9. Detailed Investigations of Concrete in Constructions

9.1 *Procedures*—A detailed investigation of concrete in constructions should include all procedures that are required to achieve the approved scope and objectives within the authorized budget and time schedule. After the preliminary investigation to establish the general condition of the concrete and the extent of any unsatisfactory performance, the detailed investigation may comprise: (*a*) thorough examination of the concrete constructions; (*b*) surveys and field tests to define and evaluate the condition of the concrete in place and the safety of the constructions; and (*c*) taking samples to be examined and tested by laboratory procedures.

9.2 *Scope of Field Examination*—A detailed visual examination should be made by personnel familiar with concrete and concrete constructions. This examination should locate and describe all of the categories of concrete. All affected constructions or portions thereof should be identified and the external aspects of failure should be described as quantitatively as possible. The examination may be extended to aggregate sources in accordance with the procedures described in Practice C 295. Photographs of pertinent features of the constructions, their environs, and the manifestations of failure are valuable and should be obtained.

9.3 *Observations*—Features of the concrete to be noted especially include: (*a*) the nature and extent of cracking and fractures; (*b*) evidences of volume change, deflection, or dislocation of the constructions or portions thereof, which may include the closing or opening of joints, tilting, shearing, or misalignment of structural elements and shifting or misalignment of machinery; (*c*) the condition of exposed surfaces, especially such features as spalling, popouts, unusual weakness, disintegration, excessive wear, and discoloration; (*d*) evidences of cement-aggregate reactions; (*e*) secondary deposits on surfaces, in cracks, and in voids; and (*f*) the presence and extent of repair work and the quality of its bond to the original concrete.

9.3.1 Some of the features listed in this section can be detected more readily in laboratory examination.

9.3.2 Some of the other properties of the concrete requiring observation include: the thoroughness of consolidation; whether the concrete is air-entrained; evidences of segregation and bleeding; indications of extremely high, low, or normal water content; in the case of reinforced concrete, the condition of the steel and its location in the section; and the nature and condition of other embedded items.

9.3.3 Any phenomena indicating distress of the concrete should be studied in relation to possible causative or contributory factors, such as varying conditions of exposure over the area of the constructions; the sequence of placing operations; conditions prevailing during construction; sources of supply of concrete and concrete-making materials; identifiable problems of handling, placing, and finishing; conditions of curing and early protection; and the adequacy of the structural design and conformance to the plans. Varying conditions of exposure over the area of the constructions during and after construction may include the following:

9.3.3.1 Differences in thermal exposure to solar heating. Shaded portions probably are subjected to the lowest range of diurnal thermal cycles,

9.3.3.2 Differences in exposure to moisture, which may arise by orientation of the construction with respect to prevailing winds during times of rainfall or snowfall, and which will be affected by the diurnal thermal cycles,

9.3.3.3 Differences in the mineral composition of the subgrade so that part of the construction is located on a foundation containing swelling clay or containing unstable sulfides or sulfates, or

9.3.3.4 Differences of the moisture content of the subgrade during or after construction.

9.3.4 The foundation and subgrade materials and conditions should also be carefully examined if there is a possibility of their involvement in serviceability of the concrete.

9.3.5 The observations made, together with relevant information developed as described under Assembly of Records, and the results of the preliminary investigations as described in

[3] The boldface numbers in parentheses refer to the list of references at the end of this practice.

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Preliminary Investigations, shall be assembled as may be appropriate into a report which shall either be submitted to those for whom the study was conducted or prepared for incorporation in a more comprehensive document covering other phases of an investigation of broader scope.

SAMPLING CONCRETE IN CONSTRUCTIONS

10. Requirements

10.1 Sampling each category of concrete should be done objectively so that the suite of samples taken is not weighted with unusually poor or unusually sound concrete. Samples may be taken to exemplify unusual or extreme conditions or features to aid in the identification of causes of distress or failure of concrete, but these samples should be kept apart from samples that are taken to exemplify statistically the properties of the concrete in place. Thus, the samples may be of two types, namely, (*a*) those that, together, are intended to be representative of the variability of the concrete in place, and (*b*) those that display specific features of interest but are not intended, individually or collectively, to be representative of any substantial proportion of the concrete in place. In order to be suitable for sampling, the concrete must have developed sufficient strength to allow removal of forms or temporary supports or to sustain required loads.

10.2 The samples should include portions of both near-surface concrete and concrete at depth, because the concrete may vary substantially with depth in the development of cracking, deterioration of the cement paste, progress of cement-aggregate reactions, and other features.

10.3 The samples should be sufficient in size and number to permit application of all necessary laboratory procedures upon different samples or portions of samples than those used for other tests except as noted under the section on Sampling for Compliance with Construction Specifications. Therefore, the sampling program should be arranged with foreknowledge of the laboratory testing program to be covered by the plan of the investigation.

10.4 The samples secured for each test procedure should be sufficient in number to provide an estimate that is of acceptable reliability as described in the Sampling Plan Section.

11. Sampling Plan

11.1 Representative samples should be taken in accordance with a prearranged plan that will meet the stipulations given under Sampling Concrete in Constructions. The plan should also conform with the recommendations of the Sections on Characteristics of a Probability Sampling Plan and Minimum Standards for a Probability Sampling Plan in Practice E 105. For guides in application of statistical methods to small numbers of samples, see Ref (**4**). Two sampling situations may arise, namely:

11.1.1 *Situation 1*—The preliminary examination and other information indicate that all of the concrete is in a similar condition and is of similar quality, or that it is infeasible without taking and testing samples, to determine whether or not the concrete is essentially uniform; and

11.1.2 *Situation 2*—The preliminary examination and other information indicate that the concrete is in two or more categories or comprises two or more portions that are or are likely to be of differing composition or quality.

11.2 Under Situation 1, sampling locations should be spread randomly or systematically over the area of interest. For large structures and substantial areas of pavement, the sampling sequence should be repeated at some predetermined frequency, such as for each 50, 100, 500 m^2 (500, 1000, or 5000 ft^2) of exposed concrete, as may be appropriate. Any method for determining sampling locations may be employed provided the locations are established without bias.

11.3 In Situation 2, samples may be taken for comparison with respect to several categories of performance by using the Chi-Square test (**5**).

11.4 *Recommended Sampling Method*—Prepare to scale an outline sketch or sketches or obtain scaled large photographs of the surface or surfaces from which representative samples are to be extracted, and subdivide the entire area, comprising all of the separate surfaces, into equal or approximately equal sections, at least ten in number and not less than the number of separate areas that are included in the investigation. Designate each section by a number or letter. Choose sections to be sampled by drawing numbered or lettered slips of paper at random from a container, or by using a list of random numbers or letters. Take samples, as by drilling, in accordance with the provisions of the section on Sampling Procedures at locations that are marked at random on the sketch of each of the indicated sections (Note 1).

11.4.1 In an investigation of test specimens or concrete products, the units to be examined and tested should be selected randomly by similar means from the lot or lots.

11.4.2 Prefabricated products of large dimension, such as building units, pipe, and piling, can be sampled by the recommended method as it is applied to structures and pavements.

11.4.3 The procedure should be modified as appropriate to provide for sampling concrete members or elements that have been removed from constructions that are under investigation.

NOTE 1—If it is necessary to avoid critical reinforcement, embedded hardware, or other construction features, shift the sampling location a minimum necessary distance to the north (or up on vertical surfaces). If such a move is not feasible, shift to the east, south, or west (or right, down, or left), alternatively considered, in that order.

11.5 *Sample Size*—For samples to be subjected to tests yielding a numeric value, the number of samples should be determined in accordance with the recommendations of Practice E 122, based upon the degree of confidence desired to be placed in the result. The quantity of concrete and the dimensions of pieces secured in the sampling operation should conform with the stipulations of the applicable method of test.

11.6 *Evaluation of Test Results*—Test results from samples obtained in accordance with Situation 1 are evaluated on the basis of the following statistics, average or mean values, $\bar{X}$; standard deviation of individual values, s. These statistics are computed as follows:

$$\bar{X} = \frac{\Sigma X_i}{n} \quad (1)$$

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$$s = \sqrt{\frac{\Sigma(X_i - \bar{X})^2}{n - 1}} \quad (2)$$

where:
X_i = an individual test result, and
n = the number of test results averaged.

11.6.1 *Evaluation of Test Results on the Basis of Variability*—Variability of test results within a group is indicated by *s*. Whether or not these statistics are excessively large can only be determined by comparing them with some prior knowledge about what the variability ought to be. The best information on what the variability should be is contained in the precision statement in the test method by which the results were obtained. Directions for obtaining an acceptable range for *n* individual results and an acceptable difference between the averages of two groups of tests from the same category of concrete are given in Practice C 670.

11.6.2 *Evaluation of the Quality of Concrete*—Quality of the concrete in question can be assessed by comparing the average of test measurements from a group within the category of questionable quality with one obtained from a category of good quality. A Student's *t* test may be applied to the difference between the two averages to make a decision whether the difference is significant or not (**6**). Before conducting the *t* test, other considerations must be borne in mind. These include the nature and intent of the constructions, the kinds of properties relevant to successful concrete in the constructions, the nature of any distress, the economics of maintenance, the need for repair, if any, and the desired service life of the structure.

11.7 Under Situation 2, each separate category of exposed surface of the concrete constructions, or each category of test specimens or concrete products should be treated individually as under Situation 1 to establish sampling locations and number of samples and to select particular specimens or product units for examination. For example, completely scaled, partially scaled, and unscaled areas of pavement concrete of a specified level of quality should be sampled separately in accordance with the recommended method so that three suites of samples are secured, each suite comprising concrete of a specific category and each conforming with the recommendations of Practices E 105 and E 122. Any number of suites of samples may be required for proper investigation of concrete that is within the scope of an approved plan so as to adequately evaluate concrete of differing specified levels of quality and concrete in differing condition following the service exposure.

11.8 For purposes of engineering surveys and research programs, the number of samples and their characteristics may be established by responsible personnel in accordance with the scope and objectives of the investigation.

12. Sampling for Compliance with Construction Specifications

12.1 To determine compliance of hardened concrete with requirements of codes or contract specifications, each sample of concrete should be sufficient in quantity and dimensions to permit performance of the applicable test procedure in accordance with the stipulations of the method of test.

12.2 The number of samples to be taken from each category of concrete should be established in accordance with recommendations of Practices E 105 and E 122 so as to provide a reliable estimate of the standard deviation and average value of the test results. The level of reliability required and the criteria for acceptance of the results as set forth in Practice E 141 should be established as a part of construction specifications or, if not, as a part of the sampling plan. In the event that no such stipulation has been established beforehand, not less than five samples shall be taken from each category of concrete for each test procedure stipulated in the Procedural Plan, except as provided in 12.3.

12.3 In some instances, two or more tests may be performed on the sample or samples, provided the tests performed initially do not modify the properties of the concrete to be evaluated by subsequent tests. Any such reuse or successive use of samples shall be stipulated in detail beforehand in the sampling plan so as to specify the kinds of tests that may be performed successively, the sequence of testing, and precautions to be taken in performance of the tests and handling of the sample during the course of the testing. Examples of permissible successive testing are unit weight followed by a compression test, air void content in accordance with Test Method C 457 followed by petrographic examination, and compression test followed by chemical test for cement content (provided care is taken to avoid loss of fragments of the specimen).

13. Sampling Procedures

13.1 In general, samples of hardened concrete from constructions, concrete products of large size, or large test specimens should be secured in accordance with the applicable sections of Test Method C 42/C 42M. Specimens of hardened concrete may be obtained by coring, sawing, or otherwise removing portions of the concrete (Note 2). Sawing or coring by rotary drilling (Note 3) is preferred for samples to be subjected to tests of physical properties or to petrographic examination. Caution should be used to avoid or to minimize fracturing the concrete or contamination of the sample with foreign substances. Use of sledges, chisels, and similar tools should be avoided. Their possible effects on the integrity of the sample must be considered during examination and testing of the samples.

NOTE 2—Care should be taken to avoid cutting critical sections of reinforcement, conduit, and duct-work.

NOTE 3—Diamond-drilled cores are preferred to shot-drilled cores, because the outer surfaces are smoother and reveal the composition and fabric of the concrete more clearly than shot-drilled cores.

13.2 Samples for examination may be secured from small beam or slab specimens or from small prism-shaped or columnar concrete products by sawing across the entire width and depth, for example at the third-points and the middle of the length. Samples from vertically cast concrete cylinders should be secured from top and bottom halves or top, middle, and bottom portions or by sawing the specimen longitudinally. These samples will represent any variability arising as a consequence of placing and compaction procedures, segregation, or bleeding. Similar procedures and precautions should be employed in securing samples from other types of test specimens and concrete products. Methods for obtaining portions of samples for testing purposes are outlined in 13.1, 13.2, and in Table 1.

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TABLE 1 Minimum Depth of Sampling of Concrete for Testing Purposes[A]

Types of Construction	Thickness of Section, m (ft)	Minimum Depth to Be Sampled, m (ft)
Slabs, pavements, walls, linings, foundations, structural elements accessible from one side only	0.3 (1.0) or less	entire depth
	0.3 (1.0) or greater	0.3 (1.0)
Suspended slabs,[B] walls, conduits, foundations, structural elements exposed to the atmosphere at two or more sides; concrete products	0.15 (0.5) or less	entire depth
	0.15–0.6 (0.5–2.0)	one half the thickness or 0.15 (0.5) whichever is greater
Massive sections	0.6 (2.0) or greater	0.6 (2.0)

[A] The requirements of Table 1 may not provide the quantities or dimensions of samples that are required by the stipulations of Sections 11 and 12. In that case, the necessary additional quantity of concrete in pieces of appropriate minimum size should be taken at each sampling location in accordance with the requirements of Section 13.

[B] When suspended slabs are cored, it is desirable to leave the lower 1 in. or 25 mm uncored, so as not to lose the core by its falling from the barrel and to make it easier to patch the core hole.

13.3 If feasible, samples should be taken perpendicular to the layers in which the concrete was deposited. The sample should include the exposed surface, near-surface concrete, any concrete in contact with aggressive waters or other aggressive substances, and concrete at depth. Samples of isolated spalls or popouts should include representative examples of the spalls and popouts and the underlying and adjacent concrete. For sampling, various common types of concrete constructions, recommended minimum depths or thicknesses across which samples should be taken, are shown in Table 1. Deeper drilling may be required to determine the extent of cracking, condition of construction joints, extent of any cement-aggregate reactions, condition of concrete in contact with subgrade material, and variability of the concrete.

13.4 Samples should be identified and oriented by painted or inked markings on the material itself, if feasible. The concrete should be wrapped and sealed as may be appropriate to preserve the moisture content representative of the structure at the time of sampling, and should be packed so as to be properly protected from freezing or damage in transit or storage, especially if the concrete is very weak.

14. Information to Accompany Samples

14.1 The personnel who will supervise the laboratory tests, analyses, or examinations of the samples should receive complete information on the identity and sources of the samples and on the problem that is being investigated. In particular, they should be advised of and, preferably, consulted about the specific questions that are to comprise the objectives of the investigation.

14.2 Specific items of information that should be available to the supervisor or consultant are:

14.2.1 Location of the source of each sample, orientation of the sample, depth from which the sample was taken, and sampling procedures. Photographs of samples and of the sampling locations should be provided, if possible.

14.2.2 Report of both the preliminary and detailed field investigations, including a description of the performance of concrete in service and the results of the examination of the concrete in the field. The surveys, field tests, and other pertinent information on the constructions and sources of the concrete and concrete-making materials should be included.

14.2.3 Results of any tests or analyses that were performed on the concrete or concrete-making materials.

15. Keywords

15.1 construction; coring; deterioration; exposure condition; field inspection; hardened concrete; performance; petrographic examination; photograph; representative sample

REFERENCES

(1) Trantina, J. A., and Cluff, L. S.,“ ′ NX’ Borehole Camera,’’ *Symposium on Soil Exploration, ASTM STP 351,* Am. Soc. Testing Mats., 1964, pp. 108–120.

(2) Burwell, E. B., Jr., and Nesbitt, R. H., “The NX Borehole Camera,’’ *Mining Engineering,* MIENA Vol 6, No. 8, 1954, pp. 805–808; or *Journal of Metals,* American Institute of Mining, Metallurgical and Petroleum Engineers, JOMTA, Vol 6, No. 11, Section 1, Nov 1954, pp. 1197–1198.

(3) Burwell, E. B., Jr., and Nesbitt, R. H., “The NX Borehole Camera,’’ *Systems,* Vol 18, No. 3, 1954, pp. 12–13.

(4) Simpson, G. G., Roe, Anne, and Lewontin, R. C., *Quantitative Zoology,* Revised Ed., Harcourt Brace and Co., New York, N. Y., 1960.

(5) Natrella, M. G., *Experimental Statistics, NBS Handbook 91,* National Bureau of Standards, NBSHA, Chapter 9, August 1963; Crow, E. L., Davis, F. A., and Maxfield, M. W., *Statistics Manual,* Dover Publications, New York, N.Y., Chapter 8, 1960, p. 209ff; MIL-STD-105 D, 29 April 1963, Military Standard Sampling Procedures and Tables for Inspection by Attributes.

(6) Natrella, M. G., *Experimental Statistics,* Chapter 3, 1963.

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SUMMARY OF CHANGES

Committee C09 has identified the location of selected changes to this practice since the last issue, C 823 – 00, that may impact the use of this practice. (Approved July 15, 2007)

(*1*) Changed the standard into a dual designation, adding new 1.2 and renumbering subsequent paragraphs.

(*2*) Revised the order of units in 11.2 and Table 1.

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Designation: C 827 – 01a (Reapproved 2005)

Standard Test Method for Change in Height at Early Ages of Cylindrical Specimens of Cementitious Mixtures[1]

This standard is issued under the fixed designation C 827; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

This standard has been approved for use by agencies of the Department of Defense.

1. Scope

1.1 This test method covers the determination of change in height of cylindrical specimens from the time of molding until the mixture is hard.

1.2 This test method covers height change measurements at early ages for cementitious mixtures of paste, grout, mortar, and concrete.

1.3 This test method is intended for determination of changes in height that occur from the time of placement until the specimen is fully hard. These include shrinkage or expansion due to hydration, settlement, evaporation, and other physical and chemical effects.

1.4 The values stated in SI units are to be regarded as the standard.

1.5 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

1.6 The text of this test method references notes and footnotes that provide explanatory information. These notes and footnotes shall not be considered as requirements of the test method.

2. Referenced Documents

2.1 *ASTM Standards:* [2]

C 109/C 109M Test Method for Compressive Strength of Hydraulic Cement Mortars (Using 2-in. or [50-mm] Cube Specimens)

C 125 Terminology Relating to Concrete and Concrete Aggregates

C 138/C 138M Test Method for Density (Unit Weight), Yield, and Air Content (Gravimetric) of Concrete

C 143/C 143M Test Method for Slump of Hydraulic-Cement Concrete

C 185 Test Method for Air Content of Hydraulic Cement Mortar

C 191 Test Method for Time of Setting of Hydraulic Cement by Vicat Needle

C 192/C 192M Practice for Making and Curing Concrete Test Specimens in the Laboratory

C 305 Practice for Mechanical Mixing of Hydraulic Cement Pastes and Mortars of Plastic Consistency

C 403/C 403M Test Method for Time of Setting of Concrete Mixtures by Penetration Resistance

C 670 Practice for Preparing Precision and Bias Statements for Test Methods for Construction Materials

C 807 Test Method for Time of Setting of Hydraulic Cement Mortar by Modified Vicat Needle

C 939 Test Method for Flow of Grout for Preplaced-Aggregate Concrete (Flow Cone Method)

C 953 Test Method for Time of Setting of Grouts for Preplaced-Aggregate Concrete in the Laboratory

C 1437 Test Method for Flow of Hydraulic Cement Mortar

3. Terminology

3.1 *Definitions*—The terms used in this test method are defined in Terminology C 125.

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *early-age change in height*, *n*—the measured increase or decrease in height of a laterally confined cylindrical test specimen from the time of molding to when the mixture becomes hard. The user may want to define this age as the time when a companion specimen of the same batch has reached the time of final setting by Test Method C 191 (paste), C 953 (mortar or grout), C 403/C 403M (concrete), or establish a predetermined age in minutes from the time the specimen is cast as the defined age to record the final measurement.

[1] This test method is under the jurisdiction of ASTM Committee C09 on Concrete and Concrete Aggregates and is the direct responsibility of Subcommittee C09.68 on Volume Change.

Current edition approved July 1, 2005. Published August 2005. Originally approved in 1975. Last previous edition approved in 2001 as C 827 – 01a.

[2] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

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Changes in height are measured and expressed as a positive or negative change in the height of a test specimen that is restrained from lateral movement.

4. Significance and Use

4.1 This test method provides a means for comparing the relative shrinkage or expansion of cementitious mixtures. It is particularly applicable to grouting, patching, and form-filling operations where the objective is to completely fill a cavity or other defined space with a freshly mixed cementitious mixture that will continue to fill the same space at time of hardening. It would be appropriate to use this test method as a basis for prescribing mixtures having restricted or specified volume change before the mixture becomes hard.

4.2 This test method can be used for research purposes to provide information on volume changes taking place in cementitious mixtures between the time just after mixing and the time of hardening. However, the specimen used in this test method is not completely unrestrained so that the measurements are primarily useful for comparative purposes rather than as absolute values. Further, the degree of restraint to which the specimen is subjected varies with the viscosity and degree of hardening of the mixture.

5. Apparatus (see Fig. 1)

5.1 *Projected Light Source*, a lamp and a condensing lens of sufficient intensity to adequately project a light beam on a wall about 5 m (15 ft) from the light source. Protect the test specimen from heat from the light source and limit air movement (Note 1).

NOTE 1—Placing a sheet of transparent glass or plastic between the light source and the test specimens may be beneficial.

5.2 *Indicator Ball*, a spherical ball of nonabsorptive material with a density that is 55 ± 5 % of the density of the cementitious mixture being tested, having a diameter not more than 16 mm (⅝ in.) nor less than 6 mm (¼ in.), and composed of materials that have no reaction with the cementitious mixture during the test period.[3]

NOTE 2—A density of approximately 1.2 Mg/m^3 has been found appropriate for most uses of this test method. The density of the cementitious mixture may be calculated from values for "unit weight" obtained using Test Method C 138/C 138M (concrete) or C 185 (mortar, grout, or paste).

5.3 *Magnifying Lens System*, a magnifying lens system such that the image of the indicator ball produced by the projected light source is cast on the indicating chart about 5 m (15 ft) away at a magnification of 90–110×, mounted so as not to touch the test specimen when a test is in progress (see Note 3), and having a separate magnifying lens system for each specimen tested simultaneously.

NOTE 3—One magnifying lens system that has been found acceptable consists of two lenses: a projection and a relay lens enclosed in a sealed tube. In this system, the relay lens is located nearer the test specimen and has a focal length of 50.8 mm (2 in.) and is located approximately 115 mm (4½ in.) from the indicator ball. The projection lens has a focal length of 41.4 mm (1⅝ in.), and relative aperture of *f*1.6 and is 133.1 mm (5¼ in.) from the relay lens.

5.4 *Indicating Charts*, composed of stiff material approximately 600 mm (24 in.) high by 250 mm (10 in.) wide, with a white surface and a vertical black line 2 mm (1/16 in.) wide, centered and running the complete length of the chart, and a horizontal black line 1 mm (1/32 in.) in width midway on the chart, identified as the zero (0) or starting line, and 2-mm (1/16-in.) horizontal graduations above and below the zero line on the entire length of the vertical line, and a means for attaching this chart vertically and firmly to a distant wall.

5.5 *Molds*, rigid, watertight molds with a smooth interior surface made of steel, cast iron, or other nonabsorbent material nonreactive with the cementitious mixture being tested, cylindrical in shape, with internal height twice the internal diameter. Three sizes of molds are used in this test method with heights of 100, 150, 300 mm (4, 6, 12 in.).

5.6 *Rods*, two straight, steel tamping rods: one 10 mm (⅜ in.) in diameter and approximately 300 mm (12 in.) in length and the other 16 mm (⅝ in.) in diameter and approximately 600 mm (24 in.) in length. The 10-mm rod shall be used with paste, grout, and mortar. The 16-mm rod shall be used with concrete.

6. Test Specimen

6.1 Unless otherwise specified, prepare two test specimens from each batch to be tested simultaneously using duplicate test apparatus. For cement pastes, grouts, and mortars where all the aggregate will pass through a 4.75-mm (No. 4) sieve, use the 100-mm (4-in.) mold. For cementitious mixtures containing

[3] An 11-mm (7/16-in.) nylon plastic indicator ball has been found acceptable for most tests and is available from U.S. Plastics Corp., 1390 Neubrecht Rd., Lima, OH 45801.

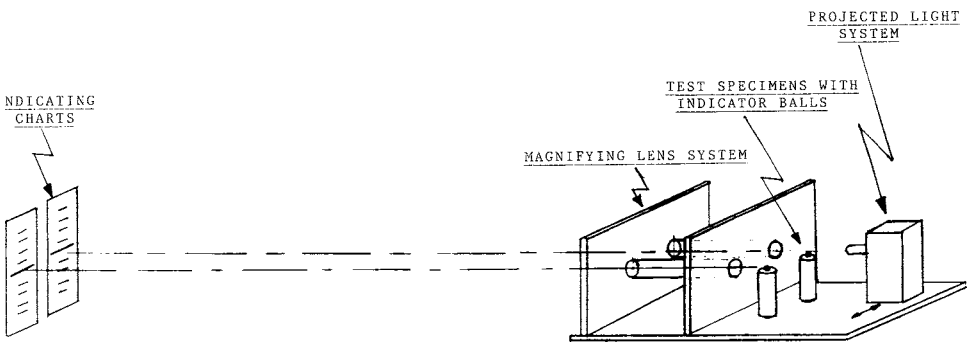

FIG. 1 Apparatus for Early Change in Height

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aggregate that will not all pass through a 4.75-mm sieve, but which will all pass the 12.5-mm (½-in.) sieve, use the 150-mm (6-in.) mold. For concrete mixtures having particles retained on the 12.5-mm (½-in.) sieve or larger, use the 300-mm (12-in.) mold.

7. Calibration

7.1 *General*—Minimize any sources of light not required for the tests. Locate the test equipment and specimens on a surface substantially free of vibration during the test. If desired, use a single projected light source for both test specimens with duplicate magnifying lens systems and indicating charts.

7.2 *Apparatus Calibration*—Calibrate the entire apparatus prior to the start of each test. Darken the room, illuminate the projected light source, and place the dummy test specimens (preferably hardened test specimens) in the light beam before each of the magnifying lens systems. Adjust the location of each test specimen until a sharp, clear image of the indicator ball is produced on the indicating chart. Then reposition the indicating chart so that the indicating ball image falls on the zero line. Place a steel rod of known diameter (see Note 4) horizontally on top of each indicator ball and record the height of the image it produces on its respective indicating chart. The ratio of the image height to the actual rod diameter is the magnification of the lens system. Moving the projected light source, test specimen, and magnifying lens system toward or away from the indicating chart can change the magnification. Once proper magnification (90 to 110×) is obtained, remove the dummy test specimens and do not change the relative locations of the test apparatus during the test.

NOTE 4—The shank of a 2-mm (1/16-in.) twist drill bit has been found satisfactory for most tests.

8. Preparation of Mixtures

8.1 *General*—Bring all materials to a temperature of 23 ± 2.0 °C (73 ± 3 °F) before mixing. Other material temperatures shall be used for this test method when specified. Proportion all materials by mass in accordance with the specifications for the cementitious mixtures to be tested.

8.2 *Mortars, Pastes, and Grouts*:

8.2.1 Either hand mix or use a suitable mechanical mixer (see Note 5) for a mixing time of 4 min, unless otherwise recommended by the manufacturer. Place all the mixing water in the mixing bowl prior to introduction of the other materials for the batch. For mortar materials that are not premixed, the sequence of mixing shall be in accordance with Practice C 305.

NOTE 5—The mechanical mixer described in Practice C 305 is a suitable mixer. However, the clearances between paddle and bowl specified in this test method are suitable only for mortars made with fine aggregates that are finer than the 850-µm (No. 20) sieve. Mortars made with aggregates containing particles coarser than the 850-µm sieve may require special clearances or a different type of paddle to permit the mixer to operate freely and to avoid damage to the paddle and bowl.

8.2.2 Determine the consistency of he mixtures by the flow test in accordance with the applicable provisions of Test Method C 1437. If this procedure is used, the flow after 5 drops of the flow table in 3 s is 145 or less. A plastic mixture should have a flow of 100 to 125, and a flowable mixture should have a flow above 125 when tested by the preceding modification of Test Method C 109/C 109M but not less than 30 s when tested using the flow-cone procedure of Test Method C 939. A fluid mixture should have a time of efflux of 10 to 30 s when tested by the flow-cone procedure. The water required to produce the specified consistency shall be determined by the testing of trial batches. Fresh materials shall be used to make each trial. If not specified or recommended otherwise, use sufficient mixing water to produce a flow of 135 ± 5. For premixed mortars or grouts, use the amount of water suggested by the manufacturer for the intended application. The consistency should be determined and the values recorded for all tests.

8.3 *Concrete*—Mix concrete either manually or in a suitable laboratory mixer in accordance with the applicable provisions of Practice C 192/C 192M. Determine the consistency of the concrete by the slump test in accordance with the applicable portions of Test Method C 143/C 143M, and unless otherwise specified, use sufficient mixing water to produce a slump of 90 ± 15 mm (3½ ± ½ in.).

9. Molding Specimens

9.1 Fabricate 100-mm and 150-mm (4-in. and 6-in.) specimens by filling the mold in a continuous pouring operation for pourable mixtures or in three layers with consolidation of each layer by tapping the outside of the mold ten times with a 10-mm (⅜-in.) diameter rod in the case of mixtures that are not pourable. Fabricate 300-mm (12-in.) specimens in accordance with Practice C 192/C 192M.

9.2 Screed off the surface of the test specimen to the top of the mold. In cases where extreme shrinkage or expansion of material is anticipated, adjust the height of the test material to ±6 mm (¼ in.) with respect to the mold height.

10. Procedure

10.1 Place an indicator ball in the center of the surface of each specimen. Tap the indicator ball lightly so that approximately one half of the ball's diameter penetrates the test specimen mixture. Remove pieces of large aggregate directly under the indicator balls, and repeat the procedure. Then tap the outer side of the molds lightly three times so that the indicator balls can adjust to their own natural displacement level in the mixture. Position each specimen between the projected light source and the magnifying lens system. Adjust the position of the test specimens horizontally until the images of the indicator balls on the indicating charts are sharp and clear. Reposition the indicating charts so that the indicating ball images fall on the zero lines. Complete these activities in not more than 5 min after completion of mixing unless otherwise specified. Record this time as the start of the test. Unless otherwise specified, conduct tests with test specimens that are free to evaporate to the atmosphere. Record ambient air temperature and humidity. If a moist storage condition is specified, place a few drops of medium-weight motor oil on the test specimen surface to allow an oil film to cover the exposed surface of the test specimen. During the test, carefully place additional drops of oil on the test specimen surface by an eyedropper or other suitable means, taking care not to touch the indicator ball.

10.2 *Test Measurements*—Once the test specimens are placed in position, do not jar, touch, or move the test apparatus

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until the completion of the test. Record movements of the indicator balls as projected on the indicating charts at 5-min intervals during the first 90 min, at 10-min intervals for the next 1 h, and at 20-min intervals thereafter until the mixture has hardened (Note 6). Clearly identify all readings from the charts as positive (+) for increase in height, and negative (–) for decrease in height, read to the nearest 0.1-in. (2-mm) graduation vertically, and record the time to the nearest 1 min (see Note 7).

NOTE 6—Time of hardening may be taken as the time of final setting as determined by Test Methods C 191 for cement pastes, C 807 for mortars and nonfluid grouts, C 953 for fluid grouts, and C 403/C 403M for concrete mixtures. Measurements may be continued after hardening, if desired.

NOTE 7—Automated recording of time and height is permitted as long as requirements for precision and accuracy are met

11. Calculation

11.1 *Change in Height of Specimen*—Calculate the changes in height of the test specimens as follows:

$$°H = (I/MH) \times 100 \quad (1)$$

where:

$°H$ = change in height, %: positive (+) for increase, negative (–) for decrease,
I = indicating chart reading, in. (mm): positive (+) for increase, negative (–) for decrease in height,
H = initial height of test specimen, in. (mm), and
M = magnification of lens system.

12. Report

12.1 Plot the changes in height as points on a graph, with increase (+) above the zero line and decrease (–) below the zero line. Report all change in height and time readings from the start of the test to conclusion, as percent versus time. Show the average of the data as a smooth curve. Calculate the maximum change in height using the largest indicating chart reading obtained during the test period and report as increase or decrease. In the event that both increase and decrease result, report the maximum change in height.

12.2 Report the following information:

12.2.1 Number and size of specimens tested and the date,

12.2.2 Source and identification of all materials used in the mixtures,

12.2.3 Flow, slump, or qualitative consistency of the mixture,

12.2.4 Magnification,

12.2.5 Temperature of the test mixture, ambient temperature at time of molding specimens, and ambient temperature and relative humidity throughout the test period if the test specimens are allowed to dry by exposure to the atmosphere,

12.2.6 Time interval from addition of the dry materials to the mixing water in the mixer to the time of start of test,

12.2.7 Magnitude and time of occurrence of maximum decrease, maximum increase in height, change in height at time of hardening of the mixture, and change in height at the conclusion of the test,

12.2.8 Appearance of bleed water on the test specimen surface during the test period, and

12.2.9 Any other information that may be pertinent.

13. Precision and Bias

13.1 *Precision*—The single-operator standard deviation for sand/cement mixtures has been found to be 0.12 % (Note 8) change in height. Therefore, results of two properly conducted tests by the same operator on the same material should not differ by more than 0.34 % change in height.

13.2 The single-operator standard deviation for cement paste has been found to be 0.43 % (Note 8) change in height. Therefore, results of two properly conducted tests by the same operator on the same material should not differ by more than 1.22 % change in height.

NOTE 8—These numbers represent, respectively, the (1s) and (d2s) limits as described in Practice C 670. Data were from tests of specimens 4 in. in height.

13.3 *Bias*—This test method has no bias because the value of the change in height can only be defined in terms of a test method.

14. Keywords

14.1 change in height; cementitious mixtures; concrete; expansion; grout height change; mortar; paste; shrinkage

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Designation: C 840 – 08

Standard Specification for Application and Finishing of Gypsum Board[1]

This standard is issued under the fixed designation C 840; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

This standard has been approved for use by agencies of the Department of Defense.

1. Scope*

1.1 This specification covers the minimum requirements for the methods of application and finishing of gypsum board, including related items and accessories.

1.2 Details of construction for a specific assembly to achieve the required fire resistance shall be obtained from reports of fire-resistance tests, engineering evaluations, or listings from recognized fire testing laboratories.

1.2.1 Where this specification is more stringent (size or thickness of framing: size and spacing of fasteners) than the fire-rated construction, this specification shall govern.

1.3 Where sound control is required for a gypsum board assembly, details of construction shall be in accordance with reports of acoustical tests of assemblies that have met the required acoustical values.

1.4 Unheated spaces above gypsum board ceilings shall be properly ventilated (see Appendix X2).

1.5 The various application systems are located in the following sections:

I	Application of Single-Ply Gypsum Board to Wood Framing Members	8
II	Application of Two-Ply Gypsum Board to Wood Framing Members	9
III	Application of Gypsum Board by Adhesive Nail-On to Wood Framing Members	10
IV	Semi-Solid Gypsum Board Partitions	11
V	Solid Gypsum Board Partitions	12
VI	Application of Gypsum Board with Adhesives to Interior Masonry or Concrete Walls	13
VII	Application of Gypsum Board to Rigid Foam Insulation	14
VIII	Application of Gypsum Board to Steel Framing and Furring	15
IX	Arches and Bending Radii	16
X	Application of Gypsum Board to Receive Tile by Adhesive Application	17
XI	Exterior Application of Gypsum Wallboard and Exterior Gypsum Soffit Board	18
XII	Floating Interior Angles	19
XIII	Control (Expansion) Joints	20
XIV	Foil-Backed Gypsum Board	21

The values stated in inch-pound units are to be regarded as standard. The values given in parentheses are mathematical conversions to SI units that are provided for information only and are not considered standard.

1.6 The text of this specification references notes and footnotes which provide explanatory material. These notes and footnotes (excluding those in tables and figures) shall not be considered as requirements of the specification.

1.7 The following precautionary caveat pertains only to Sections 6-24. *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

1.7.1 For specific precautionary statements, see 4.1.1, 4.1.2, and 22.5.

2. Referenced Documents

2.1 *ASTM Standards:* [2]

C 11 Terminology Relating to Gypsum and Related Building Materials and Systems

C 475/C 475M Specification for Joint Compound and Joint Tape for Finishing Gypsum Board

C 514 Specification for Nails for the Application of Gypsum Board

C 557 Specification for Adhesives for Fastening Gypsum Wallboard to Wood Framing

C 645 Specification for Nonstructural Steel Framing Members

C 754 Specification for Installation of Steel Framing Members to Receive Screw-Attached Gypsum Panel Products

C 920 Specification for Elastomeric Joint Sealants

C 954 Specification for Steel Drill Screws for the Application of Gypsum Panel Products or Metal Plaster Bases to Steel Studs from 0.033 in. (0.84 mm) to 0.112 in. (2.84 mm) in Thickness

C 1002 Specification for Steel Self-Piercing Tapping Screws for the Application of Gypsum Panel Products or

[1] This specification is under the jurisdiction of ASTM Committee C11 on Gypsum and Related Building Materials and Systems and is the direct responsibility of Subcommittee C11.03 on Specifications for the Application of Gypsum and Other Products in Assemblies.

Current edition approved May 1, 2008. Published June 2008. Originally approved in 1979. Last previous edition approved in 2007 as C 840 – 07.

[2] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

***A Summary of Changes section appears at the end of this standard.**

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Metal Plaster Bases to Wood Studs or Steel Studs
C 1007 Specification for Installation of Load Bearing (Transverse and Axial) Steel Studs and Related Accessories
C 1047 Specification for Accessories for Gypsum Wallboard and Gypsum Veneer Base
C 1396/C 1396M Specification for Gypsum Board
C 1546 Guide for Installation of Gypsum Products in Concealed Radiant Ceiling Heating Systems

2.2 *U.S. Department of Commerce Publication:*
PS20 American Softwood Lumber Standard[3]

2.3 *ANSI Standard:*
ANSI A 136.1 Organic Adhesives for Installation of Ceramic Tile, Type I and Type II[4]

3. Terminology

3.1 *Definitions*—Definitions shall be in accordance with Terminology C 11.

3.2 *Descriptions of Terms Specific to This Standard:*

3.2.1 *all-purpose compound*, *n*—a compound formulated and manufactured to serve as a taping or finishing compound, or both.

3.2.2 *critical lighting*, *n*—a condition where interior surfaces are flooded by natural or artificial lighting at an oblique angle.

3.2.3 *decoration*, *n*—paint (including primers), texture, coatings, and coverings such as wallpaper and sheet plastic materials designed to conceal or protect the surface of the gypsum board (see Appendix X3).

3.2.4 *dry type*, *n*—a compound in powder form to be mixed with water before use.

3.2.5 *drying type*, *n*—a compound that hardens by the evaporation of the vehicle used to make the paste.

3.2.6 *drywall primer*, *n*—a paint material specifically formulated to fill the pores and minimize the suction difference between gypsum board surface paper and the compound used on finished joints, angles, fastener heads and accessories, and over skim coatings.

3.2.7 *face panel*, *n*—outside ply of multiple layer gypsum board assemblies.

3.2.8 *finished wallboard*, *n*—wallboard that has had the joints taped, has had the joints, fastener heads, and flanges of accessories concealed with joint compound, and has been sanded to prepare the surface to receive job applied decoration.

3.2.9 *finishing*, *n*—the preparation of gypsum board surfaces to receive the field application of decoration.

3.2.10 *finishing compound (sometimes called topping compound)*, *n*—a compound used for successive coats over the taping or all-purpose compound that provides a smooth and level surface for the application of decoration.

3.2.11 *finishing of accessories*, *n*—the application of compound to flanges of accessories to create a monolithic surface.

3.2.12 *flange*, *n*—that part of an accessory extending over the face of the gypsum wallboard intended to become a part of the monolithic plane of the prepared surface.

3.2.13 *framing member*, *n*—that portion of the framing, furring, and blocking to which the gypsum board is attached.

3.2.14 *harden*, *v*—a condition reached when the compound has lost its plasticity to an arbitrary degree, measured in resistance to penetration or deformation.

3.2.15 *joint photographing*, *n*—a condition where the finished joint areas visible after final decoration.

3.2.16 *joint tape*, *n*—a strip of material designed to be embedded in compound to reinforce joints, cracks, or other small openings in or between gypsum boards.

3.2.17 *joint treatment*, *n*—application of joint tape and compound to the joint between gypsum boards.

3.2.18 *laminating compound*, *n*—a compound (abrasive) used to adhere gypsum board to gypsum board or other monolithic materials.

3.2.19 *moderate contact*, *n*—the edges and ends are butted at joints but not forced together.

3.2.19.1 *Discussion*—Small gaps not greater than ¼ in. (6 mm) are acceptable (see 7.4)

3.2.20 *parallel or vertical application*, *n*—gypsum board applied with the edges parallel to the framing member to which it is attached.

3.2.21 *perpendicular or horizontal application*, *n*—gypsum board application with the edges applied at right angles to the framing member to which it is attached.

3.2.22 *ready-mix type*, *n*—a factory-prepared compound ready to be used without the addition of water.

3.2.23 *required*, *adj*—pertaining to a mandatory obligation imposed by a force outside this standard, such as a building code, project specification, contract, or purchase order.

3.2.24 *setting type*, *n*—a compound that hardens by a chemical reaction and increases in straight through drying.

3.2.25 *skim coat*, *n*—a thin layer of skim coat compound applied over the entire surface of finished gypsum board.

3.2.25.1 *Discussion*—A skim coat is essentially a film of joint compound and is not applied at a readily measurable thickness. There is no specific mil thickness that constitutes a proper skim coat (See Appendix X8).

3.2.26 *skim coat compound*, *n*—joint compound, or a material specifically formulated and manufactured for use as a skim coat.

3.2.27 *specified*, *adj*—pertaining to a mandatory requirement of this standard or a referenced requirement (see 3.2.21).

3.2.28 *spotting fastener heads*, *n*—the application of compound to cover the fastener head to create a monolithic surface.

3.2.29 *taping compound (sometimes called embedding compound)*, *n*—a compound used for embedding and bonding joint tape and for the first coat over the heads of fasteners and flanges of accessories.

3.2.30 *taping of joints*, *n*—the application of compound and joint reinforcing tape to the joints between adjoining gypsum boards.

3.2.31 *treated joint*, *n*—a joint between gypsum boards that has been covered with joint tape and joint compound as specified in 22.3.3.1, 22.3.3.2, or 22.3.3.3.

3.2.31.1 *Discussion*—Strip moldings or similar devices shall be permitted.

[3] Available from U.S. Government Printing Office, Washington, DC 20402.
[4] Available from American National Standards Institute (ANSI), 25 W. 43rd St., 4th Floor, New York, NY 10036, http://www.ansi.org.

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4. Environmental Conditions

4.1 *Application of Gypsum Board, Joint Treatment Materials, and Adhesives*—Room temperature shall be maintained at not less than 40 °F (4 °C) during application of gypsum board except when adhesive is used for the attachment of gypsum board. For the bonding of adhesive, joint treatment, texturing, and decoration, the room temperature shall be maintained at not less than 50 °F (10 °C) for 48 h prior to application and continuously thereafter until completely dry.

4.1.1 When a temporary heat source is used, the temperature shall not exceed 95 °F (35 °C) in any given room or area.

4.1.2 Adequate ventilation shall be maintained in the working area during installation and curing period.

4.2 Gypsum board shall be protected from direct exposure to rain, snow, sunlight, or other excessive weather conditions.

NOTE 1—Where manufacturers' recommendations differ from the above, follow their recommendations.

4.3 Ready-mixed joint compounds shall be protected from freezing, exposure to extreme heat, and direct sunlight.

5. Materials and Manufacture

5.1 *Gypsum Boards*— A family of gypsum sheet products as defined in Terminology C 11.

5.1.1 *Type X (Special Fire-Resistant) Gypsum Wallboard, Gypsum Backing Board, Water-Resistant Gypsum Backing Board, or Exterior Gypsum Soffit Board*—Gypsum board that provides a greater degree of fire resistance than regular gypsum board as defined in Specification C 1396/C 1396M.

5.1.2 *Foil-Backed Gypsum Wallboard or Gypsum Backing Board*—Regular or Type X gypsum board with foil laminated to the back surface. The foil is a vapor retarder.

5.1.3 *Predecorated Gypsum Board*—Gypsum board with a decorative wall covering or coating applied in-plant by the gypsum board manufacturer.

5.2 *Gypsum Wallboard*— See Specification C 1396/C 1396M.

5.3 *Gypsum Backing Board and Coreboard*—See Specification C 1396/C 1396M.

5.4 *Water-Resistant Gypsum Backing Board*—See Specification C 1396/C 1396M.

5.5 *Exterior Gypsum Soffit Board*—See Specification C 1396/C 1396M.

5.6 *Gypsum Ceiling Board*—See Specification C 1396/C 1396M.

5.7 *Finishing Materials*:

5.7.1 *Compounds*—Taping compound, finishing compound, and all-purpose compound shall meet the requirements of Specification C 475/C 475M.

5.7.2 Mix compounds in accordance with the manufacturers' directions.

5.7.3 *Joint Tape*—See Specification C 475/C 475M.

5.8 *Fasteners*:

5.8.1 *Nails*—See Specification C 514.

5.8.2 *Screws*:

5.8.2.1 See Specification C 1002 for screws for fastening gypsum board to wood members, steel members less than 0.03 in thickness, and to gypsum board.

5.8.2.2 See Specification C 754 and Specification C 954 for screws for fastening gypsum board to steel members from 0.033 to 0.112 in. in thickness.

5.8.3 *Staples*—No. 16 USS gage flattened galvanized wire staples with 7⁄16-in. (11.1-mm) wide crown outside measurement. Legs shall have divergent points.

NOTE 2—Use only for the base ply of two-ply gypsum board application.

5.9 *Adhesives*:

5.9.1 *Fastening Gypsum Board to Wood Framing*—See Specification C 557.

5.9.2 *Fastening Gypsum Board to Steel Framing*—As specified by the manufacturer.

5.9.3 *Laminating Gypsum Board to Gypsum Board*—Laminating compounds, taping compound, or adhesive shall be as specified by the manufacturer.

NOTE 3—Adhesives for the installation of ceramic tile, see Appendix X4.

5.10 *Framing Members*:

5.10.1 Wood framing members shall conform to PS20, American Softwood Lumber Standards. The surface to which abutting edges or ends are attached shall be not less than 1 ½ in. (38.1 mm) wide. For internal corners or angles, the bearing surface shall not be less than ¾ in. (19.1 mm).

5.10.2 *Steel Studs, Furring Channels, and Runners,* Non-Load Bearing—See Specification C 645.

5.10.3 *Gypsum Studs*— Specification C 1396/C 1396M, not less than 1 in. (25.4 mm) thick by 6 in. (152 mm) wide. Studs shall be either solid or laminated.

5.11 *Accessories*—See Specification C 1047.

5.12 *Water*—Water shall be clean, fresh, and potable (suitable for domestic consumption).

5.13 *Face Panels*—Face panels shall be ½ in. (12.7 mm), 5⁄8 in. (15.9 mm), or multiple laminations of regular or Type X gypsum board.

5.14 *Core Board*—Core board shall be ¾ in. (19.1 mm) or 1 in. (25.4 mm) either single thickness or multiple layers to the required thickness.

6. Substrate, Surface Preparation

6.1 The attachment surface of any framing member shall not vary more than 1⁄8 in. (3.2 mm) from the plane of the faces of adjacent framing members.

6.2 Wood framing shall be as straight and true as possible. Wood framing shall be securely attached following acceptable engineering practices and as required for the intended design.

NOTE 4—For installation of wood framing, see Appendix X5.

6.3 Metal framing members shall be of the proper size and design for their intended use and shall be installed in accordance with Specifications C 754 or C 1007 as required.

6.4 Devices or items attached to framing members, including the fasteners used to attach such devices or items, shall not protrude more than 1⁄8 in. beyond the surface to which the gypsum board is to be applied.

6.5 Masonry or concrete walls shall be dry, free of dust, oil, or form release agents, protrusions or voids, or foreign matter that inhibit bond for adhesively applied gypsum board.

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6.6 All framing members and substrate shall be installed so that after the gypsum board has been applied, the finished surface will be in an even plane.

6.7 Gypsum board shall be kept free of any dirt, oil, or other foreign matter that cause a lack of bond. Foreign matter shall be removed.

6.8 All dents or gouges on the face of the gypsum board shall be brought up to a smooth level plane with the surface of the board.

6.9 Mechanical fasteners shall be set below the plane of the surface of the board.

6.10 All joints shall be true and even.

6.11 All gypsum board shall be tight against the framing member or substrate.

6.12 Deflection at design load of horizontal (ceiling) framing members supporting gypsum board shall be not more than L/240 of the span.

7. Application of Gypsum Board

7.1 *General*:

7.1.1 *Method of Cutting and Installation*—Gypsum board shall be cut by scoring and breaking or by sawing, working from the face side. When cutting by scoring, the face paper shall be cut with a sharp knife or other suitable tool. Gypsum board shall be broken by snapping the gypsum board in the reverse direction, or cut the back paper with a knife or suitable tool.

7.1.2 Cut edges and ends of the gypsum board shall be smoothed to obtain neat joints when installed. Holes for pipes, fixtures, or other small openings shall be scored on the back and the face in outline before removal or cut out with a saw or special tool designed for this purpose. Where gypsum board meets projecting surfaces, it shall be scribed and cut neatly.

7.1.3 When gypsum board is to be applied to both ceiling and walls, the gypsum board shall be applied first to the ceiling and then to the walls.

7.1.3.1 Gypsum board applied to walls shall be applied with the bottom edge spaced not less than ¼ in. (6 mm) above the floor.

7.1.4 Where used at edges or ends, fasteners shall be spaced not more than 1 in. (25 mm) from edges and not less than ⅜ in. (9.5 mm) from edges and ends of gypsum board (except where floating angles are used). Perimeter fastening into the partition plate or sole at the top and bottom shall not be required except where the fire ratings, structural performance, or other special conditions require such fastening. While driving the fasteners, the gypsum board shall be held in firm contact with the underlying support. Application of fasteners shall proceed from the center or field of the gypsum board to the ends and edges.

7.1.5 Nails shall be driven with the heads slightly below the surface of the gypsum board, avoiding damage to the face and core of the board, such as breaking the paper or fracturing the core.

7.1.5.1 Length of nails shall be as shown in Table 1.

7.1.6 Screws shall be driven to provide screwhead penetration just below the gypsum board surface without breaking the surface paper of the gypsum board or stripping the framing member around the screw shank.

7.1.6.1 Length of screws shall be as shown in Table 1.

7.1.7 Staples shall be driven with the crown parallel to the framing members, in such a manner that the crown bears tightly against the gypsum board without cutting into the face paper.

7.1.7.1 Staple attachment shall be restricted to the base plies only of gypsum board in a multi-ply system.

7.1.7.2 Length of staples shall be as shown in Table 1.

7.1.8 The gypsum board shall be kept tight against the framing.

7.1.9 The external corners shall be protected with a metal corner bead or other suitable type of corner protection that shall be attached to supporting construction with fasteners or a crimping tool nominally 6 in. (152 mm) on centers (see Section 3 and Fig. 1).

7.2 Gypsum board shall not be used where it will be exposed to temperatures more than 125 °F (52 °C) for extended periods of time.

7.3 Gypsum board joints shall be located so that no joint will align with the edge of an opening unless control joints are to be installed at these locations.

7.4 Joints between gypsum boards shall be constructed with the gypsum board edges in moderate contact.

TABLE 1 Fastener Length for Gypsum Board Application to Wood Framing[A]

Gypsum Board Thickness[B] in. (mm)	Minimum Nail Length[C] in. (mm)	Minimum Screw Length in. (mm)	Minimum Staple[D] Length in. (mm)
¼ (6.4)	*E*	*E*	*E*
⅜ (9.5)	1 ¼ (32)	1 (25)	1 (25)
½ (12.7)	1 ⅜ (35)	1 ⅛ (28)	1 ⅛ (28)
⅝ (15.9)	1 ½ (38)	1 ¼ (32)	1 ¼ (32)

[A] Where fire resistance is required for gypsum board systems, fasteners of the same or larger length, shank diameter, and head bearing area as those described in the fire-rated design shall be used.

[B] For other thicknesses, for multi-layer applications, or for application over rigid foam insulation, fasteners shall be of sufficient length to penetrate framing not less than ⅞ in. (22 mm) for nails, ⅝ in. (15 mm) for screws, and ⅝ in. (15 mm) for staples.

[C] The maximum penetration for nails shall not exceed 1 ¼ in. (32 mm).

[D] Staple attachment is restricted to base layers of multi-layer systems only. See 7.1.7.1.

[E] For application over existing solid surfaces or in multi-layer applications only—see [B] above for required fastener length.

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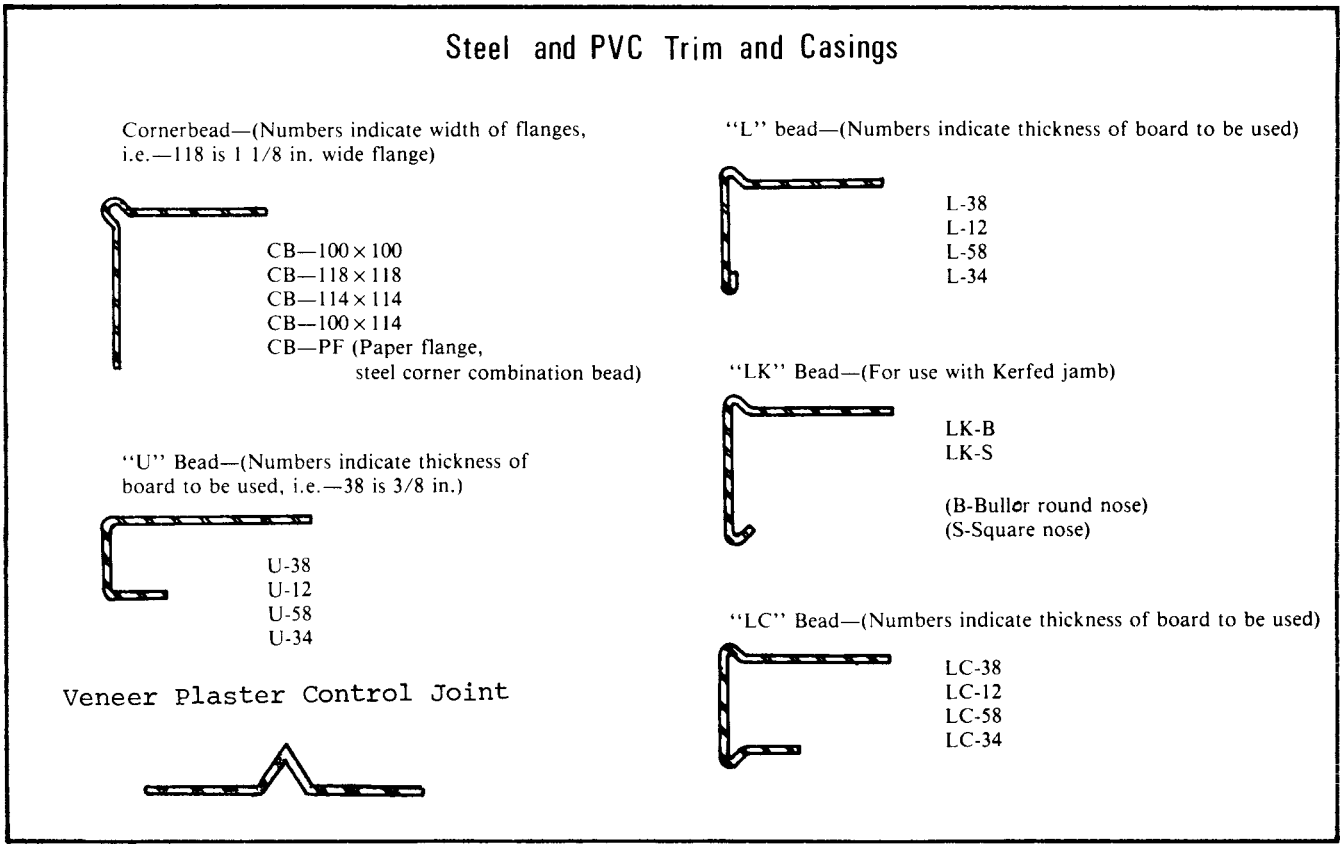

NOTE 1—All dimensions are in inch-pound units.

FIG. 1 Accessories

7.5 Joints shall be staggered, and joints on opposite sides of a partition shall not occur on the same stud.

7.6 Gypsum board used in building construction shall be not less than 8 in. (203 mm) from the finished grade in fully weather and water protected siding systems, and not less than 12 in. (305 mm) from the ground within properly drained and ventilated crawl spaces. Where ground moisture or humidity is extreme and/or continuous, the crawl space ground surface shall be covered with a vapor barrier.

8. System I: Application of Single-Ply Gypsum Board to Wood Framing Members

8.1 The maximum spacing for framing members for single-ply gypsum board assembly shall not exceed those shown in Table 2.

8.1.1 The ¼-in. (6.4-mm) thick gypsum board shall not be used in single-ply applications on either walls or ceilings.

8.2 In single-ply installation, all ends and edges of gypsum board shall occur over framing members or other solid backing except where treated joints occur at right angles to framing or furring members.

8.3 End joints shall be staggered and joints on opposite sides of a partition shall be arranged to occur on alternate framing members.

8.4 Application using nails.

8.4.1 Where a specific degree of fire resistance is required for gypsum board assemblies, nails of the same length, shank diameter, and head bearing area, as those described in the fire test report, shall be used.

8.4.2 *Single Nailing*—Nails shall be spaced a maximum of 7 in. (177.8 mm) on centers on ceilings, and a maximum of 8 in. (203.2 mm) on centers on walls (see Fig. 2).

TABLE 2 Maximum Framing Spacing for Single-Ply Construction[A]

Single-Ply Gypsum Board Thickness, in. (mm)	Application[B]	Maximum Framing Members On Centers Spacing, in. (mm)
Ceilings:		
⅜ (9.5)[C]	perpendicular	16 (406.4)
½ (12.7)	parallel	16 (406.4)
⅝ (15.9)	parallel	16 (406.4)
½ (12.7)	perpendicular	24 (609.6)
⅝ (15.9)	perpendicular	24 (609.6)
Sidewalls:		
⅜ (9.5)	perpendicular or parallel	16 (406.4)
½ (12.7) or ⅝ (15.9)	perpendicular or parallel	24 (609.6)

[A] Gypsum board ceilings to receive hand or spray-applied water-based texture material shall be applied perpendicular to framing and shall be either (i) ½ in. (12.7 mm) Gypsum Ceiling Board (see Specification C 1396/C 1396M) applied to framing not more than 24 in. (610 mm) on center, or (ii) other gypsum boards not less than ½ in. (12.7 mm) thick for 16 in. (406 mm) on center framing and not less than ⅝ in. (15.9 mm) thick for 24 in. (610 mm) on center framing.

[B] Nails for gypsum board applied over existing surfaces shall have a flat head and diamond point, and shall penetrate not less than ⅞ in. (22.2 mm), nor more than 1 ¼ in. (31.8 mm) into the framing member.

[C] ⅜-in. (9.5-mm) single-ply gypsum board shall not be applied to ceilings where the gypsum board supports insulation.

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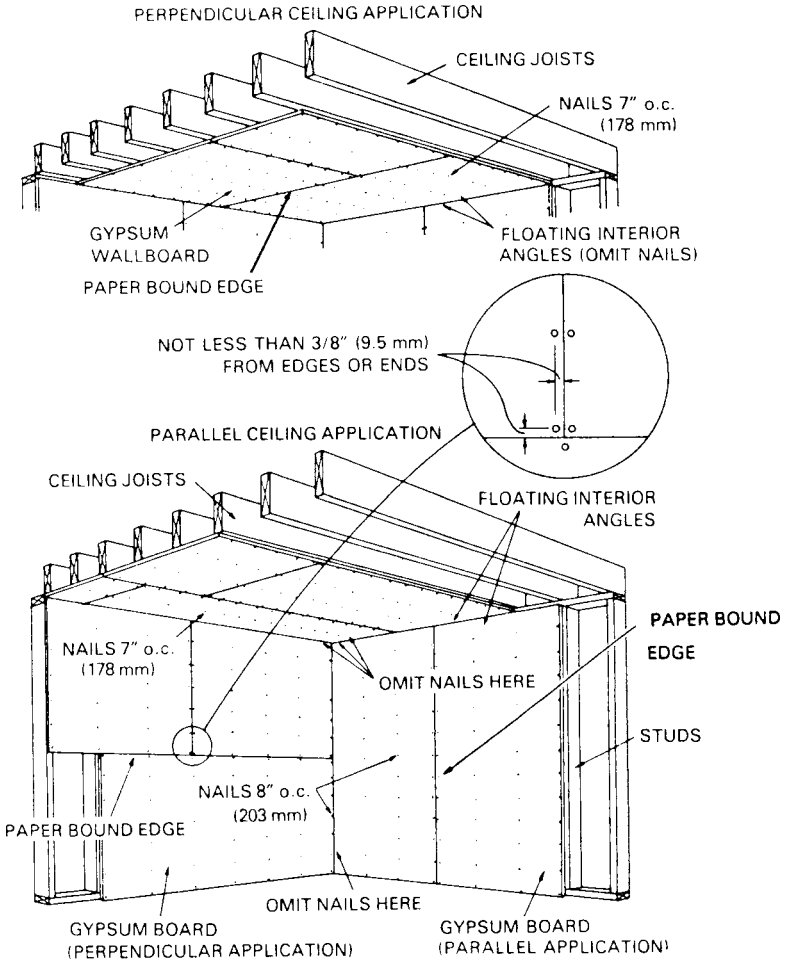

FIG. 2 Single Nailing

8.4.3 *Double Nailing*—Nails shall be spaced as shown in Fig. 3 and driven as follows:

8.4.3.1 Starting at the center of the gypsum board, nails shall be applied as shown in solid dots in row 1, then rows 2 and 2A, 3 and 3A, 4 and 4A, always nailing from center to edges of sheet. The gypsum board shall be kept tight against the framing.

8.4.3.2 Second nails, shown by circles, shall be applied in the same manner as the first nails, also starting at row 1.

8.4.3.3 As an alternative procedure, the second nail shall be applied immediately after all nails in each row are driven in accordance with 8.4.3.2.

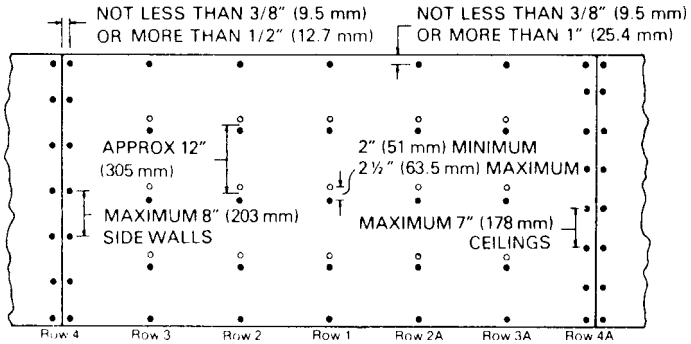

FIG. 3 Double Nailing

8.4.3.4 Single nailing shall be used on the perimeter of the gypsum board, unless otherwise specified.

8.4.3.5 Nails shall be inspected for compliance with 7.1.5 after the second nails have been set.

8.5 *Spacing of Screws*—Screws shall be spaced not more than 12 in. (304.8 mm) on centers along framing members for ceilings and 16 in. (406.4 mm) on centers for walls where the framing members are 16 in. on centers. Screws shall be spaced not more than 12 in. on centers along framing members for ceilings and walls where the framing members are 24 in. (609.6 mm) on centers.

8.5.1 When using a combination of fasteners consisting of nails along the perimeter and screws in the field of the gypsum board, the spacing between a nail and an adjacent screw shall be not more than the spacing specified for screws in 8.5.

9. System II: Application of Two-Ply Gypsum Board to Wood Framing Members

9.1 The maximum spacings for framing members for two-ply gypsum board assemblies shall not exceed those shown in Tables 3 and 4.

NOTE 5—See Section 2 for adhesive application method.

9.2 The fastener length for the base ply of gypsum board shall be as indicated in Table 1.

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TABLE 3 Maximum Framing Spacing for Two-Ply Assemblies, Fasteners Only, No Adhesive Between Plies[A]

Gypsum Board Thickness, in. (mm)		Application Direction		Maximum On Centers Spacing of Framing, in. (mm)
Base Ply	Face Ply	Base Ply	Face Ply	
Ceilings:				
¼ (6.4)	⅜ (9.5) or ½ (12.7)	perpendicular	perpendicular	16 (406.6)
⅜ (9.5)	⅜ (9.5) or ½ (12.7)	perpendicular	perpendicular	16 (406.6)
½ (12.7)	⅜ (9.5) or ½ (12.7)	parallel	perpendicular	16 (406.6)
½ (12.7)	½ (12.7) or ⅝ (15.9)	perpendicular	perpendicular	24 (609.6)
⅝ (15.9)[B]	½ (12.7) or ⅝ (15.9)	perpendicular	perpendicular	24 (609.6)
Walls:				
¼ (6.4)	¼ (6.4) or ⅜ (9.5) or ½ (12.7)	perpendicular or parallel	perpendicular or parallel	16 (406.6)
⅜ (9.5)	¼ (6.4) or ⅜ (9.5)	perpendicular or parallel	perpendicular or parallel	16 (406.6)
½ (12.7)	¼ (6.4) or ⅜ (9.5) or ½ (12.7)	perpendicular or parallel	perpendicular or parallel	24 (609.6)
⅝ (15.9)	¼ (6.4) or ⅜ (9.5) or ½ (12.7) or ⅝ (15.9)	perpendicular or parallel	perpendicular or parallel	24 (609.6)

[A] Gypsum board ceilings to receive hand or spray-applied water-based texture material shall be applied perpendicular to framing and shall be either (i) ½ in. (12.7 mm) Gypsum Ceiling Board (see Specification C 1396/C 1396M) applied to framing not more than 24 in. (610 mm) on center, or (ii) other gypsum boards not less than ½ in. (12.7 mm) thick for 16 in. (406 mm) on center framing and not less than ⅝ in. (15.9 mm) thick for 24 in. (610 mm) on center framing.
[B] ⅝-in. (15.9-mm) board shall be permitted to be applied perpendicularly at 16 in. (406 mm) spacing.

TABLE 4 Maximum Framing Spacing for Two-Ply Assembly Fasteners with Adhesive Between Plies[A]

Gypsum Board Thickness, in. (mm)		Application Direction		Maximum On Centers Spacing of Framing, in. (mm)
Base Ply	Face Ply	Base Ply	Face Ply	
Ceilings:				
¼ (6.4)	¼ (6.4) or ⅜ (9.5) or ½ (12.7)	perpendicular	perpendicular	16 (406.6)
⅜ (9.5)	¼ (6.4) or ⅜ (9.5) or ½ (12.7)	perpendicular	perpendicular	16 (406.6)
½ (12.7)	¼ (6.4) or ⅜ (9.5) or ½ (12.7)	parallel	perpendicular	16 (406.6)
½ (12.7)	¼ (6.4) or ½ (12.7) or ⅝ (15.9)	perpendicular	perpendicular	24 (609.6)
⅝ (15.9)	¼ (6.4) or ½ (12.7) or ⅝ (15.9)	perpendicular	perpendicular	24 (609.6)
Walls:				
¼ (6.4)	¼ (6.4) or ⅜ (9.5) or ½ (12.7)	perpendicular or parallel	perpendicular or parallel	16 (406.6)
⅜ (9.5)	¼ (6.4) or ⅜ (9.5)	perpendicular or parallel	perpendicular or parallel	16 (406.6)
½ (12.7)	¼ (6.4) or ⅜ (9.5) or ½ (12.7)	perpendicular or parallel	perpendicular or parallel	24 (609.6)
⅝ (15.9)	¼ (6.4) or ½ (12.7) or ⅝ (15.9)	perpendicular or parallel	perpendicular or parallel	24 (609.6)

[A] Adhesive between plies shall be dried or cured prior to joint treatment application.

9.2.1 Base layer end joints parallel to and on the same side of framing members shall be staggered between alternate courses of gypsum board and from base layer joints on the opposite side of the framing members.

9.2.2 Base layer edge joints parallel to framing members shall be staggered on opposite sides of the framing members.

9.3 When adhesive is not used between the plies, the two plies of gypsum board shall be applied as indicated in Tables 3 and 5. The face ply shall be applied with the number of nails or screws required for normal single-ply application. Fastener length for face ply application shall be as indicated in [B] of Table 1. Face ply joints that are parallel to framing shall fall over framing members and be offset from the base ply joints when two plies of gypsum board are parallel.

9.4 When an adhesive is used between the plies (laminated face ply), the two plies shall be applied as indicated in Tables 4 and 5. If the two plies are applied in parallel direction, the joints in the face ply shall be offset from the joints in the base ply.

9.4.1 Joints in the face ply need not occur over the framing members. The adhesive used between the two plies of gypsum board shall be uniformly applied over the back surface of the face ply of the gypsum board before it is erected or to the face surface of the base ply. The face ply of gypsum board shall be placed in position and fastened with nails or screws to hold gypsum board in place until the adhesive develops a bond.

9.4.2 Permanent fasteners shall be used around the perimeter 12 in. (304.8 mm) on centers and 16 in. (406.4 mm) on

TABLE 5 Base Layer Fastener Spacing for Multi-Layer Gypsum Board Application

		Base Layer Nail Spacing in. (mm)		Base Layer Screw Spacing in. (mm)		Base Layer Staple Spacing in. (mm)	
Location	Framing Spacing in. (mm)	Where Face Layer is Laminated	Where Face Layer is Mechanically Attached	Where Face Layer is Laminated	Where Face Layer is Mechanically Attached	Where Face Layer is Laminated	Where Face Layer is Mechanically Attached
Walls	16 (406)	8 (203)	24 (610)	16 (406)	24 (610)	7 (178)	16 (406)
	24 (610)	8 (203)	24 (610)	12 (305)	24 (610)	7 (178)	16 (406)
Ceilings	16 (406)	7 (178)	16 (406)	12 (305)	24 (610)	7 (178)	16 (406)
	24 (610)	7 (178)	16 (406)	12 (305)	24 (610)	7 (178)	16 (406)

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centers along framing members for the face ply of gypsum board applied on ceilings.

9.4.3 In place of nails and screws, the face ply of gypsum board applied on walls shall be held in position by shoring with props and headers, or other temporary support to ensure a pressure for bonding. Permanent fasteners shall be used on top and bottom of wall not more than 16 in. (406 mm) on centers. Nails or screws used to hold the gypsum board face ply shall be left in place and finished in the same manner as for single-ply gypsum board application (see Section 10).

9.5 Base layer joints and fasteners shall not be required to be taped or finished. Face layer joints and fasteners in multi-layer systems shall not be required to be finished unless required for appearance or decoration or as required for fire resistance.

10. System III: Application of Gypsum Board by Adhesive Nail-on to Wood Framing Members

10.1 Except as herein modified, application shall be in conformance with Section 8.

10.2 Surfaces of gypsum board and framing to receive the adhesive shall be free of dust, dirt, grease, or any other foreign matter that cause bond loss. Foreign matter shall be removed.

10.3 A bead of adhesive ⅜ in. (9.5 mm) in diameter shall be applied to the face of all wood framing members, except plates, that support the gypsum board. The adhesive shall be spread to an average width of ¾ in. (19 mm) and an average thickness of 1⁄16 in. (1.6 mm). See Fig. 4 for application patterns.

10.3.1 Where a joining of two adjacent pieces of gypsum board occurs on a framing member, two parallel beads of adhesive shall be applied, one near each edge of the framing member.

10.4 Adhesive shall be applied to no greater area than can be covered with gypsum board within the "open time."

NOTE 6—"Open time" is the time period available for working with certain adhesives before they set in accordance with the adhesive manufacturer's specification.

10.5 *Fastener Spacing*:

10.5.1 If the properties of the adhesive ensure bridging between the gypsum board and the wood framing, nailing shall not be required in the field of the board for walls. In such cases, perimeter nailing, 16 in. (406.4 mm) on centers, shall be required.

10.5.2 When the properties of the adhesive are such that there is no positive bridging between the gypsum board and the wood framing, either temporary field nailing or temporary bracing shall be used to ensure contact between the gypsum board, the adhesive, and the wood framing, until the adhesive develops a bond.

10.5.3 Unless specified otherwise by the adhesive manufacturer, fastener spacing shall be in accordance with Table 6.

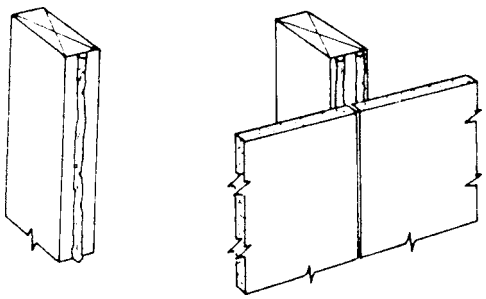

FIG. 4 Adhesive Application Patterns

11. System IV: Semi-Solid Gypsum Board Partitions

11.1 *Installation*:

11.1.1 Runners or studs shall be installed where required to provide support at exterior walls, partition junctions, terminals, external corners, door frames, and at other locations.

11.1.2 The gypsum board face panels and studs shall be positioned vertically.

11.1.3 The gypsum studs shall be laminated to face panels not more than 24 in. (609.6 mm) on centers and located at face panel vertical joints and at vertical centerline of panel.

11.1.4 Gypsum studs shall be laminated to face panels prior to erection or as erection of partition proceeds. A starter face panel shall be erected vertically at an intersecting wall. The starter panel shall be plumb and secured to the floor, the ceiling, and the vertical runners.

11.1.5 The next face panel adjacent to the starter panel shall be erected by butting its edge and end firmly to the starter panel and the ceiling. Erection of the face panels shall continue by laminating exposed faces of gypsum studs as work progresses.

11.1.6 Openings in partitions for doors and electrical outlets shall be carefully and accurately marked and cut.

11.1.7 Laminating compounds or adhesives shall be of a consistency and volume that will cover approximately three-fourths of the stud surface after lamination.

11.1.8 Type G screws shall be used to ensure a continuous bond between face panels and studs, and shall be spaced not more than 36 in. (914 mm) on centers.

11.1.9 Openings or changes in direction of partitions shall be reinforced with additional studs laminated in place at the following locations:

11.1.9.1 *External Corners*—Between the face panels in the corner opposite vertical runners.

11.1.9.2 *Abutting Walls*—Between the face panels of a partition to reinforce junction of an abutting wall.

11.1.9.3 *Door Openings*—Locate a vertical stud within 3 in. (76.2 mm) of door frame for reinforcement, and place a stud horizontally over the door header.

12. System V: Solid Gypsum Board Partitions

12.1 Non-load bearing solid partition consisting of gypsum coreboard faced on each side with gypsum board panels.

12.2 *Installation*:

12.2.1 Floor and ceiling runners shall be installed according to the layout and shall be secured not more than 24 in. (610 mm) on centers. Vertical runners shall be installed where specified in 11.1.1.

12.2.2 For partitions located parallel to and between ceiling members, steel or wood blocking not more than 24 in. (609.6 mm) on centers shall be provided to fasten ceiling runners prior to erection of ceiling.

12.2.3 Face panels shall be attached to runners at not more than 24 in. (609.6 mm) on centers.

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TABLE 6 Fastener Spacing with Adhesive or Mastic Application and Supplemental Fastening

Framing Member Spacing, in. (mm) On Centers	Ceilings, in.		Partitions Load Bearing, in.		Partitions Nonload Bearing, in.	
	Nail	Screw	Nail	Screw	Nail	Screw
16 (406.4)	16	16	16	24	24	24
24 (609.6)	12	16	12	16	16	24

12.2.4 Coreboard shall be installed prior to the installation of the face panel. Coreboard shall be attached not more than 24 in. (610 mm) on centers to the steel angles when steel angles are used as runners. When steel channels are used as runners to secure coreboard, attachment shall not be required.

NOTE 7—Combinations of wood and steel channels or angles will vary the installation procedure.

12.2.5 The adhesive shall be applied to the back surface of the face panels or the face of the coreboard as described for two-ply gypsum board construction (see Section 9).

12.2.6 The face panels shall be laminated to the core with sufficient pressure to ensure bonding. The joints of the face panels and core shall be staggered. To ensure the bond between face panels and core, fasteners shall be permitted.

13. System VI: Application of Gypsum Board with Adhesive to Interior Masonry or Concrete Walls

13.1 When applying gypsum board to monolithic concrete, brick, or concrete block, the adhesive shall be applied directly to the back of the gypsum board or on the wall in continuous beads not more than 12 in. (304.8 mm) on centers or daubs spaced not more than 12 in. (304.8 mm) on centers each way.

13.1.1 Beads shall be not less than ⅜ in. (9.6 mm) in diameter to provide a continuous bond between the gypsum board and the wall surface.

13.1.2 Daubs shall be 2 to 3 in. (50.8 to 76.2 mm) in diameter.

13.2 The gypsum board shall be positioned ⅛ in. (3.2 mm) from the floor and provide a tight fit at abutting edges or ends. The gypsum board shall not be slid on the adhesive. Mechanical fasteners, or temporary bracing, shall be used to support gypsum board until adhesive sets.

13.3 Delay the joint treatment until the gypsum board is firmly bonded.

13.4 Foil-backed gypsum board shall not be used for direct adhesive application.

13.5 Direct adhesive application shall be used only on interior masonry or concrete walls above grade, or the inside of exterior masonry cavity walls with 1-in. (25.4 mm) minimum width cavity between the inside and outside masonry for the full height of the above grade surface to receive gypsum board. Surfaces to which gypsum board is to be adhesively attached shall be free of any foreign matter, projections, or depressions that will impair the bond.

14. System VII: Application of Gypsum Board to Rigid Plastic Foam Insulation

14.1 *Application of Furring and Plastic Foam Insulation to Masonry and Concrete Walls*:

14.1.1 Rigid foam insulation shall be applied to the masonry or concrete in accordance with the foam manufacturer's specifications.

14.1.2 Furring strips or special metal furring members shall be attached by mechanical means to the masonry or concrete wall surface either before or after application of the insulation, depending on the system used. The furring members shall be installed in accordance with Table 2 and at gypsum board terminations above suspended ceilings, around doors, windows, or other openings, and for cabinet and fixture attachment.

14.2 The gypsum board shall be applied to furring as described in 8.4.1 or 8.5. The mechanical fasteners shall not penetrate completely to the masonry or concrete.

15. System VIII: Application of Gypsum Board to Steel Framing and Furring

15.1 Screw application shall be applied in accordance with 7.1.6.

15.1.1 Screws shall be of sufficient length so that the threaded portion shall penetrate not less than ⅜ in. (9 mm) into the framing members.

15.1.2 Where resilient furring channels are used, the screws used to attach gypsum board to the furring channels shall not contact the framing.

15.2 *Framing Spacing*—Maximum spacing of steel framing and furring for screw application shall be as specified in Table 2 for single-ply gypsum board and as specified in Tables 3 and 4 for two-ply gypsum board.

15.2.1 Installation of steel framing shall be in accordance with Specifications C 754 or C 1007.

15.3 *Screw Spacing*:

15.3.1 Screw spacing for single-ply gypsum board and face ply of two-ply gypsum board with no adhesive shall be in accordance with 8.5.

15.3.2 Screw spacing for parallel applied base-ply of two-ply gypsum board over steel framing with no adhesive between the plies shall be not more than 12 in. (304.8 mm) on centers along the edges of the gypsum board and 24 in. (609.6 mm) on centers into the stud or furring channel in the field of the gypsum board.

15.3.3 Screw spacing for a perpendicularly applied base-ply of two-ply gypsum board over steel framing with no adhesive between the plies shall be not less than one screw at each edge of the gypsum board at each framing member and one screw midway between the edges at each framing member.

15.3.4 Screw spacing for perpendicular or parallel applied base-ply of two-ply gypsum board over steel framing with adhesive between plies shall be not more than as specified for single-ply gypsum board in 8.5.

15.3.5 Screw spacing on ceilings for the face-ply of two-ply gypsum board over steel framing with adhesive between plies shall be the same as specified for the base-ply gypsum board in 15.3.2 and 15.3.3.

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15.3.6 On wall surfaces with adhesive between the plies, the face-ply shall have only a sufficient number of screws to hold gypsum board in place.

16. System IX: Arches and Bending Radii

16.1 Where gypsum board is to be applied to the soffit of arches, it shall be carefully bent into place (see Table 7). If necessary, it first shall either be dampened or cut approximately 1 in. (25.4 mm) on centers on the back side. In the latter case, after the core has been broken at each cut, the gypsum board shall be applied to the curved framing member and fastened in place. At the arises of the arch (exterior or interior "corners" formed at the meeting of the adjoining angle surfaces), joint compound and joint tape or corner bead shall be applied. The tape or corner bead shall be snipped at intervals along one side so that the applied tape or corner bead conforms to the curved contour.

NOTE 8—To apply the board, place a stop at one end of the curve, then gently and gradually push on the other end of the board, forcing the center against the framing until the curve is complete.

NOTE 9—By thoroughly moistening the face and back paper and allowing the water to soak well into the core, the board will bend to still shorter radii. When the board thoroughly dries, it will regain its original hardness. Any subsequent joint treatment or decoration shall not be started until the gypsum board is thoroughly dry.

17. System X: Application of Gypsum Board to Receive Tile by Adhesive Application

17.1 Framing around tub enclosures and shower stalls shall maintain sufficient room to accommodate the inside lip of the tub, prefabricated receptor, shower pan, or membrane as shown in Figs. 5-7.

NOTE 10—This will necessitate furring out from the framing members the thickness of the gypsum board to be used (½ or ⅝ in. (12.7 or 15.9 mm)) less the thickness of the lip, on each wall abutting a tub receptor or subpan.

17.2 *Blocking or Backing*:

17.2.1 Where framing is spaced more than 16 in. (406 mm) o.c., blocking or backing shall be provided ¾ –1¼ in. (20–30 mm) above the top of the tub or receptor and at gypsum board horizontal joints in the area to receive tile.

17.2.2 Interior angles shall be framed or blocked to provide solid backing for interior corners.

17.2.3 Blocking, headers, or supports shall be provided to support the tub and other plumbing fixtures and to receive soap dishes, grab bars, towel racks, and similar items.

17.3 *General*:

17.3.1 Water-resistant gypsum backing board shall be used as a base for adhesive application of ceramic or plastic wall tile in wet areas such as tub and shower enclosures. Either regular gypsum board or water-resistant gypsum backing board shall be used as a base for tile in other areas. Water-resistant gypsum backing board and regular gypsum board shall not be used in extremely critical areas such as saunas, steam rooms, or gang shower rooms. Foil-backed gypsum board shall not be used as a base for tub or shower enclosures. Water-resistant gypsum board used as a base for tile or wall panels in tub and shower enclosures shall not be applied directly over a vapor retarder.

NOTE 11—The use of water-resistant gypsum backing board as a base for tile in wet areas is regulated by local codes. Consult local building codes for requirements.

17.3.1.1 Gypsum board shall not be used where there will be direct exposure to water or continuous high humidity

TABLE 7 Bending Radii

Gypsum Board Thickness, in. (mm)	Bent Lengthwise, ft (m)	Bent Widthwise, ft (m)
½ (12.7)	10 (3.05)[A]	—
⅜ (9.5)	7 ½ (2.29)	25 (7.62)
¼ (6.4)	5 (1.52)	15 (4.57)

[A] Bending two ¼-in. (6.4-mm) pieces successively permits radii shown for ¼ in. (6.4 mm).

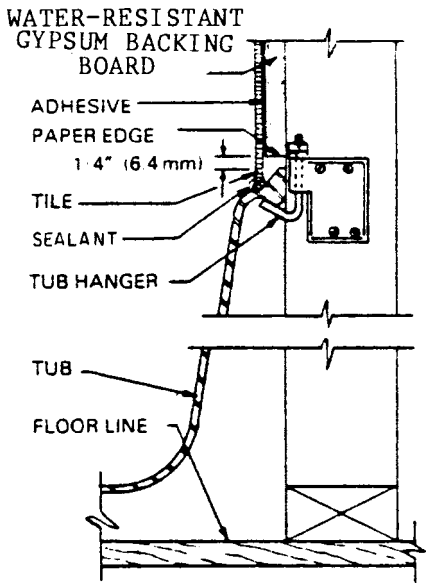

FIG. 5 Application of Gypsum Board at Bathtub Where WR Board Will Receive Ceramic Tile or Other Protective Covering

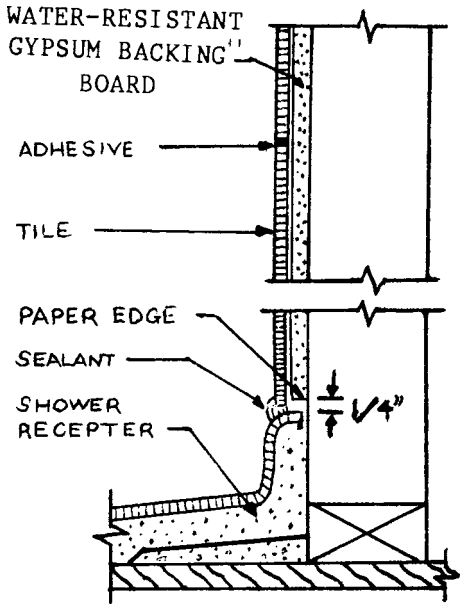

FIG. 6 Adhesive Application of Gypsum Board at Shower Where WR Board Will Receive Ceramic Tile or Other Protective Covering

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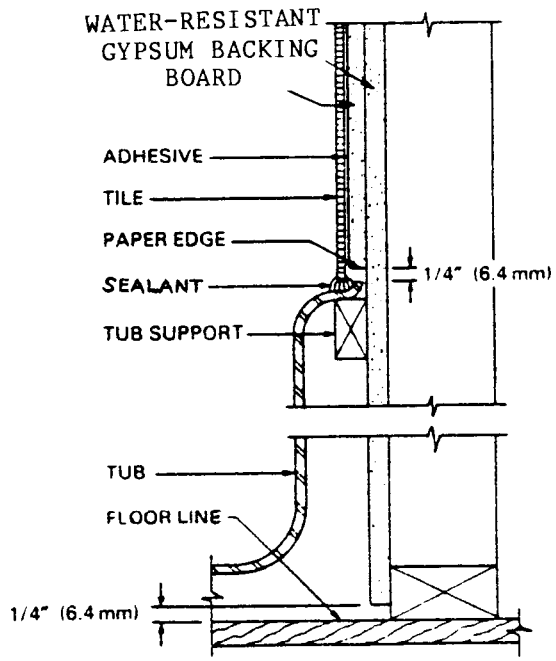

FIG. 7 Adhesive Application of Tile Over Gypsum Board

conditions such as are found in saunas, steam rooms, gang shower rooms, or indoor pools.

17.3.1.2 Foil-backed gypsum board shall not be used as a base for tub or shower enclosures.

17.3.1.3 Water-resistant gypsum backing board used as a base for tile or wall panels in tub and shower enclosures shall not be applied directly over a vapor retarder.

17.3.1.4 Ceiling framing spacing for water-resistant gypsum backing board ½ in. (12.7 mm) thick applied to ceilings shall be not more than 12 in. (305 mm) on centers.

17.3.1.5 Ceiling framing spacing for water-resistant gypsum backing board ⅝ in. (15.9 mm) thick applied to ceilings shall be not more than 16 in. (406 mm) on centers.

NOTE 12—Asphalt-impregnated felt is not considered a vapor retarder.

17.3.2 All multiple plies of gypsum board in wet areas shall be attached with mechanical fasteners.

17.3.3 Waterproof receptors, pans, or sub-pans shall have an upstanding lip or flange that shall be a minimum of 1 in. (25.4 mm) higher than the water dam or threshold contained in the entry way to the shower.

17.4 *Installation*:

17.4.1 Water-resistant gypsum backing board shall be applied with the factory edge spaced not less than ¼ in. (6.4 mm) above the lip of the receptor, tub, or sub-pan. Shower pans, receptors, or tubs shall be installed prior to the erection of the water-resistant gypsum backing board.

17.4.2 Water-resistant gypsum backing board shall be attached by nails or screws spaced not more than 8 in. (203.2 mm) on centers. When ceramic tile more than ⅜ in. (9.5 mm) thick is to be applied, the nail or screw spacing shall be not more than 4 in. (101.6 mm) on centers.

17.4.3 Where treatment of water-resistant gypsum backing board joints under tile in wet areas (tub and shower enclosures) is required, the compound and application thereof, shall be as required by the joint compound manufacturer for this specific use, or shall be protected from penetration of moisture or water (see X4.2).

17.4.4 All cut edges and openings around pipes and fixtures shall be sealed with a water-resistant flexible sealant to create a water-repellant barrier where water-resistant gypsum backing board has been cut and the gypsum core is exposed. Sealant shall be as specified in 17.4.4.1 and 17.4.4.2 or equivalent.

17.4.4.1 Ceramic tile adhesive complying with ANSI A 136.1, Type I or Type II.

17.4.4.2 Flexible sealant complying with Specification C 920, Type S, Grade NS, Class 25.

17.4.5 Certain fire or sound-rated gypsum board assemblies require the installation of an additional layer of water-resistant gypsum backing board (see Fig. 7). A ¼ in. (6.4 mm) clearance shall be maintained between the wallboard and tub rim, or shower base, as shown in Figs. 6 and 7.

NOTE 13—For installation of ceramic tile to gypsum boards, see X4.3.

18. System XI: Exterior Application of Gypsum Wallboard and Exterior Gypsum Soffit Board

18.1 Where gypsum wallboard or exterior gypsum soffit board is used for ceilings of carports, open walkways, porches, and soffits of eaves that are horizontal or inclined downward away from the building, the gypsum board shall be either ½ or ⅝ in. (12.7 or 15.9 mm) in thickness. Framing shall be not more than 16 in. (406 mm) on centers for ½-in. (12.7-mm) thick gypsum board and not more than 24 in. (610 mm) on centers for ⅝-in. (15.9-mm) thick gypsum board. The gypsum board shall be installed perpendicularly in accordance with the foregoing specifications except as herein modified.

18.2 Suitable facia and molding shall be provided around the perimeter to protect the gypsum wallboard and exterior gypsum soffit board from direct exposure to water. Unless protected by metal or other water stops, the edges of the gypsum wallboard and exterior gypsum soffit board shall be placed not less than ¼ in. (6.4 mm) away from abutting vertical surfaces. (See Figs. 8-10.) Joints and fastener heads shall be treated as specified in X3.6.

18.3 Exposed surface of gypsum board and exterior gypsum soffit board shall be treated as specified in X3.6.

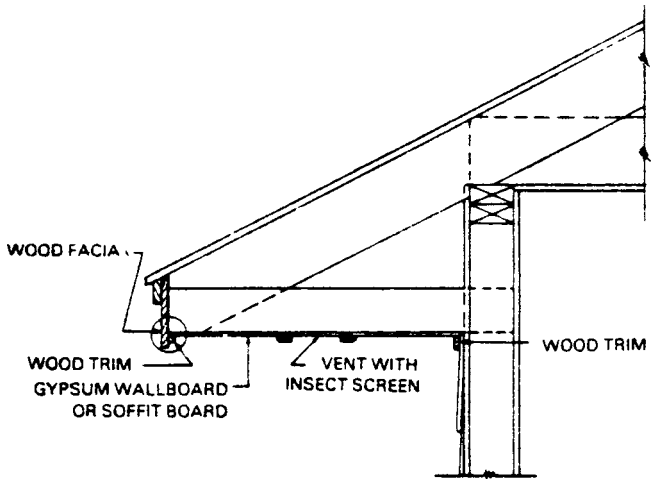

FIG. 8 Frame Wall

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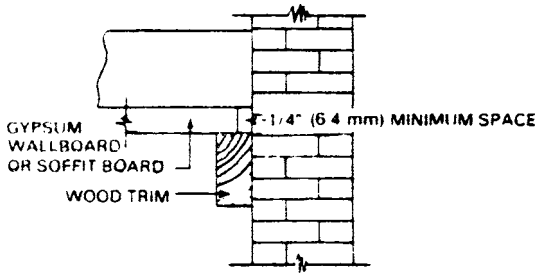

FIG. 9 Masonry Wall

18.4 Adequate ventilation shall be provided for the space immediately above installations (see Appendix X2).

19. System XII: Floating Interior Angles

19.1 Gypsum board shall be applied to ceiling first. (See Figs. 11-13.)

19.1.1 The floating angle method of application minimizes the possibility of fastener popping in areas adjacent to the wall and ceiling intersections for single-ply or two-ply applications of gypsum board to wood framing.

19.2 *Ceilings*—The first fastener into each ceiling framing member framed perpendicular to the intersection shall be located 7 in. (117.8 mm) out from the wall intersection for single nailing, and 11 to 12 in. (279.4 to 304.8 mm) for double nailing, or screw application.

19.3 *Walls*—Gypsum board shall be applied on walls so as to provide support for the floated edges of the ceiling gypsum board. The top fastener into each vertical framing member shall be located 8 in. (203.2 mm) down from the ceiling intersection for single nailing, and 11 to 12 in. (279.4 to 304.8 mm) for double nailing, or screw application. (See Figs. 11 and 12.) At wall vertical angles, the over-lapping board shall be applied so as to bring the back of the underlying board into firm contact with the face of the framing member behind it. Fasteners shall be omitted from the underlying board at the intersection. (See Fig. 13.)

20. System XIII: Control (Expansion) Joints

20.1 Control joints shall be either manufactured devices designed for this purpose or field fabricated from suitable materials.

20.2 Control joints shall be installed where indicated on the plans. Full height door frames shall be considered equivalent to a control joint.

20.3 Control joints in the gypsum board shall be specified by the architect or designer where any of the conditions described in 20.3.1-20.3.5 exist.

20.3.1 A control joint shall be installed where a partition, wall, or ceiling traverses a construction joint (expansion, seismic, or building control element) in the base building structure.

20.3.2 Control joints shall be installed where a wall or partition runs in an uninterrupted straight plane exceeding 30 linear feet (9100 mm).

20.3.3 Control joints in interior ceilings with perimeter relief shall be installed so that linear dimensions between control joints do not exceed 50 ft (15000 mm) and total area between control joints does not exceed 2500 sq ft (230 m^2).

20.3.4 Control joints in interior ceilings without perimeter relief shall be installed so that linear dimensions between control joints do not exceed 30 ft (9100 mm) and total area between control joints does not exceed 900 sq ft (84 m^2).

20.3.5 Control joints in exterior ceilings and soffits shall be installed so that linear dimensions between control joints do not exceed 30 ft (9100 mm) and total area between control joints does not exceed 900 sq ft (84 m^2).

20.3.6 A control joint or intermediate blocking shall be installed where ceiling framing members change direction.

20.3.7 Control joints shall be installed where specified by the architect or designer as a design accent or architectural feature.

20.4 Where a control joint occurs in an acoustical or fire-rated system, blocking shall be provided behind the control joint by using a backing material such as ⅝ in. (15.9 mm) type X gypsum board, mineral fiber, or other tested equivalent.

21. System XIV: Foil-Backed Gypsum Board

21.1 The application of foil-backed gypsum board shall conform to the specifications for the application of gypsum board. The reflective surface shall be placed against the face of the framing members. Foil-backed gypsum board shall not be used in the following areas:

21.1.1 As a backing material for tile in wet areas.

21.1.2 For the second ply on two-ply laminating systems.

21.1.3 For laminating directly to masonry or concrete.

21.1.4 In conjunction with electric heating cables.

22. Finishing of Gypsum Wallboard

22.1 *General*:

22.1.1 Compound for taping and finishing shall be either drying or setting types. Drying and setting type compounds shall not be mixed together unless specified otherwise by the joint compound manufacturer.

22.1.2 When applied, the compounds shall be of a chemical composition compatible with previous and successive coats.

22.1.3 No finishing operation shall be started until the interior temperature has been maintained at a minimum of 50 °F (10 °C) for a period of at least 48 h and thereafter until the compounds have completely dried.

22.1.4 When two-ply application is used with adhesives between plies, precautions shall be taken to ensure that the adhesive is thoroughly dried before any decorative finish is applied.

22.1.5 Adequate and continuous ventilation shall be provided to ensure proper drying and hardening of the compounds.

22.2 *Surface Preparation*:

22.2.1 Dirt, oil, and other materials that cause a lack of bond shall be removed from all surfaces to receive joint compound.

22.2.2 All dents, gouges, recesses, or other depressions shall be filled with compound and drawn to a level plane.

22.3 *Taping*:

22.3.1 Joint tape and joint compounds shall be applied using tools designed for this work and the compounds being used. Such tools include hand-held broad knives, trowels, or mechanical tools.

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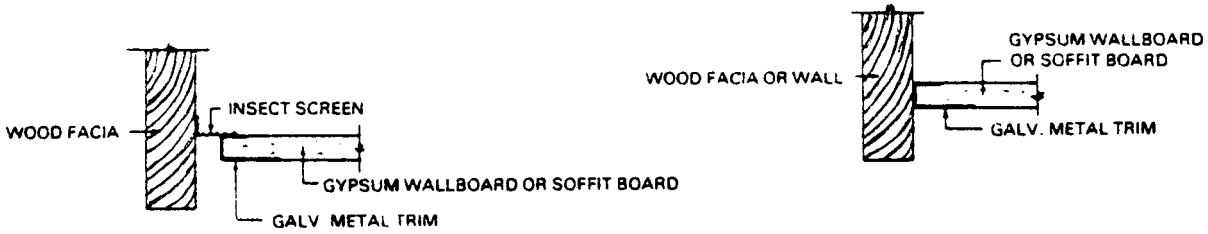

FIG. 10 Alternate Facia Details

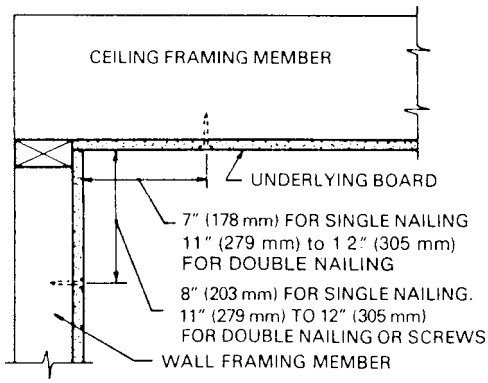

FIG. 11 Vertical Section, Ceiling Framing Member Perpendicular to Wall

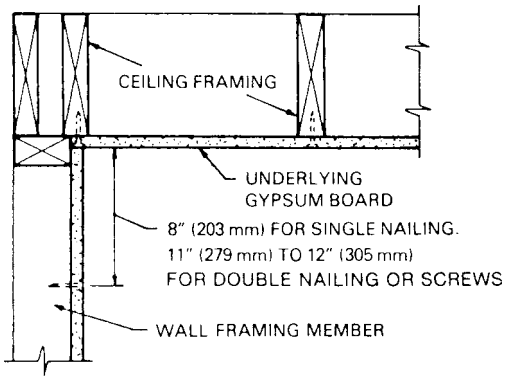

FIG. 12 Vertical Section, Ceiling Framing Parallel to Wall

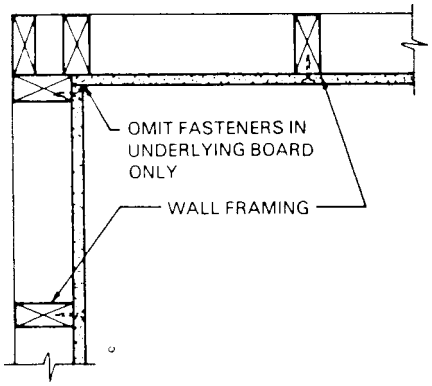

FIG. 13 Horizontal Section Through Interior Vertical Angle

22.3.2 Joint gaps not greater than ⅛ in. (3 mm) shall be prefilled with either ready-mix or setting type joint compound; joint gaps greater than ⅛ in. (3 mm) shall be prefilled with setting-type joint compound.

22.3.3 Joint tape shall be applied as described in 22.3.3.1, 22.3.3.2, or 22.3.3.3.

22.3.3.1 Paper tape shall be applied by applying joint compound to the joint (buttering), centering and pressing in the paper tape and wiping off the excess compound, or by mechanical tools designed for this purpose. Sufficient compound shall be left under the paper tape to bond the paper tape to the gypsum board.

22.3.3.2 Self-adhering glass mesh tape shall be applied to clean, dry gypsum board by centering the tape over the joint and pressing the tape firmly to ensure proper adhesion. A coat of setting type joint compound shall be applied over the tape and forced through the mesh so that it fills the joint in the underlying gypsum board and completely hides the weave of the glass mesh tape.

22.3.3.3 Glass mesh tape that is not self-adhering shall be applied and held in place with a rust resistant fastener (a staple or nail, etc.). A coat of setting type joint compound shall be applied over the tape and forced through the mesh so that it fills the joint in the underlying gypsum board and completely hides the weave of the glass mesh tape.

22.4 *Finishing*:

22.4.1 Finishing compound and all-purpose compound shall be applied with tools of sufficient width to extend a minimum of 3½ in. (89 mm) beyond both sides of the center of the joint tape. The compound shall be drawn down to a level plane. After the compound has dried, the surface shall be sanded (see 22.5) or wiped with a dampened sponge to eliminate high spots and excessive compound.

22.4.1.1 Coats of non-setting type compounds shall be thoroughly dry before sanding or the application of additional coats.

22.4.1.2 Additional coats of compounds shall be applied over setting-type compound either after it has set or, after it has set and dried.

22.4.2 Additional coats of finishing compound shall be applied with tools that will feather the material not less than 6 in. (152 mm) beyond both sides of the center of the joint tape. The compound shall be drawn down to a level plane.

NOTE 14—A smooth surface is achieved by lightly sanding or wiping the joint compound with a dampened sponge. Do not raise the nap of the paper of the gypsum board (see 22.5). See Appendix X3.

22.4.3 Fastener heads shall be covered (spotted) with successive coats of joint compound. The first coat shall be taping or all-purpose compound; the additional coats shall be finishing or all-purpose compound.

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22.4.4 All cut-outs shall be back filled with the compound used for taping and finishing so there is no opening larger than ¼ in. (6 mm) between the gypsum board and the penetrating element.

22.4.5 Accessories shall be finished with successive coats of joint compound. This surface, when completed, shall be flush with the surface of the gypsum board. The first coat over the flanges shall be taping or all-purpose compound; the additional coats shall be finishing or all-purpose compound.

22.4.6 The skim coat of joint compound or a material manufactured especially for this purpose shall be applied to the entire surface where Level 5 is required.

22.4.7 All tools and containers shall be kept clean and free from foreign materials.

22.4.8 Only potable water shall be used for mixing powder compounds or to thin premixed materials.

22.5 Approved protective respirators shall be worn when mixing dry compound or sanding.

22.6 *Levels of Finish*:

NOTE 15—The required level or extent of finishing of gypsum wallboard joints, fastener heads, and overall surface can vary with the location in a structure and the intended type of decoration. This section describes various levels of finishing, that is, number of applications of joint compound, sanding or other finishing techniques; the recommendations of manufacturers may vary from what is specified herein and as such are not part of these specifications. The relationship of levels of finishing with location and intended decoration is described in Appendix X8.

22.6.1 *Level 0*:

22.6.1.1 No taping, finishing or corner beads are required.

22.6.2 *Level 1*:

22.6.2.1 All joints and interior angles shall have tape embedded in joint compound. Surface shall be free of excess joint compound. Tool marks and ridges shall be acceptable.

22.6.2.2 Where glass mesh tape is used, the glass mesh tape shall be adhered or attached to the wall and have one coat of setting type joint compound over the surface of the joint.

22.6.3 *Level 2*:

22.6.3.1 All joints and interior angles shall have tape embedded in joint compound and shall be immediately wiped with a joint knife or trowel leaving a thin coating of joint compound over all joints and interior angles. Fastener heads and accessories shall be covered with a coat of joint compound. Surface shall be free of excess joint compound. Tool marks and ridges are acceptable.

22.6.3.2 Joint compound applied over the body of the tape at the time of tape embedment shall be considered a separate coat of joint compound and shall satisfy the conditions of this level.

22.6.4 *Level 3*:

22.6.4.1 All joints and interior angles shall have tape embedded in joint compound and shall be immediately wiped with a joint knife or trowel leaving a thin coating of joint compound over all joints and interior angles as described for Level 2. One additional coat of joint compound shall be applied over all joints and interior angles. Fastener heads and accessories shall be covered with two separate coats of joint compound. All joint compounds shall be smooth and free of tool marks and ridges (see 22.4.1.1).

22.6.5 *Level 4*:

22.6.5.1 All joints and interior angles shall have tape embedded in joint compound and shall be immediately wiped with a joint knife or trowel leaving a thin coating of joint compound over all joints and interior angles as described for Level 2. Two separate coats of joint compound shall be applied over all flat joints. One separate coat of joint compound shall be applied over interior angles. Fastener heads and accessories shall be covered with three separate coats of joint compound. All joint compounds shall be smooth and free of tool marks and ridges (see 22.4.1).

22.6.6 *Level 5*:

22.6.6.1 All joints and interior angles shall have tape embedded in joint compound and shall be immediately wiped with a joint knife or trowel leaving a thin coating of joint compound over all joints and interior angles as described for Level 2. Two separate coats of joint compound shall be applied over all flat joints. One separate coat of joint compound shall be applied over interior angles. Fastener heads and accessories shall be covered with three separate coats of joint compound. A thin skim coat of joint compound shall be trowel-applied to the entire surface. Excess compound is immediately sheared off, leaving a film of skim coating compound completely covering the paper. As an alternate to a skim coat, a material manufactured especially for this purpose shall be applied. The surface shall be smooth and free of tool marks and ridges (see 22.4.1.1).

23. Decoration

23.1 Surfaces finished to Levels 3, 4, or 5 shall be covered with a drywall primer compatible with the final decoration prior to the application of the final decoration.

NOTE 16—It is not the intent of this specification to assign responsibility for performance to specific trades.

24. Delivery, Identification, Handling, and Storage

24.1 All materials shall be delivered in the original factory sealed, unopened packages, containers, or bundles bearing the brand name, applicable standard designation, and the name of the manufacturer, or the supplier for whom the product is manufactured.

24.2 All materials shall be kept dry. Where gypsum board is stored outside, it shall be off the ground, properly supported on a level platform and fully protected from the weather or direct sunlight exposure. Adequate ventilation shall be provided to prevent condensation.

24.3 Gypsum board shall be neatly stacked flat, not on its end or edge, to prevent toppling, sagging or damage to the ends, edges, and surfaces.

NOTE 17—Gypsum board stacked on edge or end is unstable and presents a serious hazard in the workplace should it accidentally topple.

24.4 Ready mixed and dry compounds which have been mixed with water shall be stored at temperatures above freezing or temperatures specified by the manufacturer.

25. Keywords

25.1 ceiling; gypsum; wallboard; walls

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APPENDIXES

(Nonmandatory Information)

X1. GENERAL INFORMATION

INTRODUCTION

These Appendixes give general information and also suggestions for inclusions to be made elsewhere by the specifier. They are not a part of this specification.

X1.1 Scaffolding shall be constructed and maintained in strict conformity with applicable laws and ordinances.

X1.2 This work shall be properly coordinated with the work of other trades.

X1.3 Gypsum board shall be protected from the elements of weather before, during, and after application.

X2. VENTILATION ABOVE GYPSUM BOARD CEILINGS

X2.1 Adequate ventilation of attics or similar unheated spaces above gypsum board systems is essential to the performance of these systems and shall be designed and provided by others per ASHRAE Fundamentals Handbook or applicable building code.

X3. JOB APPLIED DECORATION

X3.1 Prolonged exposure of gypsum board to sunlight may cause problems in decoration.

X3.2 With the joints and fastener head depressions treated as specified in Section 10, interior walls of gypsum board may be decorated in any of the popular variety of finishes, such as texture or stipple, flat paint or flat enamel paint, wall paper, or vinyl wall coverings.

X3.3 Because the porosity and texture of the gypsum board differs from that of the joint treatment, the surface shall be primed and sealed as may be required for the subsequent finish coats.

X3.4 In rooms where high humidity may be encountered, such as the kitchen, bath, or utility room, a flat or semigloss enamel finish is recommended.

X3.5 Care should be exercised in the selection of primer and sealer paints to make sure they will perform satisfactorily, and fulfill the following functions:

X3.5.1 Equalize variations of suction over the entire surface.

X3.5.2 Provide a bonding surface or “tooth” for the paint to be applied.

X3.5.3 Avoid nap raising.

X3.6 Before applying the sealer, remove all loose dirt and dust by brushing with a soft brush or by rubbing with a dry cloth. Be sure the joint treatment is thoroughly dry before any application of sealer or paint.

X3.7 In applying primers or sealers, apply sufficient quantity to assure that the surface is completely covered. Follow the manufacturer’s printed directions and do not over thin. It is good practice to tint the sealer to approximately the shade of the finish coat. This will lead to better results in the finished job.

X3.8 In all cases where deep tones are to be used in the finish paint, best results will be achieved if the surface is first sealed. More than one coat of sealer may be necessary. Each coat must be thoroughly dry before applying another.

X3.9 Under normal atmospheric conditions, a waiting period of 12 to 18 h after application of primer-sealer should be observed before decoration is applied. In rainy, humid, and cold weather, a longer waiting period; sometimes as long as 36 to 48 h; may be necessary to make certain the sealer coat is absolutely dry.

X3.10 Exposed surfaces of gypsum board, as specified in Section 10 shall be painted with not less than two coats of exterior paint.

X3.11 Where semi-gloss or high-gloss paints are required or where severe lighting conditions occur, and prior to the application of a primer, a skim coat shall be applied to the

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entire surface of the wallboard, including the taped joints, covered fasteners, and accessories, to reduce the absorption and texture difference between the joint compound and the face of the wallboard.

X4. APPLICATION OF SURFACING MATERIALS AND CAULKING

X4.1 Caulk all cut edges and openings around pipes and fixtures flush with waterproof, nonhardening caulking compound or Type I adhesive complying with ANSI A 136.1.

X4.2 Wall tile shall be used in combination with adhesive to protect the gypsum board and any water sensitive materials if present (such as joint compound) from penetration of moisture or water. Responsibility for performance of completed installation shall rest with the surface materials manufacturer or with the tile applicator.

X4.3 For application of ceramic, plastic, or metal wall tile, or plastic finished rigid wall panels, or other types of surfacing materials over gypsum board in wet or dry areas, the recommendations of the manufacturer of tile, wall panel, or other surfacing materials shall be followed.

X4.4 Apply the surfacing material down to the top surface or edge of the finished shower floor, return, or tub, or install so as to overlap the top lip of receptor, sub-pan, or tub. It shall completely cover the following areas:

X4.4.1 *Over Tubs without Showerheads*—Six in. (152.4 mm) above the rim of the tub.

X4.4.2 *Over Tubs with Showerheads*—A minimum of 5 ft (1.52 m) above the rim or 6 in. (152.4 mm) above the height of the showerhead, whichever is higher.

X4.4.3 *Shower Stalls*—A minimum of 6 ft (1.83 m) above the shower dam or 6 in. (152.4 mm) above the showerhead, whichever is higher.

X4.4.4 All gypsum board window sills and jambs in shower or tub enclosures shall be covered to a like height.

X4.4.5 The surfacing material shall be applied to the full specified height for a distance of at least 4 in. (101.6 mm) beyond the external face of the tub or receptor. Areas beyond an exterior corner are excluded.

X4.5 Where plastic finished rigid wall panels are used as a surfacing material, the following precautions shall be taken:

X4.5.1 The type and shape of moldings recommended by the manufacturer of the surfacing material shall be used. Recommended tub moldings shall be used at the base where the surfacing materials abut the tub, shower, floor, or curb. Such moldings shall be set in waterproof, nonhardening caulking compound.

X4.5.2 Joints shall be filled in such a manner as to leave no voids for water penetrations.

X4.5.3 A bead of adhesive shall be applied as a dam between the back surface of the finishing material and the tub or receptor to prevent any leakage of water at the joint.

X5. WOOD FRAMING REQUIREMENTS

X5.1 The following requirements should be included in the project specifications for framing and furring and are essential to provide a proper base to receive the gypsum board.

X5.2 All framing members to which gypsum board will be fastened shall be straight and true. Framing shall be in alignment and spaced not to exceed the maximum spacings shown in Table 2. Framing, bridging, and furring members shall be the proper grade for the intended use and members 2 by 4 in. nominal size or larger shall bear the grade mark of a recognized inspection agency. Framing, bridging, and furring shall be adequate to meet the design, or code loading, or both. Where there is an applicable local code, the framing shall be in accordance with the Manual for House Framing by the National Lumber Manufacturers. Supports shall be provided as necessary for the support of fixtures.

X5.3 When gypsum board is nailed to wood cross furring on ceilings, these furring members shall have a minimum cross section of 1½ by 1½ in. (38.1 by 38.1 mm) actual size and be spaced in accordance with 9.2 and 9.3. Where screw application is used, the furring member may be ¾ in. by 2½ in. (19.1 by 63.5 mm) actual size.

X5.4 Where wood furring is used over masonry or concrete, fasteners should be of a length that does not come into contact with the masonry surface.

X5.5 Insulating blankets or flanges of blankets shall not be applied over framing members that are to receive gypsum board.

X5.6 Foil-backed gypsum board may be used where a vapor retarder is required.

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X6. PRECAUTIONS TO MINIMIZE POTENTIAL OF SAGGING

X6.1 Ensure framing spacing is adequate for thickness of board to be used. Ensure board is applied perpendicular to framing.

X6.2 Determine that excessive weight of insulation will not be added.

X6.3 Control the relative humidity within the structure by providing adequate ventilation before, during, and after board application. Watch for pouring of basement floors after board application.

X6.4 In cold weather, maintain inside temperature between 50 °F (10 °C) and 70 °F (20 ° C). Where portable heaters are used, make sure to remove the extra humidity they produce.

X6.5 Ensure the gypsum board is thoroughly dry and at ambient temperature before application.

X6.6 Ensure joint treatment is thoroughly dry before applying any decoration.

X6.7 Ensure that primer and paint coats are dry before the application of successive coats.

X6.8 Where hand or spray-applied water-based texture finishes are to be used on gypsum board ceilings under this specification either (1) ½ in. (12.7 mm) Gypsum Ceiling Board (see Specification C 1396/C 1396M) shall be used perpendicular to framing not more than 24 in. (610 mm) on center, or (2) other gypsum boards shall be used perpendicular to framing and board thickness shall be not less than ½ in. (12.7 mm) thick for 16 in. (406 mm) on center framing and not less than ⅝ in. (15.9 mm) thick for 24 in. (610 mm) on center framing.

X7. ELECTRIC RADIANT HEATING SYSTEMS FOR GYPSUM BOARD CEILINGS

X7.1 For guidance on the application of gypsum board in conjunction with a concealed radiant ceiling heating system constructed from thin sheet flexible radiant heating panels, or for the application of gypsum board after repair of existing concealed radiant ceiling heating systems constructed from heating cable or thin sheet flexible radiant heating panels see Guide C 1546.

X8. LEVELS OF FINISH

NOTE X8.1—Joint compounds used to conceal the joints and fastener heads can vary in density and surface character from the adjacent wallboard surface. Terms such as “industry standard” or “workman-like finish” are often used but not specific and can lead to subjective interpretation.

The architect, general contractor and owners frequently anticipate or expect a higher level of finish than the sub-contractor can determine from the specifications that are furnished for the bid process.

Reasons for specifying levels are: (*1*) many building are designed with walls and partitions abutting window mullions, long hallways, or atriums with large surface areas flooded with artificial and natural lighting; (*2*) paints and painting methods have changed over the years with wider use of spray equipment and reduce solids in paint; and (*3*) differences in absorption and drying, shrinkage of the compound, tool marks and ridges in the compound, or scuffing or raising of the nap of the face paper may all, or in part, combine to emphasize visual differences.

It is recommended that the painting specification provide for proper treatment to ensure uniform absorption over the entire surface. Any special finish such as gloss, which demands a more stringent requirement than the standard surface provides, should be specifically pointed out in the design process.

X8.1 *Level 0:*

X8.1.1 As stated, there is no finish required. To be used in temporary construction or whenever the final finish level has not been determined.

X8.1.2 Also could be used where non-predecorated panels will be used in demountable type partitions which are to be painted as a final finish.

X8.2 *Level 1:*

X8.2.1 Frequently used in plenum areas above ceilings, in attics, in areas where the assembly would generally be concealed, or in building service corridors and other areas not normally open to public view. Some degree of sound and smoke control is provided; in some geographic locations referred to as fire-taping. Where a fire resistance rating is required for gypsum board assembly, details of construction shall be in accordance with reports of fire tests of assemblies that have met the requirements of the fire rating imposed. Accessories optional at specifier discretion in corridors and other areas with pedestrian traffic. Tape and fastener heads need not be covered with a joint compound.

X8.3 *Level 2:*

X8.3.1 May be used when Water Resistant Gypsum Backing Board, Specification C 1396/C 1396M, is used as a substrate, or in garages, warehouse storage, or other similar areas where surface appearance is not of primary concern.

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X8.4 *Level 3:*

X8.4.1 Used in appearance areas that are to receive heavy texture (spray or hand applied) finishes before final painting. Should not be used under smooth painted surfaces.

X8.5 *Level 4:*

X8.5.1 This method should be used where wallcoverings, flat paints, or light textures are specified.

X8.5.2 Release agents for wall coverings are specifically formulated to minimize damage if coverings are subsequently removed.

X8.5.3 The weight texture and sheen level of the wallcovering selected should be taken into consideration when specifying wallcoverings over this level of drywall treatment. Joints and fasteners must be sufficiently concealed if the material is lightweight, contains limited patterns, has a glossy finish or any combination of these areas. Unbacked vinyls are not recommended.

X8.5.4 In critical lighting areas, flat paints applied over light textures tend to reduce joint photographing. Gloss, semi-gloss and enamel paints are not recommended over this level of finish.

X8.6 *Level 5:*

X8.6.1 The highest quality finish is the most effective method to provide a uniform surface and minimize the possibility of joint photographing and of fasteners showing through the final decoration.

X8.6.2 This level of finish is required where gloss, semi-gloss, or enamel flat paints are specified or where critical lighting conditions occur.

X8.6.3 *Skim Coating with Joint Compound*

X8.6.3.1 A Level 5 gypsum board finish consists of joints finished with joint tape set in joint compound followed by a specified number of additional coats of compound over the tape, joint compound applied all over fastener heads and accesories, then the application of a "skim coat" of joint compound over the entire surface.

X8.6.3.2 A skim coat of joint compound is intended to conceal small imperfections in joints and on the surface of the gypsum board, smooth the texture of the paper, minimize differences in surface porosity, and create a more uniform surface to which the final decoration can be applied.

X8.6.3.3 A "skim coat" is essentially a "film" of joint compound and is not a readily measurable thickness. There is no specific mil thickness that constitutes a proper "skim coat."

X8.6.3.4 Section 22.6.6.1 describes a "skim coat" as being "trowel-applied" with intent being that the consistency (viscosity) of the joint compound be such that it can be applied by trowel if that is the tool chosen for the task. Other tools may be used for application so long as the trowel consistency is achieved.

X8.6.3.5 The objective of the application is to achieve total coverage of the entire surface with the "skim coat." This is typically accomplished by delivering the compound to the surface and using a drywall broad knife to force the compound into the surface pores and imperfections while shearing excess compound from the surface.

X8.6.3.6 A "skim coat" will not approximate a plastered surface.

X8.6.3.7 Once the skim coat dries, the gypsum board paper may show through and the treated joints, filled voids, and spotted fasteners will likely be visible.

X8.6.4 *Alternative Materials*

X8.6.4.1 When alternative skim coat materials as described in 3.2.26, 22.4.6, and 22.6.6.1 are used, the statements in X8.6.3 are applicable, except that the consistency (viscosity) of the material and the application procedure shall be as recommended by the manufacturer.

SUMMARY OF CHANGES

Committee C11 has identified the location of selected changes to this specification since the last issue, C 840 – 07, that may impact the use of this specification. (Approved May 1, 2008)

(*1*) Revised Table 5.

Committee C11 has identified the location of selected changes to this specification since the last issue, C 840 – 06, that may impact the use of this specification. (Approved January 1, 2007)

(*1*) Added new 7.1.3.1.
(*2*) Revised 17.4.4 and added new 17.4.4.1 and 17.4.4.2.
(*3*) Revised 22.3.3, added new 22.3.3.1, 22.3.3.2, and 22.3.3.3.
(*4*) Revised 22.6.2.2, 22.6.3.2, 22.6.4.1, 22.6.5.1, and 22.6.6.1.
(*5*) Revised Table 5
(*6*) Added new Note 11 and renumbered subsequent notes.

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Designation: C 841 – 03(Reapproved 2008)ε1

Standard Specification for Installation of Interior Lathing and Furring[1]

This standard is issued under the fixed designation C 841; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

This standard has been approved for use by agencies of the Department of Defense.

ε[1] NOTE—The units statement in subsection 1.2 was corrected editorially in July 2008.

1. Scope

1.1 This specification covers the minimum requirements for, and the methods of application of, interior lathing and furring to receive gypsum plaster applied in accordance with Specification C 842. Other materials are not prohibited from being used provided that their physical characteristics and durability under conditions of usage are at least equal in performance to those described.

1.2 The values stated in inch-pound units are to be regarded as standard. The values given in parentheses are mathematical conversions to SI units that are provided for information only and are not considered standard.

1.3 Details of construction for a specific assembly to achieve the required fire resistance shall be obtained from reports of fire-resistance tests, engineering evaluations, or listings from recognized fire testing laboratories.

1.4 Where a specific degree of sound control is required for plastered assemblies and constructions, details of construction shall be obtained from reports of sound tests of assemblies that have met the requirements of Test Method E 492.

2. Referenced Documents

2.1 *ASTM Standards:* [2]

A 641/A 641M Specification for Zinc–Coated (Galvanized) Carbon Steel Wire

C 11 Terminology Relating to Gypsum and Related Building Materials and Systems

C 37/C 37M Specification for Gypsum Lath[3]

C 514 Specification for Nails for the Application of Gypsum Board

C 754 Specification for Installation of Steel Framing Members to Receive Screw-Attached Gypsum Panel Products

C 842 Specification for Application of Interior Gypsum Plaster

C 847 Specification for Metal Lath

C 933 Specification for Welded Wire Lath

C 954 Specification for Steel Drill Screws for the Application of Gypsum Panel Products or Metal Plaster Bases to Steel Studs from 0.033 in. (0.84 mm) to 0.112 in. (2.84 mm) in Thickness

C 1002 Specification for Steel Self-Piercing Tapping Screws for the Application of Gypsum Panel Products or Metal Plaster Bases to Wood Studs or Steel Studs

C 1007 Specification for Installation of Load Bearing (Transverse and Axial) Steel Studs and Related Accessories

C 1032 Specification for Woven Wire Plaster Base

D 1784 Specification for Rigid Poly(Vinyl Chloride) (PVC) Compounds and Chlorinated Poly(Vinyl Chloride) (CPVC) Compounds

D 3678 Specification for Rigid Poly(Vinyl Chloride) (PVC) Interior-Profile Extrusions

E 492 Test Method for Laboratory Measurement of Impact Sound Transmission Through Floor-Ceiling Assemblies Using the Tapping Machine

2.2 *National Association of Architectural Metal Manufacturers Standard*

HMMA 840 Installation and Storage of Hollow Metal Doors and Frames[4]

3. Terminology

3.1 *Definitions*—For definitions relating to ceilings and walls see Terminology C 11.

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *base coat*, *n*—the sum of the scratch and brown coats or the total coats in place prior to application of finish coats.

3.2.2 *contact ceiling*, *n*—a ceiling in which the lath is attached in direct contact with the construction above, without the use of main runners or cross furring.

[1] This specification is under the jurisdiction of ASTM Committee C11 on Gypsum and Related Building Materials and Systems and is the direct responsibility of Subcommittee C11.03 on Specifications for the Application of Gypsum and Other Products in Assemblies.

Current edition approved May 1, 2008. Published July 2008. Originally approved in 1976. Last previous edition approved in 2003 as C 841 – 03.

[2] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

[3] Withdrawn.

[4] Available from NAAMM, 8 South Michigan Avenue, Suite 1000, Chicago, IL 60603.

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3.2.3 *furred ceiling*, *n*—a ceiling in which the furring used for the support of the lath is attached directly to the structural members of the building.

3.2.4 *suspended ceiling*, *n*—a ceiling in which the main runners and cross furring are suspended below the structural members of the building.

3.2.5 *main runners*, *n*—the members that are attached to or suspended from the construction above for the support of cross furring.

3.2.6 *cross furring*, *n*—furring members that are attached at right angles to the underside of the main runners or construction above for support of the lath.

3.2.7 *furring*, *n*—spacer strips fastened to a wall, ceiling, or planar element that create an even surface for the application of metal plaster bases or gypsum lath.

3.2.8 *primary members*, *n*—the members (main runners or structural supports) to which the cross furring is attached.

3.2.9 *metal plaster bases*, *n*—expanded metal lath, sheet metal lath, welded or woven wire lath.

3.2.10 *face side (gypsum lath)*, *n*—the side opposite the paper cover seam laps.

3.2.11 *surface transition*, *n*—the change in width of a surface, usually as a result of penetrations (doors, windows) or architectural demands.

4. Delivery of Materials

4.1 All materials shall be delivered in the original packages, containers, or bundles bearing the brand name and manufacturer's (or supplier's) identification.

5. Storage of Materials

5.1 All materials shall be kept dry, preferably by being stored inside. Where necessary to be stored outside, materials shall be stacked off the ground, supported on a level platform, and protected from the weather and surface contamination.

5.2 Materials shall be neatly stacked flat with care taken to avoid damage to edges, ends, or surfaces.

6. Materials

6.1 Wire Specification A 641/A 641M, Class 1 coating (galvanized) soft temper.

6.1.1 *Tie Wire and Hanger Wire*—Zinc-coated (galvanized) soft-annealed steel, or a material having equivalent size, corrosion resistance and strength. Wire diameters (uncoated) specified herein correspond with United States steel wire gage numbers as follows:

Diameter, in.[A]	(mm)	Wire Gage (U.S. Steel Wire Gage)
0.0348	(0.88)	No. 20
0.0410	(1.04)	No. 19
0.0475	(1.21)	No. 18
0.0540	(1.37)	No. 17
0.0625	(1.59)	No. 16
0.0800	(2.03)	No. 14
0.0915	(2.32)	No. 13
0.1055	(2.68)	No. 12
0.1205	(3.06)	No. 11
0.1350	(3.43)	No. 10
0.1483	(3.77)	No. 9
0.1620	(4.11)	No. 8

[A] Allowable variations in diameter shall be in accordance with tolerances as established in A 641/A 641M.

6.2 *Gypsum Lath*—Specification C 37.

6.3 *Expanded Metal Lath*—Specification C 847.

6.4 *Wire Lath*:

6.4.1 *Welded Wire Lath*, Specification C 933.

6.4.2 *Woven Wire Lath*, Specification C 1032.

6.5 *Fasteners*:

6.5.1 *Nails for Attaching Gypsum Lath*—Specification C 514. Nail size shall be in accordance with Table 1.

6.5.2 *Nails for Attaching Metal Plaster Base*—Galvanized roofing nails or common nails. length shall be as specified in 7.

6.5.3 *Screws*—Specifications C 954 or C 1002.

6.5.3.1 Screws for attaching gypsum lath shall be sized in accordance with Table 1.

TABLE 1 Screws, Nails and Staples[A,B] for Attaching Gypsum Lath to Horizontal and Vertical Wood Supports

Maximum Spacing, in. (mm)					Minimum Gage Requirements, in. (mm)			
Width of Lath	Thickness of Lath	Distance Between Supports	Number of Attachments per Bearing	Approximate Spacing *c* to *c* of Attachments	Length of Leg	Depth of Support Penetration	Diameter of Flat Head or Blued Nails or Crown Width of Staples[A]	Gage of Shank of Nails or Staples[A]
16 (406)	⅜ (9.5)	16 (406)	4	5 (127)	1⅛ (28.6) 1 (25.4)[A]	¾ (19) ⅝ (15.9)[A]	19/64 (7.5) 7/16 (11)[A]	13 16[A]
24 (610)	⅜ (9.5)	16 (406)	6	4½ (114)	1⅛ (28.6) 1 (25.4)[A]	¾ (19) ⅝ (15.9)[A]	19/64 (7.5) 7/16 (11)[A]	13 16[A]
16 (406)	½ (12.7)	24 (610)	4	5 (127)	1¼ (32) 1⅛ (28.6)[A]	¾ (19) ⅝ (15.9)[A]	19/64 (7.5) 7/16 (11)[A]	13 16[A]
24 (610)	½ (12.7)	24 (610)	6	4½ (114)	1¼ (32) 1⅛ (28.6)[A]	¾ (19) ⅝ (15.9)[A]	19/64 (7.5) 7/16 (11)[A]	13 (330) 16[A]
48 (1219)	⅜ (9.5) ½ (12.7)	16 (406) 24 (610)	8	4½ (114)	1⅛ (28.6) 1 (25.4)[A] 1¼ (32) 1⅛ (28.6)[A]	¾ (19) ⅝ (15.9)[A] ¾ (19) ⅝ (15.9) [A]		

[A] Galvanized staples.
[B] Screws for attaching gypsum lath to wood supports shall be Type W as described in Specification C 1002.

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6.5.3.2 Screws for attaching metal plaster base shall have a 7⁄16 in. (11.1 mm) diameter pan washer head and a 0.120 in. (3.0 mm) diameter shank. The length shall be sufficient enough to allow for the threaded portion of the screw to project not less than 3⁄8 in. (9.5 mm) through steel framing when the lath is installed.

6.5.4 *Staples*—Staples for attaching gypsum lath shall conform to the requirements of Table 1.

6.5.4.1 Staples for attaching metal plaster base shall be 0.062 in. (1.6 mm) diameter, round or flattened steel wire with 3⁄4 in. (19.0 mm) crown. Lengths shall be as specified for individual systems.

6.6 *Paper or Other Backing*—When used on metal plaster bases, over solid backing, backing shall be securely held in place by, or attached to the metal plaster base. Metal plaster base shall allow for 1⁄4 in. (6.4 mm) self furring. The backing shall permit embedment of plaster.

6.7 *Accessories*—Shall be steel, coated, with a protective rust inhibitive coating after fabrication, or fabricated from zinc-coated (galvanized) steel, aluminum, zinc alloy, or high impact plastic. Plastic accessories shall be nmanufactured in accordance with Specifcation D 1784 or Specification D 3678. Aluminum accessories shall be clear plastic coated. All accessories shall have perforated or expanded flanges or clips shaped so as to permit complete imbedment in the plaster, to provide means for secure alignment, and to secure attachment of the accessory to the underlying surface. Accessories shall be designed for the intended use and to receive or to permit application of the specified plaster thickness.

6.7.1 Thickness of base material for accessories shall be not less than as shown in the following:

Base Material (mm)	Thickness of Base Material, in.
Uncoated steel/zinc	0.014 (0.36)
PVC	0.030 (0.76)
Aluminum	0.050 (1.27)

6.7.2 *Control Joints*—Shall be formed by using a single prefabricated member or fabricated by installing casing beads back to back with a flexible barrier membrane behind casing beads. The separation spacing shall be not less than 1⁄8 in. (3.2 mm) or as required by the anticipated thermal exposure range.

6.7.3 *Cornerite*—shall be not less than 1.75 lb/yd^2 (0.85 kg/m^2) expanded metal lath, galvanized, or given a protective coating of rust inhibitive paint after fabrication, or woven or welded fabric not less than 0.041 in. (1.04 mm) thick an weighing not less than 1.75 lb/yd^2 (0.85 kg/m^2), fabricated from galvanized wire. When shaped for angle reinforcing, cornerite shall have outstanding legs of not less than 2 in. (50.8 mm).

6.7.4 *Channels*—Shall be cold-rolled steel, free of rust with a coating of rust inhibitive paint or galvanized. Channels used in areas subject to corrosive action of salt air or other corrosive environments, shall be hot-dip galvanized. Weight of the channel shall be not less than as shown in the following:

Size		Weight	
in.	(mm)	lb/1000 lf	(kg/m)
3⁄4	(19)	277	(0.412)
1 1⁄2	(38)	414	(0.616)
2	(50)	506	(0.753)
2 1⁄2	(64)	597	(0.888)

6.7.5 Rod and flat (strap) hangers shall be mild steel, zinc coated or protected with a rust-inhibiting paint.

6.7.6 *Clips*—Devices for attaching framing members to supports or to each other; for attaching lath to framing members; or for securing lath to lath, shall be formed of zinc-coated (galvanized) steel wire or sheet, and of sufficient size and strength to support the intended load

6.7.7 *Striplath*—Shall be not less than 1.75 lb/yd^2 (0.85 kg/m^2) expanded metal lath, or woven or welded fabric of not less than 0.041 in. (1.04 mm) thick weighing not less than 1.75 lb/yd^2 (0.85 kg/m^2) fabricated from galvanized steel.

7. Installation

7.1 *General Requirements for Application of Lath and Accessories*:

7.1.1 Lath shall be installed with the long dimension at right angles to supports, unless otherwise specified.

7.1.2 Corner beads shall be installed to protect all external corners and to establish grounds. Corner beads shall be attached to the substrate in such a manner as to ensure proper alignment during application of plaster.

7.1.3 Metal accessories shall be installed so that flanges and clips provided for their attachment are covered by the base coat plaster.

7.1.4 *Control Joints*—Shall be installed in ceilings greater than 2500 ft^2 (232 m^2) in area and in partition, wall, and wall furring runs greater than 30 ft (9 m) in length. The distance between ceiling control joints shall not be more than 50 ft (15 m) in either direction. A control joint shall be installed where the ceiling framing or furring changes direction. The distance between control joints in walls or wall furring shall be not more than 30 ft (9 m). A control joint shall be installed where an expansion joint occurs in the base exterior wall or ceiling. A ceiling height door frame, installed in accordance with the spacing requirements set forth in this section, is not prohibited from being used as a control joint.

7.1.5 Where partition assemblies require the installation of control joints over the head of door frames to relieve stresses within the assemblies, such control joints shall be installed in the following manner:

7.1.5.1 Where control joints are located at the vertical center of the door opening two metal studs shall be installed not more than 1⁄2 in. (12.7 mm) apart over the center of the span at the head of the frame, with the lath installed so that a vertical joint occurs between the studs. A prefabricated control joint or casing beads shall be installed at the joint location.

7.1.5.2 Where control joints are located in line with the door jambs the procedure in 7.1.5.1 shall be followed with the exception that supporting members shall consist of two studs placed side-by-side.

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7.1.6 Casing beads or other suitable accessories, shall be used to isolate non-load bearing partitions from load bearing members.

7.1.7 *Workmanship*—Metal construction furring and lathing shall be erected so that finished plaster surfaces will be true to line, level, plumb, square, curved, or as required to receive specified plaster thickness.

7.1.8 Except where frames are required to be fully grouted with plaster, lath shall be inserted into jambs as far as possible and notched to pass anchors.

7.2 *Application of Gypsum Lath to Supports*:

7.2.1 *General*—Gypsum lath shall be installed so that vertical joints occur not less than one full stud space from edges of openings in walls or partitions.

7.2.2 Gypsum lath shall be installed with the face side out and the edges and ends butted together. End joints shall fall on different supports in alternate courses, or the lath shall be installed so that end joints are continuous on one support. In the latter case, the continuous end joints shall be covered with 3-in. (76-mm) wide strips of metal lath or welded or woven wire fabric, and the long edge joints of lath in alternate courses shall be offset or staggered.

7.2.3 Cornerite shall be installed on gypsum lath at all internal angles, and lightly nailed or stapled to the gypsum lath and not to the framing members. Cornerite shall not be used in unrestrained construction, or where other provisions are made for the treatment of internal angles.

7.2.4 Where gypsum lath sheets intersect or where joint surfaces are to be plastered without lathing (such as masonry), a casing bead shall be installed at the intersection or joining.

7.2.5 Gypsum lath shall be reinforced at the corners of doors, windows, or other openings with diagonally installed strips of striplath or wire lath, not less than 6 in. (152 mm) wide by 12 in. (305 mm) long.

7.2.6 Metal lath stripping shall be used to cover chases and similar breaks in continuity or horizontal or vertical surfaces that are to receive plaster. Stripping shall be extended not less than 3 in. (76 mm) on all sides of the openings.

7.3 *Application of Gypsum Lath to Wood Supports*:

7.3.1 Except where required otherwise, for certain fire-resistant construction, gypsum lath shall be securely attached to wood supports using nails, screws, or staples conforming to Table 1.

7.3.2 Nails and screws shall be driven so that the face of the head is flush with the face of the gypsum lath, and not less than ⅜ in. (9.5 mm) from the edges of the lath. Staples shall be driven with the crown parallel to the nailing members. The crown shall bear lightly against, but not cut into, the face of the lath.

7.4 *Application of Gypsum Lath to Metal Supports*:

7.4.1 Gypsum lath shall be attached to horizontal or vertical metal supports with staples, screws, or nails, or a combination thereof.

7.4.2 Screws shall be driven so that the face of the head is flush with the face of the gypsum lath and not less than ⅜ in. (9.5 mm) from the edges of the lath.

7.5 *Studless Solid Partitions (Gypsum Lath and Plaster)*:

7.5.1 Gypsum lath shall be plain, ½ in. (12.7 mm) thick, 24 in. (610 mm) wide, and, when applied vertically, shall be not more than 12 ft (3.7 m) in length.

7.5.2 Wood floor runners shall be secured to the floor using anchors spaced not more than 24 in. (610 mm) on center. Anchors shall penetrate floor surface to a depth of not less than ⅝ in. (15.9 mm). The width of such runners shall correspond to the overall partition thickness and their upper surface shall be grooved parallel to the length of the runner in the center to a depth of not less than ½ in. (12.7 mm) and to a width to accommodate snugly the thickness of the lath.

7.5.3 Metal floor runnersshall be anchored to bases and clips at not more than 24 in. (610 mm) on center. Runners shall be designed to hold the lower edge of the lath securely in position.

7.5.4 Metal ceiling runners shall be aligned with floor runners to ensure plumb installation of the lath. Metal ceiling runners shall be firmly secured to the ceiling construction.

7.5.5 Gypsum lath shall be of such length as to allow not less than ¼ in. (6.4 mm) nor more than 1-in. (25.4-mm) top clearance in the ceiling runner. Erect gypsum lath vertically so as to engage the ends in or to the floor and ceiling runners.

7.5.6 the vertical edges of the lath shall be aligned with the vertical joints interlocked or mechanically fastened with type G screws spaced not more than 12 in. (305 mm) on centers.

7.6 *Application of Metal Plaster Bases to Framing Members*:

7.6.1 *General*—The spacing of supports for the type and weight of metal lath used shall be in accordance with the requirements of Table 2.

7.6.2 *Attachments for Metal Plaster Bases to Wood Framing Members*:

7.6.2.1 Diamond mesh expanded metal lath, flat rib expanded metal lath, and welded wire lath shall be attached to horizontal wood supports with 1½ in. (38 mm), 0.1205 in. (3.06 mm) shank, 7⁄16 in. (11 mm) diameter head, barbed, galvanized, or blued roofing nails driven flush with the lath. The metal lath shall be attached to vertical wood supports with 6d common nails, or 1-in. (25-mm) long roofing nails driven driven in accordance with Table 1 or 1-in. No. 14 gage wire staples driven flush with the lath.

7.6.2.2 ⅜-in. (9.5-mm) rib expanded metal lath shall be attached to horizontal and vertical wood supports with nails or staples not less than ⅜ in. (9.5 mm) longer than required (7.6.2.1) to provide not less than ⅜-in. (9.5-mm) longer than required (see 7.6.2.1) to provide penetration in accordance with Table 1.

7.6.2.3 When used on vertical wood supports, common nails shall be bent over to engage not less than three strands of lath. When used for the application of rib lath, common nails shall be bent over to engage not less than one rib of the lath.

7.6.2.4 Other methods of attachment shalll be used when it can be shown they provide a carrying strength not less than that described in 7.6.2.1-7.6.2.3 may be used.

7.6.3 *Attachments for Metal Plaster Bases to Metal Framing Members*:

7.6.3.1 Metal plaster bases shall be attached to metal framing members with 0.048 in. (1.2 mm) diameter wire ties, clips, or modified truss (wafer-headed) screws installed so that the

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TABLE 2 Types and Weights of Expanded Metal Lath, Sheet Lath, or Welded Wire Lath and Corresponding Maximum Permissible Spacing of Supports[A]

Type of Metal Plastering Base	Minimum Weight of Metal Base, lb/yd² (kg/m²)	Maximum Permissible Spacing of Supports Center for Center, in. (mm)				
		Walls (Partitions)			Ceilings	
		Wood Studs	Solid Partitions	Steel Studs, Wall Furring, etc.	Wood or Concrete	Metal
Expanded metal lath:						
Diamond mesh	2.5 (0.08)	16 (406)	16 (406)	16 (406)	12 (305)	12 (305)
	3.4 (0.12)	16 (406)	16 (406)	16 (406)	10 (254)	16 (406)
Flat rib	2.5 (0.08)	16 (406)	12 (305)	12 (305)	12 (305)	12 (305)
	2.75 (0.09)	16 (406)	16 (406)	16 (406)	16 (406)	16 (406)
	3.4 (0.12)	19 (483)	24 (610)	19 (483)	19 (483)	19 (483)
Flat rib (large opening)	1.8 (0.06)	24 (610)	24 (610)	24 (610)	16 (406)	16 (406)
⅜-in. (9.5-mm) rib						
	3.4 (0.12)	24 (610)	N/A	19 (482)	19 (482)	19 (482)
	4.0 (0.14)	24 (610)	N/A	24 (610)	24 (610)	24 (610)
Wire lath welded	1.4 (0.05)[B]	16 (406)	16 (406)	16 (406)	16 (406)	16 (406)
	1.95 (0.07)[C]	24 (610)	24 (610)	24 (610)	24 (610)	24 (610)

[A] Paper-backed lath shall be limited to lath having an absorbent and a perforated slotted paper separator only.
[B] Welded wire paper-backed lath, 16-gage, 0.0598 in., (1.52 mm).
[C] Welded wire, paper-backed lath, 16-gage face wire, 0.0598 in. (1.52 mm) face wire.

threaded portion of the screw will penetrate the metal supports not less than ⅜ in. (9.5 mm) and the head shall contact not less than three strands of lath.

7.6.3.2 Rib metal lath shall be attached to open web steel joists using single ties of galvanized, annealed steel wire, 0.048 in. (1.2 mm) in diameter, with the ends of each tie wire twisted together 1½ times.

7.6.3.3 Rib metal lath shall be installed to metal framing members with the point of the V rib in contact with the framing and attached to the framing by a screw driven through the rib so that the threaded portion of the screw penetrates the metal support not less than ⅜ in. (9.5 mm).

7.6.4 *Attachments for Metal Plaster Bases to Concrete Supports*—Rib metal lath shall be attached to concrete joists by loops of galvanized, annealed steel wire, not less than 0.076 in. (1.9 mm) in diameter, with the ends of each loop twisted together not less than 1½ times.

7.6.5 *Spacing of Attachments for Metal Plaster Bases*—Attachments for securing metal plaster bases to supports shall be spaced not more than 7 in. (178 mm) apart for diamond mesh and flat rib laths and at each rib for ⅜-in. (9.5-mm) rib lath.

7.6.6 *Lapping of Metal Plaster Bases*:

7.6.6.1 Side laps of metal plaster bases shall be secured to supports, and tied between supports at intervals not more than 9 in. (229 mm) on center.

7.6.6.2 Expanded metal lath shall be lapped ½ in. (12.7 mm) at edges, or the edge ribs shall be nested. Welded or woven wire lath shall be lapped one mesh at sides and ends. Expanded metal lath shall be lapped 1 in. (25 mm) at ends or ends shall be nested. When end laps occur between supports, the ends of sheets of all metal plaster bases shall be tied together with 0.048 in. (1.2 mm), galvanized, annealed steeel wire. Laps shall be located not more than 3 in. (76.2 mm) from the structural support. Lath shall be lapped not more than 3 in. (76.2 mm) in any direction.

7.6.6.3 Adjacent sheets of metal plaster base shall be installed so that metal laps onto metal and backing laps onto backing.

7.6.7 *Procedure for Application of Metal Plaster Bases to Ceiling Framing Members*:

7.6.7.1 Metal plaster bases shall be applied to ceilings first.

7.6.7.2 The ends of metal plaster bases shall be staggered.

7.6.7.3 Where furred or suspended ceilings greater than 50 ft (15 m) in either direction or 2500 ft² (232 m²) in area butt into or are penetrated by columns, walls, beams, or other elements, the following procedure shall be used: The sides and ends of the ceiling lath shall abut at the horizontal internal angles and terminate at a casing bead, control joint, or similar device designed to isolate the plaster membrane from the adjoining vertically oriented elements. Only casing beads shall be used at internal angles between ceilings, walls, or partitions. Lath shall not be continuous through control joints but shall be stopped and tied to the flanges of the control joint at each side.

7.6.8 Ends of sheets of diamond mesh metal lath and welded wire lath on partitions not abutting structural walls, columns, or floor-ceiling slabs shall be bent into or around vertical corners and continued on to not less than one support away from the corner. The ends of the sheets of lath shall be butted into corners when cornerite is applied over the abutting laths. Rib metal lath shall be butted into corners and cornerite shall be applied over the abutting laths.

7.6.9 The ends of metal plaster bases applied to load-bearing wall and partitions that abutt structural walls, columns, or floor-ceiling slabs shall be isolated from the adjacent surface at the interanl angle. Cornerite shall not be used at internal angles, only casing beads or control joint materials shall be used to isolate the lath and plaster from the abutting surface.

7.7 *Studless Solid Partitions (Metal Lath and Plaster)*:

7.7.1 Metal plaster bases used for studless solid partitions shall have the sides (long dimensions) of the sheet installed vertically. The plaster bases shall be wiretied to the ceiling

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runners using ties spaced not mroe than 8 in. (203 mm) on center and mechanically anchored to the floor runners or base.

7.7.1.1 At vertical internal and external corners, metal plaster bases shall be bent and returned 6 in. (152 mm) on abutting surfaces. Rib metal lath shall be lapped ½ in. (12.7 mm) at sides, or the outside ribs shall be nested. Side laps shall be wire tied between supports at intervals not more than 9 in. (229 mm) on center.

7.8 *Suspended and Furred Ceilings (Metal Lath and Gypsum Lath Construction)*:

7.8.1 Hangers shall be of sufficient length to accommodate the ceiling construction.

7.8.1.1 Hangers (without inserts) shall be secured or otherwise embedded so as to develop full strength.

7.8.1.2 *Inserts*—Inserts for hangers shall be secured in concrete reinforced slabs so as to develop the full strength of the hangers that are attached to them.

7.8.2 *Hangers for Suspended Ceilings Under Wood Constructions*—Hangers shall conform with the requirements of Table 3 both as to size and maximum area to be supported, except as modified in this section. Hangers shall be attached to supports by one of the following methods:

7.8.2.1 Insert through holes drilled not less than 3 in. (76 mm) above the bottom of the joist with the upper end of the hanger twisted not less than three times around itself (see Fig. 1).

7.8.2.2 Twisted not less than three times around itself over not less than three 12d nails driven on a downward slant into

TABLE 3 Suspended and Furred Ceilings, Minimum Sizes for Wire, Rod, and Rigid Hangers; Minimum Sizes and Maximum Spans and Spacings for Main Runners; and Minimum Sizes and Maximum Spans and Spacings for Cross Furring

NOTE 1— 1 in. = 25.4 mm; 1 ft^2 = 0.093 m^2

HANGERS		
	Maximum Ceiling Area Supported, ft^2	Minimum Size of Hangers
Hangers for Suspended Ceilings	12.5	0.148 in. wire
	16	0.162 in. wire
	18	3/16-in. diameter, mild steel rod[A]
	20	7/32-in. diameter, mild steel rod[A]
	22.5	¼-in. diameter, mild steel rod[A]
	25.0	1 by 3/16-in. mild steel strap[B]
Attachments for Tying Runners and Furring Directly to Beams and Joists		
For Supporting Runners		
Single Hangers Between Beams[C]	8	0.106 in. wire
	12	0.135 wire
	16	0.162 wire
Double Wire Loops at Beams or Joists[C]	8	0.076 wire
	12	0.106 wire
	16	0.120 wire
For Supporting Furring Without Runners[C] (Wire Loops at Supports)		
Types of Support:		
Concrete	8	0.076 wire
Steel	8	0.062 (2 loops)[D]
Wood	8	0.062 (2 loops)[D]

SPANS AND SPACINGS OF MAIN RUNNERS[E,F]		
Minimum Size and Type	Maximum Span Between Hangers or Supports, in.	Maximum Center to Center Spacing of Runners, in.
¾ in., 0.3 lb/ft, cold	24	36
1½ in. 0.475 lb/ft, cold-rolled channel	36	48
1½ in., 0.475 lb/ft, cold-rolled channel	42	42
1½ in., 0.475 lb/ft, cold-rolled channel	48	36
2 in., 0.59 lb/ft, cold-rolled channel	60	48
1½ by 1½ by 3/16-in. angle	60	42

SPANS AND SPACINGS OF CROSS FURRING[E,F]		
Minimum Size and Type	Maximum Span Between Runners or Supports, in.	Maximum Center to Center Spacing of Cross Furring Members, in.
¼-in. diameter pencil rods	24	12
3/8-in. diameter pencil rods	24	19
3/8-in. diameter pencil rods	30	12
¾ in., 0.3 lb/ft, cold	36	24
	42	19
	48	16

[A] All rod hangers shall be protected with a zinc cadmium coating.
[B] All flat hangers shall be protected with a zinc or cadmium coating or with a rust-inhibitive paint.
[C] Inserts, special clips, or other devices of equal strength are substitutes for those specified.
[D] Two loops of 0.048 in. wire are substitutes for each loop of 0.062 in. wire when used for attaching steel furring to steel or wood joists.
[E] Spans are based on webs of channels being erected and maintained in a vertical position.
[F] Other sections of cold-rolled members of equivalent beam strength are substitutes for those specified.

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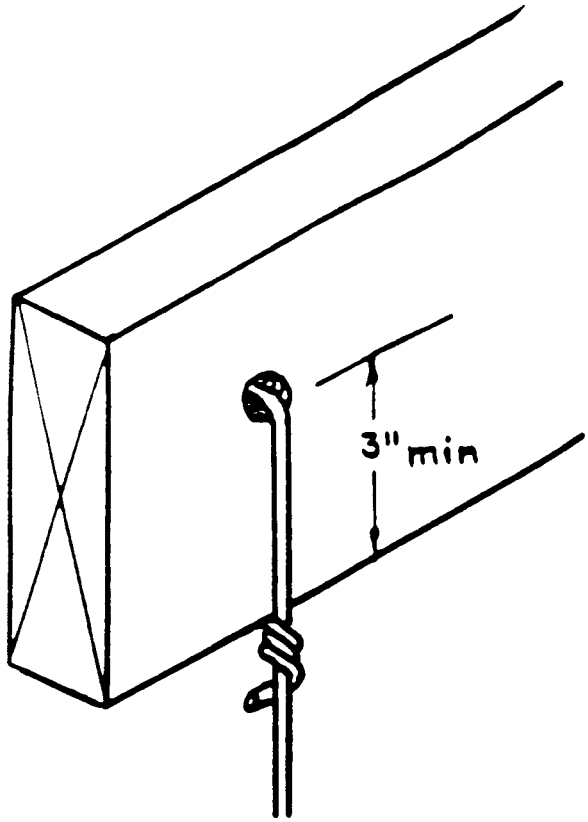

FIG. 1 Hanger Attached to Support Through a Drilled Hole

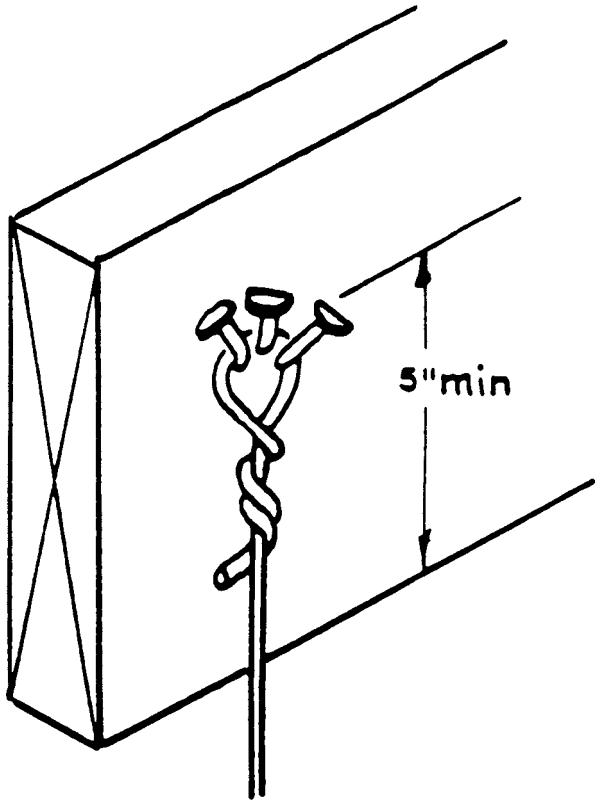

FIG. 2 Hanger Attached to Support Using Nails

the sides of joists not less than 5 in. (127 mm) from the bottom edge of the joist and not more than 36 in. (914 mm) on center (see Fig. 2).

7.8.2.3 Formed into a loop to accommodate four 1 ½-in. (38.1-mm), 0.148-in. (3.8-mm) diameter staples driven horizontally or on a downward slant into sides of joists, placing three near the upper end of the loop and the fourth to fasten the loose end (see Fig. 3).

7.8.2.4 Where spacing of supports is more than 4 ft (1.2 m) on center, 1½-in. (38.1-mm) No. 0 screw eyes, or equivalent, spaced not more than 3 ft (0.9 m) on centers shall be screwed into supporting wood construction so that the supported area shall be not more than 9 ft^2(0.8 m^2). The upper end of the wire hanger shall be inserted through the screw eye and in each case twisted not less than three times around itself.

7.8.2.5 Flat hangers shall be secured with two 12d nails driven through holes drilled in the hanger and clinched not less than 3 in. (76 mm) above the bottom of the joists (see Fig. 4).

7.8.3 *Minimum Size for Hangers*—Thickness of wire hangers, diameter of rod hangers, and sizes of flat hangers shall be in accordance with Table 3.

7.8.4 Where 1 by 3⁄16-in. (25.4 by 4.8-mm) flat inserts and hangers are used, 7⁄16-in. (11-mm) diameter holes shall be punched on the center line at the lower end of inserts and upper end of hanger to permit the attachment of the hangers to the insert.

7.8.5 Holes in both inserts and hangers shall be not less than ⅜ in. (9.5 mm) from the ends.

7.8.6 Flat steel hangers shall be bolted to 1 by 3⁄16-in. (25.4 by 4.8-mm) inserts with ⅜-in. (9.5-mm) diameter round-head stove bolts.

7.8.7 The nuts of bolts shall be drawn up tight.

7.8.8 Wire or rod hangers shall be saddle-tied or attached to main runners so as to prevent turning or twisting of the runners and to develop the full strength of the hangers and the runners. Smooth or threaded rod hangers shall be attached to inserts and runners with special attachments designed for this application.

7.8.9 The lower ends of flat hangers shall be bolted to the main runners, or bent tightly around runners and carried up and above the runners and bolted to the main part of the hanger. Bolts shall be ⅜-in. (9.5-mm) diameter, stove bolts.

7.9 *Main Runners*:

7.9.1 Minimum sizes and maximum spans and spacings of main runners for the various spans between hangers or other supports shall be in accordance with Table 3.

7.9.2 A clearance of not less than 1 in. (25.4 mm) shall be provided between the ends of main runners and abutting masonry or reinforced concrete walls, partitions and columns. Where special conditions require main runners to penetrate the plane of abutting masonry or concrete construction, a clearance shall be provided within such constructions of not less than 1 in.(25 mm) from the ends and not less than ½ in. (12.7 mm) from the tops and sides of the runners.

7.9.3 A main runner shall be located not more than 6 in. (152 mm) from the paralleling wall to support the ends of the cross furring. The ends of main runners shall be supported by hangers located not more than 6 in. (152 mm) from the ends.

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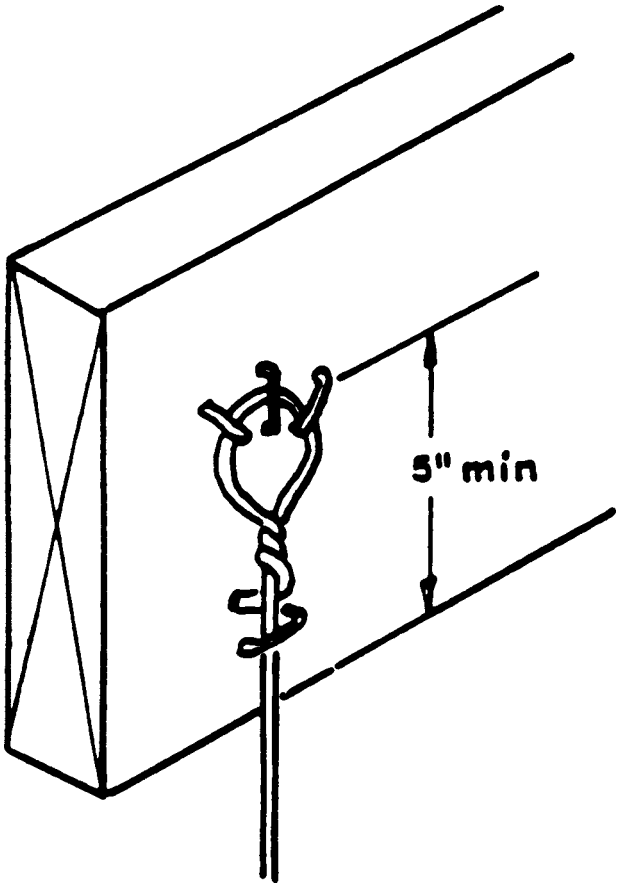

FIG. 3 Hanger Attached to Support Using Staples

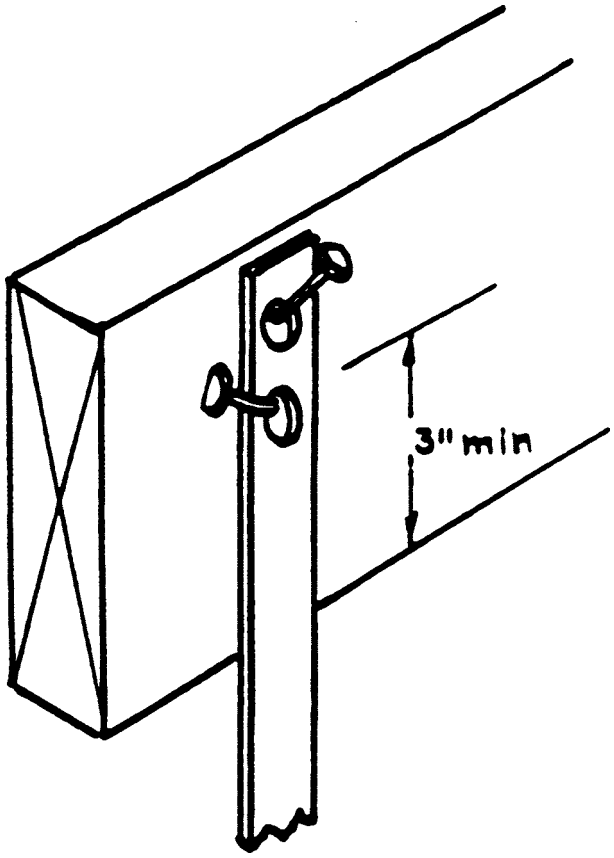

FIG. 4 Flat Hanger Attached to Support Using Nails

7.9.4 When main runners are spliced, the ends shall be overlapped not less than 12 in. (305 mm), with flanges of channels interlocked, and securely tied near each end of the splice with double loops of 0.062 in. (1.6 mm) galvanized wire or double loops of twin strands of 0.048 in. (1.2 mm) galvanized wire.

7.10 *Cross Furring*:

7.10.1 Minimum size and maximum spans and spacings of various types of cross furring for various spans between main runners and supports shall be in accordance with Table 3.

7.10.2 Cross furring shall be securely saddle-tied to main runners with 0.062 in. (1.6 mm) galvanized wire, or a double strand of 0.048 in. (1.2 mm) galvanized wire or with special galvanized clips, or equivalent attachments.

7.10.3 When cross furring members are spliced, the ends shall be overlapped not less than 8 in. (203 mm), with flanges of channels interlocked, and securely tied near each end of the splice with double loops of either 0.062 in. (1.6 mm) galvanized wire or twin strands of 0.048 in. (1.2 mm) galvanized wire.

7.10.4 Cross furring shall not contact abutting masonry or reinforced concrete walls or partitions.

7.10.4.1 Where special conditions require cross furring to penetrate the place of the abutting masonry orconcrete construction, the applicable provisions of 7.9.2 shall apply.

7.10.5 Main runners and cross furring shall be interrupted at control and expansion joints. The resulting intersections shall be constructed by splices, snugly tied, but loose enough to allow for lateral movement (telescoping) of the framing members and expansion and contraction of the plaster membrane.

7.11 *Metal Furring for Walls*:

7.11.1 Attachments for furring shall consist of nails driven securely into concrete or into masonry joints, short pieces of ¾ in. (19 mm) channels used as anchors driven into masonry joints, or other devices specifically designed as spacer elements. Furring shall be spaced horizontally not more than 2 ft (610 mm) on centers. Furring shall be spaced vertically in accordance with horizontal stiffener spacing so that it projects from the face of the wall enough to permit ties to be made.

7.11.2 Where dampproofing has been damaged in installation of attachments, the dampproofing shall be repaired with the same material before proceeding with the installation of the furring.

7.11.3 Horizontal stiffeners shall be not less than ¾-in. (19-mm) hot-rolled or cold-rolled channels, spaced not to exceed 60 in. (1524 mm) on center vertically, with the lower and upper channels not more than 6 in. (152 mm) from the floor and ceiling, and not less than ¼ in. (6.4 mm) from the face of the wall. Stiffeners shall be securely tied to attachments with three loops of 0.048 (1.2 mm) wire.

7.11.4 Vertical members shall be not less than ¾-in. (19-mm) cold-rolled channels, in accordance with requirements in Table 2. Members ahll be saddle-tied to horizontal members with three loops of 0.048 in. (1.2 mm) galvanized soft-annealed wire, or equivalent devices, at each crossing, and

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securely anchored to the floor and ceiling constructions. If furring is not in contact with the wall, then channel braces shall be installed between horizontal stiffeners and the wall, spaced not more than 2 ft (600 mm) apart (horizontal spacing).

8. Keywords

8.1 furring; gypsum; lathing; plaster

ANNEXES

(Mandatory Information)

A1. GENERAL INFORMATION

The work shall include all labor, materials, services, equipment, and scaffolding required to complete the lathing and furring of the project in accordance with the drawings and specifications.

A1.1 *Floating Angle Construction*—Except where required otherwise for certain fire-resistive construction, nails or staples occurring less than 6 in. (152 mm) from internal angles shall not be prohibited from being omitted in the application of gypsum lath, provided each piece of lath is nailed to not less than two supports. Where lath abuts masonry, the angle shall not be“ floated” and a plaster stop or casing bead shall be used.

A1.1.1 Gypsum lath, for floating angle construction, shall be applied to ceiling areas first, so that the ceiling lath will be supported in the angles by the upper edge of the top course of lath applied to walls or partitions.

A1.2 *Wood Furring*—For the attachment of wall finishes, wood furring shall be not less than ¾ in. (19 mm) by 1½ in. (38.1 mm) (actual size) where applied to solid backing such as masonry. Wood furring attached to supports, spaced not more than 24 in. (610 mm) on centers, shall be not less than 1½ by 1½ in.

A2. TECHNICAL INFORMATION

A2.1 *Solid Plaster Partitions with Steel Studs:*

A2.1.1 Steel studs for solid plaster partitions shall be installed in accordance with Specifications C 754 and C 1007 and shall be of a size and number and located to provide backing at all corners. Steel studs shall be set to the required spacing, properly aligned, made plumb and true, securely anchored to the floor and ceiling construction, and temporarily braced, if necessary.

A2.1.2 Where studs do not fall at edges of openings, extra studs shall be added. Such studs shall be securely anchored to the door frames.

A2.1.3 Space above headers of openings extending to the ceiling shall be reinforced by installing studs 16 in. (406 mm) on center over the heads of the openings.

A2.2 *Hollow Metal Door Frames* for prefabricated steel stud, channel stud, lath and plaster hollow partitions.

A2.2.1 Door frames shall be installed in accordance with NAAMM Standard HMMA 840 .

A3. DESIGN AND ERECTION OF HOLLOW DOOR METAL FRAMES FOR PREFABRICATED STEEL STUD AND CHANNEL STUD, LATH AND PLASTER HOLLOW PARTITIONS

A3.1 *Hollow Metal Frames* (for Prefabricated Steel Stud, Channel Stud, Lath and Plaster Hollow Partitions):

A3.1.1 Metal studs shall be installed at each jamb of the steel frame by wiretying, bolting, or welding them to jamb anchors in the frame. The edges of the studs shall be inserted into the notches or other devices provided in the jamb anchor insert clips.

A3.1.2 The first stud on either side of the frame shall be fastened to suitable anchorage at the top and bottom of the partition in accordance with the instructions of the stud manufacturer. A second metal stud shall be placed not more than 2 in. (50 mm) away from the first stud, using adequate means of attachments between the two; or, two metal studs shall be attached to jamb anchors and securely fastened back to back.

A3.1.3 Where metal door frames have an adjustable strut equal in stiffness to a stud, running from each jamb to the ceiling, one metal stud shall be installed at each jamb in the manner previously noted.

A3.1.4 At the head of the metal frame, a section of metal floor track shall be placed horizontally within the head section, and fastened to the jamb studs with wire ties, screws, or welds.

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Frames over 32 in. (813 mm) wide shall be provided with anchor insert clips spaced not over 24 in. (610 mm) on centers.

A3.1.5 Metal jack studs shall be installed over the head of the frame, spaced 16 in. (406 mm) on centers maximum, and shall be attached to the metal floor track. They shall be reinforced with a ¾-in. (19-mm) cold-rolled channel stiffener placed inside the partition and not more than 6 in. (152 mm) above the frame. Floor track is not required if one ¾-in. cold-rolled channel stiffener is placed horizontally on each interior face of the studs and not more than 6 in. above the frame. Channel stiffeners shall extend not less than two full stud spaces beyond the opening and shall be saddle-tied to each stud they cross.

APPENDIXES

X1. VENTILATION INFORMATION

X1.1 Adequate ventilation of attics or similar unheated spaces above gypsum plaster systems is essential to the performance of these systems and shall be designed and provided by others per ASHRE Fundamentals Handbook or applicable buildings code.

X2. GENERAL INFORMATION

X2.1 The work shall include all labor, materials, services, equipment, and scaffolding required to complete the lathing and furring of the project in accordance with the drawings and specifications.

X2.2 Scaffolding shall be constructed and maintained in strict conformity with applicable laws and ordinances.

X2.3 The work shall be coordinated with the work of other trades.

X2.4 Surfaces and openings shall be examined before furring or lathing is applied thereto, the proper authorities shall be notified, and unsatisfactory conditions shall be corrected prior to application of furring or lathing.

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Designation: C 842 – 05

Standard Specification for Application of Interior Gypsum Plaster[1]

This standard is issued under the fixed designation C 842; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope*

1.1 This specification covers the minimum requirements for full-thickness (in accordance with Table 1) interior gypsum plastering on gypsum, metal, masonry, or monolithic concrete bases designed or prepared to receive gypsum plaster.

1.1.1 Gypsum plaster applied to the interior side of exterior walls of masonry or concrete shall be isolated from the exterior wall.

1.2 Gypsum plasters shall not be used in exterior locations or interior "wet" areas.

NOTE 1—To secure desirable results, this specification should be coordinated with the provisions of Specification C 841. General information concerning full thickness gypsum plastering is contained in Annex A2, Annex A3, and Annex A4.

1.3 Details of construction for a specific assembly to achieve the required fire resistance shall be obtained from reports of fire-resistance tests, engineering evaluations, or listings from recognized fire testing laboratories.

1.4 Details of construction to achieve required sound control shall be obtained from reports of tests conducted at recognized sound testing laboratories in accordance with the applicable sound tests of Test Methods E 90, C 423, or E 492.

1.5 The values stated in inch-pound units are to be regarded as the standard. The SI (metric) values given in parentheses are approximate and are provided for information purposes only.

1.6 The text of this standard references notes and footnotes which provide explanatory material. These notes and footnotes (excluding those in tables and figures) shall not be considered as requirements of the standard.

2. Referenced Documents

2.1 *ASTM Standards:* [2]

C 5 Specification for Quicklime for Structural Purposes

C 11 Terminology Relating to Gypsum and Related Building Materials and Systems

C 28 Specification for Gypsum Plasters

C 35 Specification for Inorganic Aggregates for Use in Gypsum Plaster

C 59/C 59M Specification for Gypsum Casting and Molding Plaster

C 61/C 61M Specification for Gypsum Keene's Cement

C 206 Specification for Finishing Hydrated Lime

C 423 Test Method for Sound Absorption and Sound Absorption Coefficients by the Reverberation Room Method

C 631 Specification for Bonding Compounds for Interior Gypsum Plastering

C 841 Specification for Installation of Interior Lathing and Furring

C 1489 Specification for Lime Putty for Structural Purposes

E 90 Test Method for Laboratory Measurement of Airborne-Sound Transmission Loss of Building Partitions and Elements

E 492 Test Method for Laboratory Measurement of Impact Sound Transmission Through Floor-Ceiling Assemblies Using the Tapping Machine

3. Terminology

3.1 *Definitions:*

3.1.1 Definitions shall be in accordance with Terminology C 11.

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *catfaces*, *n*—blemishes or rough depressions in the finish coat.

3.2.2 *coat*, *n*—a thickness or layer of plaster applied over a surface in a single application.

3.2.2.1 *base coat, n*—the sum of the scratch and brown coats or the total coats in place prior to application of finish coats.

3.2.2.2 *brown coat, n*—the second coat of plaster applied in three-coat work.

3.2.2.3 *finish coat, n*—the last coat of plaster applied in either two-coat or three-coat work.

3.2.2.4 *scratch coat, n*—the first coat of plaster applied over a lath or other substrate.

[1] This specification is under the jurisdiction of ASTM Committee C11 on Gypsum and Related Building Materials and Systems and is the direct responsibility of Subcommittee C11.03 on Specifications for the Application of Gypsum and Other Products in Assemblies.

Current edition approved May 1, 2005. Published May 2005. Originally approved in 1976. Last previous edition approved in 1999 as C 842 – 99.

[2] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

***A Summary of Changes section appears at the end of this standard.**

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3.2.2.5 *three-coat work, n*—plaster applied in three successive coats, leaving time between coats for setting or drying, or both, of the plaster.

3.2.2.6 *two-coat work, n*—scratch and brown coats applied from the same mix with no time allowed for setting of the scratch coat before the brown coat is applied.

3.2.3 *gypsum ready mixed plaster, n*—calcined gypsum plaster, mixed at the mill with a mineral aggregate, designed to function as a base coat to receive various finish coats.

3.2.4 *metal bases, n*—expanded metal, welded or woven wire, or punched sheet metal plaster bases.

3.2.5 *smooth-trowel finish, n*—a finish resulting from steel troweling.

3.2.6 *texture finish, n*—a finish resulting from (*1*) trowel application followed by floating or texturing of the surface with any of a variety of tools using a minimum of water or (*2*) machine application which is or is not hand textured.

TABLE 1 Thickness of Plaster

Plaster Base	Thickness of Plaster Including Finish Coat, in. (mm)
Metal plaster base	5/8 (16) min
All other types of plaster base	1/2 (13) min
Unit masonry	5/8 (16) min
Monolithic concrete surfaces:[A]	
Vertical[BC]	5/8 (16) min
Horizontal[C]	1/8 (3) to 5/8 (10)

[A] Base coat plastering of the same proportions as specified for unit masonry is not prohibited from being used over plain or reinforced monolithic concrete, provided the surface is first covered with a metal plaster base or first coated with a bonding compound.

[B] Finish coat plaster applied direct to a bonding compound over vertical monolithic concrete shall be not more than 3/16 in. (4.8 mm) in thickness. Where more than 3/16 in. of finish coat is required to bring such vertical surface to a true plane, a base coat of plaster shall first be applied to the bonding compound.

[C] Where horizontal or vertical monolithic concrete surfaces require more than 3/8 in. (9.5 mm) or 5/8 in. (15.9 mm) of plaster, respectively, to produce required lines or surfaces, metal plaster base shall be attached to the concrete before application of plaster. Where concrete surface requires the application of more than 1 in. (25.4 mm) of plaster to produce required lines or surfaces, lath shall be applied over furring secured to the concrete.

4. Delivery of Materials

4.1 All manufactured materials shall be delivered in the original packages, containers, or bundles bearing the brand name and manufacturer (or supplier) identification.

5. Protection of Materials

5.1 Plasters and other cementitious materials shall be kept dry until used; they shall be stored off the ground, under cover, and away from walls with condensation and other damp surfaces. Metal products shall be protected, while stored, against rusting.

6. Environmental Conditions

6.1 *Temperatures*—Where the ambient outdoor temperature at the building site is less than 55 °F (13 °C), a temperature of not less than 55 °F (13 °C) and not more than 80 °F (27 °C) shall be maintained continuously inside the building for a period of not less than one week prior to the application of plaster (Note 2). Temporary heat shall be evenly distributed, using deflective or protective screens to prevent concentrated or uneven heat or cold on the plaster, and maintained until the permanent HVAC system is activated.

NOTE 2—The requirement should minimize the possibility of plaster cracking due to structural movements caused by thermal changes from outdoor temperature extremes during construction.

6.2 *Ventilation*—Sufficient ventilation shall be provided to remove excess water given off through the drying process. (See Appendix X2 for provisions for ventilating underside of roofs and glazed buildings with and without operable windows.)

7. Materials

7.1 *Gypsum Plasters*—The following plasters shall conform to Specification C 28:

7.1.1 Ready mixed.

7.1.2 Neat.

7.1.3 Wood-fibered.

7.1.4 Gauging for finish coat.

7.2 *Gypsum Casting and Molding Plasters*—Specification C 59/C 59M.

7.3 *Gypsum Keene's Cement*—Specification C 61/C 61M.

7.4 *Lime*:

7.4.1 *Finishing Hydrated Lime*—Specification C 206, Type S.

7.4.2 *Quicklime for Structural Purposes*—Specification C 5.

7.4.3 *Lime Putty for Structural Purposes*—Specification C 1489.

7.5 *Lime Putty*—Lime putty exceeding 8 weight % of unhydrated magnesium oxide shall not be used for finish coat plaster.

7.6 *Aggregates*:

7.6.1 *Aggregates for Base Coat Plaster*—Specification C 35.

7.6.2 *Aggregates for Finish Coat Plasters*—Specification C 35, except that gradation shall be within the limits specified in Table 2.

7.6.3 Sand for job mixed lime putty-gypsum gauged, sand float finish (see 9.6.6.1) shall be graded within the limits specified in Table 3.

7.7 *Water*—Water used in mixing and finishing plaster shall be potable, and free of such amounts of mineral or organic substances that affect the set, the plaster, or any metal in the system.

NOTE 3—Water containing salt or alum, or water in which tools have been washed, accelerates the "set" and may cause efflorescence. Water from stagnant pools and wells frequently contain organic or vegetable matter which may retard the "set," cause staining, or interfere with the bond.

TABLE 2 Aggregate for Finish Coat Plasters, Percentage Retained on Each Sieve, Cumulative

Sieve Size	Perlite, Natural and Manufactured Sand			
	Volume,%		Weight, %	
	max	min	max	min
No. 20 (850 µm)	0	...	0	...
No. 30 (600 µm)	10	...	0.5	...
No. 100 (150 µm)	100	40	100	40
No. 200 (75 µm)	100	70	100	70

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TABLE 3 Sand for Job-Mixed Lime Putty-Gypsum Gaged Sand Float Finish, Percent Retained on Each Sieve by Weight, Cumulative

Sieve Size	max	min
No. 16 (1.18 mm)	0	0
No. 30 (600 µm)	50	20
No. 50 (300 µm)	70	50
No. 100 (150 µm)	100	80

7.8 *Bonding Compounds*—Specification C 631.

8. Surface Preparation

8.1 *Substrates*—Surfaces of substrates for the application of gypsum plaster shall be free of materials that will inhibit bond or adhesion, shall be straight, plumb, level, square, and true to required plan angles and curves. See A2.5.

8.1.1 All accessories shall be securely attached to the substrate and be installed to accommodate embedment of flanges.

8.1.2 *Gypsum and Metal Lath*—Shall have been installed in compliance with Specification C 841.

8.2 *Conditioning of Surfaces*—All depressions in masonry and concrete surfaces deeper than ⅛ in. (3.2 mm) shall be brought flush to the surface with compatible materials prior to plaster application. Fins or protrusions extending more than 1/16 in. (1.6 mm) from the surface shall be removed. Protrusions less than 1/16 in. (1.6 mm) shall be feathered out with compatible materials prior to plaster application.

8.2.1 *Masonry*—All masonry surfaces shall be wetted immediately prior to the plaster application. No free water shall remain visible on the substrate surface.

8.2.1.1 Where the surface is too smooth to provide mechanical key, the surface shall be roughened or bonding compound shall be used. (See Annex A2.5 and A2.6.)

8.2.1.2 Where bond cannot be obtained over the entire surface by the methods specified in 8.2.1.1, self-furring metal lath shall be used in accordance with Specification C 841.

8.2.2 *Monolithic concrete*—bonding compounds shall be used prior to plastering all monolithic concrete surfaces. (See A2.6.)

8.2.3 Grounds, beads, and screeds shall be installed prior to the plastering as modified herein.

8.3 *Grouting*:

8.3.1 Metal bases for solid partitions shall be grouted with gypsum plaster leaving ¼ in. (6.4 mm) below the top edge of the base, and be formed with a center groove so that the lath extends ¾ in. (19 mm) below the top edge of the base, or plaster grout shall be placed after installation of lath.

8.3.2 *Metal Frames*—Hollow door and window frames shall be filled with gypsum plaster grout.

9. Mix Design

9.1 *Mixing, General*—All plaster mixing shall be done by mechanical means unless hand mixing is specified.

9.1.1 Retempered, partially set, frozen, caked or lumpy material shall not be used.

9.1.2 Each batch shall be mixed separately and mixers shall be free of all set and hardened materials prior to mixing each batch.

9.1.3 All tools shall be kept clean.

9.1.4 The setting time shall be not more than 4 h.

9.2 *Hand Mixing*—see Annex A3.1.

9.3 *Mechanical Mixing*—In accordance with manufacturer's printed directions. See Annex A3.2.

9.4 *Base Coat Proportions*:

9.4.1 *Gypsum Neat Plaster*—Proportions of sand, perlite, or vermiculite aggregate to 100 lb (45.4 kg) of gypsum neat plaster shall be not more than those specified in Table 4. (See A2.3 for equivalent measure for aggregates.)

9.4.2 *Gypsum Ready Mixed Plaster*—Shall be used with the addition of water only.

9.4.3 *Gypsum Wood-Fibered Plaster*—Proportion of damp, loose sand or perlite or vermiculite shall be not more than 1 ft^3 (0.028 m^3) to 100 lb (45.4 kg) of gypsum wood-fibered plaster.

9.5 *Preparation of Lime Putty*:

9.5.1 Lime putty shall be prepared from Type S hydrated lime or pulverized quicklime, in accordance with the manufacturer's printed directions.

9.5.2 *Hydrated Lime*—Type S lime shall only be used after soaking for the time period required in accordance with the manufacturer's printed directions.

9.6 *Finish Coat Proportions*:

9.6.1 Finish coats shall be either ready mixed or job mixed in accordance with Table 5 and Table 6.

9.6.1.1 Where thickness of the finish coat is more than ⅛ in. (3.2 mm), the proportion of the gypsum gauging plaster shall be increased to minimize shrinkage type cracks.

9.6.2 Troweled Finishes of lime putty gauged with gypsum gauging plaster or ready mixed gypsum plaster shall be proportioned in accordance with Table 5.

9.6.2.1 Where finish in 9.6.2 is to be applied over base coats containing perlite or vermiculite, the addition of not less than ½ ft^3(0.14 m^3) or not more than 1 ft^3 (0.028 m^3) of fine aggregate meeting the sieve analysis of Table 2 shall be added to the mix.

9.6.3 Troweled finishes of lime putty gauged with gypsum Keene's cement shall be specified as medium or hard and shall be proportioned in accordance with Table 5.

9.6.3.1 When finish in 9.6.3 is mechanically mixed, the water shall be placed in the mixer first, then the lime, the fine aggregate (if used), and finally the gypsum Keene's cement.

9.6.4 Troweled finishes of gypsum ready mixed plaster shall be mixed in accordance with Table 5.

9.6.5 Float finishes of lime putty gauged with gypsum gauging plaster shall be proportioned in accordance with Table 5.

9.6.5.1 When finish in 9.6.6 is to be mixed with sand, the sand shall be graded within the limits shown for basecoats in Specification C 35 except that all of the sand shall pass a No. 8 (2.36 mm) sieve.

9.6.6 Float finishes of lime putty gauged with gypsum Keene's cement shall be proportioned in accordance with Table 5.

9.6.6.1 When the finish in 9.6.6 is to be mechanically mixed wet, follow procedures in 9.6.3.1. For mixing dry, add lime

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TABLE 4 Base Coat Proportions[A]

Plaster Base	Aggregates[B]		
	Sand		Perlite or Vermiculite[C]
	By Volume, ft³(m³), Damp and Loose	By Weight, lb (kg), Damp and Loose	By Volume, ft³(m³)
Over Gypsum Lath			
Two-coat work:			
Base coat	2½ (0.071)	250 (113)	2 (0.06)
Three-coat work:			
Scratch coat	2 (0.056)	200 (91)	2 (0.06)
Brown coat	3 (0.085)	300 (136)	2 (0.06)
or			
Scratch and brown coats	2½ (0.071)	250 (113)	...
Over Metal Lath			
Three-coat work:			
Scratch coat	2 (0.056)	200 (91)	2 (0.06)
Brown coat	3 (0.085)	300 (136)	2 (0.06)
or			
Scratch and brown coats	2½ (0.071)	250 (113)	...
Over Unit Masonry (Note 6)			
Two-coat work:			
Base coat	3 (0.085)	300 (136)	3 (0.085)
Three-coat work:			
Scratch coat	3 (0.085)	300 (136)	3 (0.085)
Brown coat	3 (0.085)	300 (136)	3 (0.085)
Over Monolithic Concrete[D]			
For base coat proportions applicable to monolithic concrete, see 10.2.1.			

[A] The proportions in Table 3 are applicable for both hand and machine application of plaster. See plaster manufacturer's instructions for application of machine-applied plaster.

[B] Use of an accurate device to measure quantities, such as a measuring box or container of known capacity, is highly encouraged. Where such a device is not available, six No. 2, square-edge (not scoop) shovels, with a blade approximately 8½ in. (216 mm) wide and 11 in. (279 mm) long, with the maximum depth of sides not more than 1½ in. (38 mm) higher than the face of the blade, and filled to an average depth of 4 in. (102 mm) of damp, loose sand, shall be considered as the approximate equivalent to 1 ft³ (0.028 m³).

[C] Where the plaster is 1 in. (25 mm) or more in total thickness, or where the finish coat is sand float, the proportions for the brown coat shall be not more than 3 ft³ (0.085 m³).

[D] For use of bonding compounds for plastering on monolithic concrete, see 8.2.2, and Footnotes in Table 1 and A2.6.

TABLE 5 Proportion of Gypsum To Not More Than Lime/Aggregate, with Dry and Wet Equivalents

	Dry						Lime Putty Wet Equivalent		
	Weight, lb (kg)			Volume, ft³(m³)			ft³(m³)	U.S. gal (litres)	lb (kg)
	Gypsum	Lime	Aggregate	Gypsum	Lime	Aggregate			
Troweled Finishes:[A]									
Lime putty with:[B]									
Gypsum gauging	100 (45.4)	225 (102)	0[A]	1 (.028)	3 (.085)	0	6.75 (.191)	52.5 (199)	450 (204)
Gypsum Keene's cement:									
Medium	100 (45.4)	50 (22.7)	0[A]	1 (.028)	1 (.028)	0	1⅛ (.032)	8¾ (33)	100 (45.4)
Hard	100 (45.4)	25 (11.3)	0[A]	1 (.028)	½ (.014)	0	⅝ (.018)	4½ (17)	50 (22.7)
Ready-mixed gypsum plaster	100 (45.4)	0	0	1 (.028)	0	0	0	0	0
Gypsum vermiculite	100 (45.4)	0	7 to 15 (3.2 to 6.8)	1 (.028)	0	1 (.028)	0	0	0
Floated Finishes:									
Lime putty with:									
Gypsum gauging	100 (45.4)	225 (102)	200 (90.7)	1 (.028)	3 (.085)	2 (.057)	6.75 (.191)	52.5 (199)	450 (204)
Gypsum Keene's cement:									
Medium	150 (68.0)	100 (45.4)	450 (204)	1½ (.042)	2 (.057)	4½ (.127)	2¼ (.064)	17½ (66)	200 (90.7)
Ready-mixed gypsum plaster[C]	100 (45.4)	0	0	1 (.028)	0	0	0	0	0
Gypsum-vermiculite	100 (45.4)	0	7 to 15 (3.2 to 6.8)	1 (.028)	0	1 (.028)	0	0	0
Gypsum-sand (job-mixed)[D]	100 (45.4)	0	200 (90.7)	1 (.028)	0	2 (.057)	0	0	0

[A] See 9.6.2, 9.6.3, 9.6.4 and 9.6.5.

[B] If additional hardness of finish coat is desired, increased amounts of gypsum shall be used; however, hard finishes shall not be used over lightweight aggregate base coats.

[C] Mixed with water only, in accordance with manufacturers' printed directions.

[D] Gypsum shall be neat, unfibered plaster.

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TABLE 6 Trowel Finishes of Lime Putty Gaged With Gypsum Gaging Plaster Proportions

Proportions of Fine Aggregate[A,B,C]		
Not Less Than	Not More Than	Per
½ ft³(0.014 m³)	1 ft³(0.028 m³)	100 lb (45.4 kg) gypsum gauging
or ⅛ ft³(0.0035 m³)	¼ ft³(0.007 m³)	50 lb (22.7 kg) dry hydrated lime
or 1 U.S. gal (3.78 L)	2 U.S. gal (7.57 L)	1 ft³(0.028 m³) lime putty
or 1 pt (0.473 L)	1 qt (0.946 L)	1 U.S. gal (3.78 L) lime putty

[A] Where such finish coats are to be applied over base coats containing perlite or vermiculite, the addition of not less than ½ ft³ (0.014 m³) of fine aggregate, meeting the sieve analysis of Table 1 shall be added.

[B] For any of the above proportions, up to ½ ft³ (0.014 m³) of fine aggregate in accordance with Table 1 is not prohibited from being added to the mix.

[C] The largest particle size of aggregate and its proportion ratio will determine the degree of coarseness of the sand finish. The specifier shall indicate the maximum size desired.

first, then gypsum Keene's cement, and sand. This dry mix shall be mixed to a uniform color and then add water to achieve the desired consistency.

9.6.7 Float finishes of job mixed gypsum and sand shall be proportioned in accordance with Table 5 and Table 6.

9.6.8 Float finishes of ready mixed plaster and sand shall be mixed with water only in accordance with the manufacturer's printed directions.

9.6.9 Float finishes of job mixed plaster shall be proportioned in accordance with Table 6.

9.6.10 Float or textured ready mixed colored plaster shall be mixed in accordance with the manufacturer's printed directions.

9.6.11 Float or textured job mixed color plaster shall be proportioned in accordance with Table 5 or Table 6.

9.6.12 Special finishes shall be proportioned in accordance with the applicable provision of Table 5 or Table 6.

10. Application

10.1 *General*—Plaster shall be applied by hand or machine as specified herein.

10.2 *Plaster Thickness*:

10.2.1 Gypsum plaster shall be applied to the thickness specified in Table 1 . Plaster thickness shall be measured from the face plane of all plaster bases (Note 4).

NOTE 4—Installation of wood or metal grounds or plaster screeds will assist in achieving specified thicknesses.

10.3 *Application of Base Coats*:

10.3.1 *Two-Coat Work (see 3.2.2.6 and Note 5)*—The first coat shall be applied with sufficient material and applied with enough pressure to form a good bond to the substrate. The second coat shall be applied by doubling back before the first coat sets and with the plaster brought out to the grounds or screeds or specified thickness.

NOTE 5—Two coat work is not recommended over any type metal plaster base.

10.3.1.1 The plaster shall be straightened to a true plane without application of water leaving the surface porous and rough enough to provide a mechanical bond for the finish coat.

10.3.2 *Three-Coat Work (see 3.2.2.5 and Appendix X3)*—The first coat or scratch coat shall be applied with sufficient material and applied with enough pressure to form tight contact with and a good bond to solid plaster bases, or to form full keys through metal reinforcement. The first coat shall have sufficient depth of material leaving the surface sufficiently porous and rough (scratched or raked) to provide mechanical bond for the second or brown coat.

10.3.2.1 After the first or scratch coat has set, screeds shall be applied over the first coat prior to application of the second coat to ensure full plaster thickness. The second or brown coat shall be applied with sufficient material and pressure to ensure tight contact with the scratch coat and to bring the thickness of the second coat out to the grounds or specified thickness. The second coat shall straighten the surface to a true plane without application of water, and leave the surface sufficiently porous and rough enough to provide mechanical bond for the third or finish coat.

10.3.2.2 Metal base and metal frames for hollow partitions shall be plaster grouted prior to plastering, or shall be grouted solid between base or frame and plaster base at the time of plastering (see 8.3.1 and 8.3.2).

10.3.3 *Plastering on Monolithic Concrete*—All applicable requirements of 8.1, 8.1.1, 8.2, 8.2.1, 8.2.1.1, 8.2.2, A2.5, A2.6 and Table 1 footnotes shall be followed.

10.3.3.1 Walls and columns shall be prepared as in A2.5 and with one of the following: a) dash-bond coat; b) a bonding compound as in A2.6; c) metal plaster base; or d) two-coat plaster application as provided in 10.3.1 with a proportion of gypsum-neat-plaster-aggregate of 100-lb (45.4 kg) of plaster to not more than 3 ft³(0.085 m³) of aggregate.

10.3.3.2 Ceilings shall be prepared as in A2.5 and A2.6 and two coat work applied in accordance with 10.3.1.

10.3.4 *Solid Plaster Partitions with Steel Studs (Metal Lath and Plaster)*—Partitions shall be not less than 2 in. (51 mm) thick and shall have scratch, brown, and finish coats applied in accordance with 10.3.4.1-10.3.4.4. Where studs are temporarily braced, the bracing shall be maintained until the scratch coat on the lath side has set.

10.3.4.1 The scratch coat on the lath side shall be applied first, with sufficient material and pressure to form full keys and embed the lath and with sufficient depth of material to be scored to a rough surface immediately following its application.

10.3.4.2 The back-up coat on the channel side shall be applied in not less than two applications after the scratch coat on the lath side has set and partially dried. The first application shall completely cover the keys of the scratch coat. The second application shall bring the plaster out to the grounds in a true plane with the surface, left porous and sufficiently rough to provide mechanical bond for the finish coat. Extra water shall not be used in straightening the wall to a true plane.

10.3.4.3 The brown coat on the lath side shall be applied after the brown coat on the channel side has set, and left as specified for the finish coat.

10.3.4.4 Plaster shall extend to the floor, except that where plaster grouted combination metal bases and screeds are used, the plaster shall extend to the grout below the top of the base. Spaces between the grounds and all metal door frames shall be filled.

10.3.5 *Studless Solid Partitions (Metal Lath and Plaster)*—Partitions shall be not less than 2 in. (51 mm) thick, constructed

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using either rib lath or diamond mesh (flat expanded) lath, and with plaster applied in the same number of coats as for solid partitions with steel studs (see 10.3.4).

10.3.5.1 Where rib metal lath is used, the scratch coat shall be applied first to the flat side with temporary bracing on the rib side.

10.3.5.2 Where diamond mesh lath is used, the temporary bracing shall be attached to either side and the scratch coat applied on the opposite side.

10.3.5.3 Sequence application of brown coats in accordance with one of the following methods:

(*1*) Brown coat shall be applied over the face of the scratch coat followed by the brown coat on the opposite side of the partition, or

(*2*) Brown coat shall be applied on the rib side of the metal lath, or on the back side of the scratch coat followed by the brown coat applied over the face of the scratch coat.

10.3.6 *Studless Solid Partitions (Gypsum Lath and Plaster)*—Partitions shall be not less than 2 in. (51 mm) thick and shall be three-coat work on both sides.

10.3.6.1 Scratch coat shall be applied approximately ⅜ in. (9.5 mm) thick with not less than 3⁄16 in. (4.8 mm) thickness at any point. The application shall be started at the side opposite the temporary bracing, then on the braced side without removing the bracing. The thickness shall be the same on both sides.

10.3.6.2 The brown coat shall be applied to the side opposite the bracing after the scratch coat has set and is partially dry. The bracing shall be removed when this brown coat has set and is partially dry. Both sides shall have been brought to 1⁄16 to ⅛ in. (1.6 to 3.2 mm) of the required thickness leaving a surface ready to receive a finish coat (see 10.3.4.2), which will bring the partition to an overall thickness of not less than 2 in. (51 mm).

10.3.7 *Studless Solid Partitions (Multiple-Thickness Gypsum Lath and Plaster)*—Partitions shall be not less than 2 in. (51 mm) thick with three coats on each side. Each side shall be not less than ½ in. (12.7 mm) thick.

10.3.8 *Gypsum Lath Ceilings Attached by Clips*—Plastered ceiling with clip attached gypsum lath shall be covered with three-coat work with the scratch coat not less than 3⁄16 to ¼ in. (4.8 to 6.4 mm) thick over the face of the gypsum lath. The total thickness of scratch and brown coats shall be not less than 7⁄16 in. (11 mm).

10.4 *Application of Finishes*:

10.4.1 Finish coats shall be applied to a partially dry base coat or to a thoroughly dry base coat that has been evenly wetted by brushing or spraying. No water shall be left standing on the surface prior to plaster application (Note 6).

NOTE 6—Precolored plaster is not recommended for smooth-trowel finishes. Where colored plaster is being applied, excessive water causes color variations. See A2.3 and A2.4.

10.4.2 Troweled finishes shall be applied by drawing the first application down tight to the entire base coat surface and doubling back to fill out to a true even surface of from 1⁄16 to ⅛ in. (1.6 to 3.2 mm) thick, free from catfaces and other blemishes or irregularities. Final troweling or texturing shall be done with a minimum of water after the finish coat has become firm.

10.4.2.1 Lime putty-gypsum gauged Keene's cement finish (see 9.6.3 and Note 7) shall be done in accordance with 10.4.2 except that the final troweling shall be continued until the finish has set.

NOTE 7—The thickness of this finish may be increased for decorative work as required.

10.4.2.2 Ready mixed gypsum troweled finishes (see 9.4.2) shall be applied in accordance with the printed directions of the manufacturer.

10.4.3 Textured/float finishes shall be applied in accordance with 10.4.2 except the float applied finish shall also meet the requirements of the specific texture required. The texture required shall be created by the type of float surface used (wood, carpet, cork, rubber, or other) and the length of time between trowel application and floating (take-up).

10.4.3.1 The mixes in 10.4.2.1 and 10.4.2.2 used for a float finish shall be applied in accordance with 10.4.3.

10.4.4 Texture or special finishes shall be applied in accordance with the printed directions of the manufacturer.

10.4.5 Job mixed finishes shall be applied in accordance with 10.4.2 or 10.4.3. The texture or special finish coat shall reduce the total thickness by not more than 1⁄16 in. (1.6 mm) while matching the approved sample.

10.4.5.1 Special finishes shall not reduce the combined thickness of the base coat and finish coat to less than that specified in Table 1. Inorganic coloring material added to the job mix shall be in accordance with A2.4.

10.4.5.2 Acoustical plaster and finish shall be applied in accordance with the printed directions of the manufacturer.

11. Keywords

11.1 aggregate; basecoat; ceiling; finish coat; gypsum; lath; plaster; texture

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ANNEXES

(Mandatory Information)

A1. GENERAL INFORMATION

A1.1 Surfaces and openings shall be examined before plaster is applied thereto, the proper authorities shall be notified, and unsatisfactory conditions shall be corrected prior to application of plaster.

A2. TECHNICAL INFORMATION

A2.1 *Equivalent Measure for Aggregates*—Six No. 2 shovels of damp loose sand are equivalent to 1 ft^3(0.028 m^3) and 100 lb (45.4 kg). Perlite and vermiculite are normally packed in bags marked with the cubic foot (or cubic metre) content.

A2.2 *Job Addition of Fiber*—Job added fiber, where specified, shall be nonstaining natural or synthetic fiber, well-shredded and free from grease, oil, dirt, or other materials that adversely affect the strength, bond, or setting time of the plaster. Uniform quantities of the fiber, as specified, shall be added to the mixer, batch by batch, after mixing water, aggregate and plaster have been added. The type and amount of fiber to be used is dependent on job specifications or on that quantity of the selected fiber that provides the required application characteristics. Where the type and quantity of fiber is not specified by contractual agreement, gradually increased or decreased quantities shall be used until the required application characteristics are obtained, and that quantity used thereafter.

A2.3 *Ready Mixed Colored Finish Plasters*, shall be mixed and applied in strict accordance with the directions of the manufacturer. Where specified by contractual agreement, sample panels prepared in accordance with the job specifications shall be submitted to the architect or builder for approval of final color prior to the start of any job application.

A2.4 *Job Mixed Colored Finish Plasters*—Job mixed floated or textured colored finish plasters shall be prepared with inorganic or organic water-disperseable, nonbleeding, nonfading, lime-proof coloring materials, dry powdered, paste or liquid. Coloring materials shall be proportioned and thoroughly dispersed into the finish plaster in strict accordance with the directions of the manufacturer of the coloring material. In the absence of specific directions by the manufacturer of the coloring material, uniform quantities, mixer batch by mixer batch, shall be thoroughly dispersed into the mixing water. Uniform, identical proportioning by weight of coloring material, mixing water and dry finish plaster components, and uniform, identical mixing procedure, mixing time and application. Each unbroken area shall be completed in one continuous operation from angle to angle or natural interruption for best uniformity of color. Where specified by contractual agreement, sample panels prepared in accordance with the job specifications, including floating or texturing procedures, shall be submitted to the architect or builder for final color approval prior to the start of any job application. Floating or texturing procedure used for sample preparation shall be strictly followed for job application. The minimum quantity of coloring material necessary to obtain the specified or approved color shall be used, but in no case shall the proportion of coloring material exceed 8 weight % of the cementitious materials used.

A2.5 *Preparation:*

A2.5.1 All surfaces to be plastered shall be free from grease, oil, form release compounds, dirt, dust, paint, laitance, efflorescence or other foreign matter that would inhibit suction or mechanical keying, or cause staining.

A2.5.2 When plastering a cast-in-place or other monolithic wall, bond is dependent on the surface properties. Bond shall be enhanced by one or more of the following techniques to prepare the surface: a) sandblasting; b) wire brushing; c) acid wash; d) chipping; or e) coating with a plaster bonding compound.

A2.5.3 Laitance or efflorescence on concrete and masonry shall be removed by washing first with a 10 % solution of commercial hydrochloric acid (muriatic acid) and water and then with clean water to remove all traces of acid. Grease, oil, and form release compounds shall be removed with cleaning agents compatible with surface and subsequent plastering.

A2.5.4 The use of dressed (smooth) lumber, metal, plastic, or plywood forms, in conjunction with the vibration of concrete, produce bonding surfaces so dense and smooth, that the mechanical key necessary for plaster to bond is absent. In addition, certain kinds of lumber, oiled forms, and exposed reinforcement metals cause staining of the plaster.

A2.6 Bonding compounds that are water re-emulsifiable shall not be used in areas of a building exposed to cyclic or continuous exposure to very humid or wet conditions, or where a dew point condition occurs on the plaster surface. (Dew point conditions frequently occur in commercial laundries, natatoriums, and other wet areas such as showers, hydrotherapy rooms, and where walls are to be washed with water or steam.)

A2.6.1 Applied bonding compound shall be protected from dirt and dust when it will not immediately be covered with plaster. Some bonding compounds require immediate application of plaster to be effective.

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A3. MIXING

A3.1 *Hand Mixing*—Mixing boxes shall be watertight. Where mixing is done in a building, provide water-resistive protection under and around the mixing boxes and water containers.

A3.1.1 *Neat Plaster*—The aggregate shall be added to the plaster and mixed dry to a uniform color, pulled to one end of the box, hoed and chopped into water placed in the other end of the box until thoroughly mixed to the required consistency.

A3.1.2 *Gypsum Ready Mixed Plaster*—Plaster shall be placed at one end of the box without adding aggregate, water shall be placed in the other end and plaster hoed and chopped into water until thoroughly mixed to the required consistency.

A3.1.3 *Gypsum Wood-Fibered Plaster*—Where used without aggregate, the plaster shall be placed at one end of the box, hoed and chopped into water at the other end until thoroughly mixed to the required consistency. Where aggregate is added, it shall be mixed in accordance with A3.1.1.

A3.2 *Mechanical Mixing:*

A3.2.1 *Gypsum Neat Plaster*—Aggregate shall be added at the job while the mixer is in continuous operation, as follows:

A3.2.1.1 Put in less than the total required amount of water.

A3.2.1.2 If sand is used, add half the sand. If vermiculite or perlite is used, add total amount required.

A3.2.1.3 Add all of the plaster.

A3.2.1.4 Add the remainder of the sand.

A3.2.1.5 Adding water as necessary, mix to the proper consistency. Do not overmix.

A3.2.1.6 Dump the entire batch and use. Clean the mixer for the next batch.

A3.2.2 *Gypsum Ready Mixed Plaster*—Aggregate shall be added at the producer's plant. While the mixer is in continuous operation, do as follows:

A3.2.2.1 Put in less than the total required amount of water.

A3.2.2.2 Add the ready mixed plaster.

A3.2.2.3 Adding water or plaster as necessary, mix to the desired consistency.

A3.2.2.4 Dump the entire batch and use. Clean the mixer for the next batch.

A3.2.3 *Gypsum Wood-Fibered Plaster*—Where used with aggregate added, the loading and mixing cycle shall be as prescribed in A3.2.1. Where used without aggregate, the loading and mixing cycle shall be as prescribed in A3.2.2.

A4. BASE COAT PROPORTIONS

A4.1 For job mixed plaster, proportions of sand, perlite, or vermiculite aggregate to 100 lb (45.4 kg) of gypsum neat plaster shall be not more than those specified in Tables 5 and 6.

A4.1.1 Gypsum ready mixed plaster is not prohibited from being used instead of job-prepared mixes of gypsum neat plaster and aggregate provided the proportion of aggregate to plaster is not more than that specified in Tables 5 and 6. Gypsum ready mixed plaster shall be used with the addition of water only, except as otherwise specified.

A4.1.2 *Gypsum Wood-Fibered Plaster*—In no case shall the addition of sand, perlite, or vermiculite be more than 1 ft^3(0.028 m^3) to 100 lb (45.4 kg) of gypsum wood-fibered plaster.

APPENDIXES

(Nonmandatory Information)

X1. GENERAL INFORMATION

X1.1 The work includes all labor, materials, services, equipment, and scaffolding required to complete the plastering on the project in accordance with the drawings and specifications.

X1.2 Scaffolding shall be constructed and maintained in strict conformity with applicable laws and ordinances.

X1.3 The work shall be coordinated with the work of other trades.

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X2. VENTILATION INFORMATION

X2.1 Adequate ventilation of attics or similar unheated spaces above gypsum plaster systems is essential to the performance of these systems and shall be designed and provided by others per ASHRAE Fundamentals Handbook or applicable building code.

X3. RECOMMENDED LOCATIONS OF THREE COAT WORK

X3.1 *Use Three-Coat Work on the Following Types of Construction:*

X3.1.1 Over gypsum lath attached to ceiling supports spaced more than 16 in. (406 mm) on center.

X3.1.2 Over gypsum lath attached to ceiling supports by clips.

X3.1.3 Over 3⁄8-in (9.5-mm) thick gypsum lath where a vapor retarder is used adjacent to the back of the lath.

X3.1.4 Over metal plaster bases.

SUMMARY OF CHANGES

Committee C11 has identified the location of selected changes to this specification since the last issue, C 842 – 99, that may impact the use of this standard. (Approved May 1, 2005)

(*1*) Added Specification C 1489 to 7.4.3 and Referenced Documents.

(*2*) Rewrote 6.1, 10.3.3.1, and A2.5.2 to clarify the intent of those paragraphs.

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Designation: C 843 – 99 (Reapproved 2006)

Standard Specification for Application of Gypsum Veneer Plaster[1]

This standard is issued under the fixed designation C 843; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

This standard has been approved for use by agencies of the Department of Defense.

1. Scope

1.1 This specification covers the minimum requirements for and methods of applying gypsum veneer plaster.

1.2 Where a specific degree of fire resistance is required for veneer plaster systems, applicable building code regulations shall be followed.

1.2.1 Details of construction for a specific assembly to achieve the required fire resistance shall be obtained from reports of fire-resistance tests, engineering evaluations, or listings from recognized fire testing laboratories.

1.3 Where a specific degree of sound control is required for veneer plaster assemblies and constructions, details of construction shall be in compliance with official reports of tests conducted in recognized sound testing laboratories in accordance with the applicable sound tests of Test Methods E 90, C 423, or E 492.

NOTE 1—To ensure desirable results, coordinate this specification with Specification C 844.

NOTE 2—General information regarding matters of a contractual nature concerning veneer plaster work is found in Appendix X1. Additional technical information related to veneer plastering is provided in Appendix X2.

1.4 The values stated in inch-pound units are to be regarded as the standard. The values given in parentheses are for information only.

1.5 The text of this specification references notes and footnotes which provide explanatory material. These notes and footnotes (excluding those in tables and figures) shall not be considered as requirements of the specification.

2. Referenced Documents

2.1 *ASTM Standards:* [2]

C 11 Terminology Relating to Gypsum and Related Building Materials and Systems

C 423 Test Method for Sound Absorption and Sound Absorption Coefficients by the Reverberation Room Method

C 587 Specification for Gypsum Veneer Plaster

C 588/C 588M Specification for Gypsum Base for Veneer Plasters[3]

C 631 Specification for Bonding Compounds for Interior Gypsum Plastering

C 844 Specification for Application of Gypsum Base to Receive Gypsum Veneer Plaster

C 1047 Specification for Accessories for Gypsum Wallboard and Gypsum Veneer Base

E 90 Test Method for Laboratory Measurement of Airborne Sound Transmission Loss of Building Partitions and Elements

E 492 Test Method for Laboratory Measurement of Impact Sound Transmission Through Floor-Ceiling Assemblies Using the Tapping Machine

3. Terminology

3.1 *Definitions:*

3.1.1 See Terminology C 11.

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *base coat*, *n*—veneer plaster trowel or machine applied as the first coat of a two-component system.

3.2.2 *finish coat*, *n*—veneer finish plaster trowel or machine applied as the second coat over the base coat plaster in a two-component system.

3.2.2.1 *smooth-trowel finish, n*—a finish resulting from steel troweling with a minimum of water after the plaster has become firm. A smooth finish free of trowel marks, blemishes, or other imperfections.

3.2.2.2 *texture finish, n*—a finish resulting from (*1*) trowel application followed by floating or texturing of the surface with any of a variety of tools using a minimum of water or (*2*) machine application, left as applied or followed by hand texturing.

3.2.3 *joint-reinforcing embedment*, *n*—the cementitious material used to embed the strip material that is compatible with the veneer plaster used.

[1] This specification is under the jurisdiction of ASTM Committee C11 on Gypsum and Related Building Materials and Systems and is the direct responsibility of Subcommittee C11.03 on Specifications for Application of Gypsum and Other Products in Assemblies.

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[2] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

[3] Withdrawn.

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3.2.4 *one-component system*, *n*—a veneer plaster system designed for application directly over approved bases in a single plaster mix applied in a single coat or double-back operation with the same material.

3.2.5 *reinforced joint*, *n*—a joint between gypsum base that is reinforced with strip material embedded in a cementitious material.

3.2.6 *reinforcing*, *n*—joint reinforcing tape or mesh (strip material) that is applied over flat joints and interior angles.

3.2.7 *two-component system*, *n*—a veneer plaster system involving two separate materials mixed and applied separately for base coat and finish coat.

3.2.8 *veneer plaster system*, *n*—gypsum veneer plaster applied to (*1*) a gypsum base in accordance with 10.1 or (*2*) properly prepared masonry or monolithic concrete surfaces, neither side of which is exposed to moisture. The plaster shall be applied with one or more components not exceeding ¼ in. (6.4 mm) in total thickness.

4. Delivery of Materials

4.1 All manufactured materials shall be delivered in the original packages, containers, or cartons bearing the brand name and manufacturer identification.

5. Protection of Materials

5.1 Plasters and other cementitious materials shall be kept dry until ready to be used; they shall be kept off the ground, under cover, and away from damp walls and surfaces.

6. Environmental Conditions

6.1 *Temperature*—When the ambient outside temperature at the building site is less than 55 °F (13 °C), maintain a temperature in the building of not less than 55 °F (13 °C) or not more than 80 °F (27 °C) for not less than 24 h prior to the application of veneer plaster and for one week after the veneer plaster has set or until the veneer plaster has dried. Distribute heat evenly in all work areas, and use deflection or protective screens to prevent concentrated or uneven heat or cold on the veneer plaster.

NOTE 3—The requirements in 6.1 will minimize the cracking of veneer plaster due to structural movements caused by thermal changes from temperature extremes; and dry-outs due to hot spots caused by concentrated heat.

6.2 *Ventilation*—Ventilation shall be provided to remove excess water given off through the drying process.

7. Materials

7.1 *Gypsum Base for Veneer Plasters* (hereinafter referred to as "gypsum base") Specification C 588/C 588M.

7.2 *Veneer Plasters*—Specification C 587.

7.3 *Reinforcing*—Noncorrosive strip providing the joint strength requirements of Specification C 587.

7.4 *Liquid Bonding Compounds*—Specification C 631 (see X2.3).

7.5 *Water*—Water shall be clean, fresh, and of potable water quality.

7.6 *Accessories*—Specification C 1047.

8. Surface Preparation

8.1 *Examination*—Carefully examine all surfaces, including but not limited to, unit masonry, monolithic concrete, gypsum bases of all types, and accessories to receive veneer plaster, before the veneer plaster is applied. Notify the proper authorities promptly of all unsatisfactory conditions. The examination shall determine whether the gypsum base has been exposed to excessive sunlight. Do not apply veneer plaster until after such unsatisfactory conditions are rectified to the satisfaction of the plastering contractor.

NOTE 4—The bond of alkaline veneer plaster to gypsum base may be impaired if the base is exposed to direct light or sunlight for extended periods.

8.1.1 Do not apply veneer plaster over any surfaces of unit masonry or concrete that have been coated with any bituminous compound or other waterproofing or damproofing or form release agent.

8.2 *Conditioning of Surfaces*:

8.2.1 Immediately before the plaster is applied, wet down the masonry surfaces on which suction shall be reduced. Visible water shall not remain on the surface.

8.2.2 Carefully examine accessories, such as corner beads, control joints, casing beads, etc., to ensure that they are straight, curved, plumb, level, square, or true to the required angles and have been applied in a manner to ensure full coverage of flanges before the plaster is applied.

8.3 *Monolithic Concrete Surfaces*—Clean monolithic concrete surfaces of all dust, loose particles, and other foreign matter. Completely remove all grease, oil, noncompatible curing compounds, and form releasing agents. Remove all ridges and protrusions greater that ⅛ in. (3.2 mm) and fill all depressions greater than ¼ in. (6.4 mm) level with portland cement mortar and allow to set and dry. Any further preparation shall be as recommended by the veneer plaster manufacturer.

8.4 *Gypsum Base Joint Reinforcement*—Reinforce all interior angles and flat joints prior to application of the veneer plaster over the base.

8.4.1 *Interior Angles*—Position and secure reinforcement with staples (on 12-in. (305-mm) centers, one side only), veneer plaster, or other cementitious material compatible with the veneer plaster or by using self-adhering strip reinforcement. When stapling, staple along the ceiling edge only for wall-to-ceiling angles and along one edge for wall-to-wall angles. When securing reinforcement with veneer plaster, reinforcement shall be thoroughly embedded so that embedment material is both under and covering reinforcement.

8.4.2 *Flat Joints*—Center reinforcement over the joint line of the gypsum base and secure with staples or veneer plaster if not using self-adhering reinforcement. Keep reinforcement tight and flat against the gypsum base, and when stapling, position the staples no farther than 24 in. (610 mm) apart, staggered along each edge. Embed reinforcement and continue application of the veneer plaster over the field of the base. (**Warning**—This method provides minimum reinforcement of the joints. To minimize incidence and severity of joint ridging and cracking, use one of the following methods (8.4.2.1, 8.4.2.2, or 8.4.2.3) in the absence of any specific method

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recommended by the veneer plaster manufacturer. Where paper tape and setting-type joint compounds are used, use 8.4.2.3.)

8.4.2.1 *Reinforcement over Set Veneer Plaster*—Tightly trowel veneer plaster over the joint line leaving the plaster feathered out to a width of about 6 in. (152 mm) flush with the face of the gypsum base. Allow the plaster to set; then secure reinforcement over the joint line as described in 8.4.2.

8.4.2.2 *Reinforcement Secured and Embedded with Veneer Plaster*—Apply reinforcement over the joint line as described in 8.4.2. Tightly trowel the plaster over the reinforcement along the joint line to provide thorough embedment of the reinforcement. Allow the joint embedment to set before proceeding with general plastering.

8.4.2.3 *Reinforcement Embedded (no staples)*—Tightly trowel the embedment material to a depth of about 1/32 in. (0.8 mm), working the trowel in both directions along the joint line. Center the reinforcement over the joint line. Firmly and evenly press the reinforcement into the soft embedment material using a little soft material on the trowel to bury it completely, and leave the embedment material feathered out to a width of about 6 in. (152 mm) flush with the face of the gypsum base. Allow the embedment material to set before proceeding with general plastering.

9. Mixing

9.1 Do not use frozen, caked, or lumpy material. Do not retemper or use material that has partially set. Mix each batch separately. Clean mixers thoroughly after each batch so as not to accelerate the following batches. This can be done by spray hosing the mixer paddle and containers immediately after each batch. Water ratios and other techniques used for mixing shall conform to the manufacturer's recommendation for specific veneer plaster products. In the absence of explicit directions, follow the recommendations in X2.1.

9.2 *Setting Time*—Setting times are carefully controlled by the manufacturer. Do not make adjustments to the setting time on the job. If problems with setting develop under unusual job conditions, consult the manufacturer of the veneer plaster for recommendations.

9.2.1 Do not use gauging, molding, or casting plasters, lime, gypsum, Keene's cement, portland cement, etc. to adjust the veneer plaster setting time.

9.3 Occasionally, special textures are desired that require additional sand. Approval of the veneer plaster manufacturer shall be obtained prior to any such additions.

10. Application

10.1 *General*—Veneer plasters have widely differing working properties, physical characteristics, and limitations regarding their compatibility with one another and with various bases. Follow the particular methods, techniques, limitations, and procedures set forth by individual manufacturers for their product. In the absence of manufacturers' directions, follow the recommendations in X2.2.

10.2 *Plaster Thickness*—Measure the plaster thickness from the face of the base to which it is applied, exclusive of joint treatment. The minimum thickness shall be as recommended by the manufacturer of the plaster used but in no case less than shown as follows:

Base coats (trowel applied)	1/16 in. (1.6 mm) min
Base coats (spray applied)	1/16 in. (1.6 mm) min
Finishes (two-component systems)	1/32 in. (0.8 mm) to 1/16 in. (1.6 mm) min
One-component systems	1/16 in. (1.6 mm) min

10.3 Barriers shall be provided to prevent the free circulation of hot, dry winds over the face of freshly applied plaster.

11. Electric Radiant Heat Cable

11.1 Veneer plaster shall be applied to electric heat cable systems in accordance with the veneer plaster manufacturer's directions. In the absence of manufacturer's directions follow the recommendations in X2.5.

11.2 Veneer plaster shall not be applied over heating systems in which the wire temperature will, at any time, be in excess of 125 °F (52 °C).

12. Keywords

12.1 electric heat cable; gypsum; plaster; veneer plaster

APPENDIXES

(Nonmandatory Information)

X1. GENERAL INFORMATION

X1.1 Construct and maintain scaffolding in strict conformity with applicable laws and ordinances so as not to interfere with or obstruct the work of others.

X1.2 Coordinate the work with the work of other trades.

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X2. TECHNICAL INFORMATION

X2.1 *Mixing:*

X2.1.1 *Equipment*—A paddle-type agitator fitted to a ½-hp (373-W) heavy-duty, electric drill, rated from 900 to 1000 rpm (no load), and a clean drum of convenient size are recommended for rapid, efficient mixing of veneer plasters.

X2.1.2 *Procedure:*

X2.1.2.1 Put all but 1 or 2 qt (0.94 or 1.89 L) of the proper amount of water in the mixer for each bag of veneer plaster to be mixed.

X2.1.2.2 Add the veneer plaster to the water and immediately mix until uniformly wetted. Veneer plaster may be added while the agitator is turning.

X2.1.2.3 Continue mixing, adding water to obtain the desired lump-free mortar consistency.

X2.1.2.4 When mixing plaster for spray application, mix to a consistency so that 75 to 90 % of the batched mortar will pass a No. 8 (2.36-mm) sieve without shaking. Make sure the plaster is specifically designed for spray application to avoid quick set problems.

X2.1.2.5 Do not overmix. Three to four minutes is usually sufficient to attain fluidity.

X2.2 *Application:*

X2.2.1 *One-Component Plasters*—Apply the plaster with sufficient material and pressure to provide a good bond on the gypsum bases or other bases as approved by the veneer plaster manufacturer. Double back immediately with the same mixer batch of plaster to the desired thickness. Straighten to a true surface without application of water (water will cause blistering when applied at this time). Allow the material to "take-up" and texture with a float or sponge as desired. If a smooth finish is required, allow the plaster to become firm (so that water can be used without blistering) and trowel, using a minimum of water, to achieve a smooth finish, free of catfaces, trowel marks, blemishes, or other imperfections. Complete finishing before the veneer plaster sets.

X2.2.2 *Two-Component Plasters*—The finish component coat may be applied over set but still "green," partially dry, or dry base coat. Avoid application of a second component over a base coat that is damp on joints but dry in the field. It may result in photographing of the joints.

X2.2.3 *Base Coat-Hand Application*—Apply the base coat with sufficient material and pressure to provide a good bond on the gypsum bases or other bases as approved by the veneer plaster manufacturer and straighten to a true surface without application of water. Leave the surface sufficiently rough to provide a mechanical key for the finish coat.

X2.2.4 *Base Coat-Machine Application*—First spray flat joints, beads, and interior angles, and work the material with hand tools to cover the reinforcement, fill the beads, straighten the angles, and feather out the plaster over the joints. Proceed with full areas by spraying with a broad sweeping motion, holding the nozzle close enough to the surface to avoid excessive overspray and buildup in the angles. First apply a light coating while moving in one direction; then immediately double back over the same area, sweeping the nozzle in the opposite direction to obtain a level coat that requires no further working, and that is suitable to receive the finish component coat on setting.

X2.2.5 *Smooth-Trowel Finish*—Apply the plaster by troweling with firm pressure, then doubling back and filling out to a true, even surface. After the plaster has become firm, trowel it well with a minimum amount of water to a smooth finish, free of catfaces, blisters, trowel marks, blemishes, or other imperfections.

X2.2.6 *Texture Finishes*—Apply the plaster over the base coat by troweling thoroughly, building up to an even surface, and then floating with a variety of tools using a minimum of water. It may also be sprayed (depending on the type of texture desired) to a true, even surface free of slick spots or other blemishes.

X2.3 *Bonding Compounds*—Bonding compounds meeting Specification C 631 may be used to bond plaster to portland cement concrete and other sound surfaces. Such bonding agents may be used at the discretion of the specifier who may require performance records from the bonding agent manufacturer. Apply the bonding agent according to the bonding agent manufacturer's directions.

X2.4 *Heating and Ventilation*—A portion of the water used in mixing veneer plaster is necessary for the chemical reaction that rehydrates and hardens the plaster. The excess amount required for mixing and application must be removed from the plaster after set has taken place. Minimum circulation of air is desirable to prevent dry outs.

X2.4.1 Adequate ventilation of attics or similar unheated spaces above gypsum plaster systems is essential to the performance of these systems and shall be designed and provided by others per ASHRAE Fundamentals Handbook or applicable building code.

X2.5 *Electric Radiant Heat Cable*—Apply veneer plaster over electric radiant heat cable according to this specification except as follows:

X2.5.1 Treat flat joints according to 8.4.2 before the electric heating cable is installed,

X2.5.2 Inspect and test the heating system before applying the veneer plaster,

X2.5.3 Apply veneer plaster in a tight scratch coat flush with the cable, working the trowel parallel to the heating cable. Immediately double back before the scratch has set and build up a thickness of veneer plaster over the cable to a minimum of 1/16 in. (1.6 mm) or a maximum of 1/8 in. (3.2 mm),

X2.5.4 Do not turn the heating system on until the veneer plaster has dried completely. Deactivate the heating system and provide supplemental heat as required while paint is being applied. Activating the electric heating cable while the veneer plaster is wet or while paint is being applied may produce photographing of the cables. If the room temperature is more

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than 15 °F (8 °C) below the desired temperature after decoration is complete, turn up the heat in 5 °F (3 °C) increments per 24 h period.

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Designation: C 844 – 04

Standard Specification for Application of Gypsum Base to Receive Gypsum Veneer Plaster[1]

This standard is issued under the fixed designation C 844; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

This standard has been approved for use by agencies of the Department of Defense.

1. Scope*

1.1 This specification covers the minimum requirements for, and methods of, application of gypsum veneer base for gypsum veneer plasters.

1.2 Gypsum veneer base shall not be used as a base for direct adhesive application of ceramic, metal, or plastic tile in areas exposed to abnormal moisture or humidity or temperature.

1.3 Details of construction for a specific assembly to achieve the required fire resistance shall be obtained from reports of fire-resistance tests, engineering evaluations, or listings from recognized fire testing laboratories.

1.4 Where a specific degree of sound control is required for veneer plaster assemblies and constructions, details of construction shall be in accordance with official reports of tests conducted in recognized sound testing laboratories in accordance with the applicable sound tests, Test Method C 423, Test Method E 90, or Test Method E 492.

1.5 Where this specification is more stringent (size or thickness of framing; spacing of fasteners) than the fire-rated construction, this specification shall govern; otherwise, the construction described in the fire test report shall govern.

1.6 Unheated spaces above gypsum veneer base ceilings shall be properly ventilated (see Appendix X3).

1.7 The values stated in inch-pound units are to be regarded as the standard. The SI (metric) values given in parentheses are approximate and are provided for information purposes only.

1.8 The text of this standard references notes and footnotes which provide explanatory material. These notes and footnotes (excluding those in tables and figures) shall not be considered as requirements of the standard.

2. Referenced Documents

2.1 *ASTM Standards:* [2]

C 11 Terminology Relating to Gypsum and Related Building Materials and Systems

C 423 Test Method for Sound Absorption and Sound Absorption Coefficients by the Reverberation Room Method

C 514 Specification for Nails for the Application of Gypsum Board

C 587 Specification for Gypsum Veneer Plaster

C 588 Specification for Gypsum Base for Veneer Plasters

C 754 Specification for Installation of Steel Framing Members to Receive Screw-Attached Gypsum Panel Products

C 954 Specification for Steel Drill Screws for the Application of Gypsum Panel Products or Metal Plaster Bases to Steel Studs from 0.033 in. (0.84 mm) to 0.012 in. (2.84 mm) in Thickness

C 955 Specification for Load-Bearing (Transverse and Axial) Steel Studs, Runners (Tracks), and Bracing or Bridging for Screw Application of Gypsum Panel Products and Metal Plaster Bases

C 1002 Specification for Steel Self-Piercing Tapping Screws for the Application of Gypsum Panel Products or Metal Plaster Bases to Wood Studs or Steel Studs

C 1007 Specification for Installation of Load Bearing Transverse and Axial

C 1047 Specification for Installation of Load Bearing (Transverse and Axial) Steel Studs and Related Accessories

C 1546 Guide for Installation of Gypsum Products in Concealed Radiant Ceiling Heating Systems

E 90 Test Method for Laboratory Measurement of Airborne Sound Transmission Loss of Building Partitions and Elements

[1] This specification is under the jurisdiction of ASTM Committee C11 on Gypsum and Related Building Material and Systems, and is the direct responsibility of Subcommittee C11.03 on Specifications for Application of Gypsum and Other Products in Assemblies.

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[2] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

***A Summary of Changes section appears at the end of this standard.**

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E 492 Test Method for Laboratory Measurement of Impact Sound Transmission Through Floor-Ceiling Assemblies Using the Tapping Machine

2.2 *American Softwood Lumber Standard:*

PS–20 American Softwood Lumber Standard[3]

3. Terminology

3.1 *Definitions*—Definitions shall be in accordance with Terminology C 11.

3.2 *Definitions of Terms Specific to this Standard:*

3.2.1 *base ply*—first ply of gypsum base in multiple ply application.

3.2.2 *face ply*—outer or visible layer of gypsum base in multiple ply application.

3.2.3 *fastener, n*—nails, screws, or staples used for the application of the gypsum base or backing board.

3.2.4 *framing member, n*—that portion of the framing, furring, blocking, etc., to which the gypsum base is attached. Unless otherwise specified, the surface to which abutting edges or ends are attached shall be not less than 1½ in. (38 mm) wide for wood members, not less than 1¼ in. (32 mm) wide for steel members, and not less than 6 in. (152 mm) wide for gypsum studs. For internal corners or angles, the bearing surface shall be not less than ¾ in. (19 mm).

3.2.5 *parallel application, n*—gypsum base application where the gypsum base edge is applied parallel to the framing members.

3.2.6 *perpendicular application, n*—gypsum base application where the gypsum base edge is applied at right angles to the framing members.

4. Materials

4.1 Materials shall conform to the respective specifications and standards and to the requirements specified herein.

4.2 *Gypsum Base for Veneer Plasters* (hereinafter referred to as "gypsum base")—Specification C 588.

4.3 *Gypsum Backing Board or Coreboard*—Specification C 442.

4.4 *Special Fire-Retardant Gypsum Base*—Specification C 588, Type X.

4.5 *Foil-Backed Gypsum Base*—Specification C 588.

4.6 *Gypsum Veneer Plaster*—Specification C 587.

4.7 *Nails*—Specification C 514.

4.8 *Screws*:

4.8.1 *Non-load bearing steel*—Specification C 1002.

4.8.2 *Load bearing steel*—Specification C 954.

4.9 *Staples*—No. 16 USS gage 0.063 in. (1.6-mm) flattened galvanized wire with 7⁄16-in. (11.1-mm) wide-crown minimum outside measure and divergent points. Staples shall be used only for the base ply of two-ply application over wood framing.

4.10 *Steel Framing, Non-load bearing*—Specification C 645 for the specified design criteria.

4.11 *Accessories*—Specification C 1047.

4.12 *Adhesive*:

4.12.1 For application of gypsum base to steel framing, the adhesive shall be as recommended by the manufacturer of the gypsum base.

4.13 *Steel Framing Load Bearing*—Specification C 955.

4.14 *Wood Framing*—American Lumber Softwood Standard PS–20.

5. Delivery of Materials

5.1 All materials shall be delivered in the original packages, containers, or bundles bearing the brand name and manufacturer (or supplier) identification.

6. Shipping, Handling and Storage

6.1 Gypsum board shall be shipped so as to be kept dry.

6.2 Gypsum board shall be stored so as to be kept dry, preferably inside a building, under a roof. Gypsum board shall be neatly stacked flat with care taken to prevent sagging or damage to edges, ends, and surfaces.

6.3 Where necessary to store gypsum board outside, it shall be stacked flat, off the ground, supported on a level platform and fully protected from weather and direct sunlight exposure.

6.4 Prior to application, the building exterior shall be so enclosed to protect the gypsum base from exposure to weather and direct sunlight.

NOTE 1—The bond of alkaline veneer plaster to gypsum base will be impaired if the base is exposed to direct light or sunlight for extended periods.

7. Environmental Conditions

7.1 *Application of Gypsum Base and Adhesives*—A room temperature of not less than 40 °F (4 °C) shall be maintained during application of gypsum base except when adhesive is used for the attachment of gypsum base. For the bonding of adhesive, a room temperature of not less than 50 °F (10 °C) shall be maintained for 48 h prior to application and continuously thereafter until adhesive is completely dry. When a temporary heat source is used, the temperature shall not exceed 95 °F (35 °C) in any room or area. Adequate ventilation shall be maintained in the working area during the application and adhesive curing process.

8. Application of Gypsum Base

8.1 *General Requirements*:

8.1.1 Installation of steel framing shall be in accordance with applicable Specifications C 754 or C 1007 except where superseded by requirements of Table 1.

NOTE 2—For general wood framing requirements, see Appendix X2.

8.1.2 *Method of Cutting*—The gypsum base shall be cut by scoring and breaking or by sawing, working from the face side. When cutting by scoring, the face shall be cut with a knife or other suitable tool and the gypsum base snapped back away from the cut face. The back shall be broken by snapping the gypsum base in the reverse direction, or by cutting with a knife or other suitable tool.

8.1.3 All cut edges and ends of the gypsum base shall be smoothed to obtain neat jointing. Cut-outs for pipes, fixtures, or other small openings on the face and back of the base shall be scribed in outline before removing or cut out with a saw or

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TABLE 1 Maximum Framing Spacing

Single-ply Base (Thickness), in. (mm)		Application to Framing	Maximum On Center Spacing of Framing, in. (mm)
Ceilings:			
	½ (12.7)	parallel	16 (406)
	½ (12.7)[A]	perpendicular	24 (610)
	⅝ (15.9)[B]	perpendicular	24 (610)
Sidewalls:			
	⅜ (9.5)[C]	perpendicular	16 (406)
	½ (12.7)	parallel	16 (406)
	½ (12.7)[A]	perpendicular	24 (610)
	⅝ (15.9)[B]	parallel or perpendicular	24 (610)

[A] ½-in. (12.7-mm) gypsum base applied perpendicular on 24-in. (610-mm) on centers framing shall be considered to be minimum construction.
[B] For ⅝-in. (15.9-mm) base, perpendicular on ceilings and either perpendicular or parallel on sidewalls at 24-in. (610-mm) on centers spacing, only two-component veneer plaster or special joint reinforcement, as recommended by the gypsum veneer plaster manufacturer, shall be used.
[C] ⅜-in. (9.5-mm) gypsum base shall be used over wood framing with two-component veneer plaster systems only.

other suitable tool. The gypsum base shall be scribed where it meets projecting surfaces. Base shall be brought lightly into contact with adjacent panels but not forced into place. Abutting ends and edges shall fit neatly.

8.1.4 When gypsum base is to be applied to both ceiling and walls, the base shall be applied to the ceiling and then to the walls.

8.2 *Fastening, Mechanical*:

8.2.1 The gypsum base shall be held in firm contact with the underlying support while driving any fastener.

8.2.2 Fastener application shall proceed from the center of the field of the gypsum base to the ends and edges or shall begin along one edge and proceed toward the other edge.

8.2.3 Except where required for fire rating, structural performance, or other special considerations, fastening to top or bottom plates shall not be required.

8.2.4 Fasteners shall be spaced not less than ⅜ in. (9.5 mm) from the edges and ends of the gypsum base. Fasteners used at edges or at base ends in horizontal application shall not be more than 1 in. from edges or ends.

8.2.5 Nails and screws shall be driven to a point flush with the gypsum base surface without breaking the surface paper or damaging the surrounding gypsum core and without stripping the framing member around the screws.

8.2.6 Staples shall be driven so that both legs penetrate the support member and the crown bears tightly against the backing board, but does not cut into the face paper. The staple shall be driven with the crown parallel to framing members. Staples shall be used only for the first ply in two-ply gypsum base systems.

8.2.7 Penetration of mechanical fasteners into supporting framing members shall be not less than:

	Nails	Screws	Staples
Wood:	⅞ in. (22 mm)	⅝ in. (15 mm)	⅝ in. (15 mm), each leg
Steel:	...	⅜ in. (9 mm)	...

8.3 *Control Joints*

8.3.1 Control joints shall be installed in ceilings more than 2500 ft^2 (232 m^2) in area that are constructed with perimeter relief. The distance between control joints shall be not more than 50 ft (15 m) in either direction.

8.3.2 Ceilings of more than 900 ft^2 (85 m^2) in area constructed without perimeter relief shall have control joints installed with spacing not to exceed 30 ft (9 m) in either direction.

8.3.3 Control joints shall be installed where ceiling framing or furring changes direction or where construction joints occur in the base building construction. In partitions, walls, or wall furring, the distance between control joints shall be not more than 30 ft (9 m).

8.3.4 A ceiling height door frame, installed in accordance with the spacing requirements set forth in 8.3, functions as a control joint.

9. Application of Single-Ply Gypsum Base

9.1 The maximum spacing of framing members for single-ply gypsum base construction shall be not more than those shown in Table 1.

9.2 In single-ply installation, all ends and edges of gypsum base shall occur over framing members or other solid backing except where treated joints occur at right angles to framing or furring members.

9.3 Joints on opposite sides of a partition shall be arranged to occur on different framing members.

9.4 *Fasteners (Single Ply Application)*:

9.4.1 *Nail Spacing*—Space nails a maximum of 7 in. (178 mm) on centers on the ceiling and a maximum of 8 in. (203 mm) on centers on the walls.

9.4.2 *Double Nailing*—Nails shall be spaced as shown in Fig. 1 and applied as follows:

9.4.2.1 Starting at the center of the base, nails shown as solid dots shall be applied by row starting with row 1, then rows 2 and 2A, 3 and 3A, 4 and 4A. Base shall be kept tight against the framing throughout the procedure.

9.4.2.2 Using the procedure in 9.4.2.1, second nails shown by circles shall be applied.

9.4.2.3 As an alternative procedure, second nails shall be permitted to be applied immediately after all first nails in each individual row have been driven in accordance with 9.4.2.1.

9.4.2.4 Single nails shall be used on the perimeter of the base.

NOTE 3—It may be necessary to reset the first nails in each row after the second nails have been set.

9.4.3 Nails for single-ply application over wood members shall be as follows:

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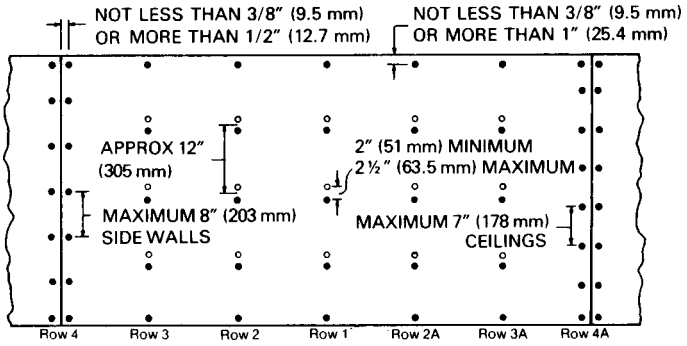

FIG. 1 Double Nailing

Gypsum Base Thickness, in. (mm)	Nails, in. (mm)
⅜ (9.5)	1¼ (32)
½ (12.7)	1⅜ (35)
⅝ (15.9)	1½ (38)

9.4.4 Where a specific degree of fire resistance is required for gypsum board assemblies and constructions, nails of same or larger length, shank diameter, and head bearing area, as those described in the applicable fire test report shall be used.

9.4.5 *Screw Spacing*—Screws shall be spaced not more than 12 in. (305 mm) on center along framing members for wall or ceiling application.

9.5 *Floating Interior Angles*—The floating angle method of application is applicable where single nailing, double nailing, or screw attachment is used, and helps to minimize the possibility of cracking in areas adjacent to a wall and ceiling intersection. When using this method the base shall be applied to ceilings first.

9.5.1 *Ceilings*—Fasteners shall be spaced in accordance with 9.4 except that for single nailing the nail adjacent to the ceiling/wall intersection shall be located 7 in. (178 mm) away from the wall, or 11 to 12 in. (279 mm to 305 mm) away for double nailing or screw application.

9.5.2 *Walls*—The gypsum base shall be fastened to walls to provide a firm support for the floated edges of the ceiling gypsum base. The top attachment shall be located into each stud 8 in. (203 mm) down from the ceiling intersection for single nailing (Fig. 2), and 11 to 12 in. (279 to 305 mm) for double nailing (Fig. 1) or screw application (see Fig. 3 and Fig. 4). At sidewall vertical angles (Fig. 5), the overlapping base shall be applied so as to bring the back of the underlying board into firm contact with the face of the framing member behind it.

10. Adhesive-Mechanical Fastener Application

10.1 Except as modified herein, application shall be in accordance with Section 9.

10.2 Surfaces of gypsum base and framing to receive adhesive shall be free of any foreign matter that impairs the bond.

10.3 A bead of adhesive ⅜ in. (9.5 mm) in diameter shall be applied to the face of all wood framing members, except plates, that support the gypsum base. As pressure is applied to the base the adhesive shall spread to an average width of ¾ in. (19 mm) approximately ⅛ in. (3.2 mm) thick. Application patterns shall be shown as in Fig. 6.

10.3.1 Where two adjacent pieces of gypsum base abut (ends or edges) on a framing member, two parallel beads of adhesive shall be applied to the framing member. Application patterns shall be as shown in Fig. 6.

10.4 Adhesive shall be applied to an area no greater than will be covered with gypsum base within the "open time" of the adhesive.

10.5 *Fastener Spacing:*

10.5.1 Where the properties of the adhesive ensure bridging between the gypsum base and the wood framing, no fastening shall be required in the field of the base for walls. In such cases, perimeter fastening, 16 in. (406 mm) on center, shall be required.

10.5.2 Where the properties of the adhesive achieve no positive bridging between the board and the wood framing, either temporary field nailing or temporary bracing shall be required to ensure contact between the base, the adhesive, and the stud face until the adhesive develops adequate bond strength. Fasteners shall be spaced in accordance with Table 2.

11. Application over Existing Surfaces

11.1 Gypsum base installed over uneven or broken surfaces, on the interior of all exterior masonry or concrete walls or columns, or over reasonably smooth, solid interior surfaces such as concrete or unit masonry shall be applied over furring strips or furring channels in accordance with Section 9 of this specification.

11.2 Over reasonably smooth, sound, existing surfaces, such as gypsum wallboard or plaster in good condition, the gypsum base shall be applied by using fasteners of sufficient length to penetrate into the underlying framing members in accordance with 8.2.7. Fasteners shall be spaced in accordance with Sections 8 and 9 of this specification.

11.3 Fastener and adhesive attachment of gypsum base to existing surfaces shall be in accordance with Section 10 of this specification.

12. Foil-Backed Gypsum Base

12.1 The application of foil-backed gypsum base shall conform to all of the specifications for the application of gypsum base except that it shall not be used as follows:

12.1.1 The face ply on a two-ply laminating system.

12.1.2 Laminated directly to masonry.

12.1.3 Directly over plaster or other existing surfaces.

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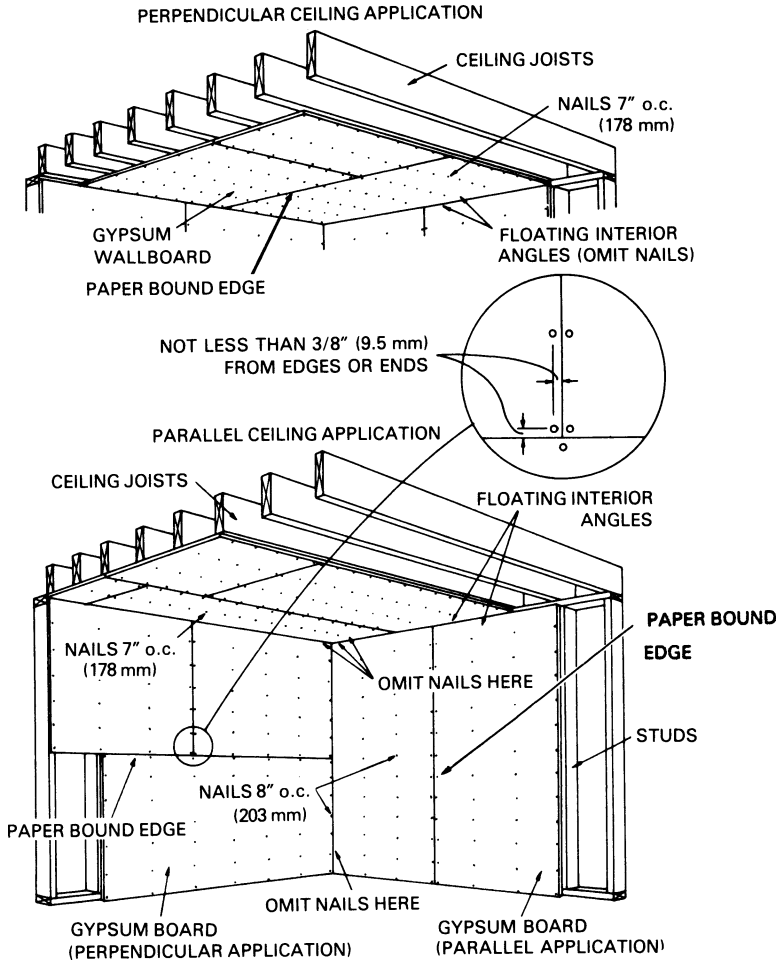

FIG. 2 Single Nailing

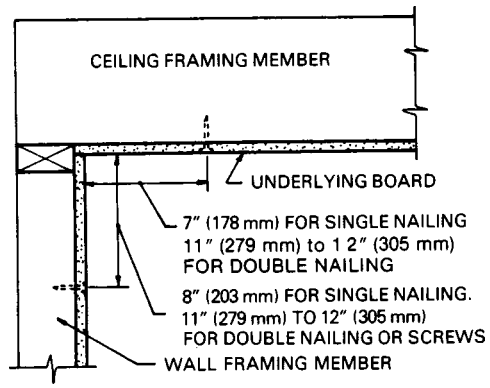

FIG. 3 Vertical Section, Ceiling Framing Perpendicular To Wall

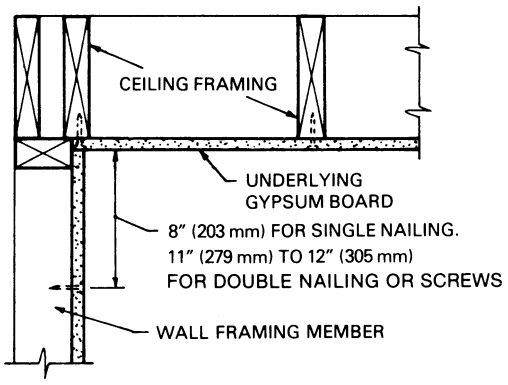

FIG. 4 Vertical Section, Ceiling Framing Parallel to Wall

12.2 The reflective surface of the foil-backed gypsum base shall be placed against the face of the framing members.

13. Application of Two-Ply Gypsum Base to Framing Members

NOTE 4—The base ply in two-ply construction may be gypsum board other than gypsum veneer base (see Section 4).

13.1 Spacing of framing members and the application direction for both plies of two-ply gypsum base construction with no adhesive between plies shall comply with Table 1.

13.2 Spacing of framing members for two-ply gypsum base construction with adhesive between plies shall comply with Table 3.

13.3 The first ply of gypsum base shall be applied using nails, screws, or staples, spaced in accordance with Table 4.

13.4 Where no adhesive is used between plies, the two plies of gypsum base shall be applied either parallel or perpendicular to each other. The face ply shall be applied with the number of nails or screws required for normal single-ply application. Face ply joints that are parallel to framing shall fall over framing

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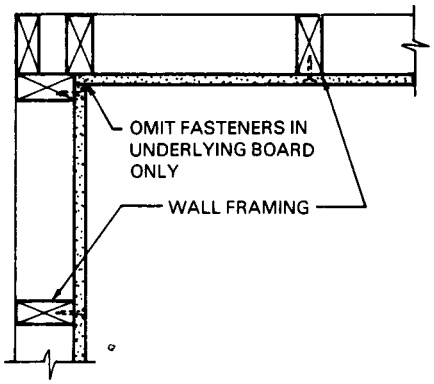

FIG. 5 Horizontal Section Through Interior Vertical Angle

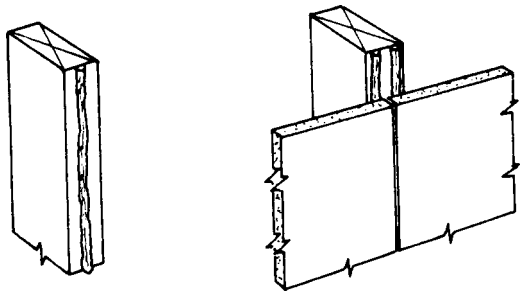

FIG. 6 Adhesive Application Patterns

members and be offset from the base ply joints when two plies of gypsum base are installed parallel to each other.

13.5 Where a laminating adhesive is used between plies, joints in the face ply shall not be required to occur over framing members. Parallel joints of the two plies shall be staggered (offset) at least 8 in. (203 mm).

13.6 Where gypsum base is adhesively installed, the face ply shall be held firmly in place with temporary fasteners or shoring (supports, props, headers, etc.) in sufficient quantity to ensure pressure for bonding. When sufficient bond has developed, supports shall be removed and temporary fasteners removed or driven flush with the surface.

14. Solid Gypsum Base Partitions

14.1 *Face Ply*—shall be ½ in. (12.7 mm), ⅝ in. (15.9 mm), or multiple laminations of gypsum base of 4-ft (1200-mm) width.

14.2 *Core*—shall be 1-in. thick gypsum panel products, either single or multiple layer in 2-ft (610 mm) or 4-ft (1220 mm) width.

14.3 *Runners*—shall be metal not less than 0.0179 in. (0.046 mm) in thickness or construction grade wood.

14.4 Floor and ceiling runners shall be not less than 24 in. (610 mm) on center. Vertical runners shall be installed at required locations, such as exterior walls, exterior corners, and door frames. Partitions shall be secured at the floor and ceiling in accordance with the gypsum base manufacturer's details or as otherwise required.

14.5 Pressure shall be applied to gypsum base laminated to the backing board to ensure a secure, firm bond. Joints between the gypsum base and the backing board shall be staggered. Fasteners shall be used to ensure a continuous bond between the gypsum base and the backing board.

14.6 Veneer plaster shall not be applied until the adhesive is fully set and the gypsum base is firmly bonded.

15. Adhesive Application of Gypsum Base to Interior Masonry or Concrete Walls

15.1 Direct adhesive application shall be used only on interior masonry or concrete walls above grade, or the inside of exterior masonry cavity walls with a cavity not less than 1-in. (25.4-mm) in width between the inside and outside masonry for the full height of the above grade surface to receive gypsum base.

15.2 Foil-backed gypsum base shall not be used for direct adhesive application.

15.3 All surfaces to be adhered shall be free of any foreign matter that impairs the bond. Projections or elevations in the masonry shall be removed by chipping or wire brushing. Large hollows or depressions shall be face-plastered with portland cement and given time to dry.

15.4 For application to monolithic concrete, porous brick, or concrete block, adhesive shall be applied to the back of the gypsum base or on the wall in continuous parallel beads spaced not more than 12 in. (305 mm) on center or daubs spaced not more than 12 in. on center each way.

15.4.1 Beads shall be not less than ⅜ in. (9.5 mm) in diameter to provide a continuous bond between the gypsum base and the wall surface.

15.4.2 Daubs shall be 2 to 3 in. (51 mm to 76 mm) in diameter. (**Warning**—Be sure that the adhesive will bond to monolithic concrete. Form release compounds may cause bond failure.)

15.5 *Gypsum Base Installation*—Gypsum base shall be positioned to provide a tight fit at abutting edges. The base shall not be slid into place. Moderate pressure shall be used to develop a full adhesive bond.

15.5.1 Veneer plaster shall not be applied until the adhesive is fully set and the gypsum base is firmly bonded.

15.6 *Gypsum Base Application over Rigid Plastic Foam*—Gypsum base is capable of being applied over rigid plastic foam insulation panels that have been applied to masonry or concrete walls.

15.6.1 Foam insulation shall be applied to the masonry or concrete in accordance with the foam manufacturer's specifications.

15.6.2 Furring strips or special metal furring members shall be attached using mechanical means to the masonry or concrete wall surface. This shall be done either before or after application of insulation, depending on the system used.

15.6.2.1 Furring members shall be installed in accordance with Table 1 of this specification and at the floor-wall angle, wall-ceiling angle (or at the termination of the gypsum base above suspended ceilings), around door, window, and other openings, and where required for cabinet or fixture attachment.

15.6.3 Gypsum base shall be applied to the furring as described in Section 9 of this specification. Mechanical fasteners shall be of such length that they shall not penetrate completely to the masonry or concrete.

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TABLE 2 Fastener Spacing with Adhesive or Mastic Application and Supplemental Fastening, in. (mm) On Center

Framing Member Spacing	Ceilings		Partitions Load Bearing		Partitions Nonload-Bearing	
	Nail	Screw	Nail	Screw	Nail	Screw
16 (406)	16 (406)	16 (406)	16 (406)	24 (610)	24 (610)	24 (610)
24 (610)	12 (305)	16 (406)	12 (305)	16 (406)	16 (406)	24 (610)

TABLE 3 Maximum Framing Spacing with Adhesive Between Plies

Gypsum Base Thickness, in. (mm)		Application Direction		Maximum On Center Spacing of Framing, in. (mm)
Ceilings				
Base	Face	Base	Face	
⅜ (9.5)	½ (12.7)	perpendicular	perpendicular or parallel	16 (406)
½ (12.7)	½ (12.7)	parallel	perpendicular or parallel	16 (406)
		perpendicular	perpendicular or parallel	24 (610)
⅝ (15.9)	½ (12.7)	perpendicular or parallel	perpendicular or parallel	24 (610)
⅝ (15.9)	⅝ (15.9)	perpendicular	perpendicular or parallel	24 (610)
Sidewalls				
⅜ (9.5)	½ (12.7)	perpendicular or parallel	perpendicular or parallel	16 (406)
½ (12.7)	½ (12.7)	perpendicular or parallel	perpendicular or parallel	24 (610)
⅝ (15.9)	½ or ⅝ (12.7 or 15.9)	perpendicular or parallel	perpendicular or parallel	24 (610)

TABLE 4 Attachment Spacing for Base Ply over Wood or Steel Framing

Fastener	Nails	Screws	Staples
Framing	wood	wood or metal	wood
No adhesive between plies	24 in. (610 mm) on centers	24 in. (610 mm) on centers	16 in. (406 mm) on centers
Adhesive between plies	Section 7.2.1	Section 7.2.2	7 in. (178 mm)

16. Gypsum Base Application over Steel Framing and Furring

16.1 *Screw Application*—shall be as specified in Section 9 of this specification.

16.2 *Framing Spacing*—Spacing of steel framing and furring for screw application shall be in accordance with Table 1 for single-ply gypsum base and as specified in Table 3 for two-ply gypsum base.

16.3 *Screw Spacing*:

16.3.1 Screw spacing for single-ply gypsum base and face ply of two-ply gypsum base with no adhesive shall be as specified in 9.4.5 of this specification.

16.3.2 Screw spacing for parallel applied first-ply of two-ply gypsum base over steel framing on side walls with no adhesive between the plies shall be 12 in. (305 mm) on center along the edges of the gypsum base and at third points into each stud or furring channel in the field of the gypsum base.

16.3.3 Screw spacing for a perpendicular applied first-ply of two-ply gypsum base over steel framing on side walls with no adhesive between the plies shall be one screw at each edge at each stud or furring channel intersection and one screw midway between edges at each stud or furring channel.

16.3.4 Screw spacing for perpendicular or parallel applied first-ply of two-ply gypsum base over steel framing with adhesive between plies shall be as specified for single-ply gypsum base in 9.4.5 of this specification.

16.3.5 Screw spacing for the first ply of two-ply gypsum base over steel framing with adhesive between plies on ceilings shall be the same as specified for the face-ply of two-ply gypsum base in 13.4 of this specification. Only a sufficient number of screws to hold the gypsum base in place until the adhesive develops a bond shall be used.

17. Application to Arches

17.1 Gypsum base applied to the soffit of arches (see Table 5) shall be carefully bent into place. If necessary, the base shall first be either dampened or scored 1 in. (25 mm) on center on the back side. In the latter case, after the core has been broken at each cut, the gypsum base shall be applied to the framing member and fastened in place. If the base is dampened, it shall be dry before plastering.

TABLE 5 Bending Radii for Application to Arches

Gypsum Base Thickness, in. (mm)	Bent Lengthwise, ft (m)	Bent Widthwise, ft (m)
½ (12.7)	10 (3.05)	–
⅜ (9.5)	7½ (2.29)	25 (7.62)

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17.2 To apply the base, a stop shall be placed at one end of the curve and the base shall be gently and gradually pushed on the other end, forcing the center against the framing until the curve is complete.

NOTE 5—By moistening the face and back paper thoroughly and allowing the water to soak well into the core, the base may be bent to still shorter radii. When it dries thoroughly, the base will regain its original hardness.

18. Keywords

18.1 electric heat cable; gypsum; gypsum base; veneer plastic

APPENDIXES

(Nonmandatory Information)

These Appendixes provide general information and also suggestions for inclusions to be made elsewhere by the specifier, and are not a part of this specification.

X1. GENERAL INFORMATION

X1.1 Scaffolding shall be constructed and maintained in strict conformity with applicable laws and ordinances and shall not interfere with or obstruct the work of others. The work shall be properly coordinated with the work of other trades.

X2. WOOD FRAMING REQUIREMENTS

X2.1 Requirements covering framing, furring, spacing, etc., are essential to provide a proper surface to receive the gypsum base. The following requirements should be included in the project specifications for framing and furring:

X2.1.1 All framing members to which gypsum base will be fastened shall be straight and true and spaced not more than the maximum spacings shown in Table 1. Wood framing, bridging, and furring members shall be the proper grade for the intended use and members 2 by 4 in. nominal size or larger shall bear the grade mark of a recognized inspection agency. Framing, bridging, and furring shall be adequate to carry the design or code loading, or both. In place of an applicable local code, the framing shall meet the minimum requirements of FHA for single or multifamily dwellings. The deflection of members supporting gypsum base shall be not more than L/360 of the span at full design load. Headers shall be provided as necessary for the support of fixtures.

X2.1.2 When the gypsum base is nailed to wood cross furring on ceilings, these members shall have a cross section of not less than 1½ by 1½ in. (38 by 38 mm) and shall be spaced in accordance with the requirements of Table 1. Where screw application is used, the furring member shall have a size of not less than ¾ by 2½ in. (19 by 64 mm) actual size. Lumber shall conform to American Softwood Lumber Standard PS-20.

X2.1.3 All vertical solid surfaces that are furred to receive gypsum base shall be furred with wood framing members not less than ¾ in. (19 mm) thick and 1½ in. (38 mm) wide. (Fastener penetration into the framing member shall be in accordance with 8.2.7 of this specification.)

X2.1.4 Insulating blankets or flanges of blankets shall not be applied over framing members that are to receive gypsum base. Foil-backed gypsum base may be used as a vapor retarder where required.

X3. VENTILATING ABOVE GYPSUM BASE CEILINGS

X3.1 Adequate ventilation of attics or similar unheated spaces above gypsum plaster systems is essential to the performance of these systems and shall be designed and provided by others per ASHRAE Fundamentals Handbook or applicable building code.

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X4. CABLE ELECTRIC RADIANT HEATING SYSTEMS FOR CEILINGS

X4.1 The application of gypsum base under this specification shall be performed in accordance with the requirements of this specification except as follows:

X4.1.1 The gypsum base shall have a thickness of ½ in. (12.7 mm). The gypsum base shall be applied perpendicular to framing members by using attachment methods as required in Section 9 of this specification.

X4.1.2 Electric heating cables shall be securely attached to the gypsum base in accordance with the recommendations of the cable manufacturer or supplier.

X4.1.3 Cables shall run at right angles to the gypsum base paperbound edges. Cables shall not be positioned directly over joints that run parallel to the direction of cable run.

X4.1.4 Cables shall be positioned not less than 6 in. (152 mm) from all wall-ceiling intersections and openings.

X4.1.5 All inspections and testing of the heating system shall be completed before application of the veneer plaster.

X4.1.6 Under no conditions shall the heating cable have an operating temperature greater than 125 °F (52 °C).

X4.1.7 Additional information on radiant heating systems is available in Guide C 1546.

SUMMARY OF CHANGES

Committee C11 has identified the location of selected changes to this specification since the last issue, C 844 – 99, that may impact the use of this specification. (Approved October 1, 2004)

(*1*) Added paragraph X4.1.7.

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Designation: C 845 – 04

Standard Specification for Expansive Hydraulic Cement[1]

This standard is issued under the fixed designation C 845; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope

1.1 This specification covers hydraulic cements that expand during the early hardening period after setting.

2. Referenced Documents

2.1 *ASTM Standards:* [2]

C 33 Specification for Concrete Aggregates

C 109/C 109M Test Method for Compressive Strength of Hydraulic Cement Mortars (Using 2-in. or [50-mm] Cube Specimens)

C 114 Test Methods for Chemical Analysis of Hydraulic Cement

C 183 Practice for Sampling and the Amount of Testing of Hydraulic Cement

C 185 Test Method for Air Content of Hydraulic Cement Mortar

C 188 Test Method for Density of Hydraulic Cement

C 465 Specification for Processing Additions for Use in the Manufacture of Hydraulic Cements

C 688 Specification for Functional Additions for Use in Hydraulic Cements

C 806 Test Method for Restrained Expansion of Expansive Cement Mortar

C 807 Test Method for Time of Setting of Hydraulic Cement Mortar by Modified Vicat Needle

3. Terminology

3.1 *Definitions:*

3.1.1 *expansive cement (K)*—an expansive cement containing anhydrous calcium aluminosulfate ($4CaO \cdot 3Al_2O_3 \cdot SO_3$), calcium sulfate, and uncombined calcium oxide.

3.1.2 *expansive cement (M)*—an expansive cement containing calcium aluminate cement and calcium sulfate.

3.1.3 *expansive cement (S)*—an expansive cement containing tricalcium aluminate (C_3A) and calcium sulfate.

3.1.4 *expansive hydraulic cement*—a cement composed essentially of hydraulic calcium silicates, calcium aluminates and calcium sulfates, which, upon being mixed with water, forms a paste that increases significantly in volume during the early hardening period occurring after setting. This volume increase is due principally to the reaction of the calcium aluminates and calcium sulfates.

3.1.5 *shrinkage-compensating concrete*—concrete that is internally restrained with resilient reinforcing and made with expansive cement which induces both compressive stress in the concrete and positive steel strain that approximately off-sets tensile stresses and negative strains induced by drying shrinkage.

4. Classification

4.1 The cement covered by this specification is suitable for use in shrinkage-compensating concrete and shall be designated as Type E-1.

NOTE 1—Three kinds of expansive cement are identified in Section 3 by the letters K, M, and S. The appropriate letter should be used as a suffix to the type designation when one of these kinds is desired. Expansive cement may also be prepared in other ways.

5. Ordering Information

5.1 When it is desired that an optional requirement apply or that the cement be of a particular kind, a specific request to this effect should be made by the purchaser.

6. Chemical Composition

6.1 Expansive cement shall conform to the requirements as to chemical composition prescribed in Table 1.

6.2 The purchaser has the option of specifying that the alkalies ($Na_2O + 0.658K_2O$) shall not exceed 0.60 % (See Table 2).

NOTE 2—This limit should be specified when the cement is to be used in concrete with aggregates that may be reactive. Reference should be made to Specification C 33 for suitable criteria of deleterious reactivity.

7. Physical Properties

7.1 Expansive cement shall conform to the physical requirements prescribed in Table 3.

[1] This specification is under the jurisdiction of ASTM Committee C01 on Cement and is the direct responsibility of Subcommittee C01.13 on Special Cements.

Current edition approved July 1, 2004. Published July 2004. Originally approved in 1976. Last previous edition approved in 1996 as C 845–96.

[2] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

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TABLE 1 Standard Chemical Requirements

	Composition, %
Magnesium oxide (MgO), max	6.0
Insoluble residue, max	1.0
Loss on ignition, max	4.0

TABLE 2 Optional Chemical Requirements

Alkalies (Na2O + 0.658 × K2O) max, %	0.60

TABLE 3 Physical Requirements

Time of setting, min, minutes	75
Air content, max, vol %	12.0
Restrained expansion of mortar:	
7-day expansion:	
min, %	0.04
max, %	0.10
28-day, percentage of 7-day expansion, max	115
Compressive strength, min:	
7-day, psi(MPa)	2100(14.7)
28-day, psi(MPa)	3500(24.5)

8. Additions

8.1 The cement covered by this specification shall contain no additions except as follows:

8.1.1 Water, or a functional addition, or both, that has been shown to meet the requirements of Specification C 688, may be added in amounts such that the limits shown in Table 1 for loss on ignition shall not be exceeded.

8.1.2 At the option of the manufacturer, processing additions may be used in the manufacture of the cement, provided such materials in the amounts used have been shown to be not harmful in accordance with Specification C 465.

9. Test Methods

9.1 The cement shall be sampled and the properties enumerated in this specification shall be determined in accordance with the following methods:

9.1.1 *Sampling*—Practice C 183.

9.1.2 *Chemical Analysis*—Test Methods C 114.

9.1.3 *Time of Setting*—Test Method C 807.

9.1.4 *Air Content*—Test Method C 185, using the actual specific gravity of the cement if it differs from 3.15 by more than 0.05 in calculating the air content.

9.1.5 *Restrained Expansion of Mortar*—Test Method C 806.

9.1.6 *Compressive Strength*—Test Method C 109/C109M, except that a water-cement ratio of 0.500 shall be used, the specimens shall be covered with a polyethylene sheet or other suitable material for preventing loss or gain of moisture at the surface of the specimens during the moist storage period in the molds, and the specimens shall remain in the molds for 3 days.

9.1.7 *Density*—Test Method C 188.

10. Inspection

10.1 Every facility shall be provided the purchaser for careful inspection and sampling of the finished cement. The finished cement may be inspected and sampled either at the mill or at the site of the work, as may be specified by the purchaser. The following periods from time of sampling shall be allowed for completion of testing:

7-day test	12 days
28-day test	33 days

10.2 The manufacturer shall provide suitable facilities to enable the inspector to check the intergrinding or blending operation used to produce cement by either means. The plant facilities for intergrinding or blending and inspection shall be adequate to ensure compliance with the provisions of this specification.

11. Rejection

11.1 The cement may be rejected if it fails to meet any of the requirements of this specification.

11.2 Cement remaining in bulk storage at the mill prior to shipment for a period greater than 6 months or cement in bags in local storage in the hands of a vendor for more than 3 months, after completion of the tests, may be retested for expansion and may be rejected if it fails to conform to the requirements of this specification for expansion.

11.3 Packages more than 2 % below the net weight marked thereon, may be rejected. Also, if the average net weight of packages in any shipment, as shown by weighing 50 packages at random, is less than that marked on the packages, the entire shipment may be rejected.

12. Certification

12.1 At the request of the purchaser, the manufacturer shall state in writing the composition of a finished cement.

12.2 The composition of any cement shall conform to that shown in the statement of the manufacturer within the following tolerances:

	Tolerance, ± %
Silicon dioxide (SiO_2)	3
Aluminum oxide (Al_2O_3)	2
Calcium oxide (CaO)	3

12.3 At the request of the purchaser, the manufacturer shall state in writing the nature, amount, and identity of any processing or functional addition that may have been used. Also, if requested, the manufacturer shall supply test data showing compliance of any processing addition with the provisions of Specification C 465, and any functional addition with the provisions of Specification C 688.

12.4 Upon request of the purchaser in the contract or order, a manufacturer's certification that the material during production was tested in accordance with this specification together with a report of the test results shall be furnished at the time of shipment.

13. Packaging and Package Marking

13.1 When the cement is delivered in packages, the words" expansive cement," the type, the kind (if the cement is one of the three kinds defined in Section 3), the name and brand of the manufacturer, and the net weight shall be plainly marked on each package. Similar information shall be provided in the shipping documents accompanying the shipment of packaged or bulk cement. All packages shall be in good condition at the time of inspection.

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14. Storage

14.1 The cement shall be stored in a manner such as to permit easy access for proper inspection and identification of each shipment and in a suitable weathertight building that will protect the cement from dampness and minimize warehouse set.

15. Keywords

15.1 calcium aluminate; calcium aluminosulfate; calcium oxide; calcium silicate; calcium sulfate; cement; expansive; hydraulic; shrinkage-compensated; tricalcium aluminate

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Designation: C 847 – 09

Standard Specification for Metal Lath[1]

This standard is issued under the fixed designation C 847; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

This standard has been approved for use by agencies of the Department of Defense.

1. Scope*

1.1 This specification covers sheet lath, expanded metal lath, diamond mesh, flat and self-furring, and rib metal lath, ⅛ and ⅜ in. (3.2 and 9.6 mm), all with or without backing and designed to be used as a base for gypsum or portland cement plaster.

1.2 The values stated in inch-pound units are to be regarded as standard. The values given in parentheses are mathematical conversions to SI units that are provided for information only and are not considered standard.

2. Referenced Documents

2.1 *ASTM Standards:*[2]

A 653/A 653M Specification for Steel Sheet, Zinc-Coated (Galvanized) or Zinc-Iron Alloy-Coated (Galvannealed) by the Hot-Dip Process

3. Material

3.1 Metal lath shall be fabricated from cold-rolled carbon steel sheet of commercial quality conforming to Specification A 653/A 653M. Galvanized metal lath shall have a G60 coating in accordance with Specification A 653/A 653M.

3.2 Backing shall be attached to the lath sufficiently enough to prevent accidental removal during shipping, handling, or installation. Attachment of backing shall also allow lapping of metal to metal and backing to backing, 1 in. (25.4 mm) on the ends and ½ in. (12.7 mm) on the sides.

4. Dimensions, Mass, and Permissible Variations

4.1 *Thickness*—The nominal thickness of diamond mesh and flat rib metal lath shall be ⅛ in. (3.2 mm). The nominal thickness of other rib metal lath shall be as designated, ⅜ in. (9.6 mm). The nominal thickness of self-furring diamond mesh shall be 5⁄16 in. (7.9 mm).

4.2 *Width*—The nominal width of metal lath shall be 27 in. (686 mm).

4.3 *Length*—The nominal length of metal lath shall be 96 in. (2438 mm).

4.4 *Weight*—The nominal weight of metal lath shall be as follows:

4.4.1 *U.S. Nominal Weights*:

Type:	Weight, lb/yd^2(kg/m^2)
Diamond mesh	2.5 (1.4); 3.4 (1.8)
Flat rib	1.8 (1.0); 2.75 (1.5); 3.4 (1.8)
⅜-in. rib	3.4 (1.8); 4.0 (2.1)
Sheet	4.5 (2.4)

4.4.2 *Canadian Nominal Weights*:

Type:	Weight, lb/yd^2(kg/m^2)
Diamond mesh	2.5 (1.4); 3.0 (1.6); 3.4 (1.8)
Flat rib	1.8 (1.0); 2.5 (1.4); 3.0 (1.6)
⅜-in. rib	3.0 (1.6); 3.5 (1.9); 4.0 (2.1)

4.5 *Permissible Variations*—The permissible variations shall be as follows:

4.5.1 *Thickness*, ±1⁄64 in. (0.4 mm).

4.5.2 *Width*, ±⅜ in. (9.5 mm).

4.5.3 *Length*, −0 in., + 2½ in. (63.5 mm).

4.5.4 *Weight*, ± 10 %.

5. Finish

5.1 Metal lath shall be fabricated from hot-dipped galvanized steel.

6. Inspection

6.1 Inspection of the material shall be agreed upon between the purchaser and supplier as part of the purchase contract.

7. Rejection and Rehearing

7.1 Any rejection shall be based upon the specific cause of failure to conform to the requirements of this specification, and shall be reported to the seller within 10 working days from the receipt of the shipment by the purchaser.

[1] This specification is under the jurisdiction of ASTM Committee C11 on Gypsum and Related Building Materials and Systems and is the direct responsibility of Subcommittee C11.02 on Specifications and Test Methods for Accessories and Related Products.

Current edition approved May 1, 2009. Published May 2009. Originally approved in 1977. Last previous edition approved in 2006 as C 847 – 06.

[2] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

***A Summary of Changes section appears at the end of this standard.**

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7.2 Claims for rehearing shall be valid only if made within 20 working days from receipt of notice of specific cause for rejection.

8. Certification

8.1 Where specified in the purchase order, a producer's or supplier's certification shall be furnished to the purchaser that the material was in accordance with this specification and has been found to meet the specified requirements.

9. Packaging and Package Marking

9.1 Metal lath shall be packaged ten sheets per bundle, and self-furring lath shall be five or ten sheets per bundle (option of manufacturer).

9.2 When shipped for resale, the name of the manufacturer or the supplier and the brand shall be legibly marked on each lath or package.

10. Keywords

10.1 gypsum cement plaster; lath; metal lath; portland cement plaster; rib lath; self-furring; sheet lath

SUMMARY OF CHANGES

Committee C11 has identified the location of selected changes to this specification since the last issue, C 847 – 06, that may impact the use of this specification. (Approved May 1, 2009)

(*1*) Revised the tolerance in 4.5.2 from 3⁄16 in. to 3⁄8 in.

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Designation: C 856 – 04

Standard Practice for Petrographic Examination of Hardened Concrete[1]

This standard is issued under the fixed designation C 856; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope

1.1 This practice outlines procedures for the petrographic examination of samples of hardened concrete. The samples examined may be taken from concrete constructions, they may be concrete products or portions thereof, or they may be concrete or mortar specimens that have been exposed in natural environments, or to simulated service conditions, or subjected to laboratory tests. The phrase "concrete constructions" is intended to include all sorts of objects, units, or structures that have been built of hydraulic cement concrete.

NOTE 1—A photographic chart of materials, phenomena, and reaction products discussed in Sections 7-12 and Tables 1-6 are available as Adjunct C856 (ADJCO856).

1.2 The petrographic procedures outlined herein are applicable to the examination of samples of all types of hardened hydraulic-cement mixtures, including concrete, mortar, grout, plaster, stucco, terrazzo, and the like. In this practice, the material for examination is designated as "concrete," even though the commentary may be applicable to the other mixtures, unless the reference is specifically to media other than concrete.

1.3 Annex A1 outlines an uranyl acetate method for identifying locations where alkali-silica gel may be present. It is a requirement that the substances in those locations must be identified using any other more definitive techniques, such as petrographic microscopy.

1.4 The purposes of and procedures for petrographic examination of hardened concrete are given in the following sections:

	Section
Qualifications of Petrographers and Use of Technicians	3
Purposes of Examination	4
Apparatus	5
Selection and Use of Apparatus	6
Samples	7
Examination of Samples	8
Specimen Preparation	9
Visual and Stereomicroscope Examination	10
Polarizing Microscope Examination	11
Paste Features	12
Report	13

1.5 The values stated in inch-pound units are to be regarded as the standard. The SI units in parentheses are provided for information purposes only.

1.6 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.* A specific hazard statement is given in 5.2.10.1.

2. Referenced Documents

2.1 *ASTM Standards:* [2]

C 215 Test Method for Fundamental Transverse, Longitudinal, and Torsional Frequencies of Concrete Specimens

C 227 Test Method for Potential Alkali Reactivity of Cement-Aggregate Combinations (Mortar-Bar Method)

C 342 Test Method for Potential Volume Change of Cement-Aggregate Combinations[3]

C 441 Test Method for Effectiveness of Pozzolans or Ground Blast-Furnace Slag in Preventing Excessive Expansion of Concrete Due to the Alkali-Silica Reaction

C 452 Test Method for Potential Expansion of Portland-Cement Mortars Exposed to Sulfate

C 457 Test Method for Microscopical Determination of Parameters of the Air-Void System in Hardened Concrete

C 496 Test Method for Splitting Tensile Strength of Cylindrical Concrete Specimens

C 597 Test Method for Pulse Velocity Through Concrete

C 803/C 803M Test Method for Penetration Resistance of Hardened Concrete

C 805 Test Method for Rebound Number of Hardened Concrete

C 823 Practice for Examination and Sampling of Hardened Concrete in Constructions

C 1012 Test Method for Length Change of Hydraulic-Cement Mortars Exposed to a Sulfate Solution

C 1260 Test Method for Potential Alkali Reactivity of Aggregates (Mortar-Bar Method)

E 3 Practice for Preparation of Metallographic Specimens

[1] This practice is under the jurisdiction of ASTM Committee C09 on Concrete and Concrete Aggregates and is the direct responsibility of Subcommittee C09.65 on Petrography.

Current edition approved Jan. 1, 2004. Published February 2004. Originally approved in 1977. Last previous edition approved in 2002 as C 856 – 02.

[2] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

[3] Withdrawn.

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TABLE 1 Visual Examination of Concrete (1)[6]

Coarse Aggregate	+ Fine Aggregate	+ Matrix	+ Air	+ Embedded Items
Composition:				
Maximum dimension,[A] in. or mm, in the range> *d*>				
Type: 1 Gravel 2 Crushed stone 3 Mixed 1 and 2 4 Other (name) 5 Mixed 1 + /or 2 + /or 4 If Type 1, 2, or 4, homogeneous or heterogeneous	Type: 1 Natural sand 2 Manufactured sand 3 Mixed 4 Other (name) 5 Mixed 1 + /or 2 + /or 4 If Type 1, 2, or 4, homogeneous or heterogeneous	color, by comparison with National Research Council *Rock Color Chart* (1963) color distribution: 1 mottled 2 even 3 gradational changes	more than 3 % of total, predominantly in spherical voids? less than 3 % of total, abundant nonspherical voids? color differences between voids and mortar?	Type, size, location; kinds of metal; other items
Lithologic types Coarse aggregate more than 20, 30, 40, or 50 % of total			voids empty, filled, lined, or partly filled	
Fabric:				
Shape Distribution Packing Grading (even, uneven, excess, or deficiency of size or sizes) Parallelism of flat sides or long axes of exposed sections, normal to direction of placement + /or parallel to formed and finished surfaces[B]	distribution particle shape grading preferred orientation } as perceptible	distribution	shape distribution grading (as perceptible) parallelism of long axes of irregular voids or sheets of voids: with each other; with flat sides or long axes of coarse aggregate	voids below horizontal or low-angle reinforcement
Condition:				clean or corroded?
Does it ring when hit lightly with a hammer or give a dull flat sound? Can you break it with your fingers? Cracks? How distributed? Through or around coarse aggregate? With cores or sawed specimens, did the aggregate tear in drilling or sawing? Crack fillings? Surface deposits? If air dry, are there unusually wet or dry looking areas? Rims on aggregate?				Are cracks associated with embedded items?

[A] A substantial portion of the coarse aggregate has maximum dimensions in the range shown as measured on sawed or broken surfaces.

[B] Sections sawed or drilled close to and parallel to formed surfaces appear to show local turbulence as a result of spading or rodding close to the form. Sections sawed in the plane of bedding (normal to the direction of placement) are likely to have inconspicuous orientation. Sections broken normal to placement in conventionally placed concrete with normal bond tend to have aggregate knobs abundant on the bottom of the upper piece as cast and sockets abundant on the top of the lower piece as cast.

E 883 Guide for Reflected-Light Photomicrography

2.2 *ASTM Adjuncts:*

Adjunct C856 (ADJCO856) A chart of 27 photos[4]

3. Qualifications of Petrographers and Use of Technicians

3.1 All petrographic examinations of hardened concrete described in this practice shall be performed by or under the technical direction of a full time supervising petrographer with at least 5 years experience in petrographic examinations of concrete and concrete-making materials. The supervising concrete petrographer shall have college level courses that include petrography, mineralogy, and optical mineralogy, or 5 years of documented equivalent experience, and experience in their application to evaluations of concrete-making materials and concrete products in which they are used and in cementitious-based materials. A resume of the professional background and qualifications of all concrete petrographers shall be available.

3.2 A concrete petrographer shall be knowledgeable about the following: concrete-making materials; processes of batching, mixing, handling, placing, and finishing of hydraulic-cement concrete; the composition and microstructure of cementitious paste; the interaction of constituents of concrete; and the effects of exposure of such concrete to a wide variety of conditions of service.

3.3 Sample preparation shall be performed by concrete petrographers or trained technicians pursuant to instructions from and under the guidance of a qualified concrete petrographer. Aspects of the petrographic examination, such as the measurement of sample dimensions, photography of as-received samples, staining of sample surfaces, that do not require the education and skills outlined in 3.1, shall be performed by concrete petrographers or by trained technicians pursuant to instructions and under the guidance of a qualified concrete petrographer. The analysis and interpretation of the features that are relevant to the investigation and evaluation of the performance of the materials represented by the sample shall be made solely by concrete petrographers with qualifications consistent with those outlined in 3.1.

3.4 A concrete petrographer shall be prepared to provide an oral statement, written report, or both that includes a description of the observations and examinations made during the petrographic examinations, and interpretation of the findings insofar as they relate to the concerns of the person or agency

[4] Available from ASTM International Headquarters, 100 Barr Harbor Drive, West Conshohocken, PA 19428. Request Adjunct No. ADJC0856.

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TABLE 2 Outline for Examination of Concrete with a Stereomicroscope (1)

NOTE 1—*Condition*—When it is examined at 6 to 10× under good light, the freshly broken surface of a concrete in good physical condition that still retains most of its natural moisture content has a luster that in mineralogical terms is subtranslucent glimmering vitreous.[A] Thin edges of splinters of the paste transmit light; reflections appear to come from many minute points on the surface, and the quality of luster is like that from broken glass but less intense. Concrete in less good physical condition is more opaque on a freshly broken surface, and the luster is dull, subvitreous going toward chalky. A properly cured laboratory specimen from a concrete mixture of normal proportions cured 28 days that has shown normal compressive or flexural strength and that is broken with a hammer and examined on a new break within a week of the time that it finished curing should provide an example of concrete in good physical condition.

Under the same conditions of examination, when there is reasonable assurance that the concrete does not contain white portland cement or slag cement, the color of the matrix of concrete in good physical condition is definitely gray or definitely tan, except adjoining old cracks or original surfaces.

Coarse Aggregate	Fine Aggregate	Matrix	Voids
Lithologic types and mineralogy as perceptible	Lithologic types and mineralogy as perceptible	Color	Grading
Surface texture	Shape	Fracture around or through aggregate	Proportion of spherical to nonspherical
Within the piece:	Surface texture	Contact of matrix with aggregate:	Nonspherical, ellipsoidal, irregular, disk-shaped
Grain shape	Grading	close, no opening visible on sawed or broken surface; aggregate not dislodged with fingers or probe; boundary openings frequent, common, rare	Color change from interior surface to matrix
Grain size extreme range observed, mm	Distribution	Width	Interior surface luster like rest of matrix, dull, shining
Median within range _ to _ mm		Empty	Linings in voids absent, rare, common, in most, complete, partial, colorless, colored, silky tufts, hexagonal tablets, gel, other
Textureless (too fine to resolve)		Filled	Underside voids or sheets of voids uncommon, small, common, abundant
Uniform or variable within the piece		Cracks present, absent, result of specimen preparation, preceding specimen preparation	
From piece to piece:		Mineral admixtures[C]	
Intergranular bond		Contamination	
Porosity and absorption[B]		Bleeding	
If concrete breaks through aggregate, through how much of what kind?			
If boundary voids, along what kind of aggregate? All? All of one kind? More than 50 % of one kind? Several kinds?			
Segregation			

[A] Dana, E. S., *Textbook of Mineralogy,* revised by W. E. Ford, John Wiley & Sons, New York, N. Y., 4th ed., 1932, pp. 273–274.

[B] Pore visible to the naked eye, or at × _, or sucks in water that is dropped on it.

[C] Dark solid spheres or hollow-centered spheres of glass, or of magnetite, or some of glass and some of magnetite, recognizable at magnification of × 9 on sawed or broken surfaces. Other mineral admixtures with characteristic particles visible at low magnification are recognizable. Ground surface of concrete containing portland blast-furnace slag cement are unusually white near-free surfaces but retain greenish or blue-greenish patches, and slag particles can be seen with the stereomicroscope or polarizing microscope.

for whom the examination was performed. Supplementary information provided to the petrographer on the concrete and concrete materials, conditions of service, or other features of the concrete construction may be helpful in interpreting the data obtained during the petrographic examinations.

3.5 This practice may form the basis for establishing arrangements between a purchaser of the consulting service and the consulting petrographer. In such cases, the purchaser of the consulting service and the consulting petrographer should together determine the kind, extent, and objectives of the examinations and analyses to be made, and may record their agreement in writing. The agreement may stipulate specific determinations to be made, observations to be reported, funds to be obligated, or a combination of these and other conditions.

4. Purposes of Examination

4.1 Examples of purposes for which petrographic examination of concrete is used are given in 4.2-4.5. The probable usefulness of petrographic examination in specific instances may be determined by discussion with an experienced petrographer of the objectives of the investigation proposed or underway.

4.2 *Concrete from Constructions*:

4.2.1 Determination in detail of the condition of concrete in a construction.

4.2.2 Determination of the causes of inferior quality, distress, or deterioration of concrete in a construction.

4.2.3 Determination of the probable future performance of the concrete.

4.2.4 Determination whether the concrete in a construction was or was not as specified. In this case, other tests may be required in conjunction with petrographic examination.

4.2.5 Description of the cementitious matrix, including qualitative determination of the kind of hydraulic binder used, degree of hydration, degree of carbonation if present, evidence of unsoundness of the cement, presence of a mineral admixture, the nature of the hydration products, adequacy of curing, and unusually high water - cement ratio of the paste.

4.2.6 Determination whether alkali - silica or alkali - carbonate reactions, or cement - aggregate reactions, or reactions between contaminants and the matrix have taken place, and their effects upon the concrete.

4.2.7 Determination whether the concrete has been subjected to and affected by sulfate attack, or other chemical attack, or early freezing, or to other harmful effects of freezing and thawing.

4.2.8 Part of a survey of the safety of a structure for a present or proposed use.

4.2.9 Determination whether concrete subjected to fire is essentially undamaged or moderately or seriously damaged.

4.2.10 Investigation of the performance of the coarse or fine aggregate in the structure, or determination of the composition of the aggregate for comparison with aggregate from approved or specified sources.

4.2.11 Determination of the factors that caused a given concrete to serve satisfactorily in the environment in which it was exposed.

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TABLE 3 Effects of Fire on Characteristics of Concrete

Characteristic	Causes and Effects	Ways of Investigation
Surface hardness	Dehydration to 100°C removes free water; dehydration is essentially complete at 540°C; calcium hydroxide goes to CaO at 450–500°C. Paste expands with thermal coefficient effect and then shrinks, cracks, decrepitates, and becomes soft **(4).**	Beneath the softened concrete, which can be tested in accordance with Test Method C 805, the concrete is probably normal if it has not undergone color change. Establish by coring for compressive tests, by wear tests (CRD-C 52) **(4),** and by scratching with a knife.
Cracking	Perpendicular to the face and internal, where heating or cooling caused excess tensile stresses. In some new concrete, resembles large-scale shrinkage cracking; may penetrate up to 100 mm but may heal autogenously **(4).**	Examination of the surface, ultrasonic tests, coring, petrographic examination **(4).**
Color change—When concrete has not spalled, observe depth of pink color to estimate the fire exposure.	Concrete made with sedimentary or metamorphic aggregates shows permanent color change on heating. Color normal to 230°C; goes from pink to red from 290 to 590°C; from 590 to 900°C color changes to gray and then to buff **(4).** For temperatures up to about 500°C temperature distribution is little affected by using carbonate rather than siliceous aggregate **(5).** At 573°C low quartz inverts to high with 0.85 % increase in volume, producing popouts. Spalling over steel to expose one fourth of the bar at 790°C; white powdered decomposed hydration products at 900°C. Surface crazing about 290°C; deeper cracking about 540°C.	Color change is the factor most useful to the investigator; permits recognizing how deeply a temperature of about 300°C occurred **(5).**
Aggregate behavior—Aggregate behavior affects strength, modulus, spalling, cracking, surface hardness, and residual thermal strains **(4).**	Aggregates differ in thermal diffusivity, conductivity, coefficient of expansion. Heat transmission decreases from concrete made with highly siliceous aggregate, sandstone, traprock, limestone, lightweight aggregates **(4).**	Changes on heating are often accompanied by volume change **(4).**
Spalling	Occurs subparallel to free face; followed by breaking off saucer-like pieces especially at corners and edges **(4).**	
Note: Compressive strength and elastic modulus. For concrete at least 1-year old, strength will increase after cooling from 300°C if design strength was attained **(5).**	Reduction in strength of concrete containing siliceous gravel after heating, then cooling and testing: Heated to Temperature ° C / Reduction, % 180 / 25 370 / 50 570 / 80 Reduction in Modulus Temperature,° C / Reduction, % 200 / 25 430 / 50 760 / 70	Determinations by compressive tests and static modulus of cores; Test Method C 805 for qualitative determination; Test Method C 597 **(4).**

4.2.12 Determination of the presence and nature of surface treatments, such as dry shake applications on concrete floors.

4.3 *Test Specimens from Actual or Simulated Service*—Concrete or mortar specimens that have been subjected to actual or simulated service conditions may be examined for most of the purposes listed under Concrete from Constructions.

4.4 *Concrete Products*:

4.4.1 Petrographic examination can be used in investigation of concrete products of any kind, including masonry units, precast structural units, piling, pipe, and building modules. The products or samples of those submitted for examination may be either from current production, from elements in service in constructions, or from elements that have been subjected to tests or to actual or simulated service conditions.

4.4.2 Determination of features like those listed under concrete from constructions.

4.4.3 Determination of effects of manufacturing processes and variables such as procedures for mixing, molding, demolding, consolidation, curing, and handling.

4.4.4 Determination of effects of use of different concrete-making materials, forming and molding procedures, types and amounts of reinforcement, embedded hardware, etc.

4.5 *Laboratory Specimens*—The purposes of petrographic examination of laboratory specimens of concrete, mortar, or cement paste are, in general, to investigate the effects of the test on the test piece or on one or more of its constituents, to provide examples of the effects of a process, and to provide the petrographer with visual evidence of examples of reactions in paste or mortar or concrete of known materials, proportions, age, and history. Specific purposes include:

4.5.1 To establish whether alkali - silica reaction has taken place, what aggregate constituents were affected, what evidence of the reaction exists, and what were the effects of the reaction on the concrete. The technique in Annex A1 is helpful for identifying locations where alkali-silica gel may be present.

4.5.2 To establish whether one or more alkali - carbonate reactions have taken place, which aggregate constituents were affected and what evidence of the reaction or reactions exists, and the effects of the reaction on the concrete properties.

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TABLE 4 Outline for Examination of Concrete in Thin Sections

Coarse and Fine Aggregate	Relict Cement Grains and Hydration Products	Characteristics of Cement Paste
Mineralogy, texture, fabric, variable or homogeneous.	In concrete over 2 years old and normally cured, the only residual cement grains are those that were largest, which may be composed of several constituents or be of alite or belite (substituted C_3S and C_2S). The latter two may be bordered by one or two layers of gel having different indexes of refraction, or by a layer of calcium hydroxide. The largest relict grains may be truly unhydrated and retain the low (dark gray) birefringence of alite in distorted quasihexagonal sections and the visible birefringence to first-order yellow of the lamellar twins in rounded grains of belite. Interstitial aluminoferrite appears as prismatic grains ranging in color from brown to greenish brown to reddish brown and having a high refractive index and pleochroism masked by the color of the grain. Tricalcium aluminate is usually not recognized in thin section because the cubic form is isotropic or because it hydrates early in the hydration history of the concrete forming submicroscopic ettringite or tetracalcium aluminum sulfate hydrate or other tetracalcium aluminum hydrates with or without other anions. These may be visible in voids in older concrete but are best discriminated by X-ray diffraction.	Normal cement paste consists in plane transmitted light of pale tan matter varying somewhat in index of refraction and containing relict unhydrated cement grains. In concrete sectioned at early age or not adequately cured, the paste contains unhydrated cement grains ranging down to a few micrometres in maximum size with an upper limit as large as 100 μm in maximum diameter if the cement was ground in open-circuit mills or was deliberately ground to low surface area to reduce the heat of hydration. With crossed polars, normal paste is black or very dark mottled gray with scattered anhedral poikilitic crystals or small segregations of calcium hydroxide and scattered relict grains of cement. In concrete of high water - cement ratio and siliceous aggregate, the calcium hydroxide crystals are as large as the maximum size of residual cement grains, about 100μ m. In concrete of lower water - cement ratio, higher cement content, and either siliceous or carbonate aggregate, the maximum size of calcium hydroxide crystals is considerably smaller. Regardless of water - cement ratio and type of aggregate, calcium hydroxide crystals occupy space tangential to the undersides of aggregate particles. Where all the aggregate is carbonate rock the maximum size of calcium hydroxide is smaller than in comparable concrete with siliceous aggregate. (Calcium hydroxide is probably epitaxial on calcite.)
Grading; excess or deficiency of sand sizes is to be judged after examination of a series of thin sections. Grain size and nature of internal boundaries in aggregate. Classification of coarse and fine aggregate.	Cements from different sources have different colors of aluminoferrite and the calcium silicates have pale green or yellow or white shades. It should be possible to match cements from one source.	Cement paste in concrete that has been subjected to prolonged acid leaching is low in calcium hydroxide which is present as recrystallized virtually anhedral grains precipitated near the exterior surfaces.
Natural mineral aggregate or crushed stone; natural or manufactured fine aggregate.		In concrete over 2 or 3 years old made with Type I, II, or III cement, some ettringite is to be expected as rosettes in air voids. This is a normal phenomenon; to demonstrate sulfate attack it must be established chemically that the SO_3 content of the concrete is greater than would be supplied by the original sulfate content of the cement. Ettringite in voids is not ettringite that has damaged concrete although it may accompany submicroscopic ettringite in the paste that has damaged the concrete.
Bond with matrix; peripheral cracks inside the borders of aggregate grains; internal cracks. General microfractures if one can establish that they existed before thin-sectioning.		
Alkali - carbonate reactions—If the coarse aggregate is a carbonate rock or rocks, are there rims or partial rims depleted in calcium hydroxide? Partly dolomitic rocks that have reacted sometimes are bordered with paste free from calcium hydroxide along the dolomitic portion while the paste along the limestone portion is normal. See other comments in Column 3.		
Alkali - silica reaction—Does the aggregate contain particles of types known to be reactive (chert, novaculite, acid volcanic glass, cristobalite, tridymite, opal, bottle glass)? If quartzite, metamorphosed subgraywacke, argillite, phyllite, or any of those listed in the sentence above, are there internal cracks inside the periphery of the aggregate? Has the aggregate been gelatinized so that it has pulled off during sectioning leaving only a peripheral hull bonded to the mortar? (This last phenomenon also occurs in concrete with air-cooled slag aggregate, where it indicates reaction between cement and slag.) Cracks that appear to be tensile and to narrow from the center toward the border of the particle are also evidence of alkali - silica reaction **(6).**		

4.5.3 To establish whether any other cement - aggregate reaction has taken place. In addition to alkali - silica and alkali - carbonate reactions, these include hydration of anhydrous sulfates, rehydration of zeolites, wetting of clays and reactions involving solubility, oxidation, sulfates, and sulfides (see Refs **1, 2,** and **3**).[5]

4.5.4 To establish whether an aggregate used in a test has been contaminated by a reactive constituent when in fact the aggregate was not reactive.

4.5.5 To establish the effects of a freezing and thawing test or other physical or mechanical exposure of concrete on the aggregate and the matrix.

4.5.6 To establish the extent of reaction, the nature of reaction products, and effects of reaction produced in exposure to a chemically aggressive environment such as in Test Method C 452 or Test Method C 1012.

4.5.7 To determine the characteristics of moist-cured concrete that has not been subjected to chemical attack or cement - aggregate reaction or freezing and thawing.

4.5.8 By comparison with appropriate laboratory specimens, a petrographer may be able to substantiate the existence of a particular reaction in concrete or determine that the reaction cannot be detected.

5. Apparatus

5.1 The apparatus and supplies employed in making petrographic examinations of hardened concrete depend on the procedures required. The following list includes the equipment generally used. Equipment needed to perform the examinations in Annex A1 is listed therein. Equipment required for field sampling is not listed. Any other useful equipment may be added.

5.2 *For Specimen Preparation*:

5.2.1 *Diamond Saw*—Slabbing saw with an automatic feed and blade large enough to make at least a 7-in. (175-mm) cut in one pass.

[5] The boldface numbers in parentheses refer to the list of references at the end of this practice.

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TABLE 5 Characteristics of Concrete Observed Using Microscopes

Characteristic	Type of Microscope		
	Stereomicroscope	Petrographic	Metallographic
Aggregate:			
Shape	X	X	X
Grading	X	...	...
Distribution	X	...	...
Texture	X	X	X
Composition	X	X	...
Rock types	X	X	...
Alteration	X	X	...
degree	X	X	
products	X	X	...
Coatings	X	X	...
Rims	X	X	X
Internal cracking	X	X	...
Contamination	X	X	
Concrete:			
Air-entrained or not	X	X	X
Air voids	...	...	...
shape	X	X	X
size	X	X	X
distribution	X	...	...
Bleeding	X	...	...
Segregation	X	...	...
Aggregate-paste bond	X	X	X
Fractures	X	X	X
Embedded items			
size	X	...	...
shape	X	...	...
location	X	...	...
type	X	...	...
Alteration			
degree and type	X	X	X
reaction products			
location	X	X	X
identification	X[A]	X	...
Nature and condition of surface treatments	X	X	...
Paste:			
Color	X	X	...
Hardness	X	...	X
Porosity	X	...	X
Carbonation	X	X	...
Residual cement			
distribution	...	X	X
particle size	...	X	X
abundance	...	X	X
composition	...	X	X
Mineral admixtures	X[B]	X	X
size	...	X	X
abundance	X	X	X
identification	X	X	X
Compounds in hydrated cement	X[C]	X	X
Contamination			
size	X	X	X
abundance	X	X	X
identification	...	X	X[D]

[A] Secondary ettringite can sometimes be recognized by crystal habit and silky luster.
[B] Fly ash can be detected by color and shape when dark spheres are present. In concrete that has not oxidized the presence of slag may be inferred from the green or blue color of the paste.
[C] Ettringite and calcium hydroxide in voids may be recognized by their crystal habits.
[D] Magnesium oxide and calcium oxide should be identifiable in polished section.

5.2.2 *Cutting Lubricant*, for diamond saw.

5.2.3 *Horizontal Lap Wheel or Wheels*, steel, cast iron, or other metal lap, preferably at least 16 in. (400 mm) in diameter, large enough to grind at least a 4 by 6-in. (100 by 152-mm) area.

5.2.4 *Free Abrasive Machine*, using abrasive grit in lubricant, with sample holders rotating on a rotating table. This type of grinding machine greatly increases the speed of preparation of finely ground surfaces.

5.2.5 *Polishing Wheel*, at least 8 in. (200 mm) in diameter and preferably two-speed, or a vibratory polisher.

5.2.6 *Hot Plate or Oven*, thermostatically controlled, to permit drying and impregnating specimens with resin or wax for preparing thin sections, ground surfaces, and polished sections.

5.2.7 *Prospector's Pick or Bricklayer's Hammer*, or both.

5.2.8 *Abrasives*—Silicon carbide grits, No. 100 (150-µm), No. 220 (63-µm), No. 320 (31-µm), No. 600 (16-µm), No. 800

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TABLE 6 Secondary Deposits in Concrete[A]

Compound and Mineral Equivalent	Indexes of Refraction	Form and Occurrence
Calcium carbonate ($CaCO_3$); calcite	ω = 1.658 ϵ = 1.486	Fine-grained, white or gray masses or coatings in the cement paste, in voids, along fractures, or on exposed surfaces; very common
Calcium carbonate ($CaCO_3$); aragonite	α = 1.530 β = 1.680 γ = 1.685	Minute, white prisms or needles in voids or fractures in concrete; rare
Calcium carbonate ($CaCO_3$); vaterite	o = 1.544–1.550 E = 1.640–1.650	Spherulitic, form-birefringent, white encrustations on moist-stored laboratory specimens (vaterite A); also identified in sound concrete from structures by X-ray diffraction (α-vaterite); common **(7)**
6-calcium aluminate trisulfate-32 hydrate $\{Ca_6[Al(OH)_6]_2 \cdot 24H_2O\}(SO_4)_3 \cdot 2H_2O$ **(8)**; ettringite	ω = 1.464–1.469[B] ϵ = 1.458–1.462	Fine, white fibers or needles or spherulitic growths in voids, in the cement paste, or in fractures; very common **(1, 7)**
Tetracalcium aluminate monosulfate-12-hydrate ($3CaO \cdot Al_2O_3 \cdot CaSO_4 \cdot 12H_2O$)	ω = 1.504 ϵ = 1.49	White to colorless, minute, hexagonal plates in voids and fractures; very rare **(7)**
Tetracalcium aluminate-13-hydrate ($Ca_4Al_2(OH)_{14} \cdot 6H_2O$)	ω = 1.53 ϵ = 1.52	Micalike, colorless, pseudohexagonal, twinned crystals in voids; very rare **(9)**
Hydrous sodium carbonate ($Na_2O \cdot CO_2 \cdot H_2O$); thermonatrite	α = 1.420 β = 1.506 γ = 1.524	Minute inclusions in alkalic silica gel; rare **(7)**
Hydrated aluminum sulfate ($2Al_2O_3 \cdot SO_3 \cdot 15H_2O$); paraluminite	α = 1.463 ± 0.003 β = 1.471 γ = 1.471	Occurring in cavities in intensely altered concrete; very rare **(9)**
Calcium sulfate dihydrate ($CaSO_4 \cdot 2H_2O$); gypsum	α = 1.521 β = 1.523 γ = 1.530	White to colorless crystals in voids, in the cement paste, or along the surfaces of aggregate particles in concrete or mortar affected by sulfate or seawater attack; unusual
Calcium hydroxide ($Ca(OH)_2$); portlandite	ω = 1.574 ϵ = 1.547	White to colorless, hexagonal plates or tablets in the cement paste, in voids, along fractures; ubiquitous in concrete
Magnesium hydroxide ($Mg(OH)_2$); brucite	ω = 1.559 ϵ = 1.580	White to yellow, fine-grained encrustations and fillings in concrete attacked by magnesian solutions or seawater; unusual **(10, 11)**
Hydrous silica ($SiO_2 \cdot nH_2O$); opal	η = 1.43 varies with water content	White to colorless, finely divided, amorphous; resulting from intense leaching or carbonation of cement paste; unusual in recognizable proportions
Alkalic silica gel ($Na_2O \cdot K_2O \cdot CaO \cdot SiO_2$)	η = 1.46–1.53	White, yellowish, or colorless; viscous, fluid, waxy, rubbery, hard; in voids, fractures, exudations, aggregate; common **(12, 13)**
Hydrated iron oxides ($Fe_2O_3 \cdot nH_2O$); Limonite	opaque or nearly so	Brown stain in fractures and on surfaces; common
Thaumasite $\{Ca_6[Si(OH)_6]_2 \cdot 24H_2O\}(SO_4)_2(CO_3)_2$ **(8)**	ω = 1.504 ϵ = 1.468± 0.002[B]	Prismatic, hexagonal; capable of growing in continuity with ettringite; in sewer pipe subject to sulfate attack, in grout, in some pavement **(14)**
Syngenite $(K_2Ca(SO_4)_2) \cdot H_2O$	α = 1.501 **(15)** β = 1.51 γ = 1.51	Found in cavities and zones peripheral to slate particles, in fibrous form **(16)**
Hydrotalcite $Mg_{3/4}Al_{1/4}(OH)_2(CO_3)_{1/8}(H_2O)_{1/2}$ **(8)**	ω = 1.510 ± 0.003 ϵ = 1.495± 0.003	Foliated platy to fibrous masses **(17, 8)**

[A] The literature and private reports include data on many unidentified secondary compounds in concrete; these are not included in the tabulation. Indexes of refraction of common mineralogic types are taken from standard works on mineralogy.

[B] Higher and lower indexes of refraction have been recorded for naturally occurring ettringite **(15)** and thaumasite **(14)**, but it is not known that the naturally occurring minerals and compounds found in hydrated cement are of the same composition.

(12-µm); optical finishing powders, such as M-303, M-204, M-309; polishing powders as needed.

5.2.9 *Plate-glass Squares*, 12 to 18-in. (300 to 450-mm) on an edge and at least ⅜ in. (10 mm) thick for hand-finishing specimens.

5.2.10 *Suitable Medium or Media*, for impregnating concrete and mounting thin sections plus appropriate solvent. Canada balsam, Lakeside 70 cement, and flexibilized epoxy formulations have been used.

5.2.10.1 **Warning**—Flexibilized epoxies form strong bonds but have higher indexes of refraction than Canada balsam or Lakeside 70 and are toxic. Do not allow to touch the skin; plastic gloves shall be worn, and the work shall be done under a hood so as not to breathe the fumes.

5.2.11 *Microscope Slides*—Clear, noncorrosive, glass approximately 24 mm wide and at least 45 mm long. Thickness may need to be specified to fit some thin section machines.

5.2.12 *Cover Glasses*, noncorrosive and preferably No. 1 (0.18-mm) thickness.

5.3 *For Specimen Examination*:

5.3.1 *Stereomicroscope*, providing magnifications in the range from 7× to 70× or more.

5.3.2 *Dollies*—Small, wheeled dollies with flat tops and with tops curved to hold a section of core assist in manipulating concrete specimens under the stereomicroscope.

5.3.3 *Petrographic Microscope or Polarizing Microscope*, for examinations in transmitted light, with mechanical stage; low-, medium-, and high-power objectives such as 3.5×, 10×,

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and 20 to 25×; 43 to 50× with numerical aperture 0.85 or more; assorted eyepieces having appropriate corrections and magnifications for use with each of the objectives; micrometer eyepiece; condenser adjustable to match numerical aperture of objective with highest numerical aperture to be used; full-wave and quarter-wave compensators, quartz wedge, and other accessories.

5.3.4 *Metallographic Microscope*, with vertical illuminator, mechanical stage, metallographic objectives of low, medium, and high magnification, and appropriate eyepieces to provide a range of magnifications from about 25× to 500×. Reflected polarized light should be available and appropriate compensators provided. Some polarizing microscopes can be equipped with accessories for metallographic examination, if the tube can be raised or the stage lowered to give adequate clearance for the vertical illuminator and the thicker specimens usually employed.

5.3.5 *Eyepiece Micrometer*—Eyepiece micrometers calibrated using a stage micrometer are useful for measuring particles of aggregate, cement grains, calcium hydroxide and other crystals, and crack widths.

5.3.6 *Stage Micrometer*, to calibrate eyepiece micrometers.

5.3.7 *Microscope Lamps*—Many modern polarizing microscopes have built-in illuminators which are convenient and satisfactory if, with the condenser, they can be adjusted to fill the back lens of the objective of highest numerical aperture with light. If the microscope requires a separate illuminator, tungsten ribbon-filament bulbs in suitable adjustable housings are satisfactory. Many kinds of illuminators are available for stereomicroscopes; some can be mounted on the microscope, some stand on their own bases; choice is a question of adequacy of illumination for the tasks intended. Focusable illuminators are preferred.

5.3.8 *Needleholders and Points*—In addition to pin vises and needles from laboratory supply houses, a No. 10 sewing needle mounted in a handle or a selection of insect pins from size 00 to size 4 are useful for prying out reaction products.

5.3.9 *Bottles with Droppers*, for acid, water, and other reagents applied during examination.

5.3.10 *Assorted Forceps*, preferably stainless steel, including fine-pointed watchmaker's forceps.

5.3.11 *Lens Paper*.

5.3.12 *Refractometer, and Immersion Media*, covering the range of refractive indexes from 1.410 to at least 1.785, in steps not larger than 0.005. Stable immersion media, calibrated at a known temperature and of known thermal coefficient, are preferable and should be used in a temperature-controlled room. A thermometer graduated in tenths of a degree Celsius should be used to measure air temperature near the microscope stage so that thermal corrections of refractive index can be made if needed.

6. Selection and Use of Apparatus

6.1 Laboratories should be equipped to provide photographs, photomacrographs, and photomicrographs to illustrate significant features of the concrete. While ordinary microscope lamps are sometimes satisfactory for photomicrography in transmitted and reflected light, lamps providing intense point or field sources, such as tungsten ribbon-filament bulbs, or zirconium or carbon arcs, are highly desirable. For much useful guidance regarding photomicrography, especially using reflected light, see Guide E 883.

6.2 The minimum equipment for petrographic examination of concrete where both specimen preparation and examination are completed within the laboratory consists of a selection of apparatus and supplies for specimen preparation, a stereomicroscope preferably on a large stand so that 6-in. (152-mm) diameter cores can be conveniently examined, a polarizing microscope and accessories, lamps for each microscope, and stable calibrated immersion media of known thermal coefficient. Specimens for petrographic examination may be obtained by sending samples to individuals or firms that offer custom services in preparing thin or polished sections and finely ground surfaces. It is more convenient to prepare specimens in house, and their prompt availability overrides their probably greater cost.

6.3 X-ray diffraction, X-ray emission, differential thermal analysis, thermogravimetric analysis, analytical chemistry, infrared spectroscopy, scanning electron microscopy, energy or wavelength dispersive analysis, and other techniques may be very useful in obtaining quick and definite answers to relevant questions where microscopy will not do so. Some undesirable constituents of concrete, some hydration products of cement, and some reaction products useful in defining the effects of different exposures, and many contaminating materials may not be identified unless techniques that supplement light microscopy are used. (**18, 19**). The uranyl-acetate technique given in Annex A1 can be helpful in locating sites where alkali-silica gel may be present.

7. Samples

7.1 The minimum size of sample should amount to at least one core, preferably 6 in. (152 mm) in diameter and 1 ft (305 mm) long for each mixture or condition or category of concrete, except that in the case of pavement the full depth of pavement shall be sampled with a 4 or 6-in. (102 or 152-mm) core. Broken fragments of concrete are usually of doubtful use in petrographic examination, because the damage to the concrete cannot be clearly identified as a function of the sampling technique or representative of the real condition of the concrete. Cores smaller in diameter than 6 in. can be used if the aggregate is small enough; in deteriorated concrete, core recovery is much poorer with 2⅛-in. (54-mm) diameter core than with 6-in. diameter core. While it is desirable in examination and testing to have a core three times the maximum size of aggregate, this circumstance is a rare occurrence when concrete with aggregate larger than 2 in. is sampled, because of the cost of large bits and the problems of handling large cores.

7.2 *Samples from Constructions*—The most useful samples for petrographic examination of concrete from constructions are diamond-drilled cores with a diameter at least twice (and preferably three times) the maximum size of the coarse aggregate in the concrete. If 6-in. (152-mm) aggregate is used, a core at least 10 in. (250 mm) in diameter is desirable; usually a 6-in. diameter core is the largest provided.

7.2.1 The location and orientation of all cores, including cores or core lengths not sent to the laboratory, should be clearly shown; and each core should be properly labeled. For

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vertically drilled cores, the elevation or depth at top and bottom of each section should be shown, and core loss and fractures antedating the drilling should be marked. For cores taken horizontally or obliquely, the direction of the vertical plane and the tops and bottoms should be marked. A field log should be provided.

7.2.2 Broken pieces of concrete from extremely deteriorated structures or pieces removed while preparing for repair work are sometimes used for petrographic examination. The samples will be more useful if their original locations in the structure are clearly described or indicated in a sketch or photographs.

7.2.3 The information provided with the samples should include:

7.2.3.1 The location and original orientation of each specimen (see Practice C 823),

7.2.3.2 The mixture proportions of the concrete or concretes,

7.2.3.3 Sources of concrete-making materials and results of tests of samples thereof,

7.2.3.4 Description of mixing, placing, consolidation, and curing methods,

7.2.3.5 Age of the structure, or in case of a structure that required several years to complete, dates of placement of the concrete sampled,

7.2.3.6 Conditions of operation and service exposure,

7.2.3.7 The reason for and objectives of the examination,

7.2.3.8 Symptoms believed to indicate distress or deterioration, and

7.2.3.9 Results of field tests such as measurements of pulse velocity (Test Method C 215), rebound hammer numbers (Test Method C 805) or probe readings (Test Method C 803/C 803M).

7.3 *Samples from Test Specimens from Natural Exposures, Concrete Products, and Laboratory Specimens*:

7.3.1 Information provided should include: materials used, mixture proportions, curing, age of concrete when placed in service or test, orientation in exposure, present age, condition surveys during exposure, characteristics of the natural or laboratory exposure, and method of manufacture of concrete products. Large concrete products may be sampled like constructions; smaller ones may be represented by one or more showing the range of condition from service or fabrication or both.

7.3.2 The exposure of laboratory specimens should be described with test results, age at test and available test results on the aggregates, hydraulic binders, and admixtures used. This information should accompany test specimens from natural exposures and concrete products or samples therefrom, if available.

8. Examination of Samples

8.1 *Choice of Procedures*—Specific techniques and procedures employed in examination of a sample depend on the purpose of the examination and the nature of the sample. Procedures to be used should be chosen after the questions that the examination is intended to answer have been clearly formulated. The procedures should be chosen to answer those questions as unequivocally and as economically as possible. The details that need to be resolved will be dictated by the objectives of the examination and will vary for different situations. Consequently, the selection and location of specimens from the samples submitted for examination should be guided by the objectives of the study. Test Method C 457 should be referred to for those relevant subjects not described here.

8.2 *Visual Examination and Outline of Additional Examination*—A petrographic examination of concrete, mortar, or cement paste should begin with a review of all the available information about the specimen or specimens, followed by a visual examination of each sample. An outline of information that can be obtained is given in Table 1. That study should be followed by an examination using a stereomicroscope (see Table 2 and the section on Visual and Stereomicroscopic Examination). In some cases, further study is unnecessary, and a report can be prepared. In other cases, specimens are chosen during the visual and stereomicroscope examination for further processing and additional stereomicroscope study, more detailed examination using the petrographic or metallographic microscopes or by X-ray diffraction and other instrumental methods, and for other chemical or physical tests. Methods for specimen preparation are outlined in the Specimen Preparation Section. Tables 2-4 summarize characteristics of concrete conveniently observed with stereomicroscopic, petrographic, and metallographic microscopes. Examination using a stereomicroscope is outlined in the Visual and Stereomicroscopic Examination Section. Examination of fire-damaged concrete is outlined in Table 3; using a polarizing microscope in the Polarizing Microscope Examination Section and Table 4; and using a metallographic microscope in the Metallographic Microscope Examination Section. During each kind of study, the petrographer should note specific examinations to be made in detail, later, and may recognize the need to reexamine specimens. Observations possible using different kinds of microscopes are shown in Table 5; properties of some relevant compounds are listed in Table 6. A broad overview of possible locations where alkali-silica gel may be present can be obtained using the uranyl-acetate method outlined in Annex A1.

8.3 *Photography*[6]—It is frequently desirable to maintain a photographic record as illustrations for the report and for future reference. Photographs which may be useful include:

8.3.1 Overlapping close-ups of a core or cores, laid out in sequence, including a dimensional scale. It is convenient to use a view camera at a constant distance using the same lighting in all photographs.

8.3.2 Photographs and photomacrographs of features of interest on a core surface, a ground surface, or an old or new crack surface, at magnifications of 0.7× to 3× are particularly useful if the specimen will be destroyed during subsequent studies. A camera equipped with a long extension bellows and lenses of focal length from 6.5 to 2.9 in. (165 to 74 mm), and a ground-glass back, is desirable.

8.3.3 Photomacrographs at magnifications of at least 3× to 10×, and sometimes at higher magnifications, may be used to illustrate reaction products or growths on the specimen or significant crack patterns. Black and white photographs such as

[6] *Annual Book of ASTM Standards*, Vol 04.02.

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4 by 5 in. (102 by 127 mm) taken at 1× magnification on fine-grained film with a long gray scale, convey a great deal of information and may be more useful than a photograph taken at a higher magnification on smaller format. As a general guide, the subject should be illuminated by oblique lighting at a low angle if the relief on the subject surface is low, and at a higher angle if the relief is high. The object of the oblique illumination is to reveal detail and contrast without obscuring features by long shadows. Details can also be enhanced by the use of colored filters such as Wratten G or other yellow filters. Cross lighting from two sides is sometimes successful in revealing detail and obliterating confusing shadows.

8.3.4 Photomicrographs of thin sections, immersion mounts, and polished sections at magnifications from 2× to an upper limit appropriate to the subject and dependent on the quality of the equipment and the skill of the photographer may be used to illustrate textures, compounds, and crack patterns.

8.3.5 The range of photographic techniques used should be adequate to provide a choice useful for illustrations for the report and for the record. The subjects may usually be selected during the visual and stereomicroscopic examinations.

9. Specimen Preparation

9.1 *Preparation for Visual and Stereomicroscope Examination*:

9.1.1 Diamond-drilled cores, formed or finished surfaces, freshly broken surfaces, or old crack surfaces should be examined in the condition received. It is sometimes helpful to have drilled surfaces and formed and finished surfaces wetted to increase contrast.

9.1.2 Diamond saw cuts should be oriented with relation to significant features of the concrete, either normal to the bedding directions in conventional concrete, or normal to a formed or finished surface, or to a crack or crack system, in order to reveal the structure and fabric of the concrete and the extent of alteration outward from the crack.

9.1.3 It is useful to prepare at least one sawed surface by grinding it with progressively finer abrasives (as described in Test Method C 457) until a smooth matte finish is achieved and to select areas on the matching opposing surface for preparation of thin sections and specimens for optical, chemical, X-ray diffraction, or other examinations.

9.1.4 Specimens obtained by diamond drilling are not ordinarily damaged in the process; however, weak concrete damaged by chemical attack, an alkali - aggregate reaction, freezing and thawing, or several of these, will give poor core recovery with many fractures if it is drilled with a 2⅛-in. or 54-mm bit and barrel while it will give essentially complete recovery if drilled with a 6-in. (152-mm) diameter bit and barrel. This difference is particularly important in petrographic examinations made during condition surveys of old structures. Weakened concrete may also break during sawing. The removal and preparation of specimens for laboratory studies usually involves the application of force and sometimes the application of heat to the specimen.

9.1.5 The effects of force can be minimized during specimen preparation by using thicker slices and making only one cut parallel to the long axis of a core section. Fractured or fragile concrete can be supported by partially or completely encasing it in plaster, epoxy resin, or other reinforcing media before sawing.

9.1.6 Heat used while impregnating concrete with thermoplastic wax or resin will cause cracking if the concrete is heated while it is wet, and will alter the optical properties of some compounds, such as ettringite. Artifacts may therefore be produced and compound identification made difficult. These artifacts may be mistaken as original features. Care must therefore be used in evaluating a particular feature and indexing it as original in the specimen, or produced during the removal of the specimen from the structure or during laboratory processing.

9.1.7 When alkali - carbonate reactions are suspected and rims around crushed carbonate aggregate are seen, it is useful to etch a sawed or ground surface in 6 *N* or weaker hydrochloric acid to see if peripheral rims on coarse aggregate particles are more or less susceptible to etching than the interior of the particle. Since etching destroys the surface, this step should not be taken until all other examinations of the surface have been completed. Etching the ground surface for 30 s in 10 % hydrochloric acid is an appropriate procedure.

9.2 *Preparation of Immersion Mounts*— Immersion mount samples are prepared for examinations using the petrographic microscope. This type of examination provides versatility because materials can be immersed in liquids having different refractive indices. Detailed knowledge of the use of the capabilities of the petrographic microscope is required to properly examine immersion mounts.

9.2.1 Immersion mounts are useful for observing and identifying a variety of aggregate components, residual and relict portland cement particles, the calcium hydroxide component of cement hydration, components of blended cements, mineral admixtures, components resulting from chemical alteration of cementitious components and of aggregates, secondary deposits from exposure of concrete to a variety of chemicals, and for confirming identifications by other methods.

9.2.2 Powders and fine chips for immersion mounts can be prepared by: (1) pulverization of samples from which specimens may be taken; (2) using a sharply pointed probe for removing specimens from small areas of aggregate and paste, material in aggregate sockets, voids, and cracks; and (3) scrapings from fracture and formed surfaces.

9.2.3 In immersion mounts, individual fragments are usually in random orientation so that the identification of principal refractive indices of a material can be determined in addition to data about other optical characteristics. Portions of powdered material, chips, or scraping are placed on a glass slide and immersed in an immersion liquid of known refractive index. A cover slip is used on top of the preparation. Based upon refractive indices and other optical properties, specific identifications can be made of unknown compounds.

9.2.4 Refractive index liquids available provide refractive index values to at least three decimal places (see 5.3.12). Liquids accurate to two decimal places can be used if the petrographer is knowledgeable about Becke line colors or other techniques.

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9.3 *Preparation of Thin Sections*—The detailed description of thin-section preparation is beyond the scope of this practice. There are many laboratories that provide this service if in-house facilities are not available. The procedure includes slicing the concrete into 1⁄16-in. (2-mm) thick wafers if the concrete is strong and thicker slices if it is not. It may be necessary to impregnate the concrete with a resin before slicing to prevent disintegration. Diluted flexibilized epoxy resins or thermoplastic resins have been used successfully. The thin concrete slices are then mounted on glass slides with either flexibilized epoxy, Canada balsam, or Lakeside 70, and ground on laps using progressively finer abrasive until a thickness of 30 µm or less is obtained; thickness not greater than 20 µm is required for detailed examination of the paste in transmitted light. It is usually necessary to check the thickness of the section by the use of birefringent colors of common minerals in the aggregate, such as quartz or feldspar, during the final grinding stages. A cover glass is placed on the cleaned, prepared section and secured with Canada balsam or other media.

9.3.1 Semiautomatic thin-section making machines are available which prepare the original surface of the blank for mounting, trim the excess thickness of the blank after mounting, and grind the section to 50 to 100 µm, leaving little thickness to be removed by hand lapping.

9.4 *Preparation for Examination with the Metallographic Microscope*:

9.4.1 The preparation of specimens for examination with the metallographic microscope is described in Practice E 3.

9.4.2 The procedures described here are intended as guides only. Methods should be used that are appropriate to the varieties of microscopical techniques to be employed, and to specimen condition and composition. It is impossible to provide instructions to suit every possible situation.

9.5 The preparation of the specimens for the uranyl-acetate method given in Annex A1 is provided therein.

10. Visual and Stereomicroscope Examination

10.1 If there is more than one specimen, arrange them in logical order to represent: position in the structure and differences in materials, proportions, and exposure, or combinations of these. Photographs and sketches of significant features should be made before specimens are altered. Tables 1 and 2 list some features to be observed during visual and stereomicroscopic examination.

10.2 *Concrete from Constructions* (Core Log):

10.2.1 Fit fragmented cores together and determine if any pieces are missing. Measure cores to verify field data and prepare a diagramatic log of each core, if necessary. The log should be made to a scale to show relevant features. The log may be used to show fresh and old fractures, reacted particles, reaction products, changes in size or type of coarse and fine aggregates, distribution of coarse aggregate, honeycomb, segregation of components, cold joints or lift or course boundaries, location and direction of steel or other embedded items, changes in color of paste, and other significant features. Notes should be taken and suitably referenced in the log. If cores have been suitably packed so as to preserve the moisture content as drilled (which may or may not be the actual in-place moisture content), specimens should be carefully handled to preserve the moisture content and avoid breakage. Tests that may be made of specimens in the as-received moisture condition include compressive strength, static or dynamic modulus of elasticity, air content by high-pressure meter, permeability, and freezing and thawing.

10.2.2 During the visual examination, general comparison of cores representing different conditions, materials, and extent and nature of deterioration should be made and recorded. The specimens should be sorted into comparable groups based on condition or location of regions designated for more detailed examination. In some cases, during the visual examination or the stereomicroscope examination, one or more specimens from each group may be selected for more detailed studies. If a reduced number of specimens is to be selected for detailed examination, the selection should be made after careful visual and stereomicroscope examinations have been used to define one or more factors that characterize each group.

10.3 *Specimens from Natural Exposures*— These specimens should be laid out in logical order, either by materials, proportions, age, or combinations of these, and compared with respect to composition and condition. Significant features for more detailed examination should be marked and noted. Table 3 shows features of fire-damaged concrete.

10.4 *Concrete Products*:

10.4.1 The samples may consist of complete units when they have relatively small dimensions (such as tile, block, or brick), or portions removed from units by coring or sawing. The samples should be organized and oriented in a manner appropriate to the objectives of the examination. So, for example, portions taken from a single product unit should be grouped together, and each sample should be described by visual observation and measurement of dimensions in relation to markings or labels. The following information should be recorded or clearly marked on the samples: location in the product unit (top, side, end, interior, etc.); vertical and horizontal directions as cast or molded; outer and inner ends; position in the product unit during curing period; position of the sample relative to highly stressed portions of the concrete adjacent to tendon anchorages; and location in the unit as put in place in construction, etc. Sketches or photographs of pertinent features should be recorded to show such conditions as cracking, staining, chemical deposits, presence of foreign matter, segregation, surface defects, and the like.

10.4.2 Procedures such as those set forth in 10.1 and 10.2 are applicable in the examination of concrete products. The investigation may be directed toward features resulting from the specific manufacturing operations involved, such as mixing, molding, demolding, curing, and any prestressing procedures. For example, lack of uniformity might originate in incomplete mixing, improper consolidation during molding, or incomplete or nonuniform curing. Surface defects and poor appearance may result from improper application of form-release agents, possibly giving rise to inhibition of hydration of the cement in a near-surface zone. Features like these can be detected and described by visual and microscopical examination of formed or molded surfaces, sawed and lapped surfaces, or fracture surfaces across the sample.

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10.5 *Laboratory Specimens*—These should be laid out in logical order and compared with respect to composition and condition, and to features influenced or expected to be influenced by the test process.

10.6 *Stereomicroscope Examination*—The stereomicroscope examination reveals additional details at magnifications from 5× to 150× (see Tables 1 and 2). The stereomicroscope examination and visual examination are often carried on alternately. Examinations at low magnifications reveal characteristics of formed, finished, deteriorated, broken, sawed, or ground surfaces. Old cracks may be opened and their surfaces examined to detect reaction products and secondary alteration. Old cracks are frequently of different color than the mass of the concrete, and appear blurred by secondary deposits.

10.6.1 Freshly broken surfaces may follow structural weaknesses and reveal significant features that have not been masked by secondary alteration.

10.6.2 Sawed and ground surfaces are examined to detect fine cracks and trace networks of cracks that are not perceptible on drilled or sawed surfaces, to examine filling and partial filling in voids and cracks, and to detect rims on aggregate particles that may indicate chemical reactions between the cement and the aggregate. Rims on gravel or natural sand should be presumed to be a result of weathering in the deposit, unless samples of aggregates used are available and show that rims were not present before the aggregate was used in the concrete. Rims produced in the concrete on particles of sand and gravel are absent or relatively thin and faint at locations where the particle is in contact with an air void. Rims produced by weathering may mask rims produced by alkali - silica reaction. Rimmed crushed stone in concrete usually indicates alteration in the concrete, as alkali - silica reaction or alkali - carbonate reaction (**12, 20, 21**). Pale rims in mortar bordering coarse aggregate (**7, 19**) and pale areas in the mortar may be gel-soaked paste (**6**) or highly carbonated paste adjoining carbonate aggregate that has undergone an alkali - carbonate reaction. The method in Annex A1 is helpful in locating deposits of alkali-silica gel.

10.6.3 Deposits in old cracks may include calcite or ettringite or calcium hydroxide, or combinations of these compounds, or more unusual crystalline substances, but sometimes include sand, silt, clay, and freshwater or saltwater organisms. Such organisms may provide evidence that a part of a structure that is not ordinarily submerged has been submerged.

10.6.4 Quantitative determination of constituents of concrete can be made by microscopical point-count or linear-traverse procedures in general accord with the requirements of Test Method C 457. A total analysis may include the proportional amounts of coarse aggregate, fine aggregate, cementitious matrix, and air voids. The differentiation of coarse and fine aggregate is not accurate unless the two fractions are distinguishable lithologically, since the maximum dimension of the particles usually is not intersected by the prepared surface. Likewise, the proportion of individual rock types can be determined quantitatively by these methods, such as, the content of unsound or reactive constituents in the coarse or fine aggregate or both; proportions of lightweight and normal weight aggregate; and the abundance of granular contaminating substances.

11. Petrographic Microscope Examination

11.1 *Characteristics of Good Concrete Thin Sections*—Features that characterize good, thin sections of concrete or mortar are as follows: the mounted lower surface is free of abrasive and has been ground to a smooth matte finish ordinarily obtained by finishing the surface with optical alumina or equivalent; the lower surface of the blank is entire; air voids have complete peripheries; there is a sharp boundary between the void and surrounding mortar; deposits in voids are preserved; and aggregate that has been observed under the stereomicroscope to be entire when the blank was selected has remained entire and microfractures have not been produced in micro fsectioning. It is very difficult to avoid production of micro fsectioning when the aggregate is principally quartzite and quartz, if it is desired to reduce the section to a thickness of 30 µm so that the brightest birefringence color of quartz is first-order white. Some cracks will be formed and some loss of paste which is softer than quartz aggregate will occur.

11.1.1 The desirable thickness of the thin sections ranges from about 40 to 20 µm. Thinner sections may be required for detailed examination of the cement paste matrix. It is sometimes necessary to give up normal thickness and use a thicker section to preserve fragile deposits in voids such as alkali - silica gel, ettringite, calcium hydroxide, calcite, aragonite, or thaumasite. When it is desired to preserve the contacts between mortar and coarse aggregate, it may be preferable to leave the section thicker than normal with the highest birefringence color of the quartz pale first-order yellow. In normal concrete, the material bordering the aggregate consists of amorphous cement gel, with calcium hydroxide crystals quite evenly distributed but with slight concentrations along the undersides of coarse aggregate and fine aggregate, if the section is cut parallel to the placement direction. In cases of alkali - silica reaction, there is usually a zone depleted in or free of calcium hydroxide surrounding reacted aggregate particles; sometimes gel is present surrounding the aggregate or soaking the paste so that it is completely dark with crossed polars and brown grading hazily to more normal paste in plane polarized light. It is fairly easy to recognize gel-soaked paste; it is possible with experience to recognize depleted calcium hydroxide around a reacted aggregate particle, so long as the fine aggregate or any crusher dust present does not contain much colorless mica. Thin flakes of muscovite can be confused with thin tablets of calcium hydroxide when both are viewed on edge; they can be distinguished if the higher index of the mica is observed.

11.1.2 It is sometimes preferable to lose part of the section or crack the quartz in order to distinguish among quartz (birefringence 0.009), calcium hydroxide (birefringence 0.027), and calcite (birefringence 0.172). When the three materials occur together, the quartz particles will be shaped like sand grains or rock fragments, while calcium hydroxide will be present either as tablets tangential to aggregate or as poikilitic crystals in the paste enclosing residual cement grains or areas of gel. The birefringence of calcium hydroxide is three times that of quartz; the birefringence of calcite is 6.4 times

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that of calcium hydroxide; and birefringence of aragonite is 5.7 times that of calcium hydroxide. While aragonite is fairly uncommon in concrete, calcite is common as a product of carbonation and as an ingredient of aggregate. At normal thickness of 30 µm, the highest birefringence of calcium hydroxide viewed parallel to the cleavage is bright first-order yellow with an occasional orange or first-order red area. Calcite in the same section has high-order white birefringence except in very minute grains in which it is very thin, approximately rhombic in shape, and the birefringence color is first-order white. The birefringence relations discussed in this paragraph are the basis that makes possible much of the interpretation of concrete thin sections.

11.2 *Choice of Areas for Thin Sections of Concrete*—Areas from which thin sections are to be prepared usually should be chosen after examining the sawed or sawed and ground surface with a stereomicroscope. Selection of the area may depend on the features to which the examination is directed, or the choice may be affected in the case of highly deteriorated concrete by the desire to choose a volume strong enough to endure sectioning even after impregnation. In that second case, an area of mortar with coarse aggregate at the corners or along the sides may be the successful choice. If it is desired to examine the aggregate to compare it with aggregate of a known source to establish whether the two probably came from the same deposit or quarry, coarse aggregate should be chosen in sufficient number to cover the range of varieties present and their physical condition. If the concrete has been subjected to alkali - silica or alkali - carbonate reactions, areas selected for sectioning should include coarse aggregate with cracks inside the periphery but surrounding the center and cracks in the middle of the particle which narrow toward the border which may or may not contain gel in the case of alkali - silica reaction. Reaction-rimmed particles may be chosen for sectioning in the case of either kind of reaction, but it is ordinarily a futile effort; the rims distinct to the naked eye or the low power of the stereomicroscope may not be visible in thin section.

11.2.1 Features visible in the examination of thin sections of concrete are shown in Table 4.

12. Paste Features

12.1 Many physical and mineralogical properties of the paste are influenced, or are in part governed by, *w/c* and *w/cm*, extent of curing, fineness and composition of the portland cement and other cementitious materials, pozzolans, mineral and chemical admixtures, and fine material from aggregates. Among these properties, with respect to the evaluation of unaltered paste, are: (a) color, hardness density, and porosity **(22, 23, 24, 25)**; (b) texture of fracture surfaces **(22, 23)**; (c) size, abundance, color, and mineralogy of non-pozzolanic, and residual and relict pozzolanic and cementitious materials **(22, 23, 24, 26)**; (d) size, abundance, and morphology of the calcium hydroxide component of cement hydration as may be affected by pozzolanic materials **(22, 23, 26)**; (e) degree of hydration of cementitious materials **(22, 23, 24, 25, 26, 27, 28)**; (f) color intensity of dye-impregnated pastes **(24,26)**; (g) nature of aggregate-paste bond; (h) rate of absorption of water droplets **(24)**; (i) depth of carbonation **(23)**; (j) magnitude of bleeding and segregation of concrete-making components **(23, 27)**; and (k) paste micro hardness **(25)**.

12.2 The *w/c* and *w/cm* and their uniform distribution throughout concrete may be affected by a number of influences that include: (a) the amount of original water, free water introduced by aggregates, and tempering and retempering water; (b) absorption of water by aggregates; (c) efficiency of mixing batch water and free water from aggregates; (d) bleeding and vibration after concrete placement; and (e) water lost due to evaporation and to absorption by the subbase.

12.3 Because of the variable nature of pastes, age of pastes, and exposure to a variety of external influences, there is no generally accepted standard procedure that employs microscopical methods for determining the *w/c* or *w/cm* of hardened concrete. A procedure for estimating *w/c* and *w/cm* **(29)** was critically evaluated in a SHRP study, but was not recommended by SHRP for inclusion in Practice C 856.

13. Report

13.1 The report of the examination should include the following:

13.1.1 Location and orientation of the samples in the construction or products or type of specimen,

13.1.2 History of the samples insofar as is available,

13.1.3 Physical and chemical tests made on the samples, with their results,

13.1.4 Description of the samples and a report on mixture proportions, if available or if estimated, workmanship, construction practice, and original quality of the concrete in the constructions, insofar as such information is available, and

13.1.5 Interpretation, insofar as possible, of the nature of the materials and the chemical and physical events that have led to the success or distress of the concrete.

14. Keywords

14.1 aggregates; air voids; alkali-silica reaction; analysis; deterioration; examination; fire effects; hardened concrete; microscopy; paste; petrographic; secondary deposits

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ANNEX

(Mandatory Information)

A1. A TECHNIQUE FOR DETECTING ALKALI-SILICA GEL SUBJECT TO CONFIRMATION BY OTHER METHODS

A1.1 Scope

A1.1.1 This technique has been used for detecting alkali-silica gel resulting from reactions of forms of silica in aggregates with alkalies in portland-cement paste. The technique involves treating the surface of conditioned concrete with a solution of uranyl-acetate and observing the treated surface exposed to short-wave ultraviolet light.

A1.1.2 This technique is one of a number of procedures that may be used to identify if alkali-silica reactions have occurred in hardened concrete. The test is ancillary to more definitive petrographic examinations and physical tests for determining concrete expansion. The petrographic examinations include identification of alkali-silica gel and the reactive aggregate component(s), as may be supplemented by electron microscopy and ancillary elemental probe analysis. The physical tests may include length change tests of prisms from the concrete.

A1.1.3 Fly ash, silica fume, and other materials that possess pozzolanic properties can react and produce secondary products similar to the gel produced by alkali-silica reaction (ASR). If these products are uniformly distributed, their effect is to create a uniform background on which the more localized and concentrated alkali-silica gel usually can be distinguished. Opal-containing materials and possibly other components of rocks, however, will also be detected. Localized concentrations of secondary ettringite have also been reported to fluoresce. Secondary ettringite is widespread as a component of concrete affected by many processes.

A1.2 Cautions

A1.2.1 Uranyl-acetate is a hazardous material that requires special handling and disposition. Ultraviolet light is hazardous to eyes and skin. Annex A1 does not address the safety problems of handling, use, and disposition of uranyl-acetate and uranyl-acetate-treated concrete. Annex A1 does not address the use and all cautions to be used regarding ultraviolet light applications and exposure to the eyes and skin.

A1.2.2 Before using uranyl-acetate and ultraviolet light involved in this technique, it is the responsibility of the user to establish adequate safety, health, and disposition of materials practices and procedures for handling uranyl-acetate and ultraviolet radiation. It is also the responsibility of the user to conform to all local, state, and federal regulatory requirements.

A1.2.3 Protective clothing, including polyethylene gloves, laboratory coat, and other clothing as may be needed should be used when handling uranyl-acetate and other chemicals.

A1.2.4 Short-wave ultraviolet light can be harmful to the eyes and skin. Ultraviolet-filtering goggles or face shields that will absorb the ultraviolet radiation should be used.

A1.2.5 Uranyl-acetate is classed by the United States Government as a hazardous material requiring special handling and disposition. Handling, storage, and disposition of the uranyl-acetate solution and materials to which it is applied and contacts must be in conformance to applicable regulations.

A1.3 Qualification

A1.3.1 This technique can be used by an adequately trained technician.

A1.4 Apparatus, Reagents, and Materials

A1.4.1 *Specimen Conditioning Apparatus*:

A1.4.1.1 *Plastic Beaker*— 500-mL capacity or larger,

A1.4.1.2 *Plastic Squeeze Bottle (for Water)*—Nominal 250-mL capacity,

A1.4.1.3 *Disposable Polyethylene Gloves*,

A1.4.1.4 *Protective Clothing* (for example, laboratory coat),

A1.4.1.5 *Absorbent Paper Towels*, and

A1.4.1.6 *Enclosed Space for Applying the Reagent*—A fume hood, glove box, or disposable glove bags have been found to be suitable for this purpose.

A1.4.2 *Specimen Treatment Apparatus*:

A1.4.2.1 *Non-Atomized or Non-Misting Type Applicator Unit for Reagent* (for example, a small, hand-held squeeze bottle for applying dilute reagent solutions), and

A1.4.2.2 *Applicator for Water*—A small hand-held squeeze bottle for applying dilute solutions.

A1.4.3 *Reagent (Uranyl-Acetate Solution)*,

A1.4.3.1 *Acetic Acid Solution (1N)*,

A1.4.3.2 *Boiling Flask*— Nominal 250-mL capacity,

A1.4.3.3 *Distilled or Deionized Water*,

A1.4.3.4 *Volumetric Flask*—Nominal 100-mL capacity,

A1.4.3.5 *Polyethylene Storage Bottle with Tight Fitting Cap*—Nominal 100-mL capacity,

A1.4.3.6 *Uranyl-Acetate Powder (ACS Reagent Grade)*,

A1.4.3.7 *Balance*—Capable of weighing up to 10 g within 0.05 g, and

A1.4.3.8 *Uranyl-Acetate Solution (prepared as follows)*—Weigh 5 g of powdered uranyl-acetate. Measure 100 mL of acetic acid solution using a 100-mL volumetric flask. (**Warning**—Use proper safety precautions in handling the uranyl-acetate and the acetic acid. Transfer the measured acetic acid solution from the volumetric flask to the boiling flask. Add 5 g of powdered uranyl-acetate to the boiling flask. Warm the mixture over a low flame until the powder is dissolved. Do not bring the mixture to a rolling boil. Remove the flask from the burner, cover, and let it cool to room temperature. Store the cooled solution at room temperature in a tightly capped polyethylene storage bottle. The reagent, when stored as described, will keep for at least one year.)

A1.4.4 *Short-Wave (254-nm) Ultraviolet (UV) Lamp*,

A1.4.5 *Viewing Cabinet or a Dark Room*, and

A1.4.6 *Goggles*—for shielding short-wave ultraviolet light.

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A1.5 Specimens

A1.5.1 Samples to be evaluated can be of any size or shape. The surface area for testing should have a nominal area of 155 cm^2 (24 $in.^2$) or sufficiently large to be representative of the concrete. The size will be dictated in part by the maximum size of the aggregate. The method is applicable to field and laboratory-prepared samples. The latter includes samples tested using Test Methods C 227, C 342, C 441, and C 1260.

A1.5.2 Break the specimen to expose the interior of the concrete using any suitable method, such as the splitting techniques of Test Method C 496. Immediately conduct the test on the freshly exposed surfaces.

A1.6 Conditioning and Pre-Screening Procedure

A1.6.1 *Conditioning and Pre-Screening*:

A1.6.1.1 Dampen the freshly broken specimen surface using the squeeze bottle filled with distilled or deionized water. Proceed with the test while the specimen is still damp.

A1.6.2 Pre-screen the specimen for natural fluorescence.

A1.6.2.1 Wear protective clothing including polyethylene gloves, laboratory coat, and UV-filtering goggles. Short-wave UV light can be harmful to the eyes and skin. Normal eyeglasses or plastic goggles or face shield will absorb the harmful rays.

A1.6.2.2 If a viewing cabinet is being used, place the UV lamp in the proper place on the viewing cabinet. Place the damp specimen inside the viewing cabinet. If a darkened room is being used, place the damp specimen on the table and turn off the lights.

A1.6.2.3 Turn on the short-wave UV light in the viewing cabinet or the darkened room, and shine it on the damp specimen. Use UV-filtering goggles and observe and note for future comparison whether any of the aggregates or other components fluoresce. Non-fluorescent aggregates will appear dark, while cement paste and naturally fluorescent aggregates, such as opal and some slags, will fluoresce mildly. Note the location and nature of any fluorescence.

A1.7 Uranyl-Acetate Treatment Procedure:

A1.7.1 Wear protective clothing including polyethylene gloves, laboratory coat, and UV filtering goggles.

A1.7.2 The test should be conducted only on freshly fractured interior surfaces. If the interior surface of the specimen is not damp, dampen it using the squeeze bottle filled with distilled or deionized water.

A1.7.3 Fill the squeeze bottle to about half its capacity with the prepared uranyl-acetate solution.

A1.7.4 Line the bottom of the glove box, glove bag, or fume hood with absorbent paper towels. Place the squeeze bottles containing the distilled or deionized water and reagent, the 500-mL plastic beaker, and the dampened specimen inside the glove box, glove bag, or fume hood.

A1.7.5 Place the specimen in a horizontal position on a paper towel. Apply the uranyl-acetate solution to the wet interior surface of the specimen. Direct the squeeze bottle nozzle on the specimen surface at all times. The nozzle should be kept approximately 25 mm (1 in.) away from the surface. The bottle pressure should be kept to a minimum to avoid misting and rebound from the specimen surface.

A1.7.6 Allow the uranyl-acetate to absorb on the interior surface of the concrete for 1 min.

A1.7.7 After 1 min, hold the specimen in a vertical position over the 500-mL plastic beaker and wash the treated surface three times with distilled or deionized water to remove excess uranyl-acetate. Collect the wash water from the specimen in the plastic beaker.

A1.7.8 Remove the specimen from the glove box, glove bag, or fume hood, and place it on a paper towel. Proceed with observation of the specimen immediately after the uranyl-acetate treatment is completed.

A1.8 Ultraviolet Exposure of Treated Surface

A1.8.1 If a viewing cabinet is being used, place the UV lamp at the proper place in the viewing cabinet. Line the bottom surface of the viewing cabinet with paper towels. If a dark room is being used, line an area of a table top with paper towels.

A1.8.2 Dampen the specimen again using the squeeze bottle filled with distilled or deionized water. Place the specimen inside the viewing cabinet on the paper towel. If a dark room is being used, place the wet specimen on the paper towel on the table top in the dark room and turn off the lights.

A1.8.3 Shine the UV light on the treated surface. Do not view, and do not allow anyone to view the UV light without eye protection.

A1.9 Identification of Alkali-Silica Gel

A1.9.1 Alkali-silica gel will fluoresce bright greenish-yellow, and usually occurs in and around aggregate particles, in voids, and in cracks. It has been reported that ettringite may similarly fluoresce.

A1.9.2 Carbonated areas of concrete also may fluoresce. The fluorescence due to carbonation products, however, is usually uniform and normally present along concrete surfaces exposed to the atmosphere. Carbonation may also be present where there is extensive deterioration or cracks, or both, which allow atmospheric carbon dioxide into the interior of the specimen.

A1.9.3 Some fly ash, silica fume, slag, and natural pozzolans can react and form reaction products that fluoresce. Well dispersed fly ash and silica fume and fine ground slag and natural pozzolans, however, cause only an increase in the generally uniform background fluorescence intensity of the paste. If these materials are not well dispersed or are clumped together, the fluorescence will be observed as discrete fine areas. The size of these areas is normally very small and usually is distinguishable from the bright fluorescence of gel derived from the coarse and fine aggregates.

A1.9.4 Identification of the presence of alkali-silica gel using this technique must be confirmed by other petrographic techniques, such as microscopical examinations of thin sections or powder mounts, or both.

A1.9.5 Literature on the development and use of this technique is given in Refs **(31-37)**.

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REFERENCES

(**1**) Mather, K., "Petrographic Examination of Hardened Concrete in Significance of Tests and Properties of Concrete-Making Materials," *Symposium on Significance of Tests and Properties of Concrete and Concrete Making Materials*, ASTM *169 A*, ASTM International, 1966, pp. 125–143.

(**2**) Hansen, W. C., "Anhydrous Minerals and Organic Materials as Sources of Distress in Concrete," *Highway Research Record No. 43*, Highway Research Board, HRBRA, 1963, pp. 1–7.

(**3**) Mielenz, R. C., "Reactions of Aggregates Involving Solubility, Oxidation, Sulfates, or Sulfides," *Highway Research Record No. 43*, Highway Research Board, HRBRA, 1963, pp. 8–18.

(**4**) Smith, Peter, "Investigation and Repair of Damage to Concrete Caused by Formwork and Falsework Fire," *ACI Journal*, JACIA, No. 11, Nov 1963; *ACI Proceedings*, PACIA, Vol 60, 1963, pp. 1535–1566.

(**5**) Green, J. Keith, "Some Aids to the Assessment of Fire Damage," *Concrete*, COCTA, Vol 10, No. 1, January 1976, pp. 14–17.

(**6**) Idorn, G. M., *Durability of Concrete Structures in Denmark*, Technical University of Denmark, Copenhagen, January 1967, p. 208.

(**7**) Mielenz, R. C., "Petrography Applied to Portland Cement Concrete," *Reviews in Engineering Geology*, edited by T. Fluhr and R. F. Legget, Geological Society of America, GAEGA, Vol I, 1962, pp. 1–38.

(**8**) Taylor, H. F. W., "Crystal Structures of Some Double Hydroxide Minerals," *Mineralogical Magazine*, MNLMB, Vol 39, No. 304, December 1973, pp. 377–389.

(**9**) Idorn, G. M., "Concrete Deterioration of a Foundation," *Acta Polytechnia* (Copenhagen, Denmark), APOBA, No. 4, 1957, pp. 5–48.

(**10**) Idorn, G. M., "Disintegration of Field Concrete," Danish National Institute of Building Research and Academy of Technical Science, Commission on Alkali Reactions in Concrete, *Progress Report N1*, DNBRA, 1956, 39 pp.

(**11**) Hutton, C. O., "Two Unusual Occurrences of Paraluminite," *New Zealand Journal of Science and Technology*, NZTBA, Vol 26B, 1945, pp. 242–244.

(**12**) McConnell, D., Mielenz, R. C., Holland, W. Y., and Greene, K. T., "Cement-Aggregate Reaction in Concrete," *Journal of the American Concrete Institute*, JACIA, *Proceedings*, Vol 44, October 1947, pp. 93–128.

(**13**) Mather, B., "Cracking of Concrete in the Tuscaloosa Lock," *Highway Research Board Proceedings*, HIRPA, Vol 51, 1951, pp. 218–233.

(**14**) Erlin, Bernard, and Stark, David C.," Identification and Occurrence of Thaumasite in Concrete," *Highway Research Record No. 113*, HRBRA, 1966, pp. 108–113.

(**15**) Winchell, A. N., and Winchell, H., *The Microscopical Characters of Artificial Inorganic Solid Substances*, Academic Press, New York and London, 1964.

(**16**) Lea, F. M., *The Chemistry of Cement and Concrete*, 3d ed., Edward Arnold Ltd., London, England, pp. XIV and 727.

(**17**) Lerch, W., Ashton, F. W., and Bogue, R. H., "The Sulfoaluminates of Calcium," *National Bureau of Standards Journal of Research*, JRNBA, Vol 2, 1929, pp. 715–731.

(**18**) Erlin, Bernard, "Methods Used in Petrographic Studies of Concrete," *Analytical Techniques for Hydraulic Cements and Concrete, ASTM STP 395*, ASTM International, 1966, pp. 3–17.

(**19**) Erlin, Bernard," Analytical Techniques, Observations of the Performance of Concrete in Service," *Highway Research Board Special Report 106*, Highway Research Board, HRBRA, Publication 309-01790-4, 1970.

(**20**) Brown, L. S., "Some Observations on the Mechanics of Alkali-Aggregate Reaction," *ASTM Bulletin No. 205*, April 1955, p. 40ff.

(**21**) *Symposium on Alkali-Carbonate Rock Reactions*, *Highway Research Record No. 45*, HRBRA, Washington, 1964.

(**22**) Erlin, Bernie, "Other Viewpoints on Petrographic Reports," *Concrete Construction Magazine*, February 2000, pp. 21–27.

(**23**) Erlin, Bernard, "Water-Cement Ratio," Concrete International, *American Concrete Institute*, March 2000, pp. 7–9.

(**24**) Liu, J.J., and Kahn, M.S., "Comparison of Known and Determined Water-Cement Ratios Using Petrography," SP-191, "Water-Cement Ratio and Other Durability Parameters," *American Concrete Institute*, 2000, pp. 11–25.

(**25**) Erlin, Bernard, Campbell, R.A., "Paste Micro-Hardness—Promising Technique for Estimating Water-Cement Ratio," SP-191, "Water-Cement Ratio and Other Durability Parameters," *American Concrete Institute*, 2000, pp. 43–55.

(**26**) Jakobsen, V.H., Laugesen, P., Thaulow, N., "Determination of Water-Cement Ratio in Hardened Concrete by Optical Fluorescence Microscopy," SP-191, "Water-Cement Ratio and Other Durability Parameters," *American Concrete Institute*, 2000, pp. 27–36.

(**27**) St. John, D.A., Poole, A.W., and Sims, I., *Concrete Petrography, A Handbook of Investigative Techniques*, Arnold, 1998, pp.141–150.

(**28**) SHRP-C-339, "Concrete Microstructure: Recommended Revisions to Test Methods," Strategic Highway Research Program, National Research Council, Washington, DC 1993.

(**29**) Nordtest Method, NT Build 361, 1991: Concrete, Hardened: Water-Cement Ratio.

(**30**) Brownmiller, L. T., "The Microscopic Structure of Hydrated Portland Cement," *Journal of the American Concrete Institute*, JACIA, *Proceedings*, Vol 39, January 1943, pp. 193–210.

(**31**) Natesaiyer, K., and Hover, K. C., "In Situ Identification of ASR Products in Concrete," *Cement and Concrete Research*, Vol 18, 1988, pp. 455–463.

(**32**) Natesaiyer, K., and Hover, K. C., "Further Study of an Insitu Technique for the Identification of Alkali-Silica Reaction Products in Concrete," *Cement and Concrete Research*, Vol 19, 1989, pp. 770–778.

(**33**) Natesaiyer, K., and Hover, K. C., "Some Field Studies of the New In situ Technique for the identification of ASR Products," *Proceedings of the 8th International Conference on Alkali Aggregate Reaction*, Kyoto, Japan, 1989, pp. 555–560.

(**34**) Natesaiyer, K., Stark, D., and Hover, K. C., "Gel Fluorescence Reveals Reaction Product Traces," *Concrete International*, January 1991.

(**35**) Pflug, H. D., and Crumpton, C. E., "Analysis of Sodium and Concrete by Fluorescence Photometry," ASTM Materials and Research Standards, July 1963.

(**36**) Natesaiyer, K., "Some Applications of the Gel Fluorescence Test for Alkali-Aggregate Reaction in Concrete," *Cement and Concrete Deposits*, El Sevier Science Publishers Limited, England, 1993.

(**37**) *Strategic Highway Research Program (SHRP)*, "Handbook for the Identification of Alkali-Silica Reactivity in Highway Structures," SHRP-C/FR-91-101, National Research Council, 1991, p. 49.

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Designation: C 869 – 91 (Reapproved 2006)

Standard Specification for Foaming Agents Used in Making Preformed Foam for Cellular Concrete[1]

This standard is issued under the fixed designation C 869; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope

1.1 This specification covers foaming agents specifically formulated for making preformed foam for use in the production of cellular concrete.

1.2 The function of this specification is to provide the means for evaluating the performance of a specific foaming agent. This is accomplished by using the foaming agent in making a standard cellular concrete test batch (see Test Method C 796) from which test specimens are cast. Then, significant properties of the concrete are determined by tests and compared with the requirements of Section 3.

1.3 The values stated in inch-pound units are to be regarded as the standard.

2. Referenced Documents

2.1 *ASTM Standards:* [2]

C 796 Test Method for Foaming Agents for Use in Producing Cellular Concrete Using Preformed Foam

3. Performance Requirements

3.1 The test batch shall conform to the requirements prescribed in Table 1.

TABLE 1 Physical Requirements

Property	Requirement
Density—The density shall satisfy either of the following:	
Density after pumping (see Test Method C 796)	40 ± 3 lb/ft^3 (641 ± 48 kg/m^3)
Oven dry density[A] (see Test Method C 796)	
For Type I cement	30.4 ± 2.5 lb/ft^3 (487± 40 kg/m^3)
For Type III cement	29.3 ± 2.5 lb/ft^3 (469± 40 kg/m^3)
Compressive Strength (see Test Method C 796), min	200 psi (1.4 MPa)
Tensile Splitting Strength (see Test Method C 796), min	25 psi (0.17 MPa)
Water Absorption (see Test Method C 796), max	25 % by volume
Loss of Air During Pumping(see Test Method C 796), max[B]	4.5 % by volume

[A] For this comparison, the calculated oven-dry density of the test batch may be determined by assuming that the water of hydration is 20 % of the weight of the cement. Then the oven−dry density $= \frac{W_c + (0.2\ W_c)}{V_{batch}}$, where W_c = weight of cement; and V_{batch} = volume of batch.

For example: using the test batch specified in Test Method C 796, for Type I cement (W_c = 100 lb; W_{TW}/W_c = 0.58, where W_{TW} = total weight of water), the total weight of materials is 100 + 0.58 × 100 = 158 lb (71.67 kg). For a wet density, after pumping, of 40 lb/ft^3(641 kg/m^3), the batch volume is 158/40 = 3.95 ft $_3$(0.11185 m^3). The calculated oven dry density is then (100 + 0.2 × 100)/3.95 = 30.4 lb/ft^3 or (45.36 + 0.2 × 45.36)/0.11185 = 487 kg/m^3. Finally, the oven-dry density as determined by Test Method C 796 shall be 30.4 ± 2.5 lb/ft^3 (487 ± 40 kg/m^3).

[B] The loss of air during pumping includes air that is accidently entrapped during mixing of the concrete.

4. Test Methods

4.1 The foaming agent being tested shall be used in making the test specimens required.

4.2 For each of the properties listed in Table 1, the test procedure, the number and type of test specimens, and the method of molding, curing, and testing shall be as described in Test Method C 796.

5. Keywords

5.1 cellular concrete; foaming agents

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1.3 The values stated in inch-pound units are to be regarded as the standard.

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4. Test Methods

4.1 The foaming agent being tested shall be used in making the test specimens required.

4.2 For each of the properties listed in Table 1, the test procedure, the number and type of test specimens, and the method of molding, curing, and testing shall be as described in Test Method C 796.

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[B] The loss of air during pumping includes air that is accidently entrapped during mixing of the concrete.

4. Test Methods

4.1 The foaming agent being tested shall be used in making the test specimens required.

4.2 For each of the properties listed in Table 1, the test procedure, the number and type of test specimens, and the method of molding, curing, and testing shall be as described in Test Method C 796.

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Designation: C 873/C 873M – 04$^{\epsilon 1}$

Standard Test Method for Compressive Strength of Concrete Cylinders Cast in Place in Cylindrical Molds[1]

This standard is issued under the fixed designation C 873/C 873M; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

This standard has been approved for use by agencies of the Department of Defense.

ε[1] NOTE—The designation was changed editorially to agree with the existing values statement in the Scope in March 2008.

1. Scope*

1.1 This test method covers the determination of strength of cylindrical concrete specimens that have been molded in place using special molds attached to formwork. This test method is limited to use in slabs where the depth of concrete is from 5 to 12 in. [125 to 300 mm].

1.2 The values stated in either inch-pounds or SI units shall be regarded separately as standard. SI units are shown in brackets. The values stated may not be exact equivalents, therefore each system must be used independently of the other. Combining values of the two units may result in nonconformance.

1.3 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to consult and establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.* (**Warning**—Fresh hydraulic cementitious mixtures are caustic and may cause chemical burns to skin and tissue upon prolonged exposure.[2])

2. Referenced Documents

2.1 *ASTM Standards:* [3]

C 39/C 39M Test Method for Compressive Strength of Cylindrical Concrete Specimens

C 42/C 42M Test Method for Obtaining and Testing Drilled Cores and Sawed Beams of Concrete

C 470/C 470M Specification for Molds for Forming Concrete Test Cylinders Vertically

C 617 Practice for Capping Cylindrical Concrete Specimens

C 670 Practice for Preparing Precision and Bias Statements for Test Methods for Construction Materials

3. Summary of Test Method

3.1 A concrete cylinder mold assembly consisting of a mold and a tubular support member is fastened within the concrete formwork prior to placement of the concrete as shown in Fig. 1. The elevation of the mold upper edge is adjusted to correspond to the plane of the finished slab surface. The mold support prevents direct contact of the slab concrete with the outside of the mold and permits its easy removal from the hardened concrete. The mold is filled at the time its location is reached in the normal course of concrete placement. The specimen in the "cured-in-place" condition is removed from its in-place location immediately prior to de-molding, capping, and testing. The reported compressive strength is corrected on the basis of specimen length-diameter ratio using correction factors provided in the section on calculation of Test Method C 42/C 42M.

4. Significance and Use

4.1 Cast-in-place cylinder strength relates to the strength of concrete in the structure due to the similarity of curing conditions since the cylinder is cured within the slab. However, due to differences in moisture condition, degree of consolidation, specimen size, and length-diameter ratio, there is not a constant relationship between the strength of cast-in-place cylinders and cores. When cores can be drilled undamaged and tested in the same moisture condition as the cast-in-place cylinders, the strength of the cylinders can be expected to be on average 10 % higher than the cores at ages up to 91 days for specimens of the same size and length-diameter ratio.[4]

4.2 Strength of cast-in-place cylinders may be used for various purposes, such as estimating the load-bearing capacity

[1] This test method is under the jurisdiction of ASTM Committee C09 on Concrete and Concrete Aggregates and is the direct responsibility of Subcommittee C09.61 on Testing for Strength.

Current edition approved June 1, 2004. Published July 2004. Originally approved in 1977. Last previous edition approved in 1999 as C 873 – 99.

[2] Section on Safety Precautions, Manual of Aggregate and Concrete Testing, *Annual Book of ASTM Standards*, Vol 04.02.

[3] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

[4] Bloem, D. L., "Concrete Strength in Structures," *Journal of the American Concrete Institute,* JACIA, March 1968, or *ACI Proceedings,* PACIA, Vol. 65, No. 3, pp. 169–248.

***A Summary of Changes section appears at the end of this standard.**

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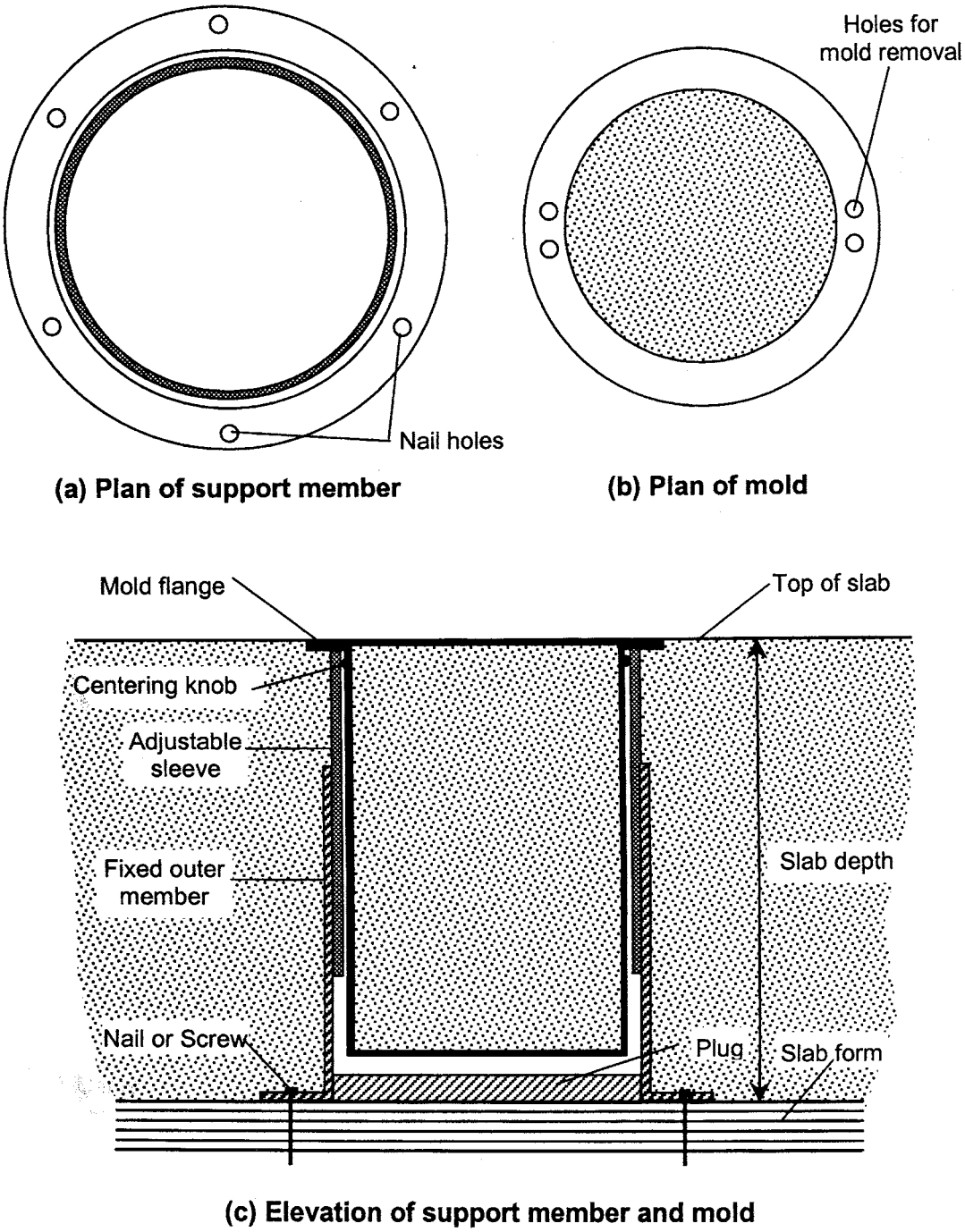

FIG. 1 Schematic of Cast-in-Place Cylinder Mold Assembly

of slabs, determining the time of form and shore removal, and determining the effectiveness of curing and protection.

5. Apparatus

5.1 Cast-in-place molds shall have a diameter at least three times the nominal maximum aggregate size. The length-diameter ratio (*L/D*) of the specimen after capping shall not be less than 1.0 and should preferably be between 1.5 and 2.0. Molds (inner member) shall be constructed in one piece in the form of right circular cylinders at least 4 in. [100 mm] in inside diameter with the average diameter not differing from the nominal diameter by more than 1 % and no individual diameter differing from any other diameter by more than 2 %. The plane of the rim of the mold and the bottom shall be perpendicular to the axis of the mold within 0.5° (approximately equivalent to ⅛ in. in 12 in. [1 mm in 100 mm]).

5.2 Molds shall be watertight and meet the criteria of the section on water leakage of Specification C 470/C 470M. Molds and auxiliary apparatus shall be made of nonabsorbent material that does not react with concrete containing portland

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or other hydraulic cements. They shall be sufficiently strong and tough to permit use under normal construction conditions without tearing, crushing, or otherwise deforming when filled with fresh concrete. They shall resist deformation to the extent that they produce hardened concrete cylinders such that two diameters measured at right angles to each other in any horizontal plane do not differ by more than 1/16 in. [2.0 mm].

5.3 The exterior top of the mold shall have outwardly extending centering knobs and an annular flange to rest on top of the support member (5.4) and to seal the annular ring space between the mold and that support member. Means for twisting and vertical withdrawal of molds shall be provided in the annular flange (see Fig. 1).

5.4 Support members shall be right circular cylinders and shall be rigid tubes of diameter required to accommodate molds stipulated in 5.1 and to concentrically contact and support the annular flange of the mold. Support members shall be provided with a means for height adjustment and shall be fitted with exterior means to permit nailing or other firm attachment to slab forms or reinforcing steel in a manner preventing entry of concrete or mortar into the annular ring space between the support member and the mold.

6. Installation of Apparatus

6.1 After completion of reinforcing steel placement and other formwork preparation, fasten the support member to slab forms using nails or screws. Adjust the support member so that the tops of the molds are aligned with the elevation of other screeds. The location of mold assemblies should be noted on the project plans for easy location after concrete placement, and for identification.

6.2 Place the mold in the support member so that the flange of the mold is uniformly supported by the sleeve to prevent concrete or mortar from penetrating into the space between the mold and support member.

NOTE 1—Insertion of compressible material between the support member and the mold is permitted to prevent mortar seepage into the annular space.

7. Procedure

7.1 Inspect the molds to ensure they are clean and free of any debris or foreign matter. Fill the molds when the concrete placement progresses to the vicinity of mold location.

7.2 Consolidation of concrete in the mold may be varied to simulate the conditions of placement. In normal field construction practice, if the surrounding concrete is consolidated by internal vibration, use the vibrator externally, briefly touching the exterior of the mold support member. Internal vibration of concrete in the mold is prohibited except under special circumstances, which shall be explained in the report of test results. Subject the specimen surface to the same finishing as the surrounding concrete.

7.3 *Curing of Specimens*—Subject the specimens to the same curing and treatment as provided to the surrounding concrete. Record maximum and minimum slab surface temperatures during the curing period for inclusion in the report. Specimen molds shall remain fully seated in place until time of removal for transportation to the testing location.

7.4 Remove molds from support members, exercising care so as not to physically damage specimens. From the time of removal from the structure until time of test, maintain test specimens at a temperature within ±10 °F [±6 °C] of the slab surface temperature at the time of removal. Transport specimens to the laboratory within 4 h after removal. During transportation protect the specimens with suitable material to prevent damage from jarring, freezing temperatures or moisture loss, or combination thereof.

7.5 *Testing of Specimens*—Remove specimens from molds. Determine the average diameter of each specimen to the nearest 0.01 in [0.2 mm] by averaging two diameters measured at right angles to each other at about the midheight of the specimen. Cap specimens in accordance with Practice C 617, measure the length of the capped specimens to the nearest 0.1 in. [2 mm], and test in accordance with Test Method C 39/C 39M. Test the specimens for compressive strength in the "as-received" moisture condition unless required otherwise by project specifications.

8. Calculation

8.1 Calculate the compressive strength of each specimen using the computed cross-sectional area based on the average diameter of the specimen. If the length-diameter ratio of the specimen is 1.75 or less, correct the calculated strength by multiplying by the applicable strength correction factor given in Test Method C 42/C 42M.

9. Report

9.1 Report the following information:

9.1.1 Identification of structure in which specimens were cast, identification of specimen, and location of the mold in the structure,

9.1.2 Diameter and length, in. [mm],

9.1.3 Maximum load, lbf [N],

9.1.4 The *L/D* strength correction factor used,

9.1.5 Compressive strength calculated to the nearest 10 psi [0.1 MPa] after multiplying by the applicable *L/D* strength correction factor, if required,

9.1.6 Type of fracture (see Test Method C 39/C 39M),

9.1.7 Defects in specimen, or caps, if observed,

9.1.8 Age of specimen,

9.1.9 Curing methods used,

9.1.10 Initial concrete temperature,

9.1.11 Maximum and minimum temperature information obtained at job site to define curing conditions of specimens in place,

9.1.12 Detailed descriptions of any internal vibration or other internal manipulations of the fresh concrete in the mold (7.2), and

9.1.13 Other information pertaining to job conditions that could affect the results.

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10. Precision and Bias

10.1 *Precision*—The single-operator coefficient of variation has been found to be 3.5 %[5] for a range of compressive strength between 1500 and 6000 psi [10 and 41 MPa].[6] Therefore, results of two properly conducted tests by the same operator on the same sample of concrete should not differ from each other by more than 10.0 %[5] of their average. Larger differences may be due to improperly prepared specimens or actual strength differences because of different batches of concrete or different curing conditions.

10.2 *Bias*—The bias of this test method cannot be determined because the strength of a cast-in-place cylindrical specimen can only be obtained by using this test method.

11. Keywords

11.1 compressive strength; concrete; cylinder molds; in-place strength

[5] These numbers represent, respectively, the (1s %) and (d2s %) limits as described in Practice C 670.

[6] This statement was derived from research data reported by Nicholas J. Carino, H. S. Lew, and Charles K. Volz in "Early Age Temperature Effects on Concrete Strength Prediction by the Maturity Method," *ACI Journal*, Vol 80, No. 2, March–April 1983.

SUMMARY OF CHANGES

Committee C09 has identified the location of selected changes to this test method since the last issue, C 873 – 99, that may impact the use of this test method. (Approved June 1, 2004)

(*1*) Simplified the wording in 1.1.
(*2*) Added a warning about chemical burns in 1.3.
(*3*) Added a step to the procedure in 7.5 to measure the diameter and length of the test specimens.
(*4*) Clarified the application of the *L/D* strength correction factor in 8.1.

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Designation: C 878/C 878M – 09

Standard Test Method for Restrained Expansion of Shrinkage-Compensating Concrete[1]

This standard is issued under the fixed designation C 878/C 878M; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope*

1.1 This test method covers the determination of the expansion of concrete made with shrinkage-compensating cement.

1.2 The values stated in either SI units or inch-pound units are to be regarded separately as standard. The values stated in each system may not be exact equivalents; therefore, each system shall be used independently of the other. Combining values from the two systems may result in non-conformance with the standard.

1.3 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.* (**Warning**—Fresh hydraulic cementitious mixtures are caustic and may cause chemical burns to skin and tissue upon prolonged exposure.[2])

2. Referenced Documents

2.1 *ASTM Standards:*[3]

C 125 Terminology Relating to Concrete and Concrete Aggregates

C 192/C 192M Practice for Making and Curing Concrete Test Specimens in the Laboratory

C 219 Terminology Relating to Hydraulic Cement

C 490 Practice for Use of Apparatus for the Determination of Length Change of Hardened Cement Paste, Mortar, and Concrete

C 670 Practice for Preparing Precision and Bias Statements for Test Methods for Construction Materials

C 806 Test Method for Restrained Expansion of Expansive Cement Mortar

C 845 Specification for Expansive Hydraulic Cement

2.2 *ACI Standards and Committee Reports:*[4]

116-R-90 Cement and Concrete Terminology

223-83 Standard Practice for the Use of Shrinkage-Compensating Concrete

3. Terminology

3.1 Terms used in this test method are defined in Terminology C 219, Terminology C 125, and ACI 116-R-90.

4. Significance and Use

4.1 Since the potential for expansion, under conditions of controlled restraint, of concrete made with shrinkage-compensating cement cannot always be satisfactorily predicted from tests of mortars made in accordance with Test Method C 806, a need has been recognized for a test method in which concrete specimens are tested.

4.2 This test method can also be adapted readily to studies of expansion involving degrees of restraint, comparisons of cements, effects of cement contents, mixture proportions, schedules, or environmental treatments that differ from the standard procedures prescribed by this test method.

5. Apparatus

5.1 *Molds*, for casting test specimens, when used in conjunction with the restraining cage described in 4.2, shall provide for forming prisms 76 mm [3 in.] square with a gage length of 250 mm [10 in.]. The molds shall otherwise conform to the requirements for molds in Practice C 490, except that the stud holder, gage studs, and spacer screws described in that practice will not be used.

5.2 *Restraining Cage*, consisting of a threaded low-carbon steel rod (plain or zinc-coated) with steel end plates held in place by hex nuts as shown in Fig. 1. The hex nuts outside the cage shall be of stainless steel. Stainless steel cap nuts shall be put on each end of the rod. When tested in tension, within the elastic range, the rod shall have a strain of 2800 kN [0.0012 ± 0.0001/630 lbf] of load (Note 1).

NOTE 1—It is intended that all rods used meet the indicated requirement for strain. When a large number of rods are obtained as a single lot,

[1] This method is under the jurisdiction of ASTM Committee C09 on Concrete and Concrete Aggregates and is the direct responsibility of Subcommittee C09.68 on Volume Change.

Current edition approved June 15, 2009. Published July 2009. Originally approved in 1978. Last previous edition approved in 2003 as C 878–03.

[2] Section on Safety Precautions, *Manual of Aggregate and Concrete Testing* , *Annual Book of ASTM Standards*, Vol. 04.02.

[3] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

[4] Available from American Concrete Institute (ACI), P.O. Box 9094, Farmington Hills, MI 48333-9094, http://www.concrete.org.

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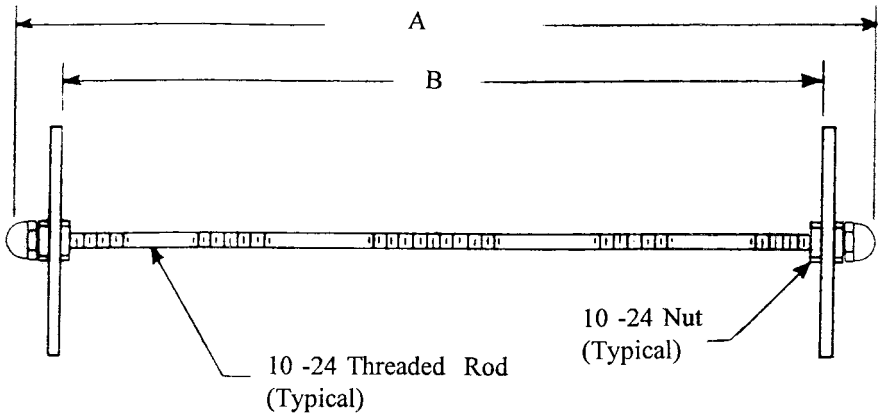
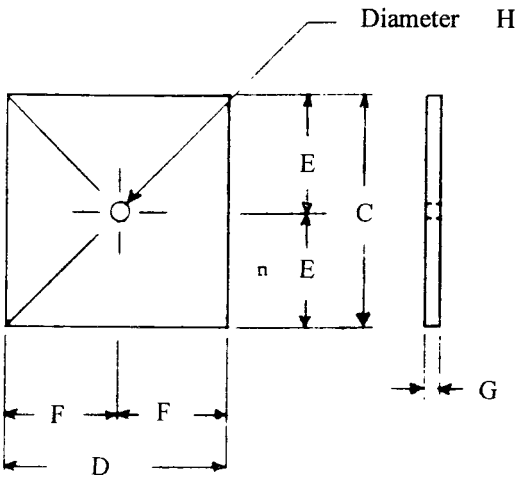


Assembled Restraining Cage



Measurement	Dimensions	
	in.	mm
A	11 9/16 ± 1/16	294 ± 1.6
B	10	254 (gage length)
C	3	76
D	2 31/32 ± 1/32	75 ± 1
E	1 1/2	38
F	1 31/64	37.7
G	3/8	10
H	3/16	5

NOTE 1—All material is mild steel, except for stainless steel cap nuts.

FIG. 1 Restraining Cage

exercise judgment as to whether or not all must be tested. The designation "10-24" is used in ordinary rods having the desired properties.

5.3 *Length Comparator*, conforming to and to be used in accordance with the requirements of Practice C 490. Use a reference bar complying with the description given in Practice C 490. If the terminals of the comparator are fitted with collars, they shall be such that the cap nuts on the ends of the threaded rod of the specimen do not rest on the collar during the measuring (see Figs. 2 and 3).

5.4 *Tamping Rod*—The tamping rod shall be a straight steel rod, 10 mm [3/8 in.] in diameter, and no less than 250 mm [10 in.] in length, having at least the tamping end rounded to a hemispherical tip of the same diameter.

5.5 *Vibrators*, conforming to the requirements for external vibrators prescribed in Practice C 192/C 192M.

6. Test Specimen

6.1 The test specimen shall be a prism: 75 mm [3 in.] square with a gage length of 250 mm [10 in.] and an overall length (including the length of the rod and cap nuts) of approximately 290 mm [11.5 in.]. At least three specimens shall be prepared for each test.

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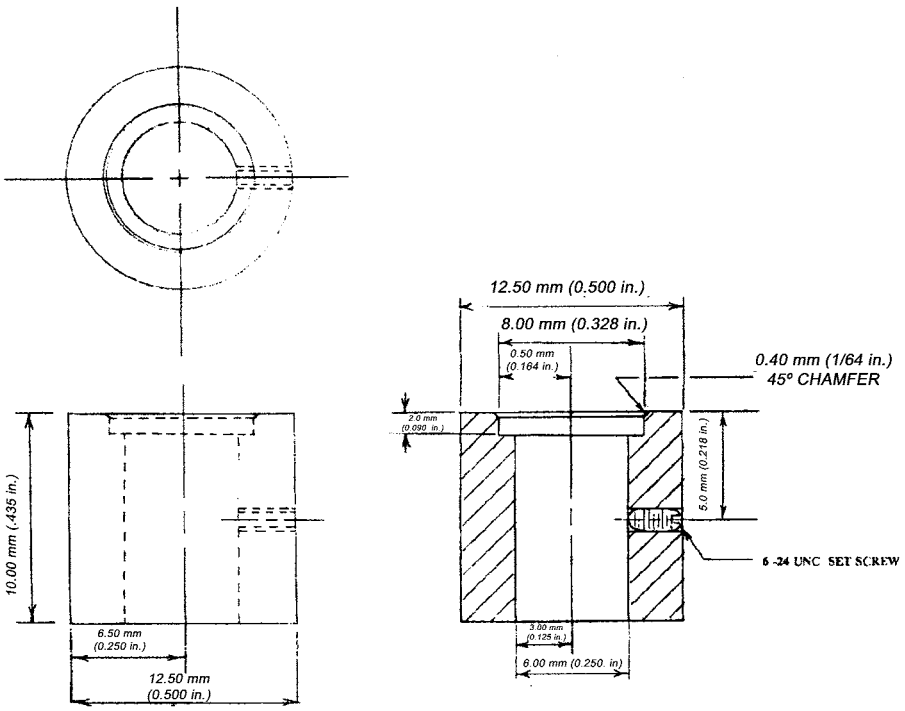

FIG. 2 Schematic of Upper and Lower Adjustable Restraining Collar for Length Comparator that Will Allow Positioning of Restraining Cage Cap Nuts to Rest on Anvils Without Interference from the Collars

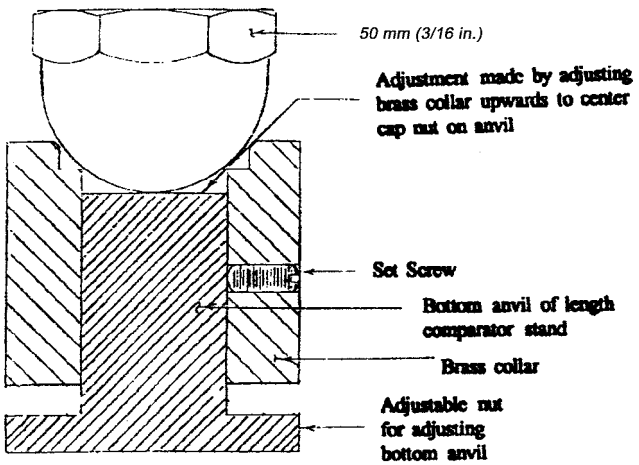

FIG. 3 Cross Section of Restraining Collar Showing Positioning of Cap Nut for Measurement

NOTE 2—Use of aggregates of nominal maximum size greater than 25.0 mm [1 in.] may adversely affect the test results.

7. Preparation and Assembly of Specimen Molds and Restaining Cage

7.1 Install the cap nuts firmly in place on the ends of the restraining rods using a suitable adhesive to keep them from loosening when comparator readings are made (Note 3). The cap nuts should not be removed after the initial comparator reading of a specimen is made. Measure the restraining cage assembly length, including the cap nuts, while it is at 23.0 ± 2 °C [73.5 ± 3.5 °F]. This is to ensure it is 30 ± 2 mm [11⁹⁄₁₆ ± 1⁄16 in.]. The measurement taken at this time is used only to ensure that comparator readings can be made.

NOTE 3—A rapid-setting epoxy has been found suitable.

7.2 Thinly cover the edges of the restraining cage end plates that contact the sides and bottom of the mold with a heavy mineral oil or light cup grease such as petrolatum. After assembly of the molds, place a restraining cage in each mold compartment. Seal the contact lines between the outer sides and base plate of the molds with paraffin or micro-crystalline wax. Thinly cover the interior faces of the molds with mineral oil and remove any oil or grease from the restraining cage rod and end plates.

8. Procedure

8.1 *Preparation and Mixing of Materials*—Mixtures using job materials shall be made in the laboratory as described in Practice C 192/C 192M, except that the material temperatures shall be approximately those anticipated in the field. Mixing procedures shall also reflect the actual mixing and delivery times expected for the particular work. Remove aggregate retained on the 25.0 mm [1 in.] sieve from that used in the mixture from which the specimens are to be molded. Select the mixture proportions according to applicable provisions of ACI 223-83.

8.2 *Molding Specimens*—Place the concrete in the mold in two approximately equal layers (the first layer shall just cover the threaded restraining rod) in accordance with the general instructions given for placing concrete in specimen molds given in Practice C 192/C 192M. Consolidate each layer by rodding or by external vibration in accordance with the

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instructions for consolidation of flexure test specimens given in Practice C 192/C 192M, except use the same method of consolidation for all specimens to be compared. The top layer shall slightly overfill the mold. After consolidation is complete, strike off the excess material with a straightedge and finish the exposed surface with a few strokes of a straight-edged trowel.

8.3 *Curing Specimens*—Cover the specimens with a polyethylene sheet or other suitable material to prevent loss or gain of moisture at the surface of the specimens.

8.4 Remove the specimens from the molds at the age of 6 h. In unusual cases the specimens may not be strong enough to demold at the age of 6 h. If this is the case, select a later time but demold as soon as practicable and report the demolding age with the results. Remove the specimens from the molds by loosening or removing the mold-fastening devices and gently tapping the base plate and side plates so as to free them from the specimens. Exercise great care in this operation, because of the fragility of the concrete at this age and in all later handling of specimens. Do not place specimens directly on hard wood or metal table tops. Placing a soft rubber mat over table tops to lessen impact force on specimens has been found to reduce scatter in data. Limit any marks placed on the specimens for identification or positioning to those made by graphite applied either by a soft pencil or as a liquid that deposits essentially graphite without binder, to those made with waterproof indelible ink, or to light scratchings in the surface of the concrete made with a sharp instrument.

8.5 *Measuring Specimens*—Take the initial comparator readings 30 ± 2 min after demolding. After the initial comparator reading, cure the specimens in lime-saturated water at 23 ± 2 °C [73.5 ± 3.5 °F] until they have reached an age of 7 days. At the end of the curing period take another comparator reading. It is permitted for comparator readings to be taken at intermediate ages between the initial comparator reading and the comparator reading at 7 days (Note 4).

NOTE 4—It is permitted to provide further water-curing, or alternatively the specimens shall be allowed to air-dry under any desired condition in order to determine later age length change data. Comparator readings shall be taken at any appropriate interval.

9. Calculation

9.1 Calculate the length changes as percent expansion or shrinkage as follows:

$$\text{Length change, \%} = [(\text{corrected comparator reading} - \text{corrected initial comparator reading})/\text{gage length}] \times 100 \quad (1)$$

where the corrected comparator reading is equal to the specimen comparator reading minus the reference bar comparator reading.

10. Report

10.1 Report the following information:

10.1.1 Identification of specimens, number of specimens for each condition, and date molded,

10.1.2 Source and identification of each material employed,

10.1.3 Type, nominal maximum size, moisture condition, and proportions of each aggregate used,

10.1.4 Concrete mixture data,

10.1.5 Consolidation method, whether rodding or external vibration was used,

10.1.6 Conditions and periods of moist curing prior to and subsequent to removal of molds, if different from those specified.

10.1.7 Description of storage conditions,

10.1.8 Total length of the period of storage and total age of the specimen, or total length of curing and storage if the same condition was used for both, for each observation, and

10.1.9 Report length change data, in % , recorded as linear expansion during moist-curing and moist storage and as linear contraction during dry storage both based on the initial comparator reading made at the time of removal from the molds, as the average percent change in linear dimension to the nearest 0.001 %.

10.1.10 Any other pertinent information.

11. Precision and Bias

11.1 *Precision*:

11.1.1 The following precision statements are applicable when a test result is the average percent restrained expansion of 3 prisms molded from a single batch of concrete and tested at the same age. It is applicable for concrete made from Type K, Type S, or Type M shrinkage-compensating cements (C 845) and tested at 3, 7, or 28 days.

11.2 The multilaboratory standard deviation has been found to be 0.015 % expansion. Therefore, the results of properly conducted tests of a single batch by two different laboratories should not differ from each other by more than 0.043 %[5].

11.3 Data necessary to determine single-laboratory precision are not available at this time.

11.4 *Bias*—Data to determine bias are not available; no standards are known to exist.

12. Keywords

12.1 expansion; restrained expansion; shrinkage compensating concrete

[5] These numbers represent, respectively, the (1s) ands (d2s) limits as described in Practice C 670.

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SUMMARY OF CHANGES

Committee C09 has identified the location of selected changes to this test method since the last issue, C 878/C 878M – 03, that may impact the use of this test method. (Approved June 15, 2009)

(*1*) Added a warning on hydraulic cementitious mixtures in accordance with ASTM Form and Style. Added new Footnote 2 and renumbered subsequent footnotes.

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Designation: C 881/C 881M – 02

Standard Specification for Epoxy-Resin-Base Bonding Systems for Concrete[1]

This standard is issued under the fixed designation C 881/C 881M; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

This standard has been approved for use by agencies of the Department of Defense.

1. Scope

1.1 This specification covers two-component, epoxy-resin bonding systems for application to portland-cement concrete, which are able to cure under humid conditions and bond to damp surfaces.

1.2 The values stated in either inch-pound units or SI units are to be regarded separately as standard. Within the text, the SI units are shown in brackets. The values stated in each system are not exact equivalents, therefore, each system shall be used independently of the other. Combining values from the two systems may result in nonconformance with this specification.

1.3 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.* For specific hazards statements, see Section 9.

2. Referenced Documents

2.1 *ASTM Standards:*

C 882 Test Method for Bond Strength of Epoxy-Resin Systems Used with Concrete by Slant Shear[2]

C 884 Test Method for Thermal Compatibility Between Concrete and an Epoxy-Resin Overlay[2]

D 570 Test Method for Water Absorption of Plastics[3]

D 638 Test Method for Tensile Properties of Plastics[3]

D 648 Test Method for Deflection Temperature of Plastics Under Flexural Load[3]

D 695 Test Method for Compressive Properties of Rigid Plastics[3]

D 1259 Test Methods for Nonvolatile Content of Resin Solutions[4]

D 1652 Test Method for Epoxy Content of Epoxy Resins[5]

D 2393 Test Method for Viscosity of Epoxy Resins and Related Compounds[6]

D 2566 Test Method for Linear Shrinkage of Cured Thermosetting Casting Resins During Cure[6]

3. Terminology

3.1 *Definitions of Terms Specific to This Standard:*

3.1.1 *binder*, *n*—the cementitious part of a grout, mortar, or concrete that binds the aggregate or filler into a cohesive mass.

3.1.2 *bonding system*, *n*—the product resulting from the combination of all the components supplied for use as a bonding material.

3.1.3 *component*, *n*—a constituent that is intended to be combined with one or more other constituents to form a bonding system.

3.1.4 *contact strength*, *n*—bond strength measured by slant shear after a specified contact and cure time.

3.1.5 *contact time*, *n*—specified time between when the epoxy system is applied and when the two segments are bonded together and still achieve a specified bond strength after a specified curing time and temperature.

3.1.6 *curing agent*, *n*—a substance that causes the conversion of a fluid resin system to a solid cured resin by means of a chemical reaction.

3.1.7 *epoxy equivalent*, *n*—the weight of resin containing one molecular weight of epoxy groups.

3.1.8 *epoxy resin*, *n*—a resin that contains or did contain epoxy groups principally responsible for its polymerization.

3.1.9 *filler*, *n*—a finely divided solid, predominantly passing the No. 200 [75-µm] sieve, that is used to improve certain properties of the bonding system or to reduce cost.

3.1.10 *formulator*, *n*—the agency responsible for preparing the separate components and for recommending the proportions to be used in preparing the final bonding system.

3.1.11 *lot or batch*, *n*—that quantity of manufactured material which has been subjected to the same unit chemical or physical processes intended to make the final product substantially uniform.

3.1.12 *manufacturer*, *n*—a producer of a basic constituent part of a component.

3.1.13 *reactive diluent*, *n*—a relatively free flowing liquid

[1] This specification is under the jurisdiction of ASTM Committee C09 on Concrete and Concrete Aggregates, and is the direct responsibility of Subcommittee C09.25 on Organic Materials for Bonding.

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[2] *Annual Book of ASTM Standards*, Vol 04.02.

[3] *Annual Book of ASTM Standards*, Vol 08.01.

[4] *Annual Book of ASTM Standards*, Vol 06.01.

[5] *Annual Book of ASTM Standards*, Vol 06.03.

[6] *Annual Book of ASTM Standards*, Vol 08.02.

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used to reduce the viscosity of the liquid resin or resin mixture, and which contains reactive groups that cause it to become an integral part of the cured resin.

3.1.14 *working (pot) life, n*—the time after mixing during which a bonding system or mixture containing it retains sufficient workability for proper use.

4. Classification

4.1 This specification provides for the classification of epoxy-resin bonding systems by type, grade, class, and color.

4.2 *Types*—Seven types of systems that are distinguished by the requirements of Table 1 are recognized:

4.2.1 *Type I*—For use in non-load bearing application for bonding hardened concrete to hardened concrete and other materials, and as a binder in epoxy mortars or epoxy concretes.

4.2.2 *Type II*—For use in non-load bearing applications for bonding freshly mixed concrete to hardened concrete.

4.2.3 *Type III*—For use in bonding skid-resistant materials to hardened concrete and as a binder in epoxy mortars or epoxy concretes used on traffic bearing surfaces (or surfaces subject to thermal or mechanical movements).

4.2.4 *Type IV*—For use in load bearing applications for bonding hardened concrete to hardened concrete and other

TABLE 1 Physical Requirements of Bonding Systems

Property	Type						
	I	II	III	IV	V	VI	VII
Viscosity, P [Pa·s]:							
Grade 1, max	20[2.0]	20[2.0]	20[2.0]	20[2.0]	20[2.0]	...	...
Grade 2, min	20[2.0]	20[2.0]	20[2.0]	20[2.0]	20[2.0]	...	...
max	100[10]	100[10]	100[10]	100[10]	100[10]	...	...
Consistency, in [mm]:							
Grade 3, Types I, II, III, IV, V, VI, VII, max	¼[6.0]	¼[6.0]	¼[6.0]	¼[6.0]	¼[6.0]	¼[6.0]	¼[6.0]
Gel time, minutes, min	30	30	30	30	30	30	30
Bond strength, min, psi [MPa]:							
2 days (moist cure)	1000[7.0]	...	...	1000[7.0]	...	1000[7.0]	...
14 days (moist cure)	1500[10.0]	1500[10.0]	1500[10.0]	1500[10.0]	1500[10.0]	...	1000[7.0]
Absorption, 24 h max, %	1	1	1	1	1	...	...
Heat Deflection Temperature, min, °F [°C]:							
7 days	...	...	...	120[50]	120[50]	...	...
14 days	...	...	...	...	...	120[50]	120[50]
Thermal compatibility	...	...	passes test	...	...	...	...
Linear coefficient of shrinkage on cure, max	0.005	0.005	...	0.005	0.005	...	...
Compressive Yield Strength, min, psi [MPa]:							
24 h	...	...	...	...	...	2000[14.0]	...
36 h	...	...	...	...	...	...	1000[7.0]
48 h	...	...	...	...	...	6000[40.0]	...
72 h	...	...	...	...	...	...	2000[14.0]
7 days	8000[55.0]	5000[35.0]	...	10 000[70.0]	8000[55.0]	...	...
Compressive Modulus, psi [MPa]							
Min	150 000[1000]	90 000[600]	...	200 000[1400]	150 000[1000]	...	...
Max	...	...	130 000[896]	...	...	...	...
Tensile Strength, 7 days min, psi [MPa][A]	5000[35.0]	2000[14.0]	...	7000[50.0]	6000[40.0]	...	...
Elongation at Break, %, min	1	1	30	1	1	...	...
Contact strength, psi [MPa] min							
2 days	...	...	...	...	...	1000[7.0]	...
14 days	...	...	...	...	...	...	1000[7.0]

[A] Not required for Viscosity Grade 3 Systems.

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materials and as a binder for epoxy mortars and concretes.

4.2.5 *Type V*—For use in load bearing applications for bonding freshly mixed concrete to hardened concrete.

4.2.6 *Type VI*—For bonding and sealing segmental precast elements with internal tendons and for span-by-span erection when temporary post tensioning is applied.

4.2.7 *Type VII*—For use as a nonstress carrying sealer for segmental precast elements when temporary post tensioning is not applied as in span-by-span erection.

NOTE 1— Epoxy resin systems will adhere to a wide variety of materials, including wood, metals, masonry, and most plastics. Polyethylene, TFE-fluorocarbon, cellophane, and greased or waxed surfaces are among the few materials to which these systems will not adhere.

4.3 *Grades*—Three grades of systems are defined according to their flow characteristics and are distinguished by the viscosity and consistency requirements of Table 1.

4.3.1 *Grade 1*—Low viscosity.

4.3.2 *Grade 2*—Medium viscosity.

4.3.3 *Grade 3*—Non-sagging consistency.

4.4 *Classes*—Classes A, B, and C are defined for Types I through V, and Classes D, E, and F are defined for Types VI and VII, in accordance with the range of temperatures for which they are suitable (Note 2).

4.4.1 *Class A*—For use below 40°F [4.0°C] the lowest allowable temperature to be defined by the manufacturer of the product.

4.4.2 *Class B*—For use between 40 and 60°F [4.0 and 15.0°C].

4.4.3 *Class C*—For use above 60°F [15.0°C] the highest allowable temperature to be defined by the manufacturer of the product.

4.4.4 *Class D*—For use between 40 and 65°F [4.0 and 18.0°C].

4.4.5 *Class E*—For use between 60 and 80°F [15.0 and 30.0°C].

4.4.6 *Class F*—For use between 75 and 90°F [25.0 and 30.0°C].

NOTE 2—The temperature in question is usually that of the surface of the hardened concrete to which the bonding system is to be applied. This temperature may be considerably different from that of the air. Where unusual curing rates are desired it is possible to use a class of bonding agent at a temperature other than that for which it is normally intended. For example, a Class A system will cure rapidly at room temperature.

4.5 *Color*—Epoxy resin systems are normally unpigmented, but they can be colored or darkened. If a specific color is desired, it should be so stated by the purchaser.

5. Ordering Information

5.1 The purchaser shall specify the type, grade, class, and color of bonding system desired and the size of units in which the components shall be furnished. Special requirements regarding filling of either the components or the final bonding system should be stated. The product furnished under this specification is intended to be resistant to moisture and therefore should be suitable for either indoor or outdoor exposure.

5.2 The purchaser may specify a minimum gel time of 5 min for Types I and IV when automatic proportioning, mixing, and dispensing equipment are used.

6. Materials and Manufacture

6.1 The systems covered by this specification shall be furnished in two components for combining immediately prior to use in accordance with written instructions of the formulator. Component A shall contain an epoxy resin with or without a reactive diluent. Component B shall contain one or more curing agents, which on mixing with Component A shall cause the mixture to harden. A suitable inert filler may be uniformly incorporated in one or both components. The filler shall be either nonsettling or readily dispersible in any component in which it is incorporated. All systems shall cure under humid conditions, and bond to damp surfaces.

7. Chemical Composition

7.1 The epoxy resin constituent of Component A shall have an epoxy equivalent of 155 to 275.

8. Physical Properties

8.1 A mixture of Components A and B in the proportions recommended by the formulator shall conform to the properties prescribed in Table 1.

9. Safety Hazards

9.1 **Caution:** Epoxy resins contain irritants, especially to the skin, eyes, and respiratory system. Persons handling these materials shall use appropriate protective clothing, including rubber or plastic gloves. If an epoxy resin should contact the skin, it shall be removed immediately with a dry cloth or paper towel, and the area of contact washed thoroughly with soap and water. Solvents shall *not* be used, because they carry the irritant into the skin. Cured epoxy resins are innocuous.

10. Sampling

10.1 Take a representative sample of each of the two components from a well-blended lot prior to packaging or by withdrawing samples from no fewer than 5 % of the containers comprising the lot or shipment. Unless the samples of the same component taken from containers show visual evidence of variability, they may be combined into a single composite sample. In place of the foregoing, packaged materials may be sampled by a random selection of containers of each component from each lot, provided such a procedure is acceptable to the purchaser.

11. Test Methods

11.1 *Consistency*—Test Method to Determine The Consistency of an Epoxy Resin System.

11.1.1 *Scope*—This test provides a method for determining the consistency of Grade 3 epoxy resin systems.

11.1.2 *Significance and Use*—This test method is used to determine compliance with the requirements of the specification.

11.1.3 *Apparatus*:

11.1.3.1 *Paper cup*—Approximately 3 oz. [approximately 0.100L] unwaxed paper cup.

11.1.3.2 *Mixing blade*—Ordinary wooden tongue depressor or stick of similar size.

11.1.3.3 *Glass panel*.

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11.1.4 *Conditioning*—Condition the individual components and any equipment with which they will come in contact to the following temperatures: Class A, 32 ± 2°F [0 ± 1°C]; Class B, 50 ± 2°F [10 ± 1°C]; Class C, 73 ± 2°F [23 ± 1°C], Class D, 65° ± 2°F [18° ± 1°C]; Class E, 80° ± 2°F [27°± 1°C]; Class F, 90° ± 2°F [32° ± 1°C] or to the temperature at which the material will be used (Note 2).

11.1.5 *Procedure*—Prepare approximately 30 cm^3 of the bonding system. Weigh the necessary amounts of the components to an accuracy of 1 % into a single 3-oz [approximately 100-cm^3] unwaxed paper cup. Mix immediately with a wooden tongue depressor or stick of similar size. Note the time at which mixing begins. Mix for 3 min, taking care to scrape the side and bottom of the cup periodically. Immediately apply about 2 cm^3 of the mixture to a glass panel. Form a semicylindrical bead of the bonding system by drawing the applicator blade through the sample in a straight line with the panel horizontal. Immediately raise the panel to a position inclined at no greater than 10° from vertical and with the bead horizontal. Maintain the panel and sample at their original temperature until the bonding system has cured, as determined by an inability to indent it appreciably with a pencil point or fingernail. Determine the consistency by measuring the flow of the lower edge of the bead from its original position at three points along its length.

11.1.6 *Report*—Report the average value to the nearest ⅛in. [1 mm].

11.1.7 *Precision and Bias*:

11.1.7.1 *Precision*—The precision of the procedure in this test method for consistency is being determined.

11.1.7.2 *Bias*—This test method has no bias since the values determined can only be defined in terms of this test method.

11.2 *Gel Time*:

11.2.1 Test Method to Determine the Gel Time of an Epoxy Resin System.

11.2.2 *Scope*—This test method determines the time after mixing when an epoxy resin system gels.

11.2.3 *Significance and Use*—This test method is used to determine compliance with the requirements of the specification.

11.2.4 *Apparatus*:

11.2.4.1 *Paper cup*—8 oz. [approximately 250 cm^3] unwaxed paper cup

11.2.4.2 *Mixing blade*—Ordinary wooden tongue depressor or stick of similar size.

11.2.5 *Conditioning*—Condition the individual components and any equipment with which they will come in contact to the temperatures set forth in 11.1, depending on the class of system in question, or to the temperature at which the material will be used, providing that temperature is within the ranges established in 4.4 for Types I, II, III, and V. For Type VI and VII use the highest temperature of the specified class (Note 2). Prepare 60 g of the bonding system for Types I through V and 1 gal [4.0 L] for Types VI and VII using the procedures set forth in 11.1.

11.2.6 *Procedure*—Transfer as much as possible of the sample into an 8-oz [approximately 250-cm^3] unwaxed paper cup and set it on a wooden surface in a location maintained at the original conditioning temperature and not subject to abnormal room air movement. Determine the time at which a soft, gelatinous mass forms in the center of the sample by probing every 2 min with a wooden tongue depressor or similar device, starting 8 min after the beginning of mixing.

11.2.7 *Report*—The gel time is the interval between the beginning of mixing and the formation of the gelatinous mass.

11.2.8 *Precision and Bias*:

11.2.8.1 *Precision*—The precision of the procedure in this test method for gel time is being determined.

11.2.8.2 *Bias*—This test method has no bias since the values determined can only be defined in terms of this test method.

11.3 *Filler Content*:

11.3.1 Test Method to Determine the Filler Content of Epoxy Resin Systems.

11.3.2 *Scope*—This test method is a quantitative test to determine the filler content of epoxy resin systems.

11.3.3 *Significance and Use*—the filler content of an epoxy resin system must be known in order to determine the epoxy equivalent.

11.3.4 *Apparatus*:

11.3.4.1 150 mL beaker.

11.3.4.2 Medium porosity, fritted disk filtering crucible.

11.3.4.3 *Mixing blade*—Ordinary wooden tongue depressor or stick of similar size.

11.3.5 *Reagents*:

11.3.5.1 *Purity of Reagents*—Reagent grade chemicals shall be used in all tests. Unless otherwise indicated, it is intended that all reagents conform to the specifications of the Committee on Analytical Reagents of the American Chemical Society where such specifications are available.[7] Other grades may be used, provided it is first ascertained that the reagent is of sufficiently high purity to permit its use without lessening the accuracy of the determination.

11.3.5.2 Methyl ethyl ketone (MEK).

11.3.5.3 Benzene.

11.3.6 *Procedure*—Weigh, to the nearest 0.1 mg, approximately 10 g of the epoxy resin component into a 150-mL beaker. Add 50 mL of methyl ethyl ketone (MEK) to the beaker, and stir the contents until all the soluble matter is dissolved. If the sample is black, owing to the presence of bituminous material, the solvent used shall be a mixture of 1+1 MEK and benzene, by volume. Dry a medium-porosity, fritted-disk filtering crucible to constant weight at 230 ± 9°F [110 ± 5°C]. Wet the filter with MEK, then filter the contents of the beaker through the filtering crucible with the aid of a vacuum. Transfer the contents of the beaker entirely to the crucible, and wash the beaker and the residue on the filter with MEK. The total volume of solvent used to transfer and wash the residue should be about 200 mL. Dry the filter and residue to constant weight at 230 ± 9°F [110 ± 5°C].

11.3.7 *Report*—Calculate the percentage of filler in the component, and report the value to the nearest 0.1 %.

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[7] *Reagent Chemicals, American Chemical Society Specifications,* American Chemical Society, Washington, DC. For suggestions on the testing of reagents not listed by the American Chemical Society, see *Analar Standards for Laboratory Chemicals,* BDH Ltd., Poole, Dorset, U.K., and the *United States Pharmacopeia and National Formulary,* U.S. Pharmacopeial Convention, Inc. (USPC), Rockville, MD.

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11.3.8 *Precision and Bias*

11.3.8.1 *Precision*—The precision of the procedure in this test method for filler content is being determined.

11.3.8.2 *Bias*—This test method has no bias since the values determined can only be defined in terms of this test method.

11.4 *Epoxy Equivalent*—Determine the epoxy equivalent of Component A in accordance with Test Method D 1652. Calculate the epoxy equivalent after correcting for any filler and volatile contents of the component as follows:

$$x = y(1 - f - v) \quad (1)$$

where:

x = corrected weight per epoxy equivalent of the component,
y = weight per epoxy equivalent of the total component as determined by Test Method D 1652,
f = weight fraction of filler in the component, and
v = weight fraction of volatile matter in the component.

11.5 *Viscosity*—Determine the viscosity of the freshly mixed resin system by means of Test Method D 2393, except that the determination shall be made at the temperature given in 11.1 for the class of material in question.

11.6 *Absorption*—Determine the absorption by means of Test Method D 570. The test specimens shall have the shape and dimensions specified for molded plastics, shall be cured for 14 days at a temperature of 73 ± 2°F [23 ± 1°C], shall be tested in accordance with the procedure for 24-h immersion and shall be reconditioned, if necessary, as directed in Test Method D 570.

11.7 *Bond Strength*—Determine the bond strength in accordance with Test Method C 882.

11.8 *Thermal Compatibility*—Determine the thermal compatibility in accordance with Test Method C 884.

11.9 *Heat Deflection Temperature*—Determine the heat deflection temperature in accordance with Test Method D 648, except condition, mix, cure, and start testing the resin components at 73 ± 2°F [23 ± 1°C].

11.10 *Linear Coefficient of Shrinkage*— Determine the linear coefficient of shrinkage in accordance with Test Method D 2566, except condition, mix, cure, and test the resin components at 73 ± 2°F [23 ± 1°C].

11.11 *Compressive Yield Strength and Modulus*—Determine the compressive yield strength and modulus in accordance with Test Method D 695, except condition, mix, and cure the resin components at the lowest application temperature of the specified class. Test at 73 ± 2°F [23 ± 1°C] without delay. Use of a 1 × 1 × 2-in. [25.4 × 25.4 × 50.8-mm] specimen is also acceptable.

11.12 *Tensile Strength and Elongation at Break*—Determine the tensile strength and elongation at break in accordance with Test Method D 638, except condition, mix, and cure at the lowest application temperature of the specified class. Test at 73 ± 2°F [23 ± 1°C] without delay.

11.13 *Contact Strength*—Determine the contact strength in accordance with Test Method C 882 except condition the material and the specimens at the highest application temperature of the specified class and apply the bonding system at a thickness of 1/16 in. [2 mm] on the slanted surface of each half cylinder. Maintain at the highest application temperature and assemble the two half cylinders after 1 h for Type VI and 8 h for Type VII. Cure at the assembly temperature and test at 73 ± 2°F [23± 1°C]. Contact strength is expressed in terms of pounds per square inch obtained after a specified time of cure.

12. Rejection and Rehearing

12.1 The purchaser has the right to reject material that fails to conform to the requirements of this specification. Rejection shall be reported to the producer or supplier promptly and in writing. In case of dissatisfaction with the results of the test, the producer or supplier has the right to a rehearing.

12.2 If all requirements of this specification are met, except those pertaining to bond strength, the bond tests shall be repeated. If the sample again fails to meet the bond strength requirements, the entire lot shall be rejected.

12.3 *Retest*—Lots of material that have been rejected may be reworked by the producer to correct the defects and resubmitted for test provided specific approval of the purchaser has been obtained for such resubmission. Before resubmission of the material, full particulars concerning the action taken to correct the defects in the original material shall be made available to the purchaser.

13. Packaging and Package Marking

13.1 *Packaging*—The two components furnished under this specification shall be supplied in separate containers that are nonreactive with the contents. They are usually supplied in amounts such that the recommended proportions of the final mixture can be obtained by combining one container of Component A with one container of Component B.

13.2 *Marking*—Containers shall be identified as "Component A—Contains Epoxy Resin'' and "Component B—Contains Curing Agent'' and shall show the type, grade, class, and color. Each container shall be marked with the name of the formulator, the lot number, the date of packaging, the quantity contained therein, and the recommended mixing ratio, by both weight and volume.

14. Keywords

14.1 bonding; bonding systems; contact strength; contact time; epoxy resin

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Designation: C 882/C 882M – 05$^{\epsilon 1}$

Standard Test Method for Bond Strength of Epoxy-Resin Systems Used With Concrete By Slant Shear[1]

This standard is issued under the fixed designation C 882/C 882M; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

This standard has been approved for use by agencies of the Department of Defense.

ε[1] NOTE—The designation was changed editorially to agree with the existing values statement in the Scope in March 2008.

1. Scope

1.1 This test method covers the determination of the bond strength of epoxy-resin-base bonding systems for use with portland-cement concrete. This test method covers bonding hardened concrete to hardened or freshly-mixed concrete.

1.2 The values stated in either inch-pound units or SI units are to be regarded separately as standard. Within the text, the SI units are shown in brackets. The values stated in each system are not exact equivalents; therefore, each system shall be used independently of the other. Combining values from the two systems may result in nonconformance with this test method.

1.3 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.* A specific hazard statement is given in Section 8.

2. Referenced Documents

2.1 *ASTM Standards:* [2]

C 39/C 39M Test Method for Compressive Strength of Cylindrical Concrete Specimens

C 109/C 109M Test Method for Compressive Strength of Hydraulic Cement Mortars (Using 2-in. or [50-mm] Cube Specimens)

C 150 Specification for Portland Cement

C 192/C 192M Practice for Making and Curing Concrete Test Specimens in the Laboratory

C 511 Specification for Mixing Rooms, Moist Cabinets, Moist Rooms and Water Storage Tanks Used in the Testing of Hydraulic Cements and Concretes

C 617 Practice for Capping Cylindrical Concrete Specimens

C 881/C 881M Specification for Epoxy-Resin-Base Bonding Systems for Concrete

3. Terminology

3.1 See Section on Terminology of Specification C 881/C 881M.

4. Summary of Test Method

4.1 The bond strength is determined by using the epoxy system to bond together two equal sections of a 3 by 6-in. [75 by 150-mm] portland-cement mortar cylinder, each section of which has a diagonally cast bonding area at a 30° angle from vertical. After suitable curing of the bonding agent, the test is performed by determining the compressive strength of the composite cylinder.

5. Significance and Use

5.1 The strength developed by a bonding system that joins two regions of concrete is its most important property.

6. Apparatus

6.1 *Apparatus to Mix Portland-Cement Mortar*—This apparatus shall be as described in Test Method C 109/C 109M, except for the sections on specimen molds, tamper, and testing machine.

6.2 *Specimen Molds*—The molds shall be constructed in the form of right cylinders, 3 ± 1/16 in. [75 ± 2 mm] in inside diameter and 6 ± 1/16 in. [150 ± 2 mm] high. All molds shall be either selected or machined so that the maximum range of the differences in each of the dimensions of the group of molds is less than 1/64 in. [0.5 mm]. The molds shall be made of metal not attacked by portland-cement mortar. The side of the mold shall be sufficiently rigid to prevent spreading or warping. The molds shall be made watertight before use. A satisfactory

[1] This test method is under the jurisdiction of ASTM Committee C09 on Concrete and Concrete Aggregates and is the direct responsibility of Subcommittee C09.25 on Organic Materials for Bonding.

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[2] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

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material for this purpose is the paraffin-rosin mixture described in Test Method C 109/C 109M.

6.3 *Dummy Section*—A dummy section (Fig. 1) shall be machined of a hard material that is not attacked by portland-cement mortar. It shall fit the mold and be equal to half the volume of the cylinder, but at an angle of 30° from the vertical. Additional dummy sections can be made by casting an epoxy-resin mortar against the machined dummy section contained in a specimen mold. Due precautions, such as waxing, shall be taken to prevent the bonding of the epoxy-resin mortar to the machined dummy section or the mold.

6.4 *Tamping Rod*—The tamping rod shall be a round rod of brass or plastic, ⅜ in. [10 mm] in diameter and approximately 12 in. [300 mm] long, having both ends rounded to hemispherical tips.

6.5 *Apparatus for Mixing Epoxy-Resin Bonding System*—A glass, plastic, or metal container of approximately 3 oz. [0.1 L] capacity shall be used to hand-mix the bonding system. A tongue depressor or wooden stick of similar dimensions shall be used as a paddle.

6.6 *Testing Machine*—The testing machine shall be as described in Test Method C 39/C 39M.

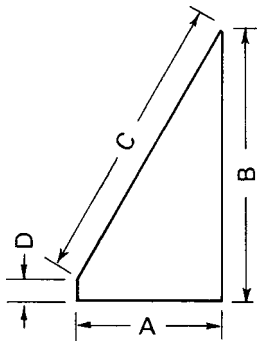
6.7 *Moist Room*—The moist room shall conform to the requirements of Specification C 511.

6.8 *Temperature-Conditioning Chambers*— Rooms or chambers in which the temperature is maintained appropriate to the class of the resin system being tested, in accordance with Specification C 881/C 881M.

7. Materials

7.1 Laboratory conditions, materials, proportions, and procedures for mixing the portland-cement mortar shall be in accordance with Test Method C 109/C 109M. A Type III cement (Specification C 150) shall be used.

7.2 Lightly oil the dummy section and the cylinder mold. Position the dummy section in the mold with the slant side up. Place the portland-cement mortar in the mold in three layers of approximately equal volume. Rod each layer with 25 strokes of the tamping rod. Distribute the strokes uniformly over the section and rod deeply enough to penetrate into any underlying layer. Rod the bottom layer as deeply as possible. Strike off the surface of the top layer with the trowel, and cover the specimen and mold with a glass or metal plate. Cure the mortar half-cylinder in accordance with Practice C 192/C 192M for at least 28 days. Then dry the half-cylinder in laboratory air for at least 7 days. As an alternative, a complete 3 by 6-in. [75 by 150 mm] cylinder shall be cast and, after cure, may be saw-cut at an angle of 30°.



	Dimensions	
	in.	mm
A—Diameter	3.000	[75±2]
B—Height	5.598	[140±2]
C—Slant height	6.000	[150±2]
D—Base height	0.402	[10±2]

FIG. 1 Dummy Section

7.3 A 3 by 6-in. [75 by 150-mm] cylinder of the mortar shall have a compressive strength, when tested in accordance with 11.3, of at least 4500 psi [31 MPa] at 28-days age.

8. Hazards

8.1 **Warning**—Epoxy resins contain irritants, especially to the skin, eyes, and respiratory system. Persons handling these materials shall use appropriate protective clothing, including rubber or plastic gloves. If an epoxy resin should contact the skin, it shall be removed immediately with a dry cloth or paper towel, and the area of contact shall be washed thoroughly with soap and water. Solvents shall *not* be used, because they carry the irritant into the skin. Cured epoxy resins are innocuous.

9. Sampling

9.1 Take samples in accordance with Specification C 881/C 881M.

10. Test Specimens

10.1 Three composite test specimens are required for all Types of resin systems.

10.2 *Conditioning*:

10.2.1 *Types I, III, IV, VI, and VII Systems*—Condition the resin system components, the mortar sections, and all equipment that will contact the resin to the temperatures specified in Specification C 881/C 881M.

10.2.1.1 Prepare the test specimens and make provision for maintaining them at the appropriate temperature during the entire cure time. Prepare the surface to be bonded by sand-blasting and dry brushing to remove all loose surface material.

10.2.1.2 Use mortar sections and assemblies that have been soaked in water for 24 h. Place the face of the mortar sections to be bonded on an absorbent material for 10 min prior to applying the adhesive. For assembled test specimens, remove all water by shaking. Allow to air dry for 15 min.

10.2.2 *Type II and Type V Systems*—Since Type II and Type V resins are appropriate for use only at temperatures that permit strength gain of the freshly prepared concrete, only the conditioning temperature for a Class C resin, 73 ± 2 °F [23 ± 1 °C], need be provided.

10.3 *Specimen Preparation*:

10.3.1 *Type I, III, IV, VI, and VII, Grade 2 or 3 Systems*—Two mortar sections will be needed for each test specimen. Wrap 4 mil (100 μm) of polyethylene film 6 by 20 in. [150 by 500 mm] around one section of each pair, even with the base and secure with masking tape. Thoroughly mix the components of the bonding system in the proportions recommended by the formulator. A mixing time of 3 min should suffice. Support the film-wrapped mortar section so that the prepared bonding surface is horizontal.

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10.3.1.1 To test Grade 2 systems, apply a 0.02 in. [0.5 mm] layer of the bonding systems to the prepared elliptical surface of the film wrapped mortar section. Using Grade 3 systems, apply a 0.02 in. [0.5 mm] layer of bonding system on the prepared elliptical surface of the mortar section not film wrapped. For the determination of contact strength (Specification C 881/C 881M) of Type VI and VII systems, apply a 1/16-in. [2.0-mm] layer to the prepared elliptical surface of both mortar sections.

10.3.1.2 Insert mortar sections not film wrapped into the cylinder formed by film surrounding other mortar sections and squeeze out the excess resin through a hole, or holes, punched in the film at the bondline, while keeping the joint horizontal. Secure the assembly with sufficient additional masking tape placed around the film. Be sure the joint is entirely filled. Keep the bonded joint horizontal for 48 h, then remove all the masking tape.

10.3.2 *Type I, III, and IV, Grade 1 Systems*—Two mortar sections will be needed for each test specimen. Prepare the elliptical bonding surface as described in 10.2. Place the two halves of the specimen together, forming a gap approximately 0.02 in. [0.5 mm]. Wrap masking tape around the periphery of the specimen close to each end. Place additional tape along the joint. Coat the tape over the joint with hot paraffin to help contain the epoxy when it is poured into the slit. Support the specimen so that the taped joint is vertical. Cut a slit in the tape to expose approximately ¾ in. (20 mm) of the upper portion of the joint. Slowly pour the resin bonding system into the exposed joint until it is completely filled. Keep the joint vertical for 48 h, then remove all masking tape.

10.3.3 *Type II and V Systems*—One hardened mortar section will be needed for each test specimen. Prepare the mortar surface as described in 10.2, but do not tape around the edge. Mix the components of the bonding system as described in 10.3. Brush the bonding system on the prepared surface. Place the primed mortar section in the cylinder mold that has previously been lined with a 4-mil (100-μm) polyethylene sheet. Support the mold so that the bonding surface of the mortar section is horizontal. Place a layer of freshly mixed portland-cement mortar over the primed surface to a depth of approximately ½ in. [15 mm]. Rod the layer with the tamping rod gently, so as to disturb the layer of resin as little as possible. Place the mold in its normal vertical position, and place additional mortar into the mold in two layers of approximately equal volume. Rod each layer with 25 strokes of the tamping rod. Distribute the strokes over the cross section, and make them deep enough to penetrate into the underlying layer. Strike off the surface of the top layer with the trowel, and cover the mold with a glass or metal plate.

10.4 *Curing*:

10.4.1 *Type I, III, IV, VI, and VII Systems*—Maintain all specimens at the preparation temperature in a moist room for the specified period of time.

10.4.2 *Type II and V Systems*—Demold the test specimens and cure in accordance with the curing section of Practice C 192/C 192M.

11. Procedure

11.1 Remove the specimens from the cure environment after the specified time.

11.2 *Capping*—Cap the specimens immediately after removal from curing in accordance with Practice C 617.

11.3 *Strength Testing*—Test the specimens at 73 ± 2 °F [23 ± 1 °C] in compression after capping in accordance with Test Method C 39/C 39M.

12. Calculation

12.1 Calculate the bond strength of the resin bonding system by dividing the load carried by the specimen at failure by the area of the bonded surface (Note 1). Reduce the area of the bonded surface by that of any voids found in the bond on inspection after test. Only voids larger than ⅛ in. [3 mm] should be counted in reducing the area. Report the results to the nearest 10 psi (0.1 MPa).

NOTE 1—The area of the elliptical bonding surface of the test cylinders specified in this test method is 14.13 in.^{2} [9116 mm^2]. The actual area should be based on measuring the lengths of the two axes for the areas of an ellipse [0.7854 a b]

13. Report

13.1 Report the following information:

13.1.1 Identification number,

13.1.2 Bond strength,

13.1.3 Bonding area,

13.1.4 Number and total area of voids in the bond,

13.1.5 Type and position of the fracture (in the bonding material, in the mortar, or in the interface between them), and

13.1.6 Defects in either the specimen or the cap.

14. Precision and Bias

14.1 *Precision*—The standard deviation was found to be 365 psi for the 14 day bond strength average of 1790 psi. Therefore, results of two properly conducted tests from two laboratories on similar batches should not differ from each other by more than 1022 psi.

14.2 *Bias*—This test method has no bias since the values determined can only be defined in terms of this test method.

15. Keywords

15.1 adhesives; bonding agents; bond strength; shear bond

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Designation: C 884/C 884M – 98 (Reapproved 2005)

Standard Test Method for Thermal Compatibility Between Concrete and an Epoxy-Resin Overlay[1]

This standard is issued under the fixed designation C 884/C 884M; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

This standard has been approved for use by agencies of the Department of Defense.

1. Scope

1.1 This test method covers the determination of which epoxy-resin formulations are subject to debonding when used as overlays for concrete when the combination of the two is subjected to temperature changes that may be met in the field.

1.2 The values stated in either inch-pound units or SI units are to be regarded separately as standard. Within the text, the SI units are shown in brackets. The values stated in each system are not exact equivalents; therefore, each system shall be used independently of the other. Combining values from the two systems may result in nonconformance with the specification.

1.3 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.* A specific hazard statement is given in Section 7.

2. Referenced Documents

2.1 *ASTM Standards:* [2]

C 33 Specification for Concrete Aggregates

C 150 Specification for Portland Cement

C 260 Specification for Air-Entraining Admixtures for Concrete

C 672/C 672M Test Method for Scaling Resistance of Concrete Surfaces Exposed to Deicing Chemicals

C 778 Specification for Sand

C 881/C 881M Specification for Epoxy-Resin-Base Bonding Systems for Concrete

3. Summary of Test Method

3.1 A layer of epoxy-sand mortar is applied to a slab of cured and dried concrete. After the epoxy has cured, the sample is subjected to five cycles of temperature change between 77°F [25°C] and – 6°F [–21°C]. Cracks near the bond line between the concrete and the epoxy mortar constitute failure of the test.

4. Significance and Use

4.1 This test method applies to materials used in making epoxy-mortar overlays for concrete pavement. When debonding occurs between the overlay and the pavement, the material is unsuitable.

5. Apparatus

5.1 *Molds*, in conformance with Test Method C 672.

5.2 *Freezer*, in conformance with Test Method C 672, except that the temperature of the freezer shall be – 6 ± 3°F [–21 ± 2°C].

5.3 *Retaining strips*, to retain the epoxy-mortar overlay. Pieces of wood or steel that can be attached to the 12 by 12 by 3-in. [300 by 300 by 75-mm] concrete block so as to enclose completely the top surface of the block and rise above it a uniform distance of 0.5 in. [15 mm].

6. Materials

6.1 *Portland Cement*, Type I or Type II, meeting the requirements of Specification C 150.

6.2 *Standard Sand*, meeting the requirements of Specification C 778.

6.3 *Aggregates*—Fine and coarse aggregate meeting the requirements of Specification C 33. The coarse aggregate shall be durable under freezing exposure and shall have a maximum size of 1 in. [25 mm]. The fine aggregate shall be a natural sand.

[1] This test method is under the jurisdiction of ASTM Committee C09 on Concrete and Concrete Aggregates, and is the direct responsibility of Subcommittee C09.25 on Organic Materials for Bonding, Patching, and Sealing.

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[2] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

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6.4 *Air-Entraining Admixture*, meeting the requirements of Specification C 260.

7. Hazards

7.1 **Warning**—Epoxy resins contain irritants, especially to the skin, eyes, and respiratory system. Persons handling these materials shall use appropriate protective clothing, including rubber or plastic gloves. If an epoxy resin should contact the skin, it shall be removed immediately with a dry cloth or paper towel, and the area of contact shall be washed thoroughly with soap and water. Solvents shall not be used, because they carry the irritant into the skin. Cured epoxy resins are considered innocuous.

8. Sampling

8.1 Take samples in accordance with Specification C 881.

9. Preparation of Concrete Blocks

9.1 *Proportions*—Proportion an air-entrain concrete in accordance with Test Method C 672. Prepare two blocks.

9.2 *Fabrication of Concrete Block*—Fabricate the concrete block in accordance with Test Method C 672, except end the fabrication operations after the strike-off operation.

9.3 *Curing*—Cure the concrete blocks in accordance with Test Method C 672, except that air-drying shall be at least 14 days.

9.4 *Surface Preparation*—Prior to the application of the epoxy mortar, sand-blast the top surface of the concrete block, and then remove any loose material with a bristle-brush.

10. Fabrication of Test Specimen

10.1 Assemble the retaining strips to the concrete blocks. Coat their inner surfaces with a suitable bond breaker.

10.2 *Preparation of Epoxy Mortar*—Prepare enough epoxy mortar to cover two concrete blocks. Mix the epoxy resin under test in accordance with the instructions of the manufacturer or formulator. To 1 part by volume of the mixed system add the following bulk or "loose" volumes (that is, that of the container in which it is) of standard sand and mix thoroughly:

	Unfilled	*Filled*
Grade 1	3 parts	2.5 parts
Grade 2	2.5 parts	2 parts
Grade 3		1 part

10.3 *Application of Epoxy Mortar*—Prime the surface of the concrete blocks with the recommended primer. Thoroughly brush on the primer in a thin coat. Apply the epoxy mortar in a layer flush with the tops of the retaining strips. Remove the retaining strips after 24 h and allow the epoxy mortar to cure an additional 6 days at 73 ± 2°F [23 ±1°C]. It may be necessary to grind or saw cut the vertical faces so as to have a visible bond line.

11. Procedure

11.1 After the completion of the curing period of the epoxy mortar, place the two specimens in the freezer for 24 h. Then remove them to room temperature (73 ± 2°F [23 ±1°C]) for 24 h. This is one test cycle. Continue for four additional cycles.

12. Interpretation of Results

12.1 Delamination of the epoxy-mortar layer from the concrete test block or the presence of horizontal cracks in the concrete near the interface shall constitute failure. If either of the companion specimens has failed, the epoxy-resin system under test shall be considered to have failed the test.

13. Report

13.1 The report shall state whether the resin system has passed or failed the test.

14. Precision and Bias

14.1 No statement is made about either precision or the bias of this test method for measuring thermal compatibility between concrete and an epoxy-resin overlay since the result merely states whether there is conformance to the criteria for success specified in the procedure.

15. Keywords

15.1 epoxy-resin overlay; thermal compatibility

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Designation: C 897 – 05 (Reapproved 2009)

Standard Specification for Aggregate for Job-Mixed Portland Cement-Based Plasters[1]

This standard is issued under the fixed designation C 897; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope

1.1 This specification covers natural or manufactured aggregate for use in job-mixed base and finish-coat full thickness portland cement, portland cement-lime and modified portland cement plasters.

1.2 The values stated in inch-pound units are to be regarded as standard. The values given in parentheses are mathematical conversions to SI units that are provided for information only and are not considered standard.

1.3 The text of this specification references notes and footnotes that provide explanatory material. These notes and footnotes (excluding those in tables and figures) shall not be considered as requirements of the specification.

2. Referenced Documents

2.1 *ASTM Standards:*[2]

C 11 Terminology Relating to Gypsum and Related Building Materials and Systems

C 40 Test Method for Organic Impurities in Fine Aggregates for Concrete

C 87 Test Method for Effect of Organic Impurities in Fine Aggregate on Strength of Mortar

C 88 Test Method for Soundness of Aggregates by Use of Sodium Sulfate or Magnesium Sulfate

C 117 Test Method for Materials Finer than 75-μm (No. 200) Sieve in Mineral Aggregates by Washing

C 123 Test Method for Lightweight Particles in Aggregate

C 125 Terminology Relating to Concrete and Concrete Aggregates

C 136 Test Method for Sieve Analysis of Fine and Coarse Aggregates

C 142 Test Method for Clay Lumps and Friable Particles in Aggregates

D 75 Practice for Sampling Aggregates

3. Terminology

3.1 *Definitions*—Definitions used in this standard shall be in accordance with Terminologies C 11 and C 125.

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *aggregate*, *n*—a granular material such as natural or manufactured sand used with a cementing medium to form plaster (stucco).

3.2.2 *manufactured sand*, *n*—the fine material resulting from the crushing and classification by screening, or otherwise, of rock, gravel, or blast furnace slag.

3.2.3 *natural sand*, *n*—the fine granular material resulting from the natural disintegration of rock.

4. Composition

4.1 *Deleterious Substances*—The amount of deleterious substances in aggregates, each determined on independent samples complying with the grading requirements of Section 6, shall not be more than the following:

Item	Maximum Permissible Weight, %
Friable particles	1.0
Light weight particles, floating on liquid having a specific gravity of 2.0	0.5

4.2 *Organic Impurities*:

4.2.1 The aggregate shall be free of injurious amounts of organic impurities. Except as herein provided, aggregates subjected to the test for Organic Impurities, Test Method C 40, and producing a color darker than the standard shall be rejected.

4.2.2 Aggregate failing the test for organic impurities may be used provided that, when tested for the effect of organic impurities on strength in accordance with Test Method C 87, the relative strength at 7 days is not less than 95 %.

5. Physical Properties

5.1 *Soundness* (see 7.1.7):

[1] This specification is under the jurisdiction of ASTM Committee C11 on Gypsum and Related Building Materials and Systems and is the direct responsibility of Subcommittee C11.02 on Specifications and Test Methods for Accessories and Related Products.

Current edition approved Sept. 1, 2009. Published September 2009. Originally approved in 1978. Last previous edition approved in 2005 as C 897 – 05.

[2] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

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5.1.1 Except as herein provided, aggregate subjected to five cycles of the soundness test shall show a loss, when weighed in accordance with the grading of a sampling complying with the limitations set forth in Section 6, not greater than 20 % when sodium sulfate is used, or 15 % when magnesium sulfate is used.

5.1.2 Aggregates failing to meet the requirements of 5.1.1 shall be accepted, provided there is evidence that plasters of comparable properties made from similar aggregates from the same source has been exposed to weathering, similar to that to be encountered, for a period of more than 5 years without appreciable disintegration.

6. Dimensions, Mass, and Permissible Variations

6.1 *Aggregate for Base Coat*—Aggregate for use in base coat portland cement-based plasters shall be graded as follows:

U.S. Standard Sieve	Percent Retained (by Weight)			
	Natural Sand		Manufactured Sand	
	max	min	max	min
No. 4 (4.75 mm)	0	0	0	0
No. 8 (2.36 mm)	10	0	10	0
No. 16 (1.18 mm)	40	10	40	10
No. 30 (600 µm)	65	30	65	30
No. 50 (300 µm)	90	70	80	60
No. 100 (150 µm)	100	95	90	75
No. 200 (75 µm)	100	97	100	90

6.1.1 Not more than 50 % shall be retained between any two consecutive sieves shown in the above table, nor more than 25 % between No. 50 (300-µm) and No. 100 (150-µm) sieves. The amount of material finer than a No. 200 (75-µm) sieve shall not exceed 3 %.

6.1.2 The fineness modulus shall fall between 2.05 and 3.05. If the fineness modulus varies by more than 0.25 from the value assumed in selecting proportions for the plaster, the aggregate shall be rejected unless adjustments are made in proportions to compensate for change in grading.

NOTE 1—The gradation of aggregate used in portland cement-based plaster affects the workability, shrinkage characteristic porosity, and durability of the plaster.

6.1.3 Aggregate failing to meet only the gradation limits of this specification shall be permitted to be used, provided the supplier furnishes satisfactory documentation to the specifier that the plaster made with the aggregate has an acceptable demonstrated performance record.

6.2 *Aggregate for Finish Coat Plaster*— Aggregate for finish coat plaster shall all pass the No. 8 (2.36 mm) sieve and meet the remaining gradation requirements of 6.1, except where special texture finishes require gradation of aggregate outside of these limits.

6.2.1 When special texture finishes require gradation of the aggregate outside of the limits of 6.1, sample panels shall be required and evaluated in accordance with criteria defined in the purchase agreement.

NOTE 2—Special texture finishes may require modification of the plaster formulation and application to compensate for the effect of aggregate gradation.

7. Sampling and Testing

7.1 The aggregate shall be sampled and tested as specified in the following methods, except as otherwise specified in this specification:

7.1.1 *Sampling*, Practice D 75.

7.1.2 *Fineness Modulus*, Terminology C 125, is obtained by adding the total percentages shown by the sieve analysis to be retained on each of the sieves in 6.1, except the No. 200 (75 µm) sieve, and dividing the sum by 100.

7.1.3 *Materials Finer than No. 200 (75-µm) Sieve*, Test Method C 117 by washing.

7.1.4 *Friable Particles*, Test Method C 142.

7.1.5 *Light Constituents*, Test Method C 123.

7.1.6 *Organic Impurities*, Test Method C 40.

7.1.7 *Soundness*, Test Method C 88.

7.1.8 *Sieve Analysis*, Test Method C 136.

8. Inspection

8.1 Inspection of the material shall be agreed upon between the purchaser and supplier as part of the purchase contract.

9. Rejection and Rehearing

9.1 Any rejection shall be based upon the specific cause of failure to conform to the requirements of this specification, and shall be reported to the seller within ten working days from the receipt of the shipment by the purchaser.

9.2 Claims for rehearing shall be valid only if made within 20 working days from receipt of notice of specific cause for rejection.

10. Certification

10.1 When specified in the purchase order a producer's or supplier's certification shall be furnished to the purchaser that the material was prepared or manufactured in accordance with this specification and has been found to meet the specified requirements.

11. Packaging and Package Marking

11.1 Where packaged, the materials shall be packaged in substantial commercial containers of the type, size, and kind commonly used for the purpose, so constructed as to preserve the contents in good condition, and to ensure acceptance and safe delivery by common or other carriers, at the lowest rate, to the point of delivery.

11.2 The containers shall be so made that the contents can be partially removed without destroying the container's ability to serve as a receptacle for the remainder of the contents.

11.3 The containers shall be labeled to show the content, weight, and the name of the manufacturer or supplier.

11.4 Where delivered in bulk quantities, the bill of lading shall show the quantity by weight, or cubic yards, and the name of the manufacturer or supplier.

11.5 Each package or container shall be marked with the name of manufacturer, description of contents, and amount.

12. Keywords

12.1 aggregate; fine aggregate; gradation; natural and manufactured sand; particle shape and size; plaster stucco; soundness

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Designation: C 900 – 06

Standard Test Method for Pullout Strength of Hardened Concrete[1]

This standard is issued under the fixed designation C 900; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope*

1.1 This test method covers determination of the pullout strength of hardened concrete by measuring the force required to pull an embedded metal insert and the attached concrete fragment from a concrete test specimen or structure. The insert is either cast into fresh concrete or installed in hardened concrete. This test method does not provide statistical procedures to estimate other strength properties.

1.2 The values stated in SI units are to be regarded as the standard.

1.3 The text of this test method references notes and footnotes which provide explanatory material. These notes and footnotes (excluding those in tables and figures) shall not be considered as requirements of this test method.

1.4 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.* (**WARNING**—Fresh hydraulic cementitious mixtures are caustic and may cause chemical burns to skin and tissue upon prolonged exposure.)[2]

2. Referenced Documents

2.1 *ASTM Standards:* [3]

C 670 Practice for Preparing Precision and Bias Statements for Test Methods for Construction Materials

E 4 Practices for Force Verification of Testing Machines

E 74 Practice of Calibration of Force-Measuring Instruments for Verifying the Force Indication of Testing Machines

3. Summary of Test Method

3.1 A metal insert is either cast into fresh concrete or installed into hardened concrete. When an estimate of the in-place strength is desired, the insert is pulled by means of a jack reacting against a bearing ring. The pullout strength is determined by measuring the maximum force required to pull the insert from the concrete mass. Alternatively, the insert is loaded to a specified load to verify whether a minimum level of in-place strength has been attained.

4. Significance and Use

4.1 For a given concrete and a given test apparatus, pullout strengths can be related to compressive strength test results. Such strength relationships depend on the configuration of the embedded insert, bearing ring dimensions, depth of embedment, and level of strength development in that concrete. Prior to use, these relationships must be established for each system and each new combination of concreting materials. Such relationships tend to be less variable where both pullout test specimens and compressive strength test specimens are of similar size, compacted to similar density, and cured under similar conditions.

NOTE 1—Published reports (**1-17**)[4] by different researchers present their experiences in the use of pullout test equipment. Refer to ACI 228.1R (**14**) for guidance on establishing a strength relationship and interpreting test results. The Appendix provides a means for comparing pullout strengths obtained using different configurations.

4.2 Pullout tests are used to determine whether the in-place strength of concrete has reached a specified level so that, for example:

(1) post-tensioning may proceed;

(2) forms and shores may be removed; or

(3) winter protection and curing may be terminated.

In addition, post-installed pullout tests may be used to estimate the strength of concrete in existing constructions.

4.3 When planning pullout tests and analyzing test results, consideration should be given to the normally expected decrease of concrete strength with increasing height within a

[1] This test method is under the jurisdiction of ASTM Committee C09 on Concrete and Concrete Aggregates and is the direct responsibility of Subcommittee C09.64 on Nondestructive and In-Place Testing.

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[2] Section on Safety Precautions, Manual of Aggregate and Concrete Testing, *Annual Book of ASTM Standards*, Vol. 04.02.

[3] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

[4] The boldface numbers refer to the list of references at the end of this test method.

***A Summary of Changes section appears at the end of this standard.**

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given concrete placement in a structural element. The measured pullout strength is indicative of the strength of concrete within the region represented by the conic frustum defined by the insert head and bearing ring. For typical surface installations, pullout strengths are indicative of the quality of the outer zone of concrete members and can be of benefit in evaluating the cover zone of reinforced concrete members.

4.4 Cast-in-place inserts require that their locations in the structure be planned in advance of concrete placement. Post-installed inserts can be placed at any desired location in the structure provided the requirements of 6.1 are satisfied.

4.5 This test method is not applicable to other types of post-installed tests that, if tested to failure, do not involve the same failure mechanism and do not produce the same conic frustum as the cast-in-place test described in this test method (**16**).

5. Apparatus

5.1 The apparatus requires three basic sub-systems: a pull-out insert, a loading system, and a load-measuring system (Note 2). For post-installed inserts, additional equipment includes a core drill, a grinding wheel to prepare a flat bearing surface, a milling tool to undercut a groove to engage the insert, and an expansion tool to expand the insert into the groove.

NOTE 2—A center-pull hydraulic jack with a pressure gauge calibrated according to Annex A1 and a bearing ring have been used satisfactorily.

5.1.1 Cast-in-place inserts shall be made of metal that does not react with cement. The insert shall consist of a cylindrical head and a shaft to fix embedment depth. The shaft shall be attached firmly to the center of the head (see Fig. 1). The insert shaft shall be threaded to the insert head so that it can be removed and replaced by a stronger shaft to pullout the insert, or it shall be an integral part of the insert and also function as the pullout shaft. Metal components of cast-in-place inserts and attachment hardware shall be of similar material to prevent galvanic corrosion. Post-installed inserts shall be designed so that they will fit into the drilled holes, and can be expanded subsequently to fit into the grooves that are undercut at a predetermined depth (see Fig. 2).

NOTE 3—A successful post-installed system uses a split ring that is coiled to fit into the core hole and then expanded into the groove.

5.1.2 The loading system shall consist of a bearing ring to be placed against the hardened concrete surface (see Figs. 1 and 2) and a loading apparatus with the necessary load-measuring devices that can be readily attached to the pullout shaft.

5.1.3 The test apparatus shall include centering features to ensure that the bearing ring is concentric with the insert, and that the applied load is axial to the pullout shaft, perpendicular to the bearing ring, and uniform on the bearing ring.

5.2 Equipment dimensions shall be determined as follows (see Fig. 1):

5.2.1 The diameter of the insert head (d_2) is the basis for defining the test geometry. The thickness of the insert head and the yield strength of the metal shall be sufficient to prevent yielding of the insert during test. The sides of the insert head shall be smooth (see Note 5). The insert head diameter shall be greater than or equal to ⅔ of the nominal maximum size of aggregate.

NOTE 4—Typical insert diameters are 25 and 30 mm, but larger

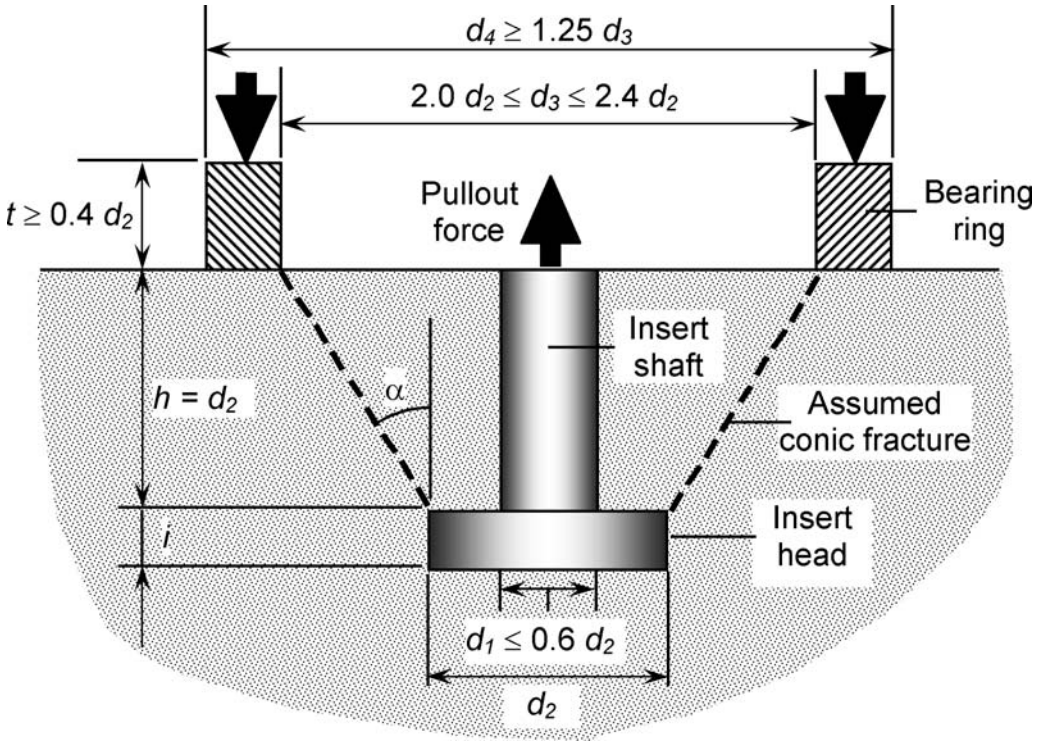

FIG. 1 Schematic Cross Section of Cast-in-Place Pullout Test

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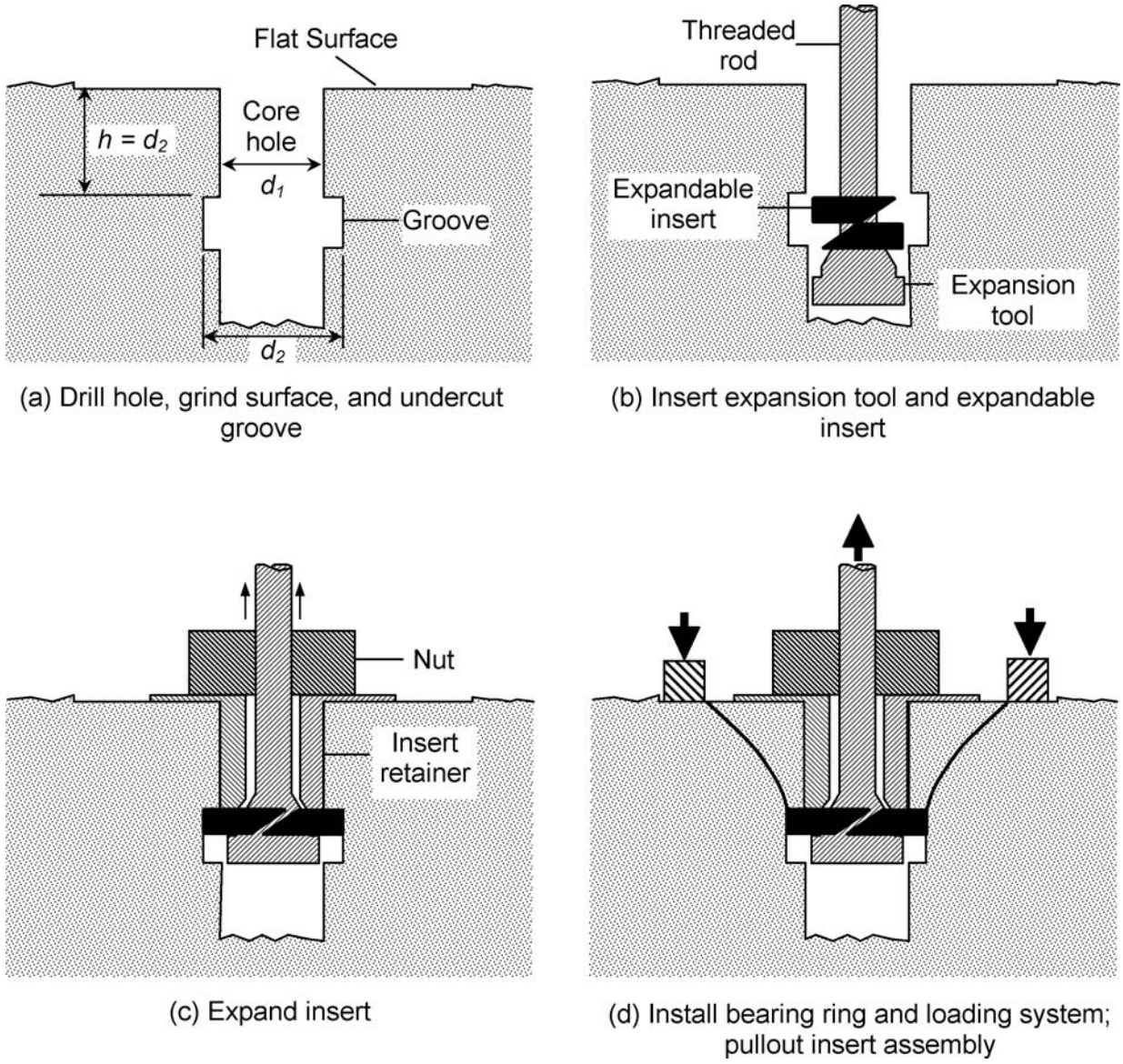

FIG. 2 Schematic of Procedure for Post-Installed Pullout Test

diameters have been used (**1, 3**). Tests (**15**) have shown that nominal maximum aggregate sizes up to 1.5 times the head diameter do not have significant effects on the strength relationships. Larger aggregate sizes may result in increased scatter of the test results because the large particles can interfere with normal pullout of the conic frustum.

NOTE 5—Cast-in–place inserts may be coated with a release agent to minimize bonding with the concrete, and they may be tapered to minimize side friction during testing. The insert head should be provided with the means, such as a notch, to prevent rotation in the concrete if the insert shaft has to be removed prior to performing the test. As a further precaution against rotation of the insert head, all threaded hardware should be checked prior to installation to ensure that it is free-turning and can be easily removed. A thread-lock compound is recommended to prevent loosening of the insert head from the shaft during installation and during vibration of the surrounding concrete.

5.2.2 For cast-in–place inserts, the length of the pullout insert shaft shall be such that the distance from the insert head to the concrete surface (h) equals the diameter of the insert head (d_2). The diameter of the insert shaft at the head (d_1) shall not exceed 0.60 d_2.

5.2.3 For post-installed inserts, the groove to accept the expandable insert shall be cut so that the distance between the bearing surface of the groove and concrete surface equals the insert diameter after expansion (d_2). The difference between the diameters of the undercut groove (d_2) and the core hole (d_1) shall be sufficient to prevent localized failure and ensure that a conic frustum of concrete is extracted during the test (see Note 6). The expanded insert shall bear uniformly on the entire bearing area of the groove.

NOTE 6—A core hole diameter of 18 mm and an undercut groove diameter of 25 mm have been used successfully.

5.2.4 The bearing ring shall have an inside diameter (d_3) of 2.0 to 2.4 times the insert head diameter (d_2), and shall have an outside diameter (d_4) of at least 1.25 times the inside diameter. The thickness of the ring (t) shall be at least 0.4 times the pullout insert head diameter.

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5.2.5 Tolerances for dimensions of the pullout test inserts, bearing ring and embedment depth shall be ±2 % within a given system.

NOTE 7—The limits for dimensions and configurations for pullout test inserts and apparatus are intended to accommodate various systems.

5.2.6 The loading apparatus shall have sufficient capacity to provide the loading rate prescribed in 7.4 and exceed the maximum load expected.

NOTE 8—Hydraulic pumps that permit continuous loading may give more uniform test results than pumps that apply load intermittently.

5.2.7 The gauge to measure the pullout force shall have a least division not larger than 5 % of the minimum value in the intended range of use.

5.2.8 The force gauge shall have a maximum value indicator that preserves the value of the maximum load during testing.

5.2.9 Pullout apparatus shall be calibrated in accordance with Annex A1 at least once a year and after all repairs. Calibrate the pullout apparatus using a testing machine verified in accordance with Practices E 4 or a Class A load cell as defined in Practice E 74. The indicated pullout force based on the calibration relationship shall be within ±2 % of the force measured by the testing machine or load cell.

6. Sampling

6.1 Pullout test locations shall be separated so that the clear spacing between inserts is at least seven times the pullout insert head diameter. Clear spacing between the inserts and the edges of the concrete shall be at least 3.5 times the head diameter. Inserts shall be placed so that reinforcement is outside the expected conical failure surface by more than one bar diameter, or the maximum size of aggregate, whichever is greater.

NOTE 9—A reinforcement locator is recommended to assist in avoiding reinforcement when planning the locations of post-installed tests. Follow the manufacturer's instructions for proper operation of such devices.

6.2 When pullout test results are used to assess the in-place strength in order to allow the start of critical construction operations, such as formwork removal or application of post tensioning, at least five individual pullout tests shall be performed as follows:

6.2.1 For a given placement, every 115 m^3, or a fraction thereof, or

6.2.2 For slabs or walls, every 470 m^2 , or a fraction thereof, of the surface area of one face.

NOTE 10—More than the minimum number of inserts should be provided in case a test result is not valid or testing begins before adequate strength has developed.

6.2.3 Inserts shall be located in those portions of the structure that are critical in terms of exposure conditions and structural requirements.

6.3 When pullout tests are used for other purposes, the number of tests shall be determined by the specifier.

7. Procedure

7.1 *Cast-in-Place Inserts*:

7.1.1 Attach the pullout inserts to the forms using bolts or by other acceptable methods that firmly secure the insert in its proper location prior to concrete placement. All inserts shall be embedded to the same depth. The axis of each shaft shall be perpendicular to the formed surface.

7.1.2 Alternatively, when instructed by the specifier of tests, manually place inserts into unformed horizontal concrete surfaces. The inserts shall be embedded into the fresh concrete by means that ensure a uniform embedment depth and a plane surface perpendicular to the axis of the insert shaft. Installation of inserts shall be performed or supervised by personnel trained by the manufacturer or manufacturer's representative.

NOTE 11—Experience indicates that pullout strengths are of lower value and more variable for manually-placed surface inserts than for inserts attached to formwork (12).

7.1.3 When pullout strength of the concrete is to be measured, remove all hardware used for securing the pullout inserts in position. Before mounting the loading system, remove any debris or surface abnormalities to ensure a flat bearing surface that is perpendicular to the axis of the insert.

7.2 *Post-Installed Inserts*:

7.2.1 The selected test surface shall be flat to provide a suitable working surface for drilling the core and undercutting the groove. Drill a core hole perpendicular to the surface to provide a reference point for subsequent operations and to accommodate the expandable insert and associated hardware. The use of an impact drill is not permitted.

7.2.2 If necessary, use a grinding wheel to prepare a flat surface so that the base of the milling tool is supported firmly during subsequent test preparation and so that the bearing ring is supported uniformly during testing. The ground surface shall be perpendicular to the axis of the core hole.

7.2.3 Use the milling tool to undercut a groove of the correct diameter and at the correct depth in the core hole. The groove shall be concentric with the core hole.

NOTE 12—To control the accuracy of these operations, a support system should be used to hold the apparatus in the proper position during these steps.

7.2.4 If water is used as a coolant, remove free-standing water from the hole at the completion of the drilling and undercutting operations. Protect the hole from ingress of additional water until completion of the test.

NOTE 13—Penetration of water into the failure zone could affect the measured pullout strength; therefore, water must be removed from the hole immediately after completion of drilling, grinding, and undercutting operations. If the test will not be completed immediately after preparation of the hole, water must not be allowed to enter the hole before completing the test.

7.2.5 Use the expansion tool to position the expandable insert into the groove and expand the insert to its proper size.

7.3 *Bearing Ring*—Place the bearing ring around the pullout insert shaft, connect the pullout shaft to the hydraulic ram, and tighten the pullout assembly snugly against the bearing surface. Ensure that the bearing ring is centered around the shaft and flush against the concrete.

7.4 *Loading Rate*—Apply load at a uniform rate so that the nominal normal stress on the assumed conical fracture surface increases at a rate of 70 ± 30 kPa/s (Note 14). If the insert is to be tested to rupture of the concrete, load at the specified uniform rate until rupture occurs. Record the maximum gauge

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reading to the nearest half of the least division on the dial. If the insert is to be tested only to a specified load to verify whether a minimum in-place strength has been attained, load at the specified uniform rate until the specified pullout load is reached. Maintain the specified load for at least 10 s.

NOTE 14—The loading rate is specified in terms of a nominal stress rate to accommodate different sizes of pullout test systems. See Appendix X1 for the formula relating the nominal normal stress and the pullout load. For a pullout test system in which d_2 = 25 mm and d_3 = 55 mm, the specified stress rate corresponds to a loading rate of approximately 0.5 ± 0.2 kN/s. If this system is used, the ranges of the times to complete a test for different anticipated ultimate pullout loads would be as follows:

Anticipated Pullout Load, kN	Minimum Time, s	Maximum Time, s
10	14	33
20	29	67
30	43	100
40	57	133
50	71	167
60	86	200
70	100	233
80	114	267
90	129	300
100	143	333

7.4.1 Do not test frozen concrete.

7.5 *Rejection*—Reject a test result if one or more of the following conditions are encountered:

7.5.1 The large end of the conic frustum is not a complete circle of the same diameter as the inside diameter of the bearing ring;

7.5.2 The distance from the surface to the insert head (*h* in Fig. 1 or Fig. 2) is not equal to the insert diameter;

7.5.3 The diameter of the groove in a post-installed test is not equal to the design value;

7.5.4 The expanded insert diameter in a post-installed test is not equal to the design value; or,

7.5.5 A reinforcing bar is visible within the failure zone after the conic frustum is removed.

8. Calculation

8.1 Convert gauge readings to pullout force on the basis of calibration data.

8.2 Compute the average and standard deviation of the pullout forces that represent tests of a given concrete placement.

9. Report

9.1 Report the following information:

9.1.1 Dimension of the pullout insert and bearing ring (sketch or define dimensions),

9.1.2 Identification by which the specific location of the pullout test can be identified,

9.1.3 Date and time when the pullout test was performed.

9.1.4 For tests to failure, maximum pullout load of individual tests, average, and standard deviation, kN. For tests to a specified load, the pullout load applied in each test, kN.

9.1.5 Description of any surface abnormalities beneath the reaction ring at the test location,

9.1.6 Abnormalities in the ruptured specimen and in the loading cycle,

9.1.7 Concrete curing methods used and moisture condition of the concrete at time of test, and

9.1.8 Other information regarding unusual job conditions that may affect the pullout strength.

10. Precision and Bias

10.1 *Single Operator Precision*—Based on the data summarized in ACI 228.1 R (**14**) for cast-in-place pullout tests with embedment of about 25 mm, the average coefficient of variation for tests made on concrete with maximum aggregate of 19 mm by a single operator using the same test device is 8 %.[5] Therefore, the range in individual test results, expressed as a percentage of the average, should not exceed the following:

Number of Tests	Acceptable range, (percent of average)
5	31 %
7	34 %
10	36 %

Similar values of within-test variability have been reported for post-installed pullout tests of the same geometry as cast-in-place tests (**15**).

NOTE 15—If the range of tests results exceeds the acceptable range, further investigation should be carried out. Abnormal test results could be due to improper procedures or equipment malfunction. The user should investigate potential causes of outliers and disregard those test results for which reasons for the outlying results can be identified positively. If there are no obvious causes of the extreme values, it is probable that there are real differences in concrete strength at different test locations. These differences could be due to variations in mixture proportions, degree of consolidation, or curing conditions.

10.2 *Multi-Operator Precision*—Test data are not available to develop a multi-operator precision statement.

10.3 *Bias*—The bias of this test method cannot be evaluated since pullout strength can only be determined in terms of this test method.

11. Keywords

11.1 concrete strength; in-place strength; in-place testing; pullout test

[5] This number represents the (1s%) limit as described in Practice C 670.

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ANNEX

(Mandatory Information)

A1. CALIBRATION OF PULLOUT-HYDRAULIC LOADING SYSTEM

A1.1 The objective of the calibration procedure is to establish a relationship between the reading of the pullout force measuring system and the tensile force in the shaft used to pullout the insert. This relationship is established using alternative approaches as indicated in Fig. A1.1. In general, calibration is achieved by correlating the gauge reading of the pullout loading system with the force measured by a testing machine that has been verified in accordance with Practices E 4 or measured with a Class A load cell that has been calibrated in accordance with Practice E 74. The time interval between testing machine verifications or load cell calibrations shall be as defined in Practices E 4 or E 74.

A1.2 Position the pullout loading system on the force measurement apparatus. Align all components so that the pullout force is concentric with the loading system and the force measurement system. Use spherical seats or other similar means to minimize bending effects in the loading system.

NOTE A1.1—When a compression-testing machine is used to measure the force, the bearing blocks should be protected against damage.

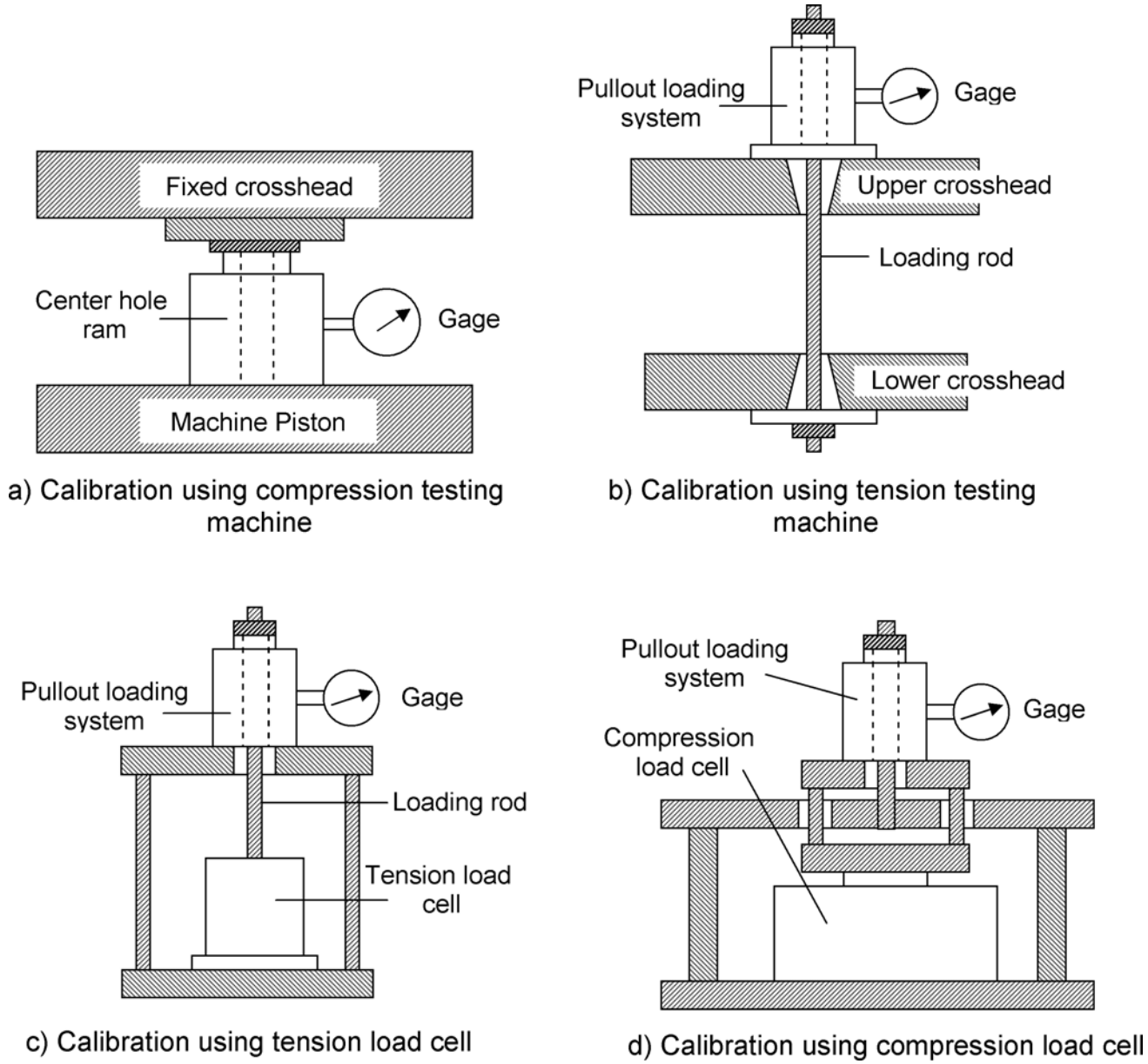

FIG. A1.1 Schematics of Acceptable Methods to Calibrate Pullout Load Measuring System

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Cold-rolled steel plate at least 13 mm thick is recommended.

A1.3 Using the pullout loading system, apply increasing loads over the operating range, and record the gauge reading and the corresponding force measured by the testing machine or load cell. Take readings at approximately 10 load levels distributed over the operating range of the pullout loading system.

NOTE A1.2—Low values of force should be avoided in the calibration process because the effects of friction may introduce significant errors. The manufacturer should provide the operating range of the pullout loading system.

A1.4 Use the readings obtained during calibration loading to calculate an appropriate regression equation using the least-squares curve-fitting method.

NOTE A1.3—Appendix X2 provides an example to illustrate the development of a calibration equation. Additional information is provided in Practice E 74.

A1.5 The difference between the force based on the regression equation and the force measured by the testing machine or the load cell shall not be greater than ±2 % of the measured force over the operating range. If this tolerance is not met, the pullout loading system shall not be used until this requirement is satisfied.

APPENDIXES

(Nonmandatory Information)

X1. STRESS CALCULATION

X1.1 When a stress calculation is desired, compute a nominal normal stress on the assumed conical fracture surface by dividing the pullout force by the area of the frustum and multiplying by the sine of one-half the apex angle (see Fig. 1). Use the following equations:

$$f_n = \frac{P}{A}\sin\alpha \tag{X1.1}$$

$$\sin\alpha = \frac{d_3 - d_2}{2S} \tag{X1.2}$$

$$A = \pi S\frac{d_3 + d_2}{2} \tag{X1.3}$$

$$S = \sqrt{h^2 + \left(\frac{d_3 - d_2}{2}\right)^2} \tag{X1.4}$$

where:

f_n = nominal normal stress, MPa,
P = pullout force, N,
α = ½ the frustum apex angle, or $\tan^{-1}(d_3 - d_2)/2h$,
A = fracture surface area, mm^2 ,
d_2 = diameter of pullout insert head, mm,
d_3 = inside diameter of bearing ring or large base diameter of assumed conic frustum, mm,
h = height of conic frustum, from insert head to large-base surface, mm , and
S = slant length of the frustum, mm.

X1.2 The above calculation gives the value of the average normal stress on the assumed failure surface shown in Fig. 1. Because the state of stress on the conic frustum is not uniform, the calculated normal stress is a fictitious value. The calculated normal stress is useful when comparing pullout strengths obtained with different test geometries that fall within the limits of this test method.

X2. EXAMPLE TO ILLUSTRATE CALIBRATION PROCESS

X2.1 This appendix provides an example to illustrate the development of the calibration equation to convert the gauge reading on the pullout loading system to the force acting on the insert. Table X2.1 shows data that were obtained using the procedure in the annex. The first column shows the gauge reading and the second column shows the measured force.

X2.2 Fig. X2.1 shows a plot of the data in Table X2.1 along with the best-fit straight line to the data. A straight line was fitted using a commercial computer program for graphing and statistical analysis. The equation of the line is shown in the table of results on the graph and is as follows:

$$P\ (\text{kN}) = -0.55 + 1.089\ G\ (\text{kN}) \tag{X2.1}$$

TABLE X2.1 Example of Calibration Data and Residuals After Regression

Gauge Reading, kN	Measured Force, kN	Residuals, kN
2.0	1.6	0.03
5.0	4.8	0.09
10.0	10.5	–0.16
15.0	15.8	–0.02
20.0	21.2	0.03
25.0	26.7	–0.03
30.0	32.0	0.12
35.0	37.4	0.16
40.0	42.8	0.21
45.0	48.6	–0.14
50.0	54.2	–0.30
55.0	59.4	–0.06
60.0	64.5	0.29

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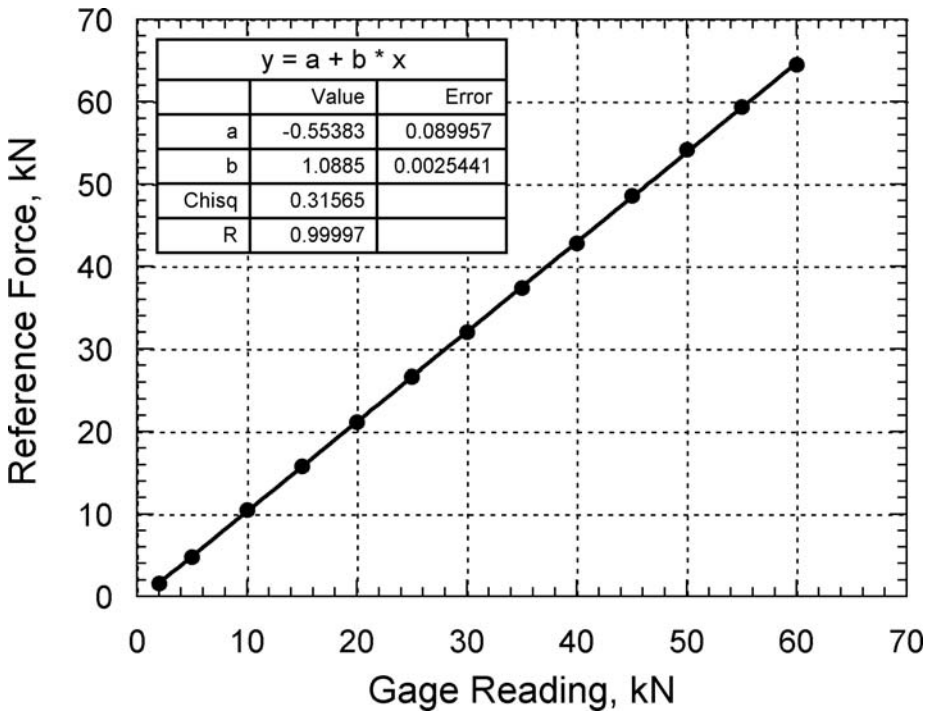

FIG. X2.1 Plot of Calibration Data from Table X2.1 and Best-Fit Straight Line

where:

P = estimated pullout force, kN, and

G = pullout force indicated by gauge of pullout loading system, kN.

The column labeled "error" in the table shown within Fig. X2.1 represents the standard deviations of the estimated intercept and slope. The low values of these standard deviations relative to the slope and intercept indicate that the intercept is not zero and that the slope is not equal to 1.00.

X2.3 Fig. X2.2 is a plot of the residuals of the best-fit line as a function of the measured force. These residuals are shown in the third column of Table X2.1, and they are the differences between the estimated force based on the best-fit equation and the measured force (Column 2 in Table X2.1). Also shown in Fig. X2.2 are the ±2 % limits required in accordance with 5.2.9. It is seen that, with the exception of the first three points, the residuals are well within the permitted tolerance. Thus, the calibration relationship for this particular apparatus satisfies the requirements of 5.2.9 provided that the pullout force is greater than about 10 kN.

X2.4 Fig. X2.2 shows that the residuals are not randomly distributed but appear to have a periodic variation with the level of force. This indicates that the true calibration equation is not a straight line. However, because the residuals are well below the ±2 % limits, it is not necessary to try to fit a higher order (polynomial) equation, and the straight line is adequate. Additional discussion on fitting higher order equations is provided in Practice E 74.

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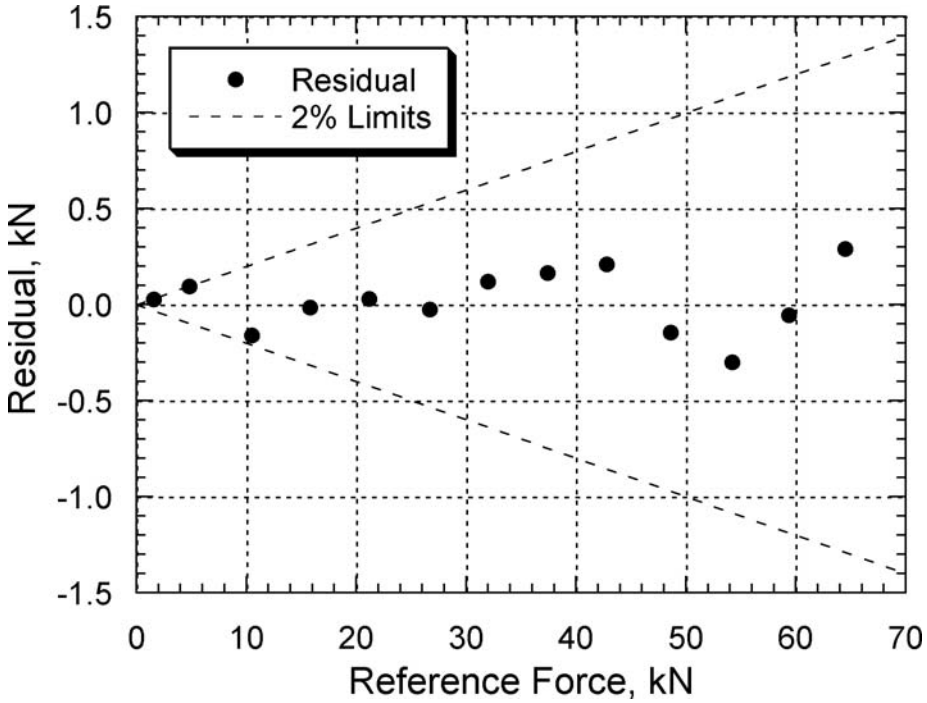

FIG. X2.2 Residuals of Best-Fit Equation as a Function of Measured Force

REFERENCES

(1) Richards, O.," Pullout Strength of Concrete," *Reproducibility and Accuracy of Mechanical Tests*, *ASTM STP 626*, ASTM 1977, pp. 32–40.

(2) Kiekegaard-Hansen, P., *Lok-Strength*, Saertryk af Nordisk Betong 3: 1975.

(3) Malhotra, V. M. and Carrette, G., "Comparison of Pullout Strength of Concrete with Compressive Strength of Cylinders and Cores, Pulse Velocity and Rebound Number," *Journal*, American Concrete Institute, Vol. 77, No. 3, May–June 1980, pp. 161–170.

(4) Bickley, J. A., "The Variability of Pullout Tests and In-Place Concrete Strength," *Concrete International*, American Concrete Institute, Vol 4, No. 4, April 1982, pp. 44–51.

(5) Dilly, R. L. and Ledbetter, W. B., "Concrete Strength Based on Maturity and Pullout," *ASCE Journal of Structural Engineering*, American Society of Civil Engineers, Vol. 110, No. 2, Feb. 1984, pp. 354–369.

(6) Stone, W. C. and Giza, B. J., "The Effect of Geometry and Aggregate on the Reliability of the Pullout Test," *Concrete International*, American Concrete Institute, Vol 7, No. 2, Feb. 1985, pp. 27–36.

(7) Hindo, K. R. and Bergstrom, W. R., "Statistical Evaluation of the In-Place Compressive Strength of Concrete," *Concrete International*, American Concrete Institute Vol. 7, No. 2, Feb. 1985, pp. 44–48.

(8) Yener, M. and Chen, W. F., "On In-Place Strength of Concrete and Pullout Tests," Cement, Concrete, and Aggregates, CCAGDP, Vol. 6, No. 2, Winter 1984, pp. 90–99.

(9) Bickley, J. A., "The Evaluation and Acceptance of Concrete Quality by In-Place Testing," *In Situ/Nondestructive Testing of Concrete*, American Concrete Institute, 1984, pp. 95–109.

(10) Carrette, G. G. and Malhotra, V. M., "In Situ Tests: Variability and Strength Prediction of Concrete at Early Ages," *In Situ/Nondestructive Testing of Concrete*, American Concrete Institute, 1984, pp. 111–141.

(11) Khoo, L. M.," Pullout Technique—An Additional Tool for In Situ Concrete Strength Determination," *In Situ/Nondestructive Testing of Concrete*, American Concrete Institute, 1984, pp. 143–159.

(12) Vogt, W. L., Beizai, V. and Dilly, R. L.,"In Situ Strength of Concrete with Inserts Embedded by 'Finger Placing'," *In Situ/Nondestructive Testing of Concrete*, American Concrete Institute, 1984, pp. 161–175.

(13) Parsons, T. J. and Naik, T. R., "Early Age Concrete Strength Determination Pullout Testing and Maturity," *In Situ/Nondestructive Testing of Concrete*, American Concrete Institute, 1984, pp. 177–199.

(14) ACI 228.1R-03,"In-Place Methods to Estimate Concrete Strength," American Concrete Institute, Farmington Hills, MI, www.concrete-.org, 44 p.

(15) Petersen, C.G., "LOK-TEST and CAPO-TEST Pullout Testing, Twenty Years Experience," *Proceedings of Conference on Nondestructive Testing in Civil Engineering*, J.H. Bungey, Ed., British Institute of Nondestructive Testing, U.K., Liverpool, 8–11 April 1997, pp. 77–96.

(16) Carino, N.J., "Pullout Test," Chapter 3 in *Handbook on Nondestructive Testing of Concrete*, 2nd Edition, V.M. Malhotra and N.J. Carino, Eds., CRC Press, Boca Raton, FL, and ASTM International, West Conshohocken, PA, www.astm.org, 2004.

(17) Soutsos, M.N., Bungey, J.H., and Long, A.E., "Pullout Test Correlations and In-Place Strength Assessment—The European Concrete Frame Building Project," *ACI Materials Journal*, Vol. 12, No. 6, Nov-Dec 2005, pp 422-428.

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SUMMARY OF CHANGES

Committee C09 has identified the location of selected changes to this test method since the last issue, C 900 – 01, that may impact the use of this test method. (Approved December 15, 2006)

(*1*) Revised 1.1 to clarify that the method does not address statistical analysis needed to estimate other types of strength.
(*2*) Revised 1.2 by deleting inch-pound values for information only.
(*3*) Revised 1.4 by adding a warning on chemical burns.
(*4*) Revised 3.1 by adding statement that test may not have to be carried out to ultimate load.
(*5*) Added 5.2.8 to make a peak load indicator mandatory.
(*6*) Revised 6.1 to permit the use of smaller specimens for correlation testing.
(*7*) Added Note 10 to recommend more than the minimum number of inserts as a precaution.
(*8*) Revised 7.1.2 by permitting the use of manually placed inserts as an alternative when specified.
(*9*) Revised 7.4 by including a minimum hold time for tests carried out to a specified load.
(*10*) Added 7.4.1 to prohibit testing frozen concrete.
(*11*) Added 10.2 to indicate that data are not available for a multi-laboratory precision statement.

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Designation: C 911 – 06

Standard Specification for Quicklime, Hydrated Lime, and Limestone for Selected Chemical and Industrial Uses[1]

This standard is issued under the fixed designation C 911; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope*

1.1 This specification covers lime and limestone products suitable for the following chemical and industrial uses:

Cooking rags
Sulfite pulp
Silica brick
Other water treatment uses
Calcium carbide
Grease
Calcium silicate products
Hypochlorite (bleach)

The following uses are addressed in other ASTM standards:

Use	Standard(s)
Neutralization of Waste Acid (Test Methods)	C 400
Agricultural Liming Materials	C 602
Soil Stabilization	C 977
Asphalt	C 1097
Flue Gas Desulfurization (Test Methods)	C 1318
Drinking Water Softening	C 1529
Waste and Wastewater Neutralization	C 1529
Wastewater Treatment Plant Residuals (Biosolids) Stabilization	C 1529 and D 6249

1.2 The type designations in Table 1 signify the following:

Limestone, high-calcium—CL
Limestone, dolomitic—DL
Limestone, magnesian—ML
Quicklime, high-calcium—CQ
Quicklime, dolomitic—DQ
Quicklime, magnesian—MQ
Hydrated lime, high-calcium—CH
Hydrated lime, dolomitic—DH
Hydrated lime, magnesian—MH

1.3 The buyer shall designate the use, as listed in Table 1, and may specify one or more of the type designations in 1.1.

1.4 This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.

2. Referenced Documents

2.1 *ASTM Standards:* [2]

C 25 Test Methods for Chemical Analysis of Limestone, Quicklime, and Hydrated Lime
C 50 Practice for Sampling, Sample Preparation, Packaging, and Marking of Lime and Limestone Products
C 110 Test Methods for Physical Testing of Quicklime, Hydrated Lime, and Limestone
C 400 Test Methods for Quicklime and Hydrated Lime for Neutralization of Waste Acid
C 602 Specification for Agricultural Liming Materials
C 977 Specification for Quicklime and Hydrated Lime for Soil Stabilization
C 1097 Specification for Hydrated Lime for Use in Asphalt Cement or Bituminous Pavements
C 1318 Test Method for Determination of Total Neutralizing Capability and Dissolved Calcium and Magnesium Oxide in Lime for Flue Gas Desulfurization (FGD)
C 1529 Specification for Quicklime, Hydrated Lime, and Limestone for Environmental Uses
D 6249 Guide for Alkaline Stabilization of Wastewater Treatment Plant Residuals

3. Chemical Composition

3.1 The requirements for quicklime, hydrated lime, and limestone for the selected end uses are as shown in Table 1, and are on the basis of the weight of sample taken at the place of manufacture, except as noted in footnote *B* after the requirement. In this case, the requirement is on a moisture and carbon dioxide-free basis.

NOTE 1—Rags are cooked for the manufacture of paper in a digester under steam pressure with lime or with lime and soda ash. They are then washed to eliminate as much of the noncellulose material as possible. A standard composition without rejection limits is specified for the reason that lime of either higher or lower total oxides, available lime, calcium oxide, or calcium hydroxide than the standard, may safely be used under suitable conditions for the purpose herein specified, depending primarily upon economic considerations. In the present state of the art, it is believed that the more serviceable type of specification for the product herein

[1] This specification is under the jurisdiction of ASTM Committee C07 on Lime and is the direct responsibility of Subcommittee C07.02 on Specifications and Guidelines.

Current edition approved Nov. 15, 2006. Published November 2006. Originally approved in 1979. Last previous edition approved in 2005 as C 911 – 05.

[2] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

***A Summary of Changes section appears at the end of this standard.**

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TABLE 1 Lime and Limestone for Chemical and Industrial Uses

Use	ASTM Specification[A]	Notes Referenced	Approved Types of Lime or Stone	Chemical Requirements, %									
				CaO min	CaO, +MgO min	SiO_2 +Fe_2O_3, +Al_2O_3, max	MgO, max	CO_2, max	SiO_2+ insoluble matter, max	Al_2O_3 + Fe_2O_3, max	Available CaO, min	Fe_2O_3, max	Chemical Other
Cooking rags	C 45	1	CH	...	...	...	...	...	...	...	64.3[B]	...	...
Cooking rags	C 45	1	CQ	...	...	...	...	...	...	...	90.0[B]	...	...
Sulfite pulp	C 46	2	CQ, MQ	...	95.0[C]	3.0[C]	...	...	...	...	...	...	...
Sulfite pulp	C 46	2	CL, ML	...	95.0[C]	3.0[C]	...	...	...	...	...	...	...
Silica brick	C 49	3	CH	90[C]	...	...	2.5[C]	2.5	3.0[C]	1.5[C]	...	...	{Free CaO ≤1.5
Silica brick	C 49	3	CQ	90[C]	...	...	2.5[C]	2.5	3.0[C]	1.5[C]	...	...	
Other water treatment uses	C 53	4	CQ, DQ, MQ	...	93.0	...	...	...	...	...	...	...	...
Other water treatment uses	C 53	4	CH, DH, MH	...	93.0[C]	...	...	...	...	...	...	...	...
Calcium Carbide	C 258		CQ	92[C]	...	...	1.75[C]	4.0	2.0[C]	1.0[C]	...	0.5	P≤ 0.02[C] {S ≤ 0.2[C]
Grease	C 259		CH	...	...	...	1.5	...	1.0	...	...	0.5	available {Ca (OH)$_2$ ≥90
Calcium silicate products	C 415		CH	90[C]	...	...	1.3[C]	2.5	3.0[C]	1.5[C]	...	...	...
Calcium silicate products	C 415		CQ	90[C]	...	...	1.3[C]	2.5	3.0[C]	1.5[C]	...	...	...
Hypochlorite (bleach)	C 433	5	CH	...	...	...	...	...	...	...	68	0.3[C]	...
Hypochlorite (bleach)	C 433	5	CQ	...	...	...	...	...	...	...	90	...	...

[A] These specifications have all been incorporated into the current issue of this specification and are now discontinued. The discontinued specifications are available through Global Engineering Documents, 15 Inverness Way, East Englewood, CO 80112–5704.
C 45 Specification for Quicklime and Hydrated Lime for Cooking of Rags in Paper Manufacture
C 46 Specification for Quicklime and Limestone for Sulfite Brick Manufacture
C 49 Specification for Quicklime and Hydrated Lime for Silica Brick Manufacture
C 53 Specification for Quicklime and Hydrated Lime for Water Treatment
C 258 Specification for Quicklime for Calcium Carbide Manufacture
C 259 Specification for Hydrated Lime for Grease Manufacture
C 415 Specification for Quicklime and Hydrated Lime for Calcium Silicate Products
C 433 Specification for Quicklime and Hydrated Lime for Hypochlorite Bleach Manufacture
[B] Standard composition.
[C] On a nonvolatile basis.

specified is that which defines a reasonable standard rather than one that fixes actual rejection limits. It is generally recognized that, other things being equal, lime meeting this standard is preferable to lime that does not, and lime surpassing the standard should be considered of premium quality.

NOTE 2—Lime is used in the "milk of lime" or "tank" system of sulfite pulp manufacture for making the cooking liquor. The milk of lime is held in solution or suspension in a series of tanks equipped with suitable agitators. The sulfur dioxide (SO_2) is forced or drawn through these tanks successively. In some cases, the tanks are built on top of each other in the form of a tower. The contents of the first tank are drawn off when the liquor has reached a certain strength (3.5 to 6 % total SO_2) and the contents of the second and third tanks progress to the first and second tanks respectively. The third tank is again charged with fresh milk of lime. There are other systems of absorption that provide for continuous instead of intermittent operation. The function of the lime is to furnish the base for the formation of the bisulfites of calcium and magnesium.

NOTE 3—In the manufacture of silica brick, silica in the form of massive quartzite or quartz conglomerate is ground until the particles are less than ¼ in. (6 mm) in size. Lime in the form of either slaked or hydrated lime is then added in quantities varying from 1.5 to 3.0 % calcium oxide (CaO), with sufficient water to produce about 5 to 7 % moisture content, and the shapes are molded and dried. They are then burned in downdraft or tunnel kilns until most of the quartzite has been converted into tridymite or cristobalite.

NOTE 4—For most water treatment applications, such as color removal and clarification of water for municipal and industrial supplies, high-calcium lime is preferred. However, for applications involving silica removal from boiler feedwater, dolomitic lime is usually preferred. Drinking water softening and wastewater neutralization are addressed in Specification C 1529.

NOTE 5—In manufacture of calcium hypochlorite bleach, lime hydrate in water suspension is reacted with chlorine. Lime hydrate suitable for this application should be rapidly reactive, low in sludge-forming impurities, and particularly low in iron oxide, that may catalyze bleach decomposition.

4. General Requirements

4.1 Quicklime shall be reasonably free of unslakable residues and shall be capable of disintegrating in water to form a suspension of finely divided material.

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5. Sampling and Inspection

5.1 Conduct the sampling, inspection, rejection, retesting, packaging, and marking in accordance with Methods C 50.

6. Test Methods

6.1 The chemical analyses shall be made in accordance with Test Methods C 25.

6.2 The physical tests shall be made in accordance with Test Methods C 110.

7. Keywords

7.1 by-product lime; calcium oxide; calcium silicate; chemical uses; color removal; dolomitic hydrated lime; dolomitic lime; dolomitic limestone; dolomitic quicklime; high calcium hydrated lime; high calcium limestone; high calcium quicklime; hydrated lime; hypochlorite bleach; industrial uses; lime; limestone; magnesian hydrated lime; magnesian limestone; magnesian quicklime; quicklime; silica brick; silica removal; sulfite pulp

APPENDIX

(Nonmandatory Information)

X1. TEST METHOD FOR FREE CALCIUM OXIDE IN HIGH-CALCIUM HYDRATED LIME

X1.1 Scope

X1.1.1 This test method covers the determination of the amount of free calcium oxide (CaO) in high-calcium hydrated lime capable of being hydrated by steam at atmospheric pressure.

X1.2 Summary of Test Method

X1.2.1 This test method is based on the principle of gain in weight of CaO when it is hydrated to form calcium hydroxide ($Ca(OH)_2$).

X1.2.2 The sample is dried, subjected to steam at atmospheric pressure, again dried, and the gain in weight calculated to CaO.

X1.3 Apparatus

X1.3.1 *Drying Oven*, thermostatically controlled, CO_2-free atmosphere.

X1.3.2 *Analytical Balance*.

X1.3.3 *Steam Bath*, as shown in Fig. X1.1.

X1.4 Procedure

X1.4.1 Weigh a clean, dry, 10-mL Erlenmeyer flask on an analytical balance.

NOTE X1.1—Once started, complete the test without interruption.

X1.4.2 Add to the flask, by means of a widestem funnel, 3 to 5 g of the lime to be tested. Reweigh to get the exact sample weight.

NOTE X1.2—The flask should be kept stoppered at all times, except when weighing, drying, or steaming.

X1.4.3 Place the flask in the drying oven that has been previously heated to 120 °C, and maintain at this temperature for 30 min. Remove, stopper, cool in a desiccator, and weigh.

NOTE X1.3—Oven atmosphere can be kept CO_2 free by placing therein a container of soda lime, quicklime, or other suitable CO_2-absorbing medium.

X1.4.4 Place the flask and the sample in a vigorously boiling steam bath and steam for 30 min. Protect the flask in

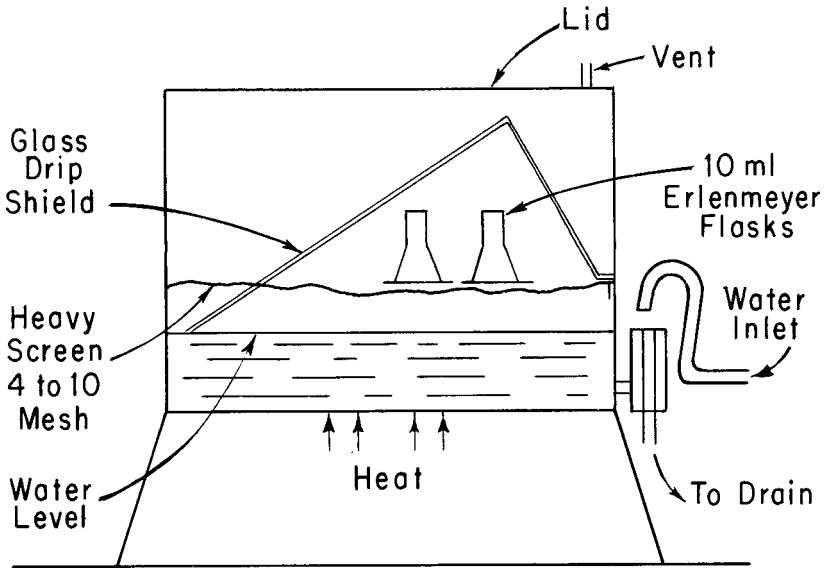

FIG. X1.1 Steam Chamber

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the steam bath by a drip shield during the steaming period. Remove the flask to the oven, dry for 30 min at 120 °C, stopper, cool in a desiccator, and weigh.

X1.4.5 Record all weighings to the fourth decimal place.

X1.5 Calculation

X1.5.1 Calculate the percentage of water and CaO as follows:

$$\text{Free water, } \% = [(W_1 - W_2)/S] \times 100 \quad \text{(X1.1)}$$

$$\text{Free CaO, } \% = \frac{(W_3 - W_2) \times 3.114}{S} \times 100$$

where:

W_1 = weight of sample and flask before drying,
W_2 = weight of sample and flask after drying,
W_3 = weight of sample and flask after steaming and drying, and
S = weight of sample.

SUMMARY OF CHANGES

Committee C07 has identified the location of selected changes to this specification since the last issue, C 911 – 05, that may impact the use of this specification. (Approved November 15, 2006)

(*1*) Revised 1.1, moving part of it to new 1.2, and renumbered subsequent paragraphs.

(*2*) Revised Note 4.

(*3*) Revised the Use column in Table 1.

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Designation: C 917 – 05

Standard Test Method for Evaluation of Cement Strength Uniformity From a Single Source[1]

This standard is issued under the fixed designation C 917; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope

1.1 This test method is intended for use in instances in which the purchaser desires information on the strength uniformity of a hydraulic cement produced at a single source. It is intended that this test method normally be used for the predominant cement manufactured at a cement plant. Guidelines for sampling, testing, presentation of results, and evaluation are given.

1.2 The values stated in inch-pound units are to be regarded as the standard. The values in parentheses are for information only.

1.3 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

2. Referenced Documents

2.1 *ASTM Standards:* [2]

C 109/C 109M Test Method for Compressive Strength of Hydraulic Cement Mortars (Using 2-in. or [50-mm] Cube Specimens)
C 150 Specification for Portland Cement
C 219 Terminology Relating to Hydraulic Cement
C 595 Specification for Blended Hydraulic Cements
C 1157 Performance Specification for Hydraulic Cement
E 456 Terminology Relating to Quality and Statistics

3. Terminology

3.1 *Definitions*—For definitions of terms relating to this test method, refer to Terminologies C 219 and E 456.

4. Significance and Use

4.1 This test method is designed to present in a standardized format information on the variability of strength of cement from a single source over a period of time. It can be applied to all hydraulic cements covered in Specifications C 150, C 595, and C 1157.

NOTE 1—It should be recognized that concrete strength variability is influenced by other factors in addition to cement strength variability.

5. Sampling

5.1 All sampling shall be performed by quality control or testing personnel or someone specifically trained for this purpose.

5.2 Take random grab samples from delivery units or during the loading or unloading process. Delivery units larger than 125 tons (115 Mg) shall be sampled during loading or unloading. If samples are taken during loading or unloading, the two or more portions that are to be composited to make a sample shall be taken during the transfer to no more than 125 tons (115 Mg) of cement. Identify samples by the date on which the cement they represent was shipped or received.

NOTE 2—Standard statistical procedures are recommended for ensuring that samples are selected by a random procedure. These procedures can be used to select the days within a month or within a week that samples will be taken. Then the delivery unit or the time of day can be chosen randomly.

5.3 If taken from a truck or rail car, take at least two separate 5-lb (approximately 2.3-kg) grab samples and thoroughly mix together to obtain a minimum 10-lb (4.5-kg) test sample. Sample only through hatches in the top of the unit. Remove approximately a 12-in. (300-mm) layer of cement. Make a hole before obtaining a sample to avoid collecting dust collector material that may be discharged into the delivery unit after the cement flow ceases.

5.4 If taken from another point in the loading or unloading process, the sample shall consist of a minimum of two separate 5-lb (approximately 2.3-kg) grab samples thoroughly mixed together or at least 10 lb (4.5 kg) as accumulated by a continuous sampler. Take care to avoid segregation and contamination of samples taken from screws, pneumatic systems, or air slides.

5.5 When samples are taken at the cement plant and shipments or rate of production of the cement exceeds 25 000 tons (23 000 Mg) per month, take samples at a rate of at least ten per month and at least two per week. When shipment or rate

[1] This test method is under the jurisdiction of ASTM Committee C01 on Cement and is the direct responsibility of Subcommittee C01.27 on Strength.

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of production of the cement is less than 25 000 tons (23 000 Mg) per month, take samples at a rate of at least one per 2500 tons (2300 Mg). When samples are taken at the cement plant, in no instance shall samples be taken more frequently than one per 200 tons (180 Mg) of cement shipped or received, except that sampling of consecutive shipments is permitted when they result from randomization.

6. Procedure

6.1 Test all samples for 7- and 28-day compressive strength in accordance with Test Method C 109/C 109M using three specimens for each test age. To be comparable, all tests used in a single evaluation must be made in a single laboratory and preferably by the same laboratory operator.

NOTE 3—When separate evaluations of a single source are made by two or more laboratories, additional tests of a standard cement or exchange of portions of the same sample of cement may be necessary to determine differences in testing that are likely to be obtained in the different laboratories. Five or more batches may be necessary to obtain a valid comparison between laboratories. Statistical techniques must be used to assess the validity of differences that might be obtained. Participation in the Cement Proficiency Sample Program of the CCRL by both laboratories will be helpful in resolving differences that are found.

6.1.1 When two laboratories exchange portions of the same sample and prepare single batches, results from the two laboratories shall not differ by more than 18.7 % of the average of the two laboratories (see Test Method C 109/C 109M multilaboratory d2s). If a larger number of samples are exchanged the difference in average strength shall not exceed $18.7/\sqrt{n}$ % of the overall average strength, where n is the number of samples exchanged and tested by each laboratory. A more precise calculation is outlined in Appendix X1.

6.2 Mix duplicate batches of mortar to determine the effect of testing variations on the uniformity of results made in a single laboratory. Make duplicate batches on a day different from the original batch of mortar.

6.2.1 When a uniformity testing program is started on shipments from a single source, make duplicate batches of mortar from every third cement sample. When duplicate tests have been made from a minimum of five cement samples, calculate the average range, $\bar{R}$, for the available duplicates, then calculate standard deviation and coefficient of variation for testing according to 7.1.3 and 7.1.4, respectively. Increase the number of duplicate batches used in the calculation until the results of ten cement samples are used in the calculation. After that time, use only the ten most recent results of duplicate testing in the calculation of the standard deviation and coefficient of variation for testing. See Table 1.

6.2.2 When at least ten sets of duplicate batches have been made and the coefficient of variation for testing is less than 4.0 %, the frequency of testing duplicate batches can be reduced to one out of ten consecutive cement samples. Resume testing one sample out of three if the coefficient of variation later exceeds 4.0 %. If the coefficient of variation for testing exceeds 5.5 %, the data are of questionable precision, and laboratory procedures and equipment should be thoroughly examined.

6.2.3 Use the results of duplicate tests indicating acceptable precision to estimate the single-laboratory testing variation for all other types of cement tested in that laboratory during the same period of time, provided that duplicate tests have been made on at least one sample per month.

7. Calculation

7.1 The calculations shall include the following:

7.1.1 *Average Strength*:

$$\bar{X} = \frac{X_1 + X_2 + \ldots + X_n}{n} \quad (1)$$

where:

$\bar{X}$ = average strength,

$X_1, X_2, \ldots, X_n$ = strength of individual tests, each of which is composed of the average of cubes in accordance with Test Method C 109/C 109M, and

n = number of individual samples.

7.1.2 *Total Standard Deviation*:

$$S_t = \sqrt{\frac{(X_1 - \bar{X})^2 + (X_2 - \bar{X})^2 + \ldots + (X_n - \bar{X})^2}{(n - 1)}} \quad (2)$$

where:

S_t = standard deviation, psi.

7.1.3 *Standard Deviation For Testing*:

$$S_e = 0.862\bar{R}$$

S_e = standard deviation estimated from tests of duplicate batches mixed in a single laboratory,

R = range, the difference between the strengths of the duplicate batches from a single sample (all numbers are positive),

$\bar{R}$ = average of the individual ranges, R, for the preceding ten tests of duplicate batches. See 6.2.1 if fewer than ten ranges are available, and

0.862 = range coefficient for duplicate tests of the same sample of cement.

7.1.4 *Coefficient of Variation for Testing*:

$$V_e = 100\, S_e / \bar{X}$$

where:

V_e = coefficients of variation estimated from tests of duplicate batches mixed in a single laboratory, and

$\bar{X}$ = average of the strengths of the duplicate batches from which $\bar{R}$ is calculated.

7.1.5 *Standard Deviation Corrected For Testing Variations*:

$$S_c = \sqrt{S_t^2 - S_e^2} \quad (3)$$

where:

S_c = net standard deviation of cement corrected for testing error,

S_t = total standard deviations for all tests included in the calculation, and

S_e = standard deviation of duplicate tests run on split sample to evaluate testing error.

The addition of the subscript 28 or 7 indicates the type of strength data used in the calculation.

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NOTE 4—Values for averages and standard deviations can be calculated by other methods that are available in ASTM STP 15 D.[3] Electronic calculators are available for obtaining these statistics directly.

[3] *Manual on Presentation of Data and Control Chart Analysis, ASTM STP 15 D,* ASTM 1976.

TABLE 1 Calculation of Standard Deviation for Testing

Date	Sample Number	7-Day Data				Average[A]		Range[B]		$\bar{R}$ [C]		S_e [D]		V_e [E]	Note
		Test A		Test B											
		psi	(MPa)	psi	(MPa)	psi	(MPa)	psi	(MPa)	psi	(MPa)	psi	(MPa)		
01 /06	3	4900	(33.7)	4960	(34.2)	4930	(34.0)	60	(0.41)	. . .	. . .	. . .	. . .	. . .	. . .
01 /16	6	4580	(31.5)	4670	(32.2)	4625	(31.8)	90	(0.62)	. . .	. . .	. . .	. . .	. . .	. . .
01 /30	9	4650	(32.0)	4850	(33.4)	4750	(32.7)	200	(1.37)	. . .	. . .	. . .	. . .	. . .	. . .
02 /05	12	4400	(30.3)	4510	(31.1)	4455	(30.7)	110	(0.75)	. . .	. . .	. . .	. . .	. . .	. . .
02 /13	15	4380	(30.2)	4300	(29.6)	4340	(29.9)	80	(0.55)	108	(0.74)	93	(0.64)	2.02 %	Av. 5
02 /21	18	4700	(32.4)	4770	(32.8)	4735	(32.6)	70	(0.48)	102	(0.70)	88	(0.60)	1.89 %	Av. 6
03 /04	21	4470	(30.8)	4610	(31.7)	4540	(31.3)	140	(0.96)	107	(0.73)	92	(0.64)	2.00 %	Av. 7
03 /14	24	4030	(27.7)	3970	(27.3)	4000	(27.5)	60	(0.41)	101	(0.69)	87	(0.60)	1.92 %	Av. 8
03 /19	27	4970	(34.2)	4820	(33.2)	4895	(33.7)	150	(1.03)	107	(0.73)	92	(0.63)	2.01 %	Av. 9
03 /27	30	4550	(31.3)	4530	(31.2)	4540	(31.3)	20	(0.13)	96	(0.67)	84	(0.58)	1.84 %	Av. 10 (6)
04 /30	40	4750	(32.7)	4920	(33.9)	4835	(33.3)	170	(1.17)	109	(0.75)	94	(0.65)	2.06 %	Av. last 10
05 /31	50	5030	(34.6)	4820	(33.2)	4925	(33.9)	210	(1.44)	121	(0.83)	104	(0.72)	2.27 %	Av. last 10
06 /29	60	4830	(33.3)	4720	(32.5)	4775	(32.9)	110	(0.75)	112	(0.77)	97	(0.67)	2.10 %	Av. last 10
07 /28	70	4400	(30.3)	4460	(30.7)	4430	(30.5)	60	(0.41)	107	(0.73)	92	(0.64)	2.00 %	Av. last 10
08 /30	80	4550	(31.3)	4460	(30.7)	4505	(31.0)	90	(0.62)	108	(0.74)	93	(0.64)	2.02 %	Av. last 10
09 /25	90	4930	(34.0)	5000	(34.4)	4965	(34.2)	70	(0.48)	108	(0.74)	93	(0.64)	2.01 %	Av. last 10
10 /26	100	4950	(34.1)	4820	(33.2)	4885	(33.6)	130	(0.89)	107	(0.73)	92	(0.64)	1.97 %	Av. last 10
11 /25	110	4670	(32.2)	4720	(32.5)	4695	(32.3)	50	(0.34)	106	(0.73)	91	(0.63)	1.93 %	Av. last 10
12 /21	120	4450	(30.6)	4520	(31.1)	4485	(30.9)	70	(0.48)	96	(0.67)	84	(0.58)	1.80 %	Av. last 10

Date	Sample Number	28-Day Data				Average[A]		Range[B]		$\bar{R}$ [C]		S_e [D]		V_e [E]	Note
		Test A		Test B											
		psi	(MPa)	psi	(MPa)	psi	(MPa)	psi	(MPa)	psi	(MPa)	psi	(MPa)		
01 /06	3	6370	(43.9)	6620	(45.6)	6495	(44.7)	250	(1.72)	. . .	. . .	. . .	. . .	. . .	. . .
01 /16	6	6250	(43.1)	6020	(41.5)	6135	(42.3)	230	(1.58)	. . .	. . .	. . .	. . .	. . .	. . .
01 /30	9	6050	(41.7)	6120	(42.2)	6085	(41.9)	70	(0.48)	. . .	. . .	. . .	. . .	. . .	. . .
02 /05	12	6020	(41.5)	6230	(42.9)	6125	(42.2)	210	(1.44)	. . .	. . .	. . .	. . .	. . .	. . .
02 /13	15	5600	(38.6)	5420	(37.3)	5510	(38.0)	180	(1.24)	188	(1.29)	162	(1.12)	2.67 %	Av. 5
02 /21	18	5500	(37.9)	5530	(38.1)	5515	(38.0)	30	(0.20)	162	(1.11)	139	(0.96)	2.33 %	Av. 6
03 /04	21	6320	(43.5)	6280	(43.3)	6300	(43.4)	40	(0.27)	144	(0.99)	124	(0.86)	2.06 %	Av. 7
03 /14	24	5920	(40.8)	6010	(41.4)	5965	(41.1)	90	(0.62)	138	(0.94)	119	(0.82)	1.97 %	Av. 8
03 /19	27	6300	(43.4)	6050	(41.7)	6175	(42.5)	250	(1.72)	150	(1.03)	129	(0.89)	2.14 %	Av. 9
03 /27	30	6350	(43.7)	6410	(44.2)	6380	(44.0)	60	(0.41)	141	(0.97)	122	(0.84)	2.00 %	Av. 10 (6)
04 /30	40	6050	(41.7)	5940	(40.9)	5995	(41.3)	110	(0.75)	127	(0.87)	109	(0.75)	1.82 %	Av. last 10
05 /31	50	6670	(46.0)	6530	(45.0)	6600	(45.5)	140	(0.96)	118	(0.81)	102	(0.70)	1.68 %	Av. last 10
06 /29	60	6350	(43.7)	6190	(42.6)	6270	(43.2)	160	(1.10)	127	(0.87)	109	(0.75)	1.80 %	Av. last 10
07 /28	70	6500	(44.8)	6300	(43.4)	6400	(44.1)	200	(1.37)	126	(0.86)	109	(0.75)	1.78 %	Av. last 10
08 /30	80	6200	(42.7)	6150	(42.4)	6175	(42.5)	50	(0.34)	113	(0.77)	97	(0.67)	1.58 %	Av. last 10
09 /25	90	6630	(45.7)	6540	(45.1)	6585	(45.4)	90	(0.62)	119	(0.82)	103	(0.71)	1.63 %	Av. last 10
10 /26	100	6230	(42.9)	6010	(41.4)	6120	(42.2)	220	(1.51)	137	(0.94)	118	(0.81)	1.88 %	Av. last 10
11 /25	110	5920	(40.8)	6020	(41.5)	5970	(41.1)	100	(0.68)	138	(0.95)	119	(0.82)	1.90 %	Av. last 10
12 /21	120	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .

Notes: Initially one out of three samples are tested in duplicate until at least ten duplicate test results are available.

[A] Average of the test results A and B.

[B] Absolute difference between tests A and B.

[C] Average range is calculated for a minimum of five duplicate tests. Subsequently, ranges of the ten most recent duplicate tests are averaged.

[D] Standard deviation for testing is calculated as in 7.1.3: $S_e = 0.862 \times \bar{R}$.

[E] Coefficient of variation for testing is calculated as in 7.1.4: $V_e = 100\ S_e / \bar{X}$. Note that $\bar{X}$ is the average strength of the duplicate batches from which $\bar{R}$ is determined.

8. Report

8.1 Sufficient information shall be provided to identify the cement sampled including:

8.1.1 Name of manufacturer and location,

8.1.2 Type of cement or other identification,

8.1.3 Location of sampling,

8.1.4 Laboratory designation, and

8.1.5 Period of time represented by the report.

8.2 For ongoing programs, the minimum period covered by the report shall include all strength tests made in the preceding three months, but in no instance less than that period of time necessary to include 28-day strength tests of 20 consecutive samples.

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8.2.1 The report shall not cover a period of time greater than 12 months or tests of more than 120 samples.

8.3 The report of strength results shall be either in tabular form as shown in Table 2 or in graphical form as shown in Fig. 1, at the option of the reporting organization.

NOTE 5—For purposes of analyzing trends, the graphical presentation is to be preferred. Additionally, the average and standard deviation as calculated in Section 7 shall be shown.

8.4 Report the available 7 and 28-day compressive strength results on each sample including the date on which the sample was taken. Each value reported will be the average of tests of three cubes made from the same batch, except when one or more cubes are faulty. See Test Method C 109/C 109M.

8.4.1 Report the results of tests of duplicate batches tested within the period covered by the report. When duplicate batches are made from a cement other than that being tested during the same period of time, by the same laboratory, these test results will not normally be reported on a regular basis, but results of such tests will be made available on request. However, report the standard deviation, S_e, and the coefficient of variation, V_e, of duplicate batches.

8.5 The report shall include the following values calculated from the reported data. Each cement sample shall be represented only by a single result at each age in these calculations. The second of a pair of duplicate batch test results shall not be included in overall calculations, but shall be used only to establish testing error.

8.5.1 Calculated from the reported seven-day strength data:

(1) $\bar{X}_7$, the average,

(2) S_{t7}, the total standard deviation,

(3) n_7, the number of samples tested,

(4) S_{c7}, the standard deviation corrected for testing, and

(5) $\bar{X}_{5-7}$, the moving averages of the five most recent seven-day results.

8.5.2 Calculated from the reported 28-day strength data:

(1) $\bar{X}_{28}$, the average,

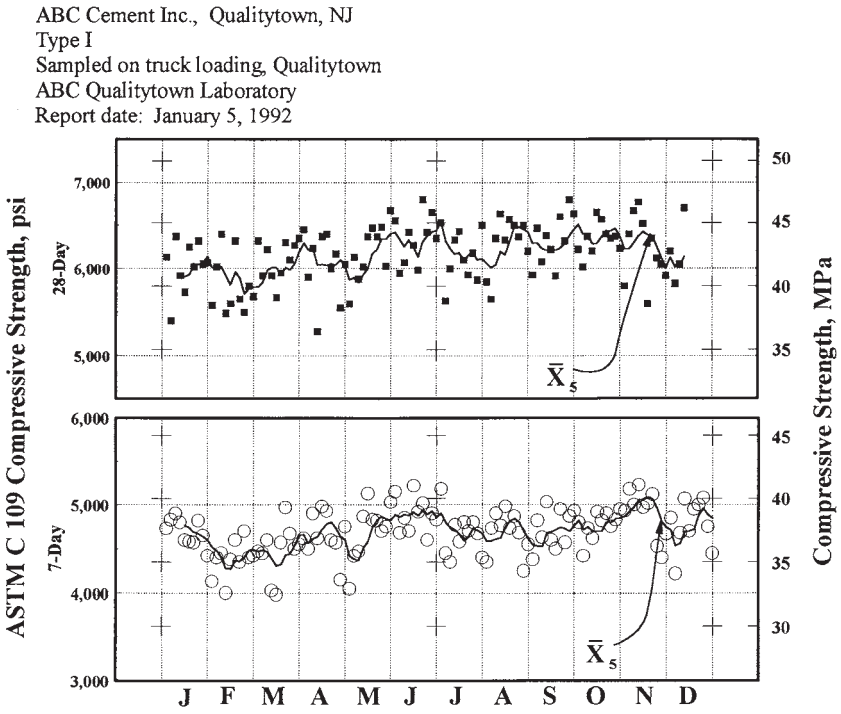

FIG. 1 Uniformity Test Report

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(2) S_{t28}, the total standard deviation,

(3) n_{28}, the number of samples tested,

(4) S_{c28}, the standard deviation corrected for testing, and

(5) $\bar{X}_{5-28}$, the moving averages of the five most recent 28-day results.

8.5.3 The calculations in 8.5.1 and 8.5.2 shall not be made and reported until five results are available. The moving average of the five most recent results should be updated with each successive result by adding the new value in the calculation and deleting the oldest previous value (see Table 1).

8.5.4 Whenever the reporting agency concludes that a consistent change in strength-producing properties has occurred, at its option, it may discontinue calculation until results from five additional samples of the cement have been obtained. In this instance, the values (8.5.1 and 8.5.2) calculated from the samples before the change shall also be reported (see 8.2.1).

8.5.5 When there is a break in the calculation, the sampling dates included in each set of calculated values (8.5.1 and 8.5.2) shall be clearly identified.

9. Keywords

9.1 cement; sampling; statistics; strength; uniformity

TABLE 2 Sample Uniformity Test Report

BC Cement Inc., Qualitytown, N.J.
Type I
Sampled on truck loading, Qualitytown
ABC Qualitytown LaboratoryReport Date: January 5, 1992

Item	7-Day	28-Day	7-Day	28-Day
Dates Represented:				
From:	01/02/91	01/02/91	(This space is provided for use if a break in the	
To:	12/21/91	12/05/91	calculation is made. See 8.5.4 and 8.5.5.)	
Average Strength, psi (MPa), $\bar{X}$	4695 (32.3)	6170 (42.5)		
Total Standard Deviation, psi (MPa), S_t	270 (1.85)	334 (2.30)		
Number of Tests (n)	120	114		
Testing Standard Deviation, psi (MPa), S_e	84 (0.58)	119 (0.82)		
Number of Tests (n)	10	10		
Corrected Standard Deviation, psi (MPa), S_c	256 (1.77)	312 (2.15)		

Date Shipped	Sample No.[A]	7-Day Test a		7-Day Average 5		28-Day Test a		28-Day Average 5		Date Shipped	Sample No.	7-Day Test a		7-Day Average 5		28-Day Test a		28-Day Average 5	
		psi	(MPa)	psi	(MPa)	psi	(MPa)	psi	(MPa)			psi	(MPa)	psi	(MPa)	psi	(MPa)	psi	(MPa)
01 /02	1	4730	(32.6)			6130	(42.3)			07 /02	61	5180	(35.7)	4906	(33.8)	6530	(45.0)	6550	(45.2)
01 /03	2	4830	(33.3)			5400	(37.2)			07 /07	62	4450	(30.7)	4792	(33.0)	5630	(38.8)	6316	(43.6)
01 /06	3a	4900	(33.8)			6370	(43.9)			07 /09	63	4350	(30.0)	4742	(32.7)	6000	(41.4)	6232	(43.0)
01 /08	4	4800	(33.1)			5920	(40.8)			07 /11	64	4770	(32.9)	4716	(32.5)	6330	(43.7)	6168	(42.5)
01 /14	5	4600	(31.7)	4772	(32.9)	5730	(39.5)	5910	(40.8)	07 /12	65	4580	(31.6)	4666	(32.2)	6430	(44.3)	6184	(42.6)
01 /16	6a	4580	(31.6)	4742	(32.7)	6250	(43.1)	5934	(40.9)	07 /13	66	4800	(33.1)	4590	(31.7)	6100	(42.1)	6098	(42.1)
01 /21	7	4570	(31.5)	4690	(32.3)	6020	(41.5)	6058	(41.8)	07 /19	67	4700	(32.4)	4640	(32.0)	5930	(40.9)	6158	(42.5)
01 /24	8	4820	(33.2)	4674	(32.2)	6320	(43.6)	6048	(41.7)	07 /20	68	4800	(33.1)	4730	(32.6)	6180	(42.6)	6194	(42.7)
01 /30	9a	4650	(32.1)	4644	(32.0)	6050	(41.7)	6074	(41.9)	07 /24	69	4670	(32.2)	4710	(32.5)	5870	(40.5)	6102	(42.1)
01 /31	10	4420	(30.5)	4608	(31.8)	6070	(41.9)	6142	(42.4)	07 /28	70a	4400	(30.3)	4674	(32.2)	6500	(44.8)	6116	(42.2)
02 /03	11	4130	(28.5)	4518	(31.2)	5580	(38.5)	6008	(41.4)	08 /02	71	4350	(30.0)	4584	(31.6)	5850	(40.3)	6066	(41.8)
02 /05	12a	4400	(30.3)	4484	(30.9)	6020	(41.5)	6008	(41.4)	08 /05	72	4730	(32.6)	4590	(31.7)	5650	(39.0)	6010	(41.4)
02 /06	13	4450	(30.7)	4410	(30.4)	6400	(44.1)	6024	(41.5)	08 /07	73	4900	(33.8)	4610	(31.8)	6350	(43.8)	6044	(41.7)
02 /07	14	4000	(27.6)	4280	(29.5)	5490	(37.9)	5912	(40.8)	08 /09	74	4760	(32.8)	4628	(31.9)	6630	(45.7)	6196	(42.7)
02 /13	15a	4380	(30.2)	4272	(29.5)	5600	(38.6)	5818	(40.1)	08 /10	75	4980	(34.3)	4744	(32.7)	6330	(43.7)	6162	(42.5)
02 /17	16	4600	(31.7)	4366	(30.1)	6320	(43.6)	5966	(41.1)	08 /19	76	4730	(32.6)	4820	(33.2)	6570	(45.3)	6306	(43.5)
02 /19	17	4350	(30.0)	4356	(30.0)	5650	(39.0)	5892	(40.6)	08 /20	77	4870	(33.6)	4848	(33.4)	6500	(44.8)	6476	(44.7)
02 /21	18a	4700	(32.4)	4406	(30.4)	5500	(37.9)	5712	(39.4)	08 /24	78	4680	(32.3)	4804	(33.1)	6370	(43.9)	6480	(44.7)
02 /25	19	4400	(30.3)	4486	(30.9)	5800	(40.0)	5774	(39.8)	08 /25	79	4250	(29.3)	4702	(32.4)	6500	(44.8)	6454	(44.5)
02 /27	20	4420	(30.5)	4494	(31.0)	5680	(39.2)	5790	(39.9)	08 /30	80a	4550	(31.4)	4616	(31.8)	6200	(42.8)	6428	(44.3)
03 /04	21a	4470	(30.8)	4468	(30.8)	6320	(43.6)	5790	(39.9)	09 /01	81	4380	(30.2)	4546	(31.4)	5930	(40.9)	6300	(43.4)
03 /07	22	4450	(30.7)	4488	(31.0)	5920	(40.8)	5844	(40.3)	09 /05	82	4820	(33.2)	4536	(31.3)	6470	(44.6)	6294	(43.4)
03 /12	23	4600	(31.7)	4468	(30.8)	6220	(42.9)	5988	(41.3)	09 /08	83	4630	(31.9)	4526	(31.2)	6080	(41.9)	6236	(43.0)
03 /14	24a	4030	(27.8)	4394	(30.3)	5920	(40.8)	6012	(41.5)	09 /10	84	5030	(34.7)	4682	(32.3)	6380	(44.0)	6212	(42.8)
03 /15	25	3980	(27.4)	4306	(29.7)	5670	(39.1)	6010	(41.4)	09 /15	85	4600	(31.7)	4692	(32.4)	6220	(42.9)	6216	(42.9)
03 /18	26	4570	(31.5)	4326	(29.8)	5950	(41.0)	5936	(40.9)	09 /20	86	4500	(31.0)	4716	(32.5)	5920	(40.8)	6214	(42.9)
03 /19	27a	4970	(34.3)	4430	(30.6)	6300	(43.4)	6012	(41.5)	09 /21	87	4950	(34.1)	4742	(32.7)	6600	(45.5)	6240	(43.0)
03 /22	28	4670	(32.2)	4444	(30.6)	6100	(42.1)	5988	(41.3)	09 /23	88	4570	(31.5)	4730	(32.6)	6320	(43.6)	6288	(43.4)
03 /25	29	4500	(31.0)	4538	(31.3)	6270	(43.2)	6058	(41.8)	09 /24	89	4870	(33.6)	4698	(32.4)	6800	(46.9)	6372	(43.9)
03 /27	30a	4550	(31.4)	4652	(32.1)	6350	(43.8)	6194	(42.7)	09 /25	90a	4930	(34.0)	4764	(32.9)	6630	(45.7)	6454	(44.5)
04 /02	31	4620	(31.9)	4662	(32.2)	6450	(44.5)	6294	(43.4)	10 /01	91	4800	(33.1)	4824	(33.3)	6220	(42.9)	6514	(44.9)
04 /05	32	4500	(31.0)	4568	(31.5)	5900	(40.7)	6214	(42.9)	10 /02	92	4420	(30.5)	4718	(32.5)	6020	(41.5)	6398	(44.1)
04 /10	33	4900	(33.8)	4614	(31.8)	6230	(43.0)	6240	(43.0)	10 /05	93	4730	(32.6)	4750	(32.8)	6370	(43.9)	6408	(44.2)
04 /12	34	4620	(31.9)	4638	(32.0)	5280	(36.4)	6042	(41.7)	10 /07	94	4620	(31.9)	4700	(32.4)	6200	(42.8)	6288	(43.4)
04 /14	35	4980	(34.3)	4724	(32.6)	6370	(43.9)	6046	(41.7)	10 /08	95	4920	(33.9)	4698	(32.4)	6650	(45.9)	6292	(43.4)
04 /16	36	4930	(34.0)	4786	(33.0)	6400	(44.1)	6036	(41.6)	10 /13	96	4820	(33.2)	4702	(32.4)	6570	(45.3)	6362	(43.9)
04 /18	37	4600	(31.7)	4806	(33.1)	6000	(41.4)	6056	(41.8)	10 /15	97	4900	(33.8)	4798	(33.1)	6400	(44.1)	6438	(44.4)
04 /23	38	4570	(31.5)	4740	(32.7)	6170	(42.6)	6044	(41.7)	10 /19	98	4750	(32.8)	4802	(33.1)	6350	(43.8)	6434	(44.4)
04 /25	39	4150	(28.6)	4646	(32.0)	5550	(38.3)	6098	(42.1)	10 /21	99	4830	(33.3)	4844	(33.4)	6370	(43.9)	6468	(44.6)
04 /30	40a	4750	(32.8)	4600	(31.7)	6050	(41.7)	6034	(41.6)	10 /26	100a	4950	(34.1)	4850	(33.4)	6230	(43.0)	6384	(44.0)

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TABLE 2 *Continued*

Date Shipped	Sample No.[A]	7-Day Test a psi	(MPa)	7-Day Average 5 psi	(MPa)	28-Day Test a psi	(MPa)	28-Day Average 5 psi	(MPa)	Date Shipped	Sample No.	7-Day Test a psi	(MPa)	7-Day Average 5 psi	(MPa)	28-Day Test a psi	(MPa)	28-Day Average 5 psi	(MPa)
05 /05	41	4050	(27.9)	4424	(30.5)	5600	(38.6)	5874	(40.5)	10 /29	101	4930	(34.0)	4872	(33.6)	5800	(40.0)	6230	(43.0)
05 /07	42	4420	(30.5)	4388	(30.3)	6130	(42.3)	5900	(40.7)	11 /02	102	5180	(35.7)	4928	(34.0)	6400	(44.1)	6230	(43.0)
05 /09	43	4470	(30.8)	4368	(30.1)	5880	(40.6)	5842	(40.3)	11 /04	103	5000	(34.5)	4978	(34.3)	6670	(46.0)	6294	(43.4)
05 /15	44	4870	(33.6)	4512	(31.1)	6020	(41.5)	5936	(40.9)	11 /06	104	5230	(36.1)	5058	(34.9)	6770	(46.7)	6374	(44.0)
05 /17	45	5130	(35.4)	4588	(31.6)	6370	(43.9)	6000	(41.4)	11 /09	105	4970	(34.3)	5062	(34.9)	6520	(45.0)	6432	(44.4)
05 /19	46	4830	(33.3)	4744	(32.7)	6470	(44.6)	6174	(42.6)	11 /12	106	5020	(34.6)	5080	(35.0)	5600	(38.6)	6392	(44.1)
05 /21	47	4820	(33.2)	4824	(33.3)	6370	(43.9)	6222	(42.9)	11 /15	107	5120	(35.3)	5068	(35.0)	6350	(43.8)	6382	(44.0)
05 /27	48	4700	(32.4)	4870	(33.6)	6480	(44.7)	6342	(43.7)	11 /17	108	4530	(31.2)	4974	(34.3)	6120	(42.2)	6272	(43.3)
05 /29	49	4750	(32.8)	4846	(33.4)	6030	(41.6)	6344	(43.8)	11 /19	109	4400	(30.3)	4808	(33.2)	6050	(41.7)	6128	(42.3)
05 /31	50a	5030	(34.7)	4826	(33.3)	6670	(46.0)	6404	(44.2)	11 /25	110a	4670	(32.2)	4748	(32.7)	5920	(40.8)	6008	(41.4)
06 /08	51	5150	(35.5)	4890	(33.7)	6550	(45.2)	6420	(44.3)	11 /26	111	4850	(33.4)	4714	(32.5)	6200	(42.8)	6128	(42.3)
06 /10	52	4680	(32.3)	4862	(33.5)	5950	(41.0)	6336	(43.7)	11 /30	112	4220	(29.1)	4534	(31.3)	5830	(40.2)	6024	(41.5)
06 /12	53	4850	(33.4)	4892	(33.7)	6070	(41.9)	6254	(43.1)	12 /04	113	4680	(32.3)	4564	(31.5)	6050	(41.7)	6010	(41.4)
06 /16	54	4700	(32.4)	4882	(33.7)	6420	(44.3)	6332	(43.7)	12 /05	114	5070	(35.0)	4698	(32.4)	6700	(46.2)	6140	(42.3)
06 /18	55	5220	(36.0)	4920	(33.9)	6270	(43.2)	6252	(43.1)	12 /10	115	4700	(32.4)	4704	(32.4)	. . .	. . .	. . .	. . .
06 /21	56	4920	(33.9)	4874	(33.6)	5980	(41.2)	6138	(42.3)	12 /12	116	4950	(34.1)	4724	(32.6)	. . .	. . .	. . .	. . .
06 /23	57	5020	(34.6)	4942	(34.1)	6800	(46.9)	6308	(43.5)	12 /14	117	5000	(34.5)	4880	(33.7)	. . .	. . .	. . .	. . .
06 /25	58	4600	(31.7)	4892	(33.7)	6420	(44.3)	6378	(44.0)	12 /16	118	5080	(35.0)	4960	(34.2)	. . .	. . .	. . .	. . .
06 /27	59	4900	(33.8)	4932	(34.0)	6650	(45.9)	6424	(44.3)	12 /19	119	4750	(32.8)	4896	(33.8)	. . .	. . .	. . .	. . .
06 /29	60a	4830	(33.3)	4854	(33.5)	6350	(43.8)	6440	(44.4)	12 /21	120a	4450	(30.7)	4846	(33.4)	. . .	. . .	. . .	. . .

[A] "a" is the first batch of two made from this sample. See Table 1.

APPENDIXES

(Nonmandatory Information)

X1. COMPARISON OF RESULTS FROM TWO LABORATORIES USING TEST METHOD C 109

X1.1 Suppose n samples are split and tested by each Laboratory A and B with a single batch of mortar prepared on each sample in each laboratory.

X1.2 Compute the difference in results on each sample as $X_a - X_b$:

$$d_i = X_a - X_b \quad \text{(X1.1)}$$

d_i values may be positive or negative.

X1.3 Compute the average of these differences:

$$\bar{D} = \frac{d_1 + d_2 + \ldots + d_n}{n} \quad \text{(X1.2)}$$

where:

$\bar{D}$ = average difference in psi and d_i values may be positive or negative.

X1.4 Compute the standard deviation of these differences (7.1.2),

where:

S_d= standard deviation of the difference, psi.

X1.5 Compute the value $\bar{D}\sqrt{n} / S_d$ and compare to Student's t[4] for $n - 1$ at $\alpha = 0.05$, where t is from Student's t distribution.

X1.6 If $\left|\bar{D}\sqrt{n} / S_d\right| \geq t$, decide that averages in the two laboratories differ significantly; otherwise, decide that there is no reason to believe they differ.

[4] For additional information see Neville, A., and Kennedy, J., *Basic Statistical Methods for Engineers and Scientists,* International Textbooks, Scranton, Pa. 1964, pp. 143–146.

n – 1	1	2	3	4	5	6	7	8	9
t[A]	12.7	4.30	3.18	2.78	2.57	2.45	2.36	2.31	2.26

[A] At $\alpha = 0.05$.

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X2. WITHIN-PLANT VARIATIONS IN CEMENT STRENGTH

X2.1 With the assistance of the Cement and Concrete Reference Laboratory (CCRL), C 917 data for 1991 was collected from 87 plants in the United States and Canada.

X2.2 Information on standard deviations, coefficients of variation, and 7- and 28-day strengths is presented in Figs. X2.1-X2.7.

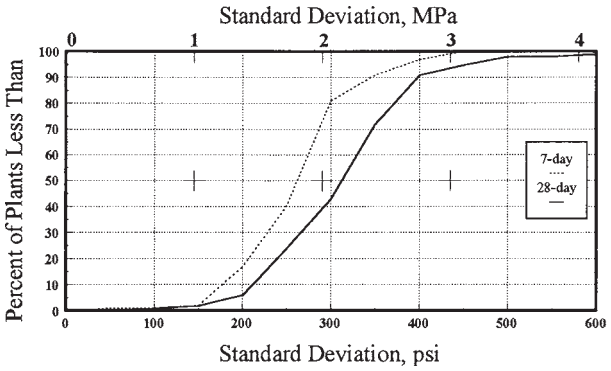

FIG. X2.1 Total Standard Deviation, St

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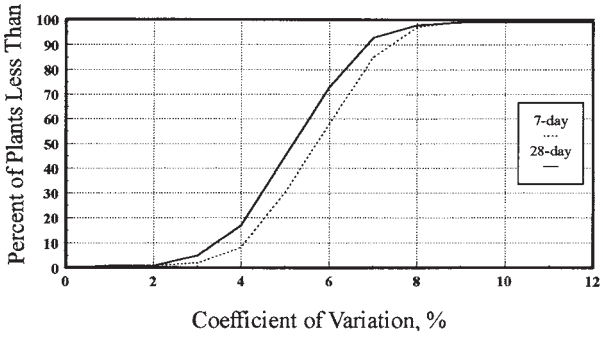

FIG. X2.2 Total Coefficient of Variation, Vt

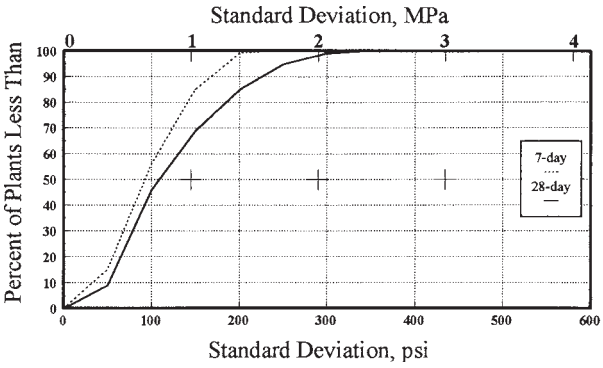

FIG. X2.3 Standard Deviation from Duplicate Batches, Se

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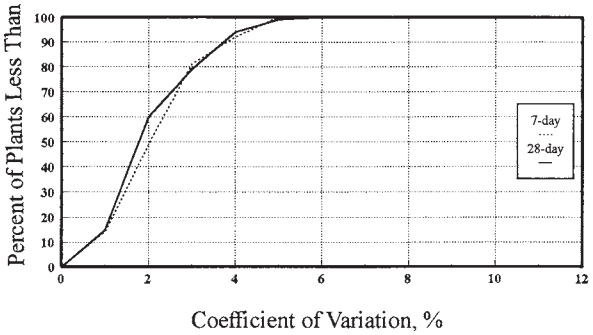

FIG. X2.4 Coefficient of Variation from Duplicate Batches, Ve

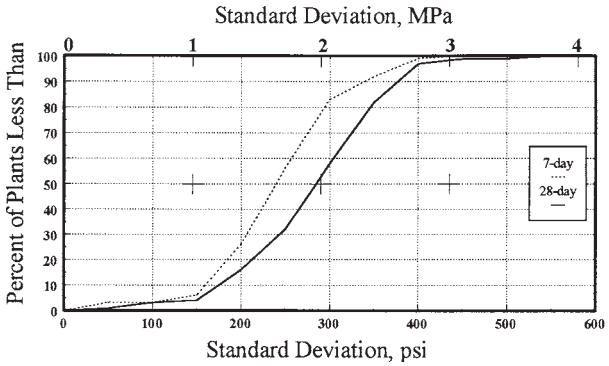

FIG. X2.5 Standard Deviation Corrected for Testing Error, Sc

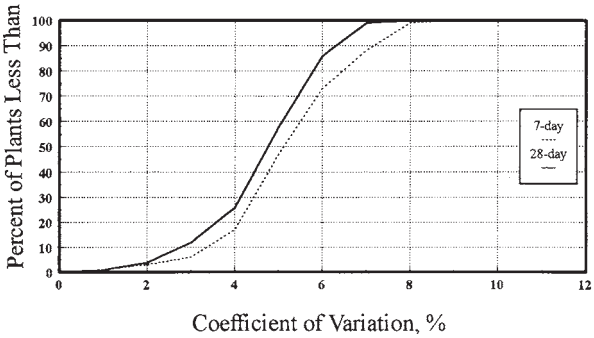

FIG. X2.6 Coefficient of Variation Corrected for Testing Error, Vc

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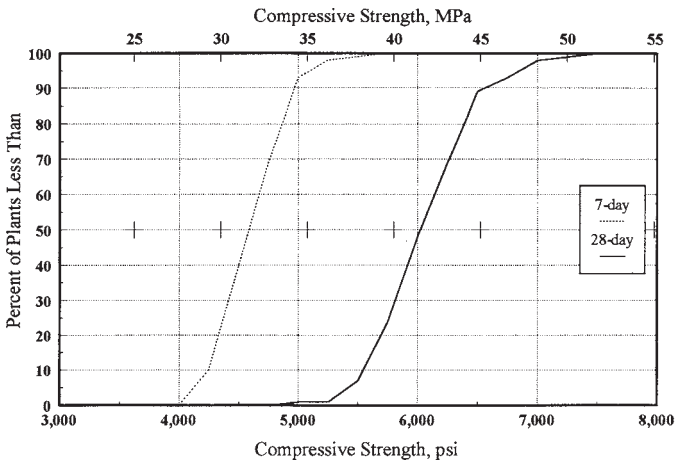

FIG. X2.7 Average Compressive Strength

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Designation: C 918/C 918M – 07

Standard Test Method for Measuring Early-Age Compressive Strength and Projecting Later-Age Strength[1]

This standard is issued under the fixed designation C 918/C 918M; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope*

1.1 This test method covers a procedure for making and curing concrete specimens and for testing them at an early age. The specimens are stored under standard-curing conditions and the measured temperature history is used to compute a maturity index that is related to strength gain.

1.2 This test method also covers a procedure for using the results of early-age compressive-strength tests to project the potential strength of concrete at later ages.

1.3 The values stated in either SI units or inch-pound units are to be regarded separately as standard. The values stated in each system may not be exact equivalents; therefore, each system shall be used independently of the other. Combining values from the two systems may result in non-conformance with the standard.

1.4 The text of this standard references notes and footnotes which provide explanatory material. These notes and footnotes (excluding those in tables and figures) shall not be considered as requirements of the standard.

1.5 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

2. Referenced Documents

2.1 *ASTM Standards:* [2]

C 31/C 31M Practice for Making and Curing Concrete Test Specimens in the Field

C 39/C 39M Test Method for Compressive Strength of Cylindrical Concrete Specimens

C 192/C 192M Practice for Making and Curing Concrete Test Specimens in the Laboratory

C 470/C 470M Specification for Molds for Forming Concrete Test Cylinders Vertically

C 617 Practice for Capping Cylindrical Concrete Specimens

C 670 Practice for Preparing Precision and Bias Statements for Test Methods for Construction Materials

C 1074 Practice for Estimating Concrete Strength by the Maturity Method

C 1231/C 1231M Practice for Use of Unbonded Caps in Determination of Compressive Strength of Hardened Concrete Cylinders

3. Terminology

3.1 *Definitions:*

3.1.1 Refer to Practice C 1074 for the definitions of the following terms: *datum temperature*, *equivalent age*, *maturity*, *maturity function*, *maturity index*, and *temperature–time factor*.

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *potential strength*, *n*—the strength of a test specimen that would be obtained at a specified age under standard curing conditions.

3.2.2 *prediction equation*, *n*—the equation representing the straight-line relationship between compressive strength and the logarithm of the maturity index.

3.2.2.1 *Discussion*—The prediction equation is used to project the strength of a test specimen based upon its measured early-age strength. The general form of the prediction equation used in this test method is:

$$S_M = S_m + b(\log M - \log m) \quad (1)$$

where:

S_M = projected strength at maturity index M,
S_m = measured compressive strength at maturity index m,
b = slope of the line,

[1] This test method is under the jurisdiction of ASTM Committee C09 on Concrete and Concrete Aggregates and is the direct responsibility of Subcommittee C09.61 on Testing for Strength.

Current edition approved July 15, 2007. Published August 2007. Originally approved in 1980. Last previous edition approved in 2002 as C 918 – 02.

[2] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

***A Summary of Changes section appears at the end of this standard.**

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M = maturity index under standard curing conditions, and
m = maturity index of the specimen tested at early age.

The prediction equation is developed by performing compressive strength tests at various ages, computing the corresponding maturity indices at the test ages, and plotting the compressive strength as a function of the logarithm of the maturity index. A best-fit line is drawn through the data and the slope of this line is used in the prediction equation.

3.2.3 *projected strength*, *n*—the potential strength estimated by using the measured early-age strength and the previously established prediction equation.

4. Summary of Test Method

4.1 Cylindrical test specimens are prepared and cured in accordance with the appropriate sections of Practice C 31/C 31M or in accordance with Practice C 192/C 192M. The temperature of a representative specimen is monitored during the curing period. Specimens are tested for compressive strength at an early age beyond 24 h, and the concrete temperature history is used to compute the maturity index at the time of test.

4.2 A procedure is presented for acquiring a series of compressive strength values and the corresponding maturity indices at different ages. These data are used to develop a prediction equation, that is, used subsequently to project the strengths at later ages based upon measured early-age strengths.

5. Significance and Use

5.1 This test method provides a procedure to estimate the potential strength of a particular test specimen based upon its measured strength at an age as early as 24 h.[3] The early-age test results provide information on the variability of the concrete production process for use in process control.

5.2 The relationship between early-age strength of test specimens and strength achieved at some later age under standard curing depends upon the materials comprising the concrete. In this test method, it is assumed that there is a linear relationship between strength and the logarithm of the maturity index. Experience has shown that this is an acceptable approximation for test ages between 24 h and 28 days under standard curing conditions. The user of this test method shall verify that the test data used to develop the prediction equation are represented correctly by the linear relationship. If the underlying relationship between strength and the logarithm of the maturity index cannot be approximated by a straight line, the principle of this test method is applicable provided an appropriate equation is used to represent the non-linear relationship.

5.3 Strength projections are limited to concretes using the same materials and proportions as the concrete used to establish the prediction equation.

NOTE 1—Confidence intervals developed in accordance with 10.2 are helpful in evaluating projected strengths.

5.4 This test method is not intended for estimating the in-place strength of concrete. Practice C 1074 provides procedures for using the measured in-place maturity index to estimate in-place strength.

6. Apparatus

6.1 *Equipment and Small Tools*, for fabricating specimens and measuring the characteristics of fresh concrete, shall conform to the applicable requirements of Practices C 31/C 31M or C 192/C 192M.

6.2 *Molds* shall conform to the requirements for cylinder molds in Specification C 470/C 470M.

6.3 *Temperature Recorder*:

6.3.1 A device is required to monitor and record the temperature of a test specimen as a function of time. Acceptable devices include thermocouples or thermistors connected to continuous chart recorders or digital data-loggers. For digital instruments, the recording time interval shall be ½ h or less for the first 48 h and 1 h or less thereafter. The temperature recording device shall be accurate to within 1 °C [±2 °F]

6.3.2 Alternative devices include commercial maturity instruments that automatically compute and display the temperature-time factor or the equivalent age as described in Practice C 1074.

NOTE 2—Commercial maturity instruments use specific values of the datum temperature to evaluate the temperature-time factor or of the Q-value to evaluate equivalent age. Refer to the Appendix of Practice C 1074 for additional explanation and recommendations.

7. Sampling

7.1 Sample and measure the properties of the fresh concrete in accordance with Practices C 31/C 31M or C 192/C 192M.

8. Procedure for Early-Age and Projected Strengths

8.1 Mold and cure the specimens in accordance with the standard curing procedure in Practice C 31/C 31M or in accordance with Practice C 192/C 192M whichever is applicable. Record the time when molding of the specimens is completed.

8.2 Embed a temperature sensor into the center of one of the specimens of the sampled concrete. Activate the temperature recording device. Continue curing for at least 24 h. Maintain a record of the concrete temperature during the entire curing period.

8.3 *Capping and Testing*—Remove the specimens from the molds as soon as practical after 24 h. Cap the specimens in accordance with Practice C 617 or Practice C 1231/C 1231M.

8.3.1 The capping materials, if used, shall develop, at the age of 30 min, a strength equal to or greater than the strength of the cylinders to be tested.

8.3.2 Do not test specimens sooner than 30 min after capping.

8.4 Determine the cylinder compressive strength in accordance with Test Method C 39/C 39M at an age of 24 h or later. Record the strength and the age at the time of the test. The age of the cylinder is measured to the nearest 15 min from the time of molding. Strength at each test age shall be the average strength of at least two cylinders.

[3] For additional information, see *Significance of Tests and Properties of Concrete and Concrete-Making Materials*, *ASTM STP 169C*, Chapter 15, "Prediction of Potential Concrete Strength at Later Ages," 1994.

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8.5 Determine the maturity index at the time of test by using the manual procedure described in the section titled Maturity Functions in Practice C 1074 or by using a maturity instrument. Record the maturity index, *m*, of the early-age test specimens.

8.6 When the data representing the compressive strength and the maturity index, *m*, are to be used to project the strength of the concrete at some later age, determine the projected strength by using the prediction equation determined in Section 9.

9. Procedure for Developing Prediction Equation

9.1 Develop a prediction equation for each concrete to be used on the job. Prepare specimens in accordance with Practice C 192/C 192M. Use the procedure in Section 8 to obtain compressive strength values and the corresponding maturity indices at the times of testing. These data shall include tests at ages of 24 h, 3, 7, 14, and 28 days. If the age for which the projected strength is to be determined exceeds 28 days, the data shall include tests at the desired later age (see 5.2). Strength at each age shall be the average strength of at least two cylinders.

9.1.1 Field data are acceptable, provided they furnish all of the information in 9.1, and provided the specimens are cured in accordance with the section on standard curing of Practice C 31/C 31M.

9.2 The constant *b* for use in the prediction equation (see Eq 1) is established using one of two alternative methods: (*1*) by regression analysis, or (*2*) by manual plotting.

9.2.1 *Regression Analysis*—Convert the values of the maturity indices by taking their logarithms. Plot the average cylinder strength versus the logarithm of the maturity index. Compute the best-fit straight line to the points using an appropriate calculator or computer program. The straight line has the following equation:

$$S_m = a + b \log m \tag{2}$$

where:
S_m = compressive strength at m,
a = intercept of line,
b = slope of line, and
m = maturity index.

Plot the best-fit straight line on the same graph as the data to verify that the correct equation has been determined.

9.2.2 *Manual Plotting*—Prepare a sheet of semi-log graph paper with the *y*-axis representing compressive strength and the logarithmic scale (*x*-axis) representing the maturity index (see Note 3). Plot the strength values from 9.1 versus the corresponding maturity index. Determine the best-fitting straight line by drawing a line that visually minimizes the distances between the points and the line. The slope of the line is the vertical distance, in units of stress, between the intersection of the line with the beginning and the end of one cycle on the *x*-axis (see Fig. X1.1). This slope is the value of *b* for use in the prediction equation (see Eq 1).

NOTE 3—The scale for the *y*-axis and the number of cycles in the semi-log graph paper should be chosen so that the data fill up as much of the paper as possible. When the maturity index is expressed as the temperature-time factor in degree-hours, three cycles are generally appropriate. If the maturity index is expressed as the equivalent age in hours, two cycles are appropriate.

9.3 Use the constant, *b*, and Eq 1 to determine the projected strength based on early-age test results.

NOTE 4—If it is desired to check the accuracy of the first estimate of the value of *b*, fabricate companion specimens to those for testing at an early age, cure them in accordance with the standard curing procedure in Practice C 31/C 31M, record their temperature histories and test them at 28 days. The value of *b* is re-estimated by use of the following equation:

$$b = \frac{\Sigma(S - S_m)}{\Sigma(\log M - \log\ m)} \tag{3}$$

where:
S = measured compressive strength at M,
M = maturity index corresponding to test at 28 days,
S_m = measured compressive strength at m, and
m = maturity index corresponding to early-age test.

10. Interpretation of Results

10.1 As stated in Section 12, the variability of early-age compressive strength obtained by this test method is the same or less than that obtained from traditional test methods. Thus results are applicable for rapid assessment of variability for process control and signaling the need for adjustments. Use of the results from this test method to predict specification compliance of strengths at later ages must be applied with caution because strength requirements in existing specifications and codes are not based upon early-age testing.

10.2 Develop a one-sided confidence interval for the projected strength for use in the acceptance decision. The confidence interval is based on the measured differences between projected and measured strengths at a designated age. Usually such an interval is developed at a 95 % confidence level, and the decision is to accept the concrete as conforming to specification requirements if the following condition is satisfied:

$$S_M > (S_L + K) \tag{4}$$

where:
S_M = projected strength at designated age,
S_L = specified lower limit, specifically, the specified strength at the designated age,

$$K = \bar{d} + t_{0.95,\,n-1}\,\frac{s_d}{\sqrt{n}} \tag{5}$$

$\bar{d}$ = average difference between the measured and projected strength.

$$\bar{d} = \frac{\sum_{i=1}^{n}(S_M - S)_i}{n} = \frac{\sum_{i=1}^{n} d_i}{n} \tag{6}$$

S = measured strength after standard curing up to designated age,
d_i = the difference between the ith pair of strength values,
n = number of paired (S_M and S) values used in the analysis,

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$t_{0.95,n-1}$ = value from the t-distribution at the 95 % level for $n - 1$ degrees of freedom, and

s_d = standard deviation for the difference between the measured and projected strengths.

$$s_d = \sqrt{\frac{\sum_{i=1}^{n}(d_i - \bar{d})^2}{(n-1)}} \quad (7)$$

11. Report

11.1 The report of the early-age test results shall include the following:

11.1.1 Identification number of test cylinder,

11.1.2 Diameter of test cylinder, mm [in.],

11.1.3 Cross-sectional area of test cylinder, mm^2 [$in.^2$],

11.1.4 Maximum test load on cylinder, N [lb],

11.1.5 Compressive strength of cylinder calculated to the nearest 0.1 MPa [10 psi],

11.1.6 Type of fracture of cylinder, if other than the usual cone,

11.1.7 Age of cylinder at the time of test,

11.1.8 Initial mix temperature to the nearest 1 °C [2 °F],

11.1.9 Temperature records, and

11.1.10 Method of transportation used for shipping the specimens to the laboratory.

11.2 If the early-age strength data are used to project later-age strength, the report shall include the following:

11.2.1 The maturity index, *m*, of the early-age specimens at the time of test,

11.2.2 The age of the projected strength, and

11.2.3 The projected strength calculated to the nearest 0.1 MPa [10 psi].

12. Precision and Bias

12.1 *Precision*:

12.1.1 The data used to prepare the following precision statements were obtained using measurements in the inch-pound system.

12.1.2 The single laboratory coefficient of variation has been determined as 3.6 % for a pair of cylinders (150 by 300 mm [6 by 12 in.]) cast from the same batch. Therefore, results of two properly conducted strength tests by the same laboratory on two individual cylinders made with the same materials should not differ more than 10 % of their average (see Note 5).

12.1.3 The single-laboratory, multi-day coefficient of variation has been determined as 8.7 % for the average of pairs of cylinders (150 by 300 mm [6 by 12 in.]) cast from single batches mixed on two days. Therefore, results of two properly conducted strength tests each consisting of the average of two cylinders from the same batch made in the same laboratory on different days with the same materials and proportions should not differ by more than 25 % of their average (see Note 5).

NOTE 5—These numbers represent, respectively, the (1s %) and d2s %) limits as described in Practice C 670.

12.2 *Bias*—This test method has no determinable bias as the values obtained can only be defined in terms of this test method.

13. Keywords

13.1 compressive strength; early-age strength; maturity; potential strength; projected strength

APPENDIX

(Nonmandatory Information)

X1. EXAMPLE OF USE

X1.1 *Development of Prediction Equation:*

X1.1.1 To establish a reliable relationship between strength and the maturity index, concrete must be made from the actual materials, including admixtures, to be used in the work. While field data are acceptable, the initial data will normally originate in the laboratory before field production begins. Compressive strength specimens will, therefore, normally be made and cured in the laboratory and tested at ages of 24 h, 3, 7, 14, and 28 days. It is suggested that a minimum of 14 cylinders be made and cured in accordance with Practice C 192/C 192M.

X1.1.1.1 *Example Data*—An example of age-strength data obtained from test cylinders (two at each age) is as follows:

Age	Average Strength, MPa [psi]
24 h	9.4 [1370]
3 days	17.1 [2480]
7 days	21.8 [3160]
14 days	25.6 [3710]
28 days	29.3 [4250]

X1.1.1.2 In this example, the temperature-time factor, with a datum temperature of 0 °C [32 °F], is used as the maturity index. Refer to Practice C 1074 for additional information. The temperature-time factor is calculated from the measured temperature history of the concrete by dividing the age into suitable time intervals and summing the products of the time

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intervals and the corresponding average temperatures for each interval. For this example, it is assumed that the concrete temperature is 21 °C [70 °F] prior to stripping the molds and is 23 °C [73 °F] thereafter. The cumulative temperature-time factor at the various test ages is calculated as shown in Table X1.1.

X1.1.2 The strength data shown in X1.1.1.1 and the temperature-time factor values in Table X1.1 can be plotted using semi-log axes as shown in Fig. X1.1, which is a computer generated plot.

X1.1.3 Determine the best-fit straight line through the plotted points. In this example, the straight line was obtained by regression analysis using a computer program. This line represents the prediction equation which is the assumed relationship between strength and the temperature-time factor for this particular concrete. The equation for this straight line is expressed in the following form:

$$S_M = S_m + b\,(\log M - \log m) \quad \text{(X1.1)}$$

where S_M and S_m are the strengths at values of the temperature-time factor equal to M and m, respectively.

X1.1.4 The value b is the slope of the prediction equation and is the vertical distance, in units of stress, between the intersections of the line with the beginning and the end of one cycle on the x-axis (see Fig. X1.1). For this particular example, $b = 13.3$ MPa [1930 psi], which represents the strength increase for a tenfold increase in the temperature-time factor.

X1.1.5 Any concrete produced from the same materials and proportions that were used to develop the prediction equation would have the same strength versus temperature-time factor relationship.

X1.2 *Projected Strength:*

X1.2.1 To use the prediction equation to project the strength of field concrete based upon early-age strengths, sample and test the fresh concrete in accordance with Practice C 31/C 31M. Mold and cure at least three specimens in accordance with the standard curing procedure in Practice C 31/C 31M. Install a temperature recording device into a cylinder to monitor the concrete temperature. Continue curing for at least 24 h.

TABLE X1.1 Temperature-Time Factor at Test Ages

Age, days	Age Increment, (Δ*t*), h	Temperature, T, °C	Temperature-Time Factor Increment, (T-0) × Δ*t*,° C·h	Cumulative Temperature-Time Factor, °C·h (°F·h)
1	24	21	504	504 [907]
3	48	23	1104	1808 [2894]
7	96	23	2208	3816 [6869]
14	168	23	2864	7680 [13 824]
28	336	23	7728	15 408 [27 734]

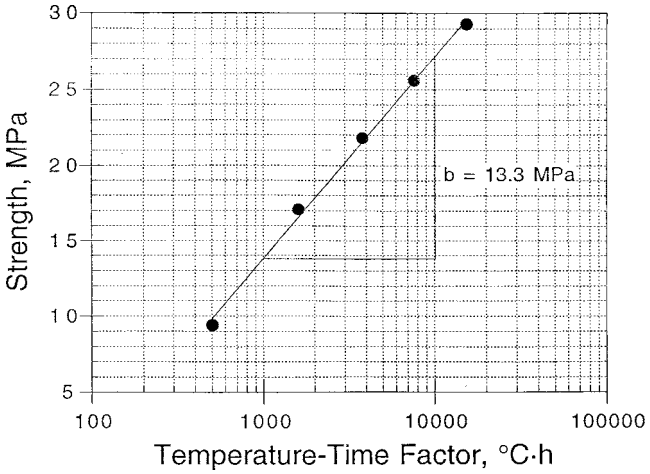

FIG. X1.1 Example Data of Strength as a Function of the Logarithm of the Temperature-Time Factor and the Best-Fit Straight Line that Represents the Prediction Equation

X1.2.2 As soon as practical after the minimum 24-h curing period, remove the specimens from the molds and prepare for testing in accordance with Test Method C 39/C 39M. Record the age at the time of test. Use this age, together with the recorded temperature history, to determine the maturity index, m, at time of test. Report the early-age compressive strength, S_m, as the average of the cylinders tested. The prediction equation is then used to project the strength of the concrete represented by the test specimens.

X1.2.3 As an example:

X1.2.3.1 Compressive strength specimens fabricated in the field were cured for 24 h under standard conditions at the job site. At an age of 24 h, the specimens were removed from their molds, capped, and the caps were allowed to harden. The cylinders were tested at an age of 26 h. The average strength at this age was 9.8 MPa [1420 psi].

X1.2.3.2 Columns 1 and 2 in Table X1.2 show the recorded temperature history obtained from the instrumented specimen. The sixth column shows the increment of temperature-time factor during each age interval. The last column shows the cumulative temperature-time factor. At an age of 26 h, the cumulative temperature-time factor m is 616 °C·h [1109 °F·h].

X1.2.3.3 The temperature-time factor after 28 days of curing at the standard temperature of 23 °C [73 °F] is:

$$M = (23 - 0)\ °C \times 28\ \text{days} \times 24\ \text{h} = 15\,456\ °C \cdot \text{h}\ [27\,829\ °F \cdot \text{h}] \quad \text{(X1.2)}$$

X1.2.3.4 The projected 28-day strength is calculated as:

$$S_M = S_m + b(\log M - \log m)$$
$$S_M = 9.8 + 13.3\ (\log 15\,546 - \log 616)$$
$$S_M = 9.8 + (4.189 - 2.790)$$
$$S_M = 9.8 + 18.6$$
$$S_M = 28.4\ \text{MPa}\ [4120\ \text{psi}]$$

Therefore, had the specimens been cured at 23 °C [73 °F] for the full 28 days, their expected average compressive strength would be 28.4 MPa [4120 psi] if tested at 28 days.

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TABLE X1.2 Example Temperature Record and Calculations to Determine the Temperature-Time Factor at Test Age

(1) Age, h	(2) Temperature, °C	(3) Age Interval, Δ *t*, h	(4) Average Temperature During Age Interval, °C	(5) Temperature – 0 °C, °C	(6) Temperature-Time Factor Increment, °C·h	(7) Cumulative Temperature-Time Factor, °C·h [°F·h]
0	21					
1	21	1	21.0	21.0	21.0	21 [38]
2	20	1	20.5	20.5	20.5	42 [75]
3	20	1	20.0	20.0	20.0	62 [111]
4	21	1	20.5	20.5	20.5	82 [148]
10	24	6	22.5	22.5	135.0	217 [391]
11	24	1	24.0	24.0	24.0	241 [434]
12	25	1	24.5	24.5	24.5	266 [478]
14	25	2	25.0	25.0	50.0	316 [568]
15	26	1	25.5	25.5	25.5	341 [614]
20	26	5	26.0	26.0	130.0	471 [848]
21	25	1	25.5	25.5	25.5	497 [894]
22	25	1	25.0	25.0	25.0	522 [939]
23	24	1	24.5	24.5	24.5	546 [983]
24	24	1	24.0	24.0	24.0	570 [1026]
25	23	1	23.5	23.5	23.5	594 [1068]
26 (test age)	22	1	22.5	22.5	22.5	616 [1109]

SUMMARY OF CHANGES

Committee C09 has identified the location of selected changes to this test method since the last issue, C 918 – 02, that may impact the use of this test method. (Approved July 15, 2007)

(*1*) Revised the standard to make it a dual-units standard.

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Designation: C 926 – 06

Standard Specification for Application of Portland Cement-Based Plaster[1]

This standard is issued under the fixed designation C 926; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope*

1.1 This specification covers the requirements for the application of full thickness portland cement-based plaster for exterior (stucco) and interior work.

1.2 This specification sets forth tables for proportioning of various plaster mixes and plaster thickness.

NOTE 1—General information will be found in Annex A1. Design considerations will be found in Annex A2.

1.3 The values stated in inch-pound units are to be regarded as the standard. The SI (metric) values given in parentheses are approximate and are provided for information purposes only.

1.4 The text of this specification references notes and footnotes that provide explanatory material. These notes and footnotes (excluding those in tables and figures) shall not be considered as requirements of the specification.

1.5 Details of construction for a specific assembly to achieve the required fire resistance shall be obtained from reports of fire-resistance tests, engineering evaluations, or listings from recognized fire testing laboratories.

2. Referenced Documents

2.1 *ASTM Standards:* [2]

C 11 Terminology Relating to Gypsum and Related Building Materials and Systems

C 25 Test Methods for Chemical Analysis of Limestone, Quicklime, and Hydrated Lime

C 35 Specification for Inorganic Aggregates for Use in Gypsum Plaster

C 91 Specification for Masonry Cement

C 150 Specification for Portland Cement

C 206 Specification for Finishing Hydrated Lime

C 207 Specification for Hydrated Lime for Masonry Purposes

C 219 Terminology Relating to Hydraulic Cement

C 260 Specification for Air-Entraining Admixtures for Concrete

C 595 Specification for Blended Hydraulic Cements

C 631 Specification for Bonding Compounds for Interior Plastering

C 897 Specification for Aggregate for Job-Mixed Portland Cement-Based Plasters

C 932 Specification for Surface-Applied Bonding Agent for Exterior Plastering

C 1063 Specification for Installation of Lathing and Furring to Receive Interior and Exterior Portland Cement-Based Plaster

C 1116 Specification for Fiber-Reinforced Concrete and Shotcrete

C 1328 Specification for Plastic (Stucco) Cement

E 90 Test Method for Laboratory Measurement of Airborne-Sound Transmission Loss of Building Partitions and Elements

E 119 Test Methods for Fire Tests of Building Construction and Materials

E 492 Test Method for Laboratory Measurement of Impact Sound Transmission Through Floor-Ceiling Assemblies Using the Tapping Machine

2.2 *ANSI Standard:*

A108.1 Specification for Installation of Ceramic Tile[3]

3. Terminology

3.1 Terms shall be defined as in Terminologies C 11 and C 219, except as modified herein.

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *accelerator*—an admixture that will shorten the setting time of plaster.

3.2.2 *admixture*—a material other than water, aggregate, or basic cementitious material added to the batch before or during job mixing.

[1] This specification is under the jurisdiction of ASTM Committee C11 on Gypsum and Related Building Materials and Systems and is the direct responsibility of Subcommittee C11.03 on Specifications for Application of Gypsum and Other Products on Assemblies.

Current edition approved June 1, 2006. Published June 2006. Originally approved in 1981. Last previous edition approved in 2005 as C 926–98a(2005).

[2] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

[3] Available from American National Standards Institute (ANSI), 25 W. 43rd St., 4th Floor, New York, NY 10036.

***A Summary of Changes section appears at the end of this standard.**

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3.2.3 *acid etching*—the cleansing and controlled erosion of a solid surface, using an acid wash.

3.2.4 *air entrainment*—the use of an air-entraining admixture or air-entraining cementitious material in a plaster mix to yield a controlled quantity of minute (typically between 10 and 1000 μm in diameter) disconnected air bubbles in the plaster (see *entrapped air*).

3.2.5 *backplaster*—plaster applied to the face of metal lath opposite a previously applied plaster.

3.2.6 *bond*—the state of adhesion between plaster coats or between plaster and plaster base.

3.2.7 *bonding compound or agent*—compounds surface applied or integrally mixed with plaster to improve the quality of bond between plaster and plaster base or between plaster coats.

3.2.8 *cementitious material*—a material that, when mixed with water and with or without aggregate, provides the plasticity and the cohesive and adhesive properties necessary for placement and the formation of a rigid mass.

3.2.9 *coat*—a thickness of plaster applied in a single operation.

3.2.9.1 *basecoat*—all plaster applied before the application of the finish coat.

3.2.9.2 *bedding coat*—a plaster coat that receives aggregate or other decorative material impinged into its surface before it sets.

3.2.9.3 *brown coat*—in three-coat work, the second coat, applied over the scratch coat. In two-coat work, brown coat refers to the double-up basecoat. In either use, the brown coat is the coat directly beneath the finish coat.

3.2.9.4 *dash-bond coat*—a thick wet mixture of portland cement and water, with or without aggregate, dashed onto the surface of a plaster base such as smooth monolithic concrete or concrete block surfaces to improve the mechanical key for subsequent plaster coats.

3.2.9.5 *double-up coat*—the brown-coat plaster applied to the scratch coat plaster before the scratch-coat plaster has set.

3.2.9.6 *finish coat*—the final layer of plaster applied over basecoat plaster.

3.2.9.7 *fog coat*—a light coat of cement and water, with or without aggregate or color pigment, applied by machine spray to improve color consistency.

3.2.9.8 *scratch coat*—the first coat of plaster applied to a plaster base.

3.2.9.9 *skim coat*—a thin finish coat applied to an existing plaster surface or other substrate to improve appearance.

3.2.9.10 *three-coat work*—application of plaster in three successive coats with time between coats for setting or drying, or both.

3.2.10 *cold joint ("joining" or "jointing")*—the juncture of fresh plaster application adjacent to set plaster, in the same plane.

3.2.11 *curing*—the act or processes of producing a moisture environment favorable to cement hydration, resulting in the setting or hardening of the plaster.

3.2.12 *entrapped air*—unintentional air voids in the plaster generally larger than 1 mm.

3.2.13 *factory prepared ("mill-mixed" or "ready mixed")*—pertaining to material combinations that have been formulated and dry-blended by the manufacturer, requiring only the addition of and mixing with water to produce plaster.

3.2.14 *fiber, natural or synthetic*—an elongated fiber or strand admixture added to plaster mix to improve cohesiveness or pumpability, or both.

3.2.15 *floating*—act of compacting and leveling brown-coat plaster to a reasonably true surface plane using a float tool or the act of bringing the aggregate to the surface of finish-coat plaster.

3.2.16 *key (also mechanical key)*—plaster that physically surrounds, penetrates, or deforms to lock onto the perforations or irregularities of the plaster base or previous coat of plaster.

3.2.17 *metal plaster base*—expanded metal lath, or welded or woven wire lath.

3.2.18 *plaster*—portland cement-based cementitious mixture (see *stucco*).

3.2.19 *required*—pertaining to a mandatory obligation imposed by a force outside of this specification, such as a building code, project specification, contract, or purchase order.

3.2.20 *rustication (also "break")*—an interruption or change in plane of a plastered surface.

3.2.21 *scoring (also known as "scratching")*—the grooving of the surface of an unset plaster coat to provide a key for a subsequent coat.

3.2.22 *set*—the chemical and physical change in plaster as it goes from a plastic, workable state to a rigid state.

3.2.23 *stucco*—portland cement-based plaster used on exterior locations.

3.2.24 *stucco finish*—a factory-prepared, dry blend of materials for finish coat applications.

3.2.25 *temper, v*—to mix or restore unset plaster with water to a workable consistency.

3.2.26 *texture*—any surface appearance as contrasted to a smooth surface.

4. Materials

4.1 Materials shall conform to the requirements of the referenced specifications and standards and to the requirements specified herein.

4.2 *Cement*:

4.2.1 *Portland Cement*—Specification C 150, Type I, II, and III, as specified. White where specified.

4.2.2 *Air-Entraining Portland Cement*—Specification C 150, type as specified. White where specified.

4.2.3 *Masonry Cement*—Specification C 91, Types N, S, and M. White where specified.

4.2.4 *Blended Hydraulic Cement*—Specification C 595, Type IP, I(PM), IS, and I(SM) as specified.

4.2.5 *Air-Entraining Blended Hydraulic Cement*—Specification C 595, Type IP-A, I(PM)-A, IS-A, and I(SM)-A as specified.

4.2.6 *Plastic Cement*—Plastic Cement shall meet the requirements of Specification C 1328, Standard Specification for Plastic (Stucco) Cement.

NOTE 2—Plastic cements are not available nationally.

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4.3 *Type "S" Hydrated Lime*—A hydrated lime that contains not more than 8 % unhydrated oxides when tested in accordance with Test Methods C 25. See Specifications C 206 and C 207 for a complete description of a Type "S" hydrated lime.

4.4 *Aggregates*:

4.4.1 *Sand for Base Coats*—Specification C 897. Aggregate failing to meet gradation limits in Specification C 897 shall be permitted to be used, provided the plaster made with this sand has an acceptable demonstrated performance record in similar construction and climate conditions.

4.4.2 *Perlite*—Specification C 35.

4.4.3 *Sand for Job-Mixed Finish Coats*—Specification C 897.

4.5 *Water*—Water used in mixing, application, and finishing of plaster shall be clean, fresh, suitable for domestic water consumption, and free of such amounts of mineral or organic substances as would affect the set, the plaster, or any metal in the system.

4.6 *Admixtures*—See 3.2.2 and .

4.7 *Fibers*—Specification C 1116 on alkali-resistant fibers, glass fibers, nylon, polypropylene or carbon fibers.

5. Requirements for Bases to Receive Portland Cement-Based Plaster

5.1 Metal bases and accessories used to receive plaster shall be installed in conformance with Specification C 1063, except as otherwise specified.

NOTE 3—All metal, or PVC, or CPVC plastic members should be free of deleterious amounts of rust, oil, or other foreign matter, which could cause bond failure or unsightly discoloration.

5.2 Surfaces of solid bases to receive plaster, such as masonry, stone, cast-in-place or precast concrete shall be straight and true within ¼ in. in 10 ft (2.1 mm/m) and shall be free of form oil or other elements, which would interfere with bonding. Form ties or other obstructions shall be removed or trimmed back even with the surface of the solid base.

5.2.1 Solid surfaces shall have the suction (ability to absorb water) or surface roughness, or both, to provide the bond required for the plaster.

5.2.2 Smooth or nonabsorbent solid surfaces, such as cast-in-place or precast concrete, shall be prepared to receive portland cement plaster by one of the following methods:

5.2.2.1 Sandblasting, wire brushing, acid etching, or chipping or a combination thereof,

5.2.2.2 Application of a dash-bond coat applied forcefully against the surface, left untroweled, undisturbed, and moist cured for at least 24 h, or

5.2.2.3 Application of a bonding compound suitable for exterior or interior exposure solid surfaces in accordance with the manufacturer's written directions.

5.2.3 Where bond cannot be obtained over the entire surface to receive plaster by one or more of the methods in 5.2.2, or where total plaster thickness will exceed the total thickness specified in Table 1 for types of solid bases, furred or self-furring metal plaster base shall be installed in accordance with Specification C 1063.

6. Plaster Proportions and Mixing

6.1 *Proportions*:

6.1.1 All portland cement plasters shall be mixed and proportioned in accordance with the following tables and accompanying requirements, using measuring devices of known volume with successive batches proportioned alike.

6.1.2 Plaster mix used shall be as designated and referenced to Table 2.

6.1.3 Base-coat proportions shall be as shown in Table 3 for the mix specified from Table 2.

6.1.3.1 *Measurement of Materials*—The method of measuring materials for the plaster shall be such that the specified proportions are controlled and accurately maintained. The weights per cubic foot of the materials are considered to be as follows:

Material	Weight, lb/ft^3(kg/m^3)
Portland cement	94 (1505)
Blended cement	Weight printed on bag
Masonry or plastic cement	Weight printed on bag
Hydrated Lime	40 (640)
Lime Putty	80 (1280)
Sand, Damp and Loose (6.1.3.2)	80 (1280) of dry sand

TABLE 1 Nominal Plaster Thickness[A] for Three- and Two-Coat Work, in. (mm)

BASE	Vertical				Horizontal			
	1st Coat	2nd Coat	3rd Coat[B]	Total	1st Coat	2nd Coat	3rd Coat[B]	Total
	Interior/Exterior							
Three-coat work:[C]								
Metal plaster base	⅜ (9.5)	⅜ (9.5)	⅛ (3)	⅞ (22)	¼ (6)	¼ (6)	⅛ (3)	⅝ (16)
Solid plaster base:								
Unit masonry	¼ (6)	¼ (6)	⅛ (3)	⅝ (16)	Use two-coat work			
Cast-in-place or precast concrete	¼ (6)	¼ (6)	⅛ (3)	⅝ (16)				⅜ (9.5), max
Metal plaster base over solid base	½ (12.5)	¼ (6)	⅛ (3)	⅞ (22)	½ (12.5)	¼ (6)	⅛ (3)	⅞ (22)
Two-coat work:								
Solid plaster base:								
Unit masonry	⅜ (9.5)	⅛ (3)		½ (12.5)				⅜ (9.5)
Cast-in-place or pre-cast concrete	¼ (6)	⅛ (3)		⅜ (9.5)				⅜ (9.5)

[A] Exclusive of texture.
[B] For solid plaster partitions, additional coats shall be applied to meet the finished thickness specified.
[C] For exposed aggregate finishes, the second (brown) coat shall become the "bedding" coat and shall be of sufficient thickness to receive and hold the aggregate.

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TABLE 2 Plaster Bases—Permissible Mixes

NOTE—See Table 3 for plaster mix symbols.

Property of Base	Mixes for Plaster Coats	
	First (Scratch)	Second (Brown)
Low absorption, such as dense, smooth clay tile, brick, or concrete	C	C, CL, M, or CM
	CM or MS	CM, MS, or M
	P	P
High Absorption, such as concrete masonry, absorptive brick, or tile	CL	CL
	M	M
	CM or MS	CM, MS, or M
	P	P
Metal plaster base	C	C, CL, M, CM, or MS
	CL	CL
	CM or MS	CM, MS, or M
	M	M
	CP	CP or P
	P	P

6.1.3.2 For purposes of this specification, a weight of 80 lb (1280 kg) of oven-dried sand shall be used. This is, in most cases, equivalent to one cubic foot of loose, damp sand.

6.1.4 Finish-coat proportions for job-mixed finish coats shall be as specified in Table 4.

6.1.5 *Factory-Prepared Finish Coats*—See 3.2.14.

6.1.6 Dash-bond coat proportions shall be 1 volume part portland cement and not more than 2 volume parts of aggregate mixed to a consistency that will permit application as specified in 7.1.5.

6.1.7 Admixtures shall be proportioned, mixed, and applied in accordance with the printed directions of the manufacturer. (See A2.5.)

6.2 *Mixing*:

6.2.1 All plaster shall be prepared in a mechanical mixer, using sufficient water to produce a workable consistency and uniform color. (See X1.1.)

6.2.2 Base-coat plasters that have stiffened because of evaporation of water shall be permitted to be tempered one time only to restore the required consistency. Plaster not used within 1½ h from start of initial mixing shall be discarded.

NOTE 4—Severe hot, dry climate conditions accelerate the stiffening of plaster and require reduction of this limit. The use of cold waters will slow the stiffening process.

6.2.3 Finish-coat plaster shall not be tempered.

7. Application

7.1 *General*:

7.1.1 Portland cement plaster shall be applied by hand or machine to the nominal thickness specified in Table 1.

7.1.2 Plaster nominal thickness shall be measured from the back plane of the metal plaster base, exclusive of ribs or dimples, or from the face of the solid backing with or without metal plaster base, to the outer surface exclusive of texture variations.

7.1.3 Portland cement-based plaster shall be applied on furred metal plaster base when the surface of solid backing consists of gypsum board, gypsum plaster, wood, or rigid foam board-type products.

NOTE 5—On horizontal ceiling supports or roof soffits protected by a drip edge, gypsum board products shall be permitted to be used as backing for metal base to receive portland cement plaster.

7.1.4 Separation shall be provided where plaster abuts dissimilar construction materials or openings. (See A2.1.4.)

7.1.5 Each plaster coat shall be applied to an entire wall or ceiling panel without interruption to avoid cold joints and abrupt changes in the uniform appearance of succeeding coats. Wet plaster shall abut set plaster at naturally occurring interruptions in the plane of the plaster, such as corner angles, rustications, openings, and control joints where this is possible. Joinings, where necessary, shall be cut square and straight and not less than 6 in. (152 mm) away from a joining in the preceding coat.

7.1.6 Metal plaster base shall be covered with three-coat work with or without solid backing. The combined total nominal thickness shall be as shown in Table 1. A dash-bond coat shall not replace one of the specified number of coats.

7.1.7 Two-coat work shall be used only over solid bases meeting the requirements of 5.2. The combined total nominal thickness shall be as shown in Table 1. A dash-bond coat shall not replace one of the specified number of coats.

7.1.8 Backplaster where required, shall be applied only after the coat on the opposite side has set sufficiently to resist breaking or cracking the plaster keys.

7.1.9 Each coat shall be permitted to set before the next coat is applied. (See X1.4.2.)

7.1.10 Plaster coats that have become dry shall be evenly dampened with water prior to applying subsequent coats to obtain uniform suction. There shall be no visible water on the surface when plaster is applied.

7.2 *Plaster Application on Metal Plaster Bases*:

7.2.1 The first (scratch) coat shall be applied with sufficient material and pressure to form full keys through, and to embed the metal base, and with sufficient thickness of material over the metal to allow for scoring the surface.

7.2.1.1 As soon as the first (scratch) coat becomes firm, the entire surface shall be scored in one direction only. The vertical surfaces shall be scored horizontally.

7.2.1.2 The first (scratch) coat shall become sufficiently rigid to support the application of the second (brown) coat without damage to the monolithic continuity of the first (scratch) coat or its key.

7.2.2 The second (brown) coat shall be applied with sufficient material and pressure to ensure tight contact with the first (scratch) coat and to bring the combined thickness of the base coat to the nominal thickness shown in Table 1.

7.2.2.1 The surface of the second (brown) coat shall be brought to a true, even plane with a rod or straightedge, filling surface defects in plane with plaster. Dry rodding the surface of the brown coat shall be permitted.

7.2.2.2 The surface shall be floated uniformly to promote densification of the coat and to provide a surface receptive to bonding of the finish coat.

7.2.3 The third (finish) coat shall be applied with sufficient material and pressure to ensure tight contact with, and complete coverage of the base coat and to the nominal thickness shown in Table 1 and 7.3.1.1.

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TABLE 3 Base-Coat Proportions,[A] Parts by Volume[B]

Plaster Mix Symbols	Cementitious Materials					Volume of Aggregate per Sum of Separate Volumes of Cementitious Materials	
	Portland Cement or Blended Cement	Plastic Cement	Masonry Cement		Lime	1st Coat	2nd[C] Coat
			N	M or S			
C	1	. . .	. . .	. . .	0–¾	2½ –4	3–5
CL	1	. . .	. . .	. . .	¾ –1½	2½ –4	3–5
M	. . .	. . .	1	. . .	. . .	2½ –4	3–5
CM	1	. . .	1	. . .	. . .	2½ –4	3–5
MS	. . .	. . .	. . .	1	. . .	2½ –4	3–5
P	. . .	1	. . .	. . .	. . .	2½ –4	3–5
CP	1	1	. . .	. . .	. . .	2½ –4	3–5

[A] The mix proportions for plaster scratch and brown coats to receive ceramic tile shall be in accordance with the applicable requirements of ANSI A108.1 series applicable to specified method of setting time.
[B] Variations in lime, sand, and perlite contents are allowed due to variation in local sands and insulation and weight requirements. A higher lime content will generally support a higher aggregate content without loss of workability. The workability of the plaster mix will govern the amounts of lime, sand, or perlite.
[C] The same or greater sand proportion shall be used in the second coat than is used in the first coat.

TABLE 4 Job-Mixed Finish Coat Proportion Parts by Volume

Plaster Mix Symbols[A]	Cementitious Materials					Volume of Aggregate per Sum of Separate Volumes of Cementitious Materials[B]
	Portland Cement or Blended Cement	Plastic Cement	Masonry Cement[A]		Lime	
			N	M or S		
F	1	. . .	. . .	. . .	¾ –1½	1½ –3
FL	1	. . .	. . .	. . .	1½ –2	1½ –3
FM	. . .	. . .	1	. . .	. . .	1½ –3
FCM	1	. . .	1	. . .	. . .	1½ –3
FMS	. . .	. . .	. . .	1	. . .	1½ –3
FP	. . .	1	. . .	. . .	. . .	1½ –3

[A] Additional portland cement is not required when Type S or M masonry cement is used.
[B] In areas not subject to impact, perlite aggregate shall be permitted to be used over base-coat plaster containing perlite aggregate.

7.3 *Plaster Application on Solid Plaster Bases*:

7.3.1 High-suction bases shall be evenly dampened with clean water prior to the application of plaster. Do not dampen low-suction solid bases, such as dense concrete or smooth brick.

7.3.1.1 Where masonry or concrete surfaces vary in plane, plaster thickness required to produce level surfaces shall not be required to be uniform.

7.3.2 *Three-Coat Application on Solid Bases*:

7.3.2.1 The first (scratch) coat shall be applied with sufficient material and pressure to ensure tight contact and complete coverage of the solid base, to the nominal thickness shown in Table 1. As soon as the first (scratch) coat becomes firm, the entire surface shall be scored in one direction only. The vertical surfaces shall be scored horizontally.

7.3.2.2 The second (brown) coat shall be applied using the same procedures specified in 7.2.2 and 7.2.2.1, bringing the surface to a true, even plane with a rod or straightedge, filling any defects in plane with plaster and darbying. The surface shall be floated uniformly to provide a surface receptive to the application of the third (finish) coat.

7.3.2.3 The third (finish) coat shall be applied as specified in 7.2.3.

7.3.3 *Two-Coat Application on Solid Plaster Bases*:

7.3.3.1 The first (scratch) coat shall be applied as specified in 7.3.2.1.

7.3.3.2 The second (finish) coat shall be applied as specified in 7.2.3.

7.4 *Finish-Coat Application*:

7.4.1 Job-mixed or factory-prepared finish coats shall be applied, by machine or by hand, as specified in 7.2.3.

7.4.2 The use of excessive water during the application and finishing of finish-coat plaster shall be avoided.

7.5 *Fog-Coat Application*—Job-mixed or factory-prepared fog coats shall be applied in accordance with the directions of the manufacturer.

8. Curing and Time Between Coats

8.1 Provide sufficient moisture in the plaster mix or by moist or fog curing to permit continuous hydration of the cementitious materials. The most effective procedure for curing and time between coats will depend on climatic and job conditions. (See X1.4.2.)

8.2 Sufficient time between coats shall be allowed to permit each coat to cure or develop enough rigidity to resist cracking or other physical damage when the next coat is applied. (See X1.4.2.)

9. Product Marking

9.1 Packaged materials shall be clearly marked or labeled to indicate product, brand name, the manufacturer, and the weight of the material contained therein. Similar information shall be provided in the shipping advices accompanying the shipment of bulk materials.

10. Delivery of Materials

10.1 Packaged materials shall be delivered in factory-sealed, unopened, and unbroken packages, containers, or bundles.

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10.2 Bulk materials shall be delivered in clean transport vessels, free of contaminates.

11. Protection of Materials

11.1 Weather-sensitive materials shall be kept in a dry condition until ready for use. (See A2.4.)

11.2 Bulk materials shall be stored to prevent subsequent contamination and segregation.

12. Environmental Conditions

12.1 Portland cement-based plaster shall not be applied to frozen base or to a base containing frost. Plaster mixes shall not contain frozen ingredients. Plaster coats shall be protected from freezing for a period of not less than 24 h after set has occurred.

12.2 Portland cement plaster shall be protected from uneven and excessive evaporation during dry weather and from strong blasts of dry air.

12.3 *Plaster Application*—When artificial heat is required, heaters shall be located to prevent a concentration of heat on uncured plaster. Heaters shall be vented to the outside to prevent toxic fumes and other products of combustion from adhering to or penetrating plaster bases and plaster. Adequate ventilation shall be maintained in all areas, particularly in interior areas with little or no natural air movement.

12.3.1 Interior environment shall be maintained at a temperature above 40 °F not less than 48 h prior to and during application of portland cement-based plaster. Interior temperature shall be maintained above 40 °F until normal occupancy.

12.3.2 For exteriors, plaster shall be applied when the ambient temperature is higher than 40 °F (4.4 °C), unless the work area is enclosed and heat is provided as described in 12.3.

13. Keywords

13.1 brown coat; cementitious; exterior plaster; fog coat—bond; portland cement; scratch coat; stucco

ANNEXES

(Mandatory Information)

A1. GENERAL INFORMATION

A1.1 The work shall include all labor, materials, services, equipment, and scaffolding required to complete the plastering of the project in accordance with the drawings and specifications, except heat, electric power, and potable water.

A1.2 Where a specific degree of fire resistance is required for plastered assemblies and constructions, details of construction shall be in accordance with official reports of fire tests conducted by recognized testing laboratories, in accordance with Test Methods E 119.

A1.3 Where a specific degree of sound control is required for plastered assemblies and constructions, details of construction shall be in accordance with official reports of tests conducted by recognized testing laboratories, in accordance with applicable sound tests of Test Methods E 90 or E 492.

A1.4 Scaffolding shall be constructed and maintained in strict conformity with applicable laws and ordinances.

A1.5 Work schedules shall provide for completion of work affecting supports, framework or lath of a suspended ceiling (such as loading) before plastering work is accomplished.

A1.6 Surfaces and accessories to receive plaster shall be examined before plastering is applied thereto. The proper authorities shall be notified and unsatisfactory conditions shall be corrected prior to the application of plaster. Unsatisfactory conditions shall be corrected by the party responsible for such conditions.

A1.6.1 Metal plaster bases, backing, attachment, and accessories to receive plaster shall be examined to determine if the applicable requirements of Specification C 1063 have been met unless otherwise required by the contract specifications.

A1.6.2 The construction specifier shall describe, in the proper section of the contract specifications, the physical characteristics of solid surface bases to receive plaster. The plane tolerance shall be not more than ¼ in. in 10 ft (3.1 mm/m). The mortar joints shall be flush and not struck. Dissimilar materials such as ties, reinforcing steel, and so forth, shall be cut back ⅛ in. (3 mm) below the surface and treated with a corrosion-resistant coating. Masonry shall be solid at corners and where masonry changes thickness in a continuous construction. Form release compounds shall be compatible with plaster or be completely removed from surfaces to receive plaster. The plastering contractor shall use this portion of the construction specifications for acceptance or rejection of such surfaces.

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A2. DESIGN CONSIDERATIONS

A2.1 Exterior plaster (stucco) is applied to outside surfaces of all types of structures to provide a durable, fire-resistant covering. Interior plaster is applied to inside surfaces that will be subjected to various exposures, such as abrasion, vibration, or to continuous or frequent moisture and wetting, or to freezing or thawing.

A2.1.1 Sufficient slope on faces of plastered surfaces shall be provided to prevent water, snow, or ice from accumulating or standing. Air-entrained portland cement plaster provides improved resistance to freeze/thaw deterioration. Resistance to rain penetration is improved where plaster has been adequately densified during application and properly cured. Plaster shall not, however, be considered to be "waterproof."

A2.1.2 The construction specifier shall describe, in the appropriate section of the contract specifications, the requirements for furnishing and application of flashing. Flashing shall be specified at openings, perimeters, and terminations to prevent water from getting behind plaster. Flashing shall be corrosion-resistant material. Aluminum flashing shall not be used. Flashing supplemented with sealant shall be permitted.

A2.1.3 Sealing or caulking of V-grooves, exposed ends, and edges of plaster panels or exterior work to prevent entry of water shall be provided.

A2.1.4 To reduce spalling where interior plaster abuts openings, such as wood or metal door or window frames, or fascia boards, the edge of three-coat plaster shall be tooled through the second and finish coats to produce a continuous small V-joint of uniform depth and width. On two-coat work, the V-joint shall be tooled through the finish coat only.

A2.1.5 Provide in the appropriate project specification section that solid bases to receive plaster shall not be treated with bond breakers, parting compounds, form oil, or other material that will prevent or inhibit the bond of the plaster to the base.

A2.1.6 Maximum allowable deflection for vertical or horizontal framing for plaster, not including cladding, shall be L/360.

A2.2 *Provisions for Drainage Behind Exterior Plaster:*

A2.2.1 In multistory construction where lath and portland cement plaster exterior walls are continuous past a floor slab, tracks or plates and studs shall be offset to provide a space not less than ⅜ in. (9.5 mm) between the inner face of the exterior plaster and the edge of the floor slab.

A2.2.2 At the bottom of exterior walls where the wall is supported by a floor or foundation, a drip screed and through-wall flashing or weep holes or other effective means to drain away any water that may get behind the plaster shall be provided.

A2.2.3 Where vertical and horizontal exterior plaster surfaces meet, both surfaces shall be terminated with casing beads with the vertical surface extending at least ¼ in. (6 mm) below the intersecting horizontal plastered surface, thus providing a drip edge. The casing bead for the horizontal surface shall be terminated not less than ¼ in. from the back of the vertical surface to provide drainage.

A2.3 *Relief from Stresses:*

A2.3.1 For information on control joints and perimeter relief see the Installation Section of Specification C 1063.

A2.3.1.1 Control joints shall be cleaned and clear of plaster within the control area after plaster application and before final plaster set.

A2.3.1.2 Prefabricated control joint members shall be installed prior to the application of plaster; therefore, the decision to use them, the type selected, their location, and method of installation shall be determined and specified in project specification sections other than the section on plastering.

A2.3.1.3 A groove or cut in plaster only shall not be considered a control or expansion joint.

A2.3.2 Where plaster and metal plaster base continues across the face of a concrete column, or other structural member, water-resistive building paper or felt shall be placed between the metal plaster base and the structural member (paper or plastic-backed metal plaster base shall be permitted). Where the width of the structural member exceeds the approved span capability of the metal plaster base, self-furring metal plaster base shall be used and sparingly scatter nailed to bring paper and metal base to general plane.

A2.3.3 Where dissimilar base materials abut and are to receive a continuous coat of plaster: (*1*) a two-piece expansion joint, casing beads back-to-back, or premanufactured control-expansion joint member shall be installed; or (*2*) the juncture shall be covered with a 6-in. (152-mm) wide strip of galvanized, self-furring metal plaster base extending 3 in. (76 mm) on either side of the juncture; or (*3*) where one of the bases is metal plaster base, self-furring metal plaster base shall be extended 4 in. (102 mm) onto the abutting base.

A2.4 *Weather-Sensitive Materials*—Water-sensitive materials shall be stored off the ground or floor and under cover, avoiding contact with damp floor or wall surfaces. Temperature-sensitive materials shall be protected from freezing. Bulk materials shall be stored in the area of intended use and caution shall be exercised to prevent contamination and segregation of bulk materials prior to use.

A2.5 *Admixtures*—Admixtures shall be proportioned and mixed in accordance with the published directions of the admixture manufacturer.

A2.5.1 The quantity of admixtures required to impart the desired performance is generally very small in relation to the quantities of the other mix ingredients. Batch-to-batch quantities shall be measured accurately.

A2.5.2 Air-entraining agents cause air to be incorporated in the plaster in the form of minute bubbles, usually to improve frost or freeze-thaw resistance, or workability of the plaster during application. Air-entraining agents for portland cement-based plaster shall meet the requirements of Specification C 260.

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APPENDIX

(Nonmandatory Information)

X1. GENERAL INFORMATION

X1.1 *Additions*—Bonding compounds or agents may be pre-applied to a surface to receive plaster. In this usage it is not considered an admixture. Bonding compounds that are integrally mixed with plaster prior to its application are considered admixtures. Where exterior exposure and cyclic wetting are anticipated, the re-emulsification capability of the bonding material must be considered. Bonding agents are only as good as the material surface to which they are applied; therefore, form release materials must be removed from concrete or be compatible with the bonding material used. Bonding agents in plaster mixes may increase the cohesive properties of the plaster. Bonding agents should meet the requirements of Specifications C 631 or C 932.

X1.1.1 By the use of a suitable admixture or additive, it is possible to improve plaster's resistance to moisture movement. However, the use of the terms damproofing or water proofing is misleading, and their use shall be discouraged.

X1.1.2 Natural or synthetic fibers, ½ to 2 in. (13 to 51 mm) in length and free of contaminates may be specified to improve resistance to cracking or to impart improved pumpability characteristics. The quantities per batch shall be in accordance with the published directions of the fiber manufacturer. No more than 2 lb (0.90 kg) of fiber should be used per cubic foot of cementitious material. Asbestos fibers should not be used. Alkaline-resistant glass fibers are recommended where glass fiber is used.

X1.1.3 Plasticizers containing hydrated lime putty, air-entraining agents, or approved fatteners to increase the workability of a portland cement plaster may be used. Plaster consistency and workability are affected by plasticizers that are beneficial in proper quantities from an economic standpoint, but in excess can be detrimental to the long-term performance of the plaster in place.

X1.1.4 Color material for integral mixing with plaster should not significantly alter the setting, strength development, or durability characteristics of the plaster. Natural or mineral pigments that are produced by physical processing of materials mined directly from the earth appear to offer the best long-term performance with respect to resistance to fading. Plaster color is determined by the natural color of the cementitious materials, aggregate, and any color pigment, and their proportions to each other. The use of white cement with the desired mineral oxide pigment color material may result in truer color.

X1.1.4.1 The uniformity of color cannot be guaranteed by the materials manufacturer of the component materials or by the applicating contractor. Color uniformity is affected by the uniformity of proportioning, thoroughness of mixing, cleanliness of equipment, application technique, and curing conditions and procedure, which are generally under the control of the applicator. Color uniformity is affected to an even greater degree by variations in thickness and differences in the suction of the base coat from one area or location to another, the type of finish selected, the migration of color pigments with moisture, and with job site climatic and environmental conditions. These factors are rarely under the control of the applicator.

X1.2 *Finish Coat Categories* (applicable to both natural and colored finishes):

X1.2.1 Texture, as a description of surface appearance, is identified generally with the method and tools used to achieve the finish. Texture can be varied by the size and shape of the aggregate used, the equipment or tools employed, the consistency of the finish coat mix, the condition of the base to which it is applied, and by subsequent decorative or protective treatment.

X1.2.2 There are many factors that affect the ultimate appearance of textured and integrally colored plaster. A suitably sized sample panel should be submitted for approval by the architect and the owner. Once approved, the sample should be maintained on site for reference and comparison.

X1.2.3 With the almost limitless variations possible for finish appearance or texture, the same term may not have the same meaning to the specifier, the contractor, and the actual applicator. The specifier is cautioned to use an approved range of sample panels. To provide some guidance, the following categories are generally understood and recognized to imply a particular method of application technique or resulting finished appearance:

X1.2.4 *Smooth Trowel*—Hand- or machine-applied plaster floated as smooth as possible and then steel-troweled. Steel troweling should be delayed as long as possible and used only to eliminate uneven points and to force aggregate particles into the plaster surface. Excessive troweling should be avoided.

X1.2.5 *Float*—A plaster devoid of coarse aggregate applied in a thin coat completely covering the base coat, followed by a second coat that is floated to a true plane surface yielding a relatively smooth to fine-textured finish, depending on the size of aggregate and technique used. It is also known as sand finish.

X1.2.6 *Trowel-Textured (such as Spanish Fan, Trowel Sweep, English Cottage)*—A freshly applied plaster coat is given various textures, designs, or stippled effects by hand troweling. The effects achieved may be individualized and may be difficult to duplicate by different applicators.

X1.2.7 *Rough-Textured (such as Rough Cast, Wet Dash, Scottish Harl)*—Coarse aggregate is mixed intimately with the plaster and is then propelled against the base coat by trowel or by hand tool. The aggregate is largely unexposed and deep textured.

X1.2.8 *Exposed Aggregate (also known at Marblecrete)*—Varying sizes of natural or manufactured stone, gravel, shell, or

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ceramic aggregates are embedded by hand or machine propulsion into a freshly applied finish "bedding" coat. The size of the aggregate determines the thickness of the "bedding" coat. It is generally thicker than a conventional finish coat.

X1.2.9 *Spray-Textured*—A machine-applied plaster coat directed over a previously applied thin smooth coat of the same mix. The texture achieved depends on the consistency of the sprayed mixture, moisture content of the base to which it is applied, the angle and distance of the nozzle to the surface, and the pressure of the machine.

X1.2.10 *Brush-Finish*—A method of surfacing or resurfacing new or existing plaster. The plaster is applied with a brush to a thickness of not less than 1/16 in. (1.6 mm). For an existing plaster surface the bond capability must be determined by test application or a bonding compound must be applied prior to the brush application.

X1.2.11 *Miscellaneous Types*—This finish coat category is somewhat similar to trowel-textured finishes, except that the freshly applied plaster is textured with a variety of instruments other than the trowel, such as swept with a broom or brush, corrugated by raking or combing, punched with pointed or blunt instrument, scored by aid of a straightedge into designs of simulated brick, block, stone, and so forth. A variation of texturing a finish coat involves waiting until it has partially set and then flattening by light troweling of the unevenly applied plaster or by simulating architectural terracotta.

X1.2.12 *Scraffitto*—A method of applying two or more successive coats of different colored plaster and then removing parts of the overlaid coats to reveal the underlaying coats, usually following a design or pattern. This is not generally considered a finish coat operation because of the number of thickness of coats.

X1.3 When specified as alternate for final coat, trowel- or plaster machine-applied textured acrylic finishes containing aggregate may be substituted for portland cement finish coats, provided brown coat is properly prepared and finish is applied according to the manufacturer's directions.

X1.3.1 *Staining of Plaster*—Staining and discoloration of plaster, caused by free water draining from one plane of plaster to another or from a dissimilar material onto a plaster surface, can be minimized by providing sufficient depth and angle for drip caps and the use of water-resistive surface coatings.

X1.3.2 Staining of plaster due to entrapment of moisture behind the plaster, can be avoided or minimized by providing an air space for ventilation between the back of the plaster and adjacent material. This type of staining may occur where insulation with or without vapor barrier, or other material containing asphaltic or coal tar derivatives, fireproofing salts, and so forth, can migrate with moisture movement to the finished plaster surface.

X1.3.3 Integrally colored plaster can be discolored or altered in shade if subjected to moisture, either from uncured base coats or external sources, such as rain, too soon after applications.

X1.4 *Installation Instructions:*

X1.4.1 Hand mixing should not be permitted, except as approved by the contract specifier.

X1.4.1.1 After all ingredients are in the mixer, mix the plaster for 3 to 5 min.

X1.4.1.2 The amount of water used in the plaster mix should be determined by the plasterer. Factors such as the suction of the base, or of the previous coat, water content of the aggregate, drying conditions, and finishing operations should be considered in determining water usage. Use of excessive water may result in dropouts, fall or slide off, excessive shrinkage, high porosity, and lower strength.

X1.4.2 *Time Between Coats and Curing for Portland Cement-Based Plaster:*

X1.4.2.1 The timing between coats will vary with climatic conditions and types of plaster base. Temperature and relative humidity extend or reduce the time between consecutive operations. Cold or wet weather lengthens and hot or dry weather shortens the time period. Moderate changes in temperature and relative humidity can be overcome by providing additional heating materials during cold weather and by reducing the absorption of the base by pre-wetting during hot or dry weather.

X1.4.2.2 In order to provide more intimate contact and bond between coats and to reduce rapid water loss, the second coat should be applied as soon as the first coat is sufficiently rigid to resist cracking, the pressures of the second coat application, and the leveling process.

X1.4.2.3 The amount of water and the timing for curing portland cement plaster will vary with the climatic conditions, the type of base, and use or nonuse of water-retentive admixtures.

X1.4.2.4 Some moisture must be retained in or added back to freshly applied portland cement-based plaster. If the relative humidity is relatively high (above 75 %), the frequency for rewetting a surface may be reduced. If it is hot, dry, and windy, the frequency of rewetting must be increased.

X1.4.2.5 Consider the physical characteristics of the structure as well as the previously mentioned conditions when selecting the method of curing. The method can be one or a combination of the following:

(*1*) Moist curing is accomplished by applying a fine fog spray of water as frequently as required, generally twice daily in the morning and evening. Care must be exercised to avoid erosion damage to portland cement-based plaster surfaces. Except for severe drying conditions, the wetting of finish coat should be avoided, that is, wet the base coat prior to application of the finish coat.

(*2*) Plastic film, when taped or weighted down around the perimeter of the plastered area, can provide a vapor barrier to retain the moisture between the membrane and plaster. Care must be exercised in placing the film: if too soon, the film may damage surface texture; if too late, the moisture may have already escaped.

(*3*) Canvas, cloth, or sheet material barriers can be erected to deflect sunlight and wind, both of which will reduce the rate of evaporation. If the humidity is very low, this option alone may not provide adequate protection.

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SUMMARY OF CHANGES

Committee C11 has identified the location of selected changes to this specification since the last issue, C 926 – 98a(2005), that may impact the use of this specification. (Approved June 1, 2006)

(*1*) Removed reference to "plastering section" in A2.3.1.3.

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Designation: C928/C928M – 09

Standard Specification for Packaged, Dry, Rapid-Hardening Cementitious Materials for Concrete Repairs[1]

This standard is issued under the fixed designation C928/C928M; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope*

1.1 This specification covers packaged, dry, cementitious mortar or concrete materials for rapid repairs to hardened hydraulic-cement concrete pavements and structures. Materials that contain organic compounds, such as bitumens, epoxy resins, and polymers, as the principal binder are not included.

1.1.1 Packaged, dry, concrete material contains aggregate of which at least 5 % by mass of the total mixture is retained on a 9.5-mm [⅜-in.] sieve.

1.1.2 Packaged, dry, mortar material contains aggregate of which less than 5 % by mass of the total mixture is retained on a 9.5-mm [⅜-in.] sieve.

1.2 Aqueous solutions, aqueous emulsions or dispersions may be included as components of the packaged materials. The manufacturer may specify that these liquids are to replace some or all of the mixing water.

1.3 Aggregates must be included as a component of the packaged materials. The manufacturer may recommend job site addition of specific amounts and types of additional aggregates to his product for some uses. However, such reformulated products are not within the scope of this specification.

1.4 The values stated in either SI units or inch-pound units are to be regarded separately as standard. The values stated in each system may not be exact equivalents; therefore, each system shall be used independently of the other. Combining values from the two systems may result in non-conformance with the standard.

1.5 The following safety hazards caveat pertains to the test methods portion of this specification: *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

2. Referenced Documents

2.1 *ASTM Standards:*[2]

C39/C39M Test Method for Compressive Strength of Cylindrical Concrete Specimens

C78 Test Method for Flexural Strength of Concrete (Using Simple Beam with Third-Point Loading)

C109/C109M Test Method for Compressive Strength of Hydraulic Cement Mortars (Using 2-in. or [50-mm] Cube Specimens)

C143/C143M Test Method for Slump of Hydraulic-Cement Concrete

C157/C157M Test Method for Length Change of Hardened Hydraulic-Cement Mortar and Concrete

C192/C192M Practice for Making and Curing Concrete Test Specimens in the Laboratory

C403/C403M Test Method for Time of Setting of Concrete Mixtures by Penetration Resistance

C494/C494M Specification for Chemical Admixtures for Concrete

C666/C666M Test Method for Resistance of Concrete to Rapid Freezing and Thawing

C670 Practice for Preparing Precision and Bias Statements for Test Methods for Construction Materials

C672/C672M Test Method for Scaling Resistance of Concrete Surfaces Exposed to Deicing Chemicals

C702 Practice for Reducing Samples of Aggregate to Testing Size

C778 Specification for Standard Sand

C882 Test Method for Bond Strength of Epoxy-Resin Systems Used With Concrete By Slant Shear

[1] This specification is under the jurisdiction of ASTM Committee C09 on Concrete and Concrete Aggregates and is the direct responsibility of Subcommittee C09.43 on Packaged Dry Combined Materials.

Current edition approved Dec. 1, 2009. Published January 2010. Originally approved in 1980. Last previous edition approved in 2008 as C928/C928M – 08. DOI: 10.1520/C0928_C0928M-09.

[2] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

***A Summary of Changes section appears at the end of this standard.**

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C1012 Test Method for Length Change of Hydraulic-Cement Mortars Exposed to a Sulfate Solution
E96/E96M Test Methods for Water Vapor Transmission of Materials

3. Materials and Manufacture

3.1 Three types of packaged, dry, rapid-hardening concrete and three types of packaged, dry, rapid-hardening mortar are identified in Table 1.

TABLE 1 Performance Requirements[A]

	3 h	1 day	7 days	28 days
Compressive Strength, min, MPa [psi]				
R1 concrete or mortar	3.5 [500]	14 [2000]	28 [4000]	[B]
R2 concrete or mortar	7.0 [1000]	21 [3000]	28 [4000]	[B]
R3 concrete or mortar	21 [3000]	35 [5000]	35 [5000]	[B]
Bond strength, min, MPa [psi]				
R1, R2 and R3 concrete or mortar	—	7 [1000]	10 [1500]	—
Length change, based on length at 3 h, max, %				
R1, R2, and R3 concrete or mortar	allowable increase after 28 days in water			+0.15
	allowable decrease after 28 days in air			–0.15
Consistency of concrete or mortar[C]			concrete slump, min, mm [in.]	Flow of mortar, min, %
R1 consistency after 15 min after addition of mixing liquid			75 [3]	100
R2 and R3 consistency at 5 min after addition of mixing liquid			75 [3]	100
Scaling resistance to deicing chemicals after 25 cycles of freezing and thawing				
Concrete, max visual rating			2.5	
Mortar, max scaled material[D]			5 kg/m^2 [1 lb/ft^2]	

[A] It is recognized that other characteristics of rapid-hardening concrete repair materials might need consideration. Such characteristics might be necessary in some environments and applications; however, to impose specification limits on all products is considered beyond the scope of this specification. Optional considerations with suggested methods of test may include tests for the following:

Time of setting	Test Method C403/C403M
Flexural strength	Test Method C78
Freeze thaw	Test Method C666/C666M, Procedure A
Sulfate expansion	Test Method C1012

[B] The strength at 28 days shall be not less than the strength at 7 days.

[C] Slump or flow requirements are waived for materials intended for vertical or overhead applications.

[D] A 250-mm [10-in.] square spalled to an average depth of 3 mm [⅛ in.] for 100 % of its surface would have about 10 kg/m^2 [2.0 lb/ft^2] of scaled material.

4. Chemical Composition

4.1 If the material contains soluble chlorides or other ingredients in sufficient quantity to cause corrosion to steel reinforcement, the package markings shall contain the following statement in letter size no smaller than the directions for use:

> This material is not recommended for use in a moist environment in contact with steel reinforcement.

4.1.1 Consider a total chloride ion content (Berman, 1972)[3,4] in the packaged repair material greater than 600 g/m^3 [1 lb/yd^3] of the hardened repair material indicative that the packaged material contains sufficient chlorides to cause corrosion to steel reinforcement when the concrete is exposed to weather, is on the ground, or is in an otherwise moist environment. A much lower chloride ion content is suggested for use in prestressed concrete. Guidance for such users is outside the scope of this specification.

4.2 If the material contains metallic iron in excess of 1 % by weight, the package markings shall contain the following statement in letter size no smaller than the directions for use:

> If small or scattered spots of iron-staining are considered objectionable, do not use this material where it will be exposed.

5. Performance Requirements

5.1 The materials shall comply with the performance requirements in Table 1 for the applicable type.

6. Sampling

6.1 A lot is the quantity of packaged repair material normally placed on a pallet. In general, this quantity will weigh from 900 to 1800 kg [2000 to 4000 lb].

6.2 A unit sample is a single package of material randomly selected from the lot.

7. Specimen Preparation

7.1 *Concrete*—Mechanically mix the packaged dry concrete material with mixing liquid. Determine the properties of the unhardened mixture, and mold and cure the specimens in accordance with Practice C192/C192M or modifications as outlined herein.

7.1.1 The sample of packaged dry material shall be any combination of whole packages yielding not less than 20 L [⅔ ft^3] of hardened material.

7.1.2 Base the quantity of water, other liquid component, or both added to the sample on the quantity per bag stated in the directions for use.

7.1.3 Place the sample in the mixing machine and add the required amount of liquid. Start mixing immediately. Continue mixing for the length of time indicated in the directions for use.

7.1.4 When making the slump test in accordance with Test Method C143/C143M, schedule work so the test will be completed in 5 ± ½ min after the mixing liquid is added to the R2 or R3 materials or 15 ± ½ min after mixing the liquid with the R1 materials.

7.1.5 Mold the required number of specimens using additional samples as may be necessary, mixed in accordance with

[3] Berman, H. A., Determination of Chloride in Hardened Portland Cement Paste, Mortar, and Concrete, *ASTM Journal of Materials*, Vol. 7 , No. 3, pp. 330–335, 1972 .

[4] Clear, K. C., and Harrigan, E. T., "Sampling and Testing for Chloride Ion in Concrete," Report No. FHWA-RD77-85, Federal Highway Administration, Washington, DC, August 1977 (Available as PB 275–428/AS National Technical Information Services).

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7.1.1-7.1.4. Do not use the mixtures for molding test specimens when the slump is less than that specified in Table 1.

NOTE 1—Where the nominal maximum particle size is not greater than 25 mm [1 in.], the use of cylindrical molds 100 mm [4 in.] in diameter by 200 mm [8 in.] in length is suggested.

7.2 *Mortar*—Mechanically mix packaged dry mortar material with mixing liquid. Determine the properties of the unhardened mixture, and mold and cure the specimens in accordance with Test Method C109/C109M or modifications as outlined herein.

7.2.1 The sample of packaged dry material shall weigh 3000 ± 3 g [6.6 ± 0.005 lb] and shall be representatively obtained from a whole package in accordance with Practice C702.

7.2.2 Base the quantity of water, or other liquid component, or both added during mixing on the quantity per unit of weight stated in the directions for use.

7.2.3 When making the flow test in accordance with the section on consistency in Test Method C109/C109M, schedule work so the test will be completed in 5 ± ½ min after the start of mixing liquid with the R2 or R3 materials or 15 ± ½ min after mixing the liquid with the R1 materials.

7.2.4 Mold the required number of specimens using additional samples as necessary mixed in accordance with 7.2.1-7.2.3. Do not use the mixtures for molding test specimens when the flow is less than that specified in Table 1.

7.3 In those cases where the manufacturer has indicated in the package markings, or elsewhere, that the packaged repair material can be mixed and applied at temperatures that lie beyond the range of 20 ± 8 °C [70 ± 15 °F], the product must meet the requirements of Table 1. Specimens must be made and cured in accordance with the procedures of this section. The mixing, molding and curing temperatures during the first 3 h after molding shall be within ±1 °C [±2 °F] of the extreme temperature(s) stated by the manufacturer in the package markings.

8. Test Methods

8.1 *Manifestly Faulty Specimens*—Treat manifestly faulty specimens in accordance with the corresponding section in Specification C494/C494M.

8.2 *Compressive Strength*—Prepare and test three test specimens for each age of test and each level of mixing temperature. Test in accordance with Test Method C39/C39M for concrete and Test Method C109/C109M for mortar.

8.3 *Length Change*—Prepare and test specimens in accordance with Test Method C157/C157M, except as modified by this section and 7.3. Use 25 mm [1-in.] prism for mortar material and 75 mm [3-in.] prism for concrete material.

8.3.1 Remove specimens from the molds at an age of 2½ to 2¾ h after the addition of mixing liquid to the dry cementitious mixture during the mixing operation.

8.3.2 Make the initial observation of length at 3 to 3¼ h after the addition of mixing liquid to the dry cementitious mixture during the mixing operation. When specimens are cured at temperatures other than 23 ± 2 °C [73.4 ± 3 °F], then both initial and final length observations must be made with the bars conditioned to ±2 °C [±3 °F] of initial temperatures.

8.3.3 Immediately store one set of specimens as for "Air Storage" and one set as for "Water Storage" except that the water-stored specimens shall be stored in untreated tap water with no more than one set of specimens per container.

8.3.4 Take observations of length at age 28 days ± 20 h. Determine the average percent change in length when stored in water, and the average change in length of specimens stored in air.

8.4 *Scaling Resistance*—Make and cure the test specimens in accordance with Test Method C672/C672M, except as provided herein. For specimens of mortar omit the visual rating procedure after every 5 cycles and after 25 cycles determine the amount of scaling as the oven dry 110 ± 5 °C [230 ± 9 °F] mass per unit area of exposed test area.

8.5 *Slant Shear Bond Strength*—Prepare six complete test specimens in accordance with Test Method C882 for Type II and V systems except as modified by this section.

8.5.1 Do not apply a bonding system to prepared surface unless a bonding system is required by the manufacturer of the rapid-hardening cementitious material. Fill the top half of the cylinder with the rapid-hardening cementitious material instead of the portland cement mortar specified.

8.5.2 Test three specimens in compression at 1 day and three at 7 days. Calculate the bond strength on the elliptical area and report the failure type.

9. Report

9.1 Report the following:

9.1.1 Source and identification, including type, of material tested,

9.1.2 Details of any variations and options practiced by the tester that are recommended or allowed by the manufacturer or others,

9.1.3 Compressive strength of material at 3 h, 1 day, 7 days and 28 days,

9.1.4 Bond strength at 1 day and 7 days,

9.1.5 Percent length change at 28 days in water and in air,

9.1.6 Percent flow in mortar at 5 or 15 min,

9.1.7 Slump in concrete at 5 or 15 min, and

9.1.8 Scaling resistance after 25 cycles.

10. Precision and Bias

10.1 *Length Change*:

10.1.1 *Precision*—The precision of the length change test method described in section 8.3 is based on an interlaboratory study that was conducted in 2007.[5] Seven laboratories tested one rapid-hardening material that consisted of commercially available rapid hardening cement blended with three parts standard graded sand complying with Specification C778. The precision values were calculated for both "water storage" and "air storage" of test specimens. A test result is defined in this specification as the average of three separate measurements (triplicate lengthchange specimens).

[5] Supporting data have been filed at ASTM International Headquarters and may be obtained by requesting Research Report RR: C09-1035.

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10.1.2 The single-operator standard deviation for water storage of test specimens has been found to be 0.0031 %.[6] Therefore, results of two properly conducted tests by the same operator on the same material are not expected to differ by more than 0.009 %.[6] The single-operator standard deviation for air storage of test specimens has been found to be 0.0067 %.[6] Therefore, results of two properly conducted tests by the same operator on the same material are not expected to differ by more than 0.019 %.[6]

10.1.3 The multi-laboratory standard deviation for water storage of test specimens has been found to be 0.0078 %.[6] Therefore, results of two properly conducted tests from two different laboratories on the same material are not expected to differ by more than 0.022 %.[6] The multilaboratory standard deviation for air storage of test specimens has been found to be 0.015 %.[6] Therefore, results of two properly conducted tests from two different laboratories on the same material are not expected to differ by more than 0.041 %.[6]

10.1.4 *Bias*—Since there is no accepted reference material suitable for determining any bias that might be associated with this test method, no statement on bias is being made.

11. Rejection

11.1 The purchaser has the right to reject material that fails to conform to the requirements of this specification. Rejection shall be reported to the producer or supplier promptly and in writing.

12. Certification

12.1 When specified in the purchase order or contract, a producer, supplier, or an independent testing laboratory shall furnish certification to the purchaser that the material has been tested in accordance with this specification and found to meet the requirements. When specified in the purchase order or contract, a report of test results on samples taken from material shipped shall be furnished.

13. Product Marking

13.1 Mark all packages to contain the following information:

13.1.1 Specification designation.

13.1.2 R1 or R2 or R3 type.

13.1.3 Directions for use that shall include but are not limited to:

13.1.3.1 When a bonding agent is used in the test of bond strength, the type and kind of adhesive recommended to bond fresh repair material to the concrete or mortar being repaired.

13.1.3.2 The recommended amount of water, other liquid component, or both, to be mixed with the package contents.

13.1.3.3 The recommended length of mixing time or sequence of mixing and resting times in minutes.

13.1.4 Date the material was packaged.

13.1.5 The yield in litres [cubic feet] or yield in square metres per centimetre [square feet per inch] thickness when mixed with the recommended amount of liquid.

13.1.6 The net weight in each container. The contents of any container shall not vary by more than 2 % from the weight stated in the markings. The average weight of filled containers in a lot shall be not less than the weight stated in the markings.

13.1.7 If the product is formulated for use in vertical or overhead applications, it shall be so stated on the package.

14. Packaging

14.1 The material from which the containers are made shall have water vapor transmission not greater than 100 g/m^2 [0.2 lb/ft^3] in 24 h as determined in accordance with Procedure B of Test Methods E96/E96M.

15. Keywords

15.1 cementitious mortar or concrete materials for repair; concrete; packaged; mortar; packaged; packaged dry materials for concrete repair; rapid hardening materials; repair materials

[6] These measurements represent, respectively, the (1s) and (d2s) limits in accordance with Practice C670.

SUMMARY OF CHANGES

Committee C09 has identified the location of selected changes to this specification since the last issue, C928/C928M – 08, that may impact the use of this specification. (Approved December 1, 2009)

(*1*) Added new Section 10 Precision and Bias and renumbered subsequent sections and footnotes.

Committee C09 has identified the location of selected changes to this specification since the last issue, C928 – 05, that may impact the use of this specification. (Approved October 1, 2008)

(*1*) Revised the standard as a combined units standard.

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Designation: C 932 – 06

Standard Specification for Surface-Applied Bonding Compounds for Exterior Plastering[1]

This standard is issued under the fixed designation C 932; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

This standard has been approved for use by agencies of the Department of Defense.

1. Scope*

1.1 This specification covers minimum requirements for exterior surface-applied bonding compounds for improving the adhesion of cementitious material to concrete or other masonry surfaces or any structurally sound surfaces.

1.2 This specification also covers test methods for determining performance requirements and physical properties.

1.3 The values stated in inch-pound units are to be regarded as the standard. The SI metric values given in parentheses are approximate and are provided for information purposes only.

1.4 The following safety hazards caveat pertains only to the test methods described in Sections 9, 10, 11, and 12 in this specification: *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

2. Referenced Documents

2.1 *ASTM Standards:* [2]

C 11 Terminology Relating to Gypsum and Related Building Materials and Systems

C 109/C 109M Test Method for Compressive Strength of Hydraulic Cement Mortars(Using 2-in. or [50-mm] Cube Specimens)

C 150 Specification for Portland Cement

C 305 Practice for Mechanical Mixing of Hydraulic Cement Pastes and Mortars of Plastic Consistency

C 511 Specification for Mixing Rooms, Moist Cabinets, Moist Rooms, and Water Storage Tanks Used in the Testing of Hydraulic Cements and Concretes

C 778 Specification for Sand

3. Terminology

3.1 Definitions used in this specification shall be in accordance with Terminology C 11.

4. Physical Properties

4.1 *Surface Applied Bonding Compound*—A freeze-thaw stable composition, suitable for brush, roller, or spray application. It shall be tinted to show by visual inspection where it has been applied. The tint shall not bleed through the material being bonded.

4.2 *Consistency*—The bonding compound shall be free of foreign matter as determined by visual inspection and shall be of such uniform consistency that when applied in accordance with the producers directions by brush, roller, or spray to concrete, masonry, or other structurally sound surface, the bonding compound shall flow on evenly and dry uniformly.

4.3 *Film Characteristics*—The film-forming property shall be determined by visual inspection to determine the presence of a continuous film not broken by fisheyes, cracking, pull-back, or any other discontinuity in the film surface. It shall not be noticeably affected by alkaline surfaces or weak acids.

4.4 *Re-Emulsification*—Product conforming with this specification shall not re-emulsify.

5. Performance Requirements

5.1 *Bonding Capability*—The bonding compound shall be capable of bonding cementitious materials when applied in accordance with the producer's directions and tested as specified in Section 12.

5.2 *Degradation*—Bonding compound which separates shall be able to be re-mixed to a uniform consistency when tested as specified in Section 10.

5.3 *High Temperature Test*—The bond strength shall be not less than 150 psi (1034 kPa) when tested as specified in Section 9.

5.4 *Freeze-Thaw Stability*—The bond strength shall be not less than 150 psi (1034 kPa) and 100 psi (690 kPa) when tested under the dry and wet conditions, respectively, as specified in Section 11.

[1] This specification is under the jurisdiction of ASTM Committee C11 on Gypsum and Related Building Materials and Systems and is the direct responsibility of Subcommittee C11.02 on Specifications and Test Methods for Accessories and Related Products.

Current edition approved March 1, 2006. Published March 2006. Originally approved in 1980. Last previous edition approved in 2005 as C 932 – 05.

[2] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

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5.5 *Tensile Bond Strength*—Bond strength of a fresh sample or a 6-month-old sample of bonding compound shall have an average tensile strength of not less than 150 psi (1034 kPa) and 100 psi (690 kPa) when tested under the dry and wet conditions, respectively, as specified in Section 12.

6. Sampling

6.1 Take a sample of not less than 2.2 lb (1000 g) from each shipment or consignment for analysis and tests. Except in special cases, take the sample from not less than three separate containers, chosen at random. In addition, take samples from containers that appear to be nonrepresentative, and test separately. Place the samples immediately in airtight glass containers and transport to the testing laboratory in these containers. Take precautions to reduce evaporation or drying to a minimum. Thoroughly mix the bonding compound in the container if there is a tendency for liquid phase separation.

7. Apparatus

7.1 *Moist Cabinet*—Specification C 511.

7.2 *Oven*—A forced draft type oven, having a temperature controlled at 140 ± 5 °F (60 ± 3 °C) for high temperature tests.

7.3 *Freezer*—A freezer having a controlled temperature of −10 ± 2 °F (-23 ± 1 °C).

7.4 *Balance*—A balance capable of weighing not less than 5.5 lb (2500 g) at a precision of 0.0002 lb (0.1 g).

7.5 *Timing Device*—An instrument capable of reading to the nearest second.

7.6 *Tamper*—A tamper made up of a nonabsorptive, nonabrasive, non-brittle material and having a cross section of ½ in. by 1 in. (13 × 25 mm) and approximately 5 to 6 in. (130 to 150 mm) long. The tamping face shall be flat and at right angles to the length of the tamper.

7.7 *Straight Edge*—A steel straight edge not less than 4 in. (100 mm) long and not less than 1⁄16 in. (1.6 mm) nor more than ⅛ in. (3.2 mm) in thickness.

7.8 *Spatula*—A spatula with a metal blade 6 in. (150 mm) in length and ½ in. (13 mm) in width, with straight edges.

7.9 *Paint Brush*—A standard 1 in. (25 mm) wide brush, with synthetic bristles.

7.10 *Testing Machine*—Any type that is of sufficient capacity and that is capable of applying the load continuously and without shock at the rate of 0.05 in. (1.27 mm) per minute, with provision for adjustment of the rate of loading.

7.11 *Briquet Molds*—The molds for making test specimens shall be made of metal not attacked by the mortar and shall have sufficient material in the sides to prevent spreading during molding. Gang molds, when used, shall be of the type shown in Fig. 1. The dimensions of the briquet molds shall conform to the following requirements: width of mold, between inside faces, at waist line of the briquet, 1 in. (25.4 mm) with permissible variations of ±0.01 in. (0.25 mm) for molds in use and ±0.005 in. (0.13 mm) for new molds; thickness of molds measured at the point of greatest thickness on either side of the mold at the waist line, 1 in. (25.4 mm) with permissible variations of +0.004 in. (0.10 mm) and – 0.002 in. (0.05 mm) for new molds and −0.02 in. (0.5 mm) for molds in use. The briquet specimens shall conform to the dimensional requirements shown in Fig. 2.

7.12 *Saw*—A table saw equipped with an abrasive cutting blade or other blade suitable for cutting cementitious materials.

7.13 *Clips for Briquet Testing Machine*—The clips for holding the tension test specimen shall be in accordance with Fig. 3.

8. Conditioning

8.1 *Room Temperature and Humidity*—Maintain the air temperature in the vicinity of the mixing and testing area at 70 ± 5 °F (21 ± 3 °C). Maintain the relative humidity at 50 ± 2 %.

8.2 *Temperature of the Mixing Water*—72 ± 2 °F (22 ± 1 °C).

9. High Temperature Test

9.1 *Significance and Use*—This test method provides procedures for evaluating the adhesive strength of bonding compounds after being exposed to accelerated aging at high temperature.

9.2 *Specimen Preparation*—For each test specimen, transfer the bonding compound, taken from the sample obtained, into a standard 1 pt. (500 mL) glass container.

9.3 *Procedure*—Place the specimen in the oven for 30 days. Remove the container, allow the compound to cool to room temperature, mix the compound to a uniform consistency, and test as specified in Section 12.

9.4 *Tests and Retests*—Test six briquets and report the average of the test results. If the result of any one of the six tests varies more than 15 % from the average, reject it and report the average of the other five tests. If the results from more than two tests vary more than 15 % from the average, reject the series and retest.

9.5 *Precision and Bias*—The precision and bias of the high temperature test for determining bond strength after exposure to high temperature are essentially the same as specified in the test method for bond strength, paragraph 12.7.

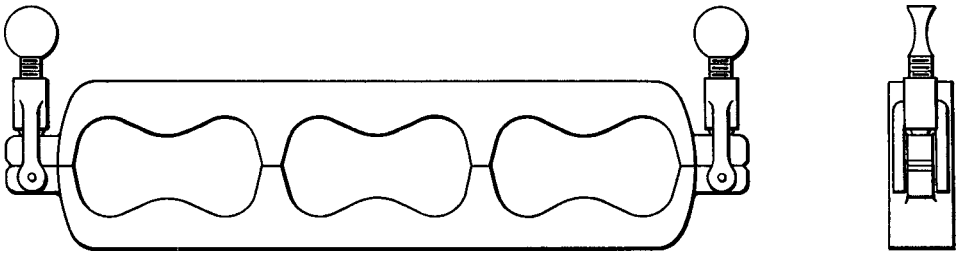

FIG. 1 Briquet Gang Mold

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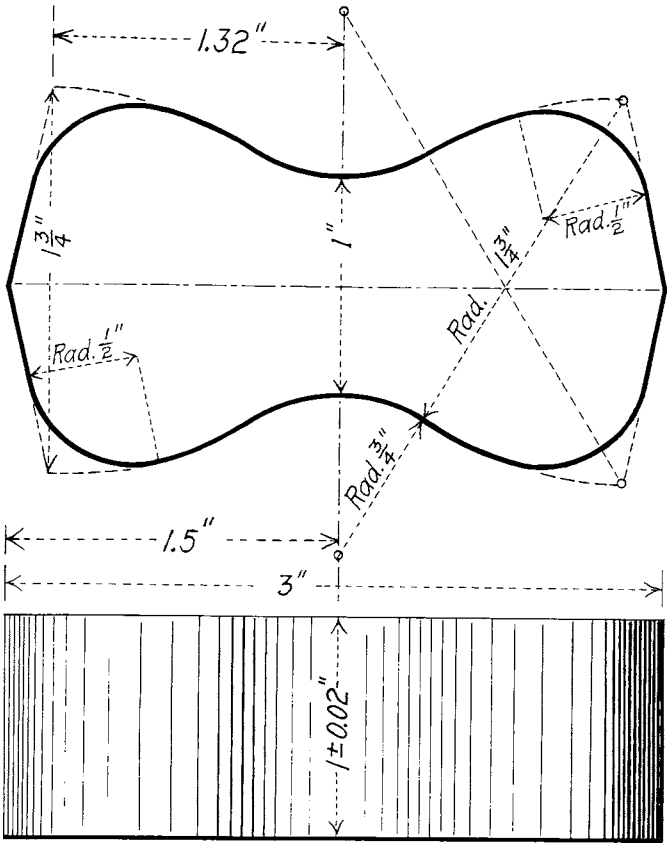

NOTE 1—1 in. = 25.4 mm.

FIG. 2 Briquet Specimen for Tensile Strength Test

10. Degradation Test

10.1 *Significance and Use*—This test method simulates the effects of high temperature storage on the physical properties of bonding compound.

10.2 *Specimen Preparation*—For each test, transfer the bonding compound, from the sample obtained, into a standard 1 pt. (500 mL) glass container.

10.3 *Procedure*—Place the specimen in the oven for 15 days. Remove the container from the oven and examine the contents for settling and separation. Place the container back in the oven for an additional 15 days. Remove the container and examine the contents again for settling and separation. Allow the compound to come to room temperature, and mix to a uniform consistency. Mix by hand stirring with a wood, metal, or plastic paddle for not more than five minutes.

10.4 *Tests and Retests*—Bonding compound that fails to be remixed to a uniform consistency shall be considered to have failed the test.

10.5 *Report*—Determine the extent of settling and separation by measuring and report as a percentage of the height of the specimen in the clear glass container, represented by the location of the liquid/solid interface.

10.6 *Precision and Bias*—No information is presented about either the precision or bias of the Degradation test for measuring settling, separation, or the ability to be mixed to a uniform consistency since the test result is non-quantitative.

11. Freeze-Thaw Cycle Test

11.1 *Significance and Use*—This test method provides procedures for determining the bond strength of bonding compounds after being exposed to accelerated storage conditions of alternate freezing and thawing.

11.2 *Specimen Preparation*—For each test specimen, transfer the bonding compound, taken from the sample obtained, into a standard 1 pt. (500 mL) glass container having a screw on or friction fit cover.

11.3 *Procedure*—Place a covered specimen in the freezer for 16 h. Remove the specimen and allow to thaw at room temperature for 8 h. Repeat this procedure for 5 cycles. After the fifth cycle, allow the compound to come to room temperature, then test as specified in Section 12.

11.4 *Tests and Retests*—Test six briquets and report the average of the test results. If the result of any one of the six tests varies more than 15 % from the average, reject it and report the average of the other five tests. If the results from more than two tests vary more than 15 % from the average, reject the series and retest.

11.5 *Precision and Bias*—The precision and bias of the freeze-thaw cycle test for determining bond strength after exposure to alternate freezing and thawing are essentially the same as specified in the test method for bond strength, paragraph 12.7.

12. Bond Strength Test

12.1 *Significance and Use*—This test method provides a method for determining the ability of bonding compound, after being subject to various simulated conditions of aging and exposure to temperature extremes, to adhere cementitious materials to a properly prepared substrate.

12.2 *Materials*:

12.2.1 *Cement*—Specification C 150.

12.2.2 *Graded Standard Sand*—Specification C 778.

12.3 *Preparation of Briquets*:

12.3.1 Prepare not less than six briquets for each series of tests.

12.3.2 Prepare the proportions of the standard mortar in accordance with the procedure given in Test Method C 109/C 109M.

12.3.3 Mechanically mix the mortar in accordance with the procedure given in Practice C 305.

12.3.4 Prepare molds by coating the molds with a thin film of mineral oil. Support the molds on a lightly oiled glass or metal plate.

12.3.5 Cast the briquets immediately after completely mixing the mortar, half fill the molds and puddle the mortar uniformly with the tamper, taking care not to displace the divider. Slightly over fill the molds with additional mortar and repeat the puddling. After the mortar has set, cut off the excess to a plane surface flush with the top of the mold, using a broad knife or similar implement.

12.3.6 Immediately after molding, place the molds, on the base plate, into the moist cabinet for 48 h.

12.3.7 Remove the briquets from the mold and store them at room temperature and humidity for not less than 48 h.

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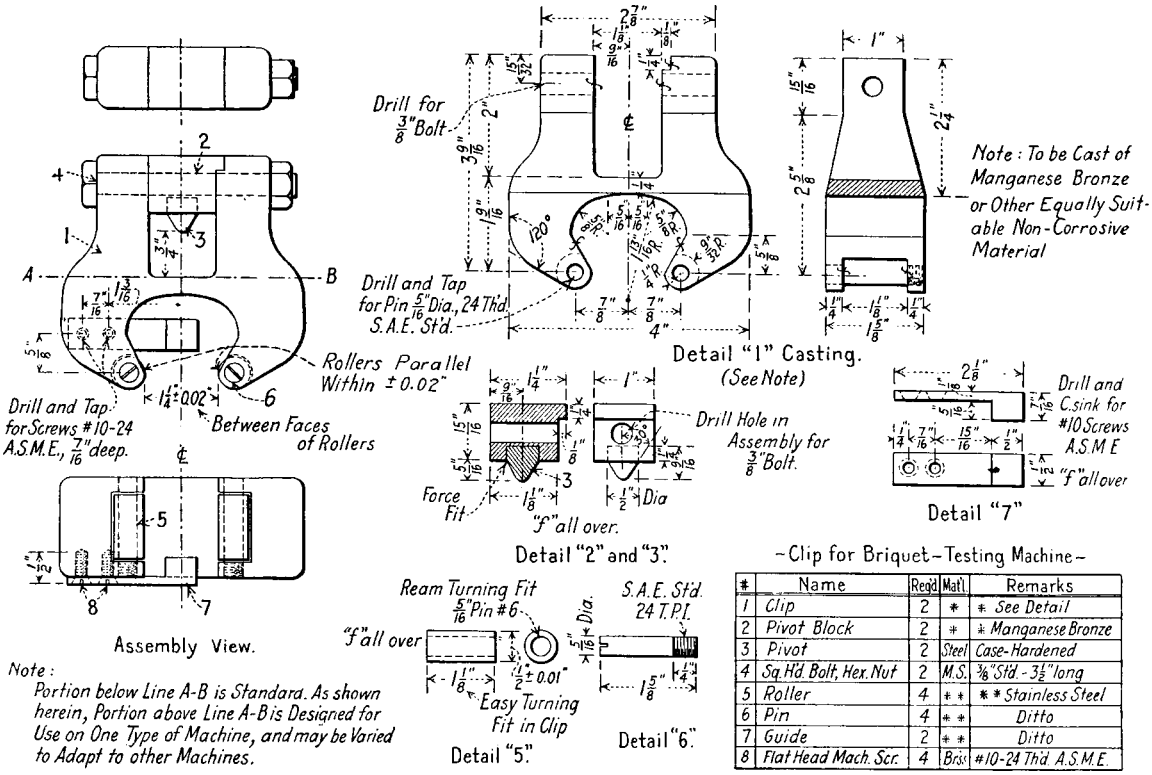

–Clip for Briquet–Testing Machine–

#	Name	Reqd	Mat'l	Remarks
1	Clip	2	*	* See Detail
2	Pivot Block	2	*	* Manganese Bronze
3	Pivot	2	Steel	Case-Hardened
4	Sq. Hd. Bolt, Hex. Nut	2	M.S.	3/8" Std. - 3 1/2" long
5	Roller	4	* *	* * Stainless Steel
6	Pin	4	* *	Ditto
7	Guide	2	* *	Ditto
8	Flat Head Mach. Scr.	4	Brass	#10-24 Th'd A.S.M.E.

NOTE 1—1 in. = 25.4 mm.

FIG. 3 Clips for Briquet Testing Machine

12.3.8 Examine the specimens, discard any that have air holes or excessively rough surfaces.

12.3.9 Saw the specimens in half at the mid-point of the waist line, aligning the saw blade so that the entire saw kerf is taken out of one side of the briquet, and the remaining side maintains a 1 in. cross section. Discard the smaller portion of the briquet.

12.4 *Procedure*:

12.4.1 Thoroughly clean dust and loose particles from the flat waist surface of the specimen. Apply the bonding compound, in accordance with the producer's directions, to the flat waist surface of the briquet by means of a paint brush.

12.4.2 Place the half briquet, coated with bonding compound, into the mold. Fill the remaining space in the mold with mortar, mixed and molded as specified in 12.3.

12.4.3 The time between coating the briquet with compound and casting the mortar against it shall be immediately after the compound has dried, or as recommended by the manufacturer, except when otherwise specified for a ten day waiting period.

12.4.4 Place the filled briquet mold in the moist cabinet for 24 h, then remove the briquets from the molds.

12.5 *Test Method*:

12.5.1 Test the briquets at the following intervals:

12.5.1.1 *Dry Condition*—Air cure three briquets for 14 days and test.

12.5.1.2 *Wet Condition*—Air cure three briquets for 7 days, soak in water for 7 days, and test.

12.5.2 Remove any loose particles or flash from the surfaces that will be in contact with the clips of the testing machine. Make sure the bearing surfaces of the clips are clean and free of sand, and the roller bearings are lubricated and maintained to ensure freedom of turning. Keep the stirrups supporting the clips free of accumulations. Keep the pivots in proper adjustment so that the clips swing freely on the pivots without binding the stirrups. Carefully center the briquets in the clips and apply the load continuously at the rate of 0.05 in. (1.27 mm)/min.

12.6 *Tests and Retests*—Test each group of three briquets for bond strength and report the average of the three briquets. If the result of any one of the three tests varies more than 15 % from the average, reject it and report the average of the other two tests. If the results from more than one test vary more than 15 % from the average, reject the series and retest.

12.7 *Precision and Bias*—Precision and bias have not been determined for the test method specified.

13. Inspection

13.1 Inspection of the bonding compound shall be agreed upon between the producer or purchaser and the supplier as part of the purchase agreement.

14. Rejection

14.1 Rejection of bonding compound that fails to conform to the requirements of this specification shall be reported to the producer or supplier promptly and in writing. The notice of rejection shall contain a statement documenting how the product has failed to conform to the requirements of this specification.

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15. Certification

15.1 When specified in the purchase agreement, the producer or supplier shall furnish a report certifying that, at the time of shipment, the bonding compound is in compliance with the requirements of this specification.

16. Package and Package Marking

16.1 *Packaging*—The bonding compound shall be packed in standard commercial containers. The containers shall be so constructed as to ensure acceptance by common or other carriers for safe transportation at the lowest rate to the point of delivery, unless otherwise specified in the purchase order.

16.2 *Marking*—Shipping containers shall be marked with the name of the bonding compound, the quantity contained therein, the name, brand, or trade mark of the producer or supplier, the shelf life, the batch number, and the ASTM designation.

17. Keywords

17.1 bond; bonding compound; mortar; surface-applied bonding compound

SUMMARY OF CHANGES

Committee C11 has identified the location of selected changes to this specification since the last issue, C 932 – 05, that may impact the use of this specification. (Approved March 1, 2006)

(*1*) Added new paragraph 4.4.

Committee C11 has identified the location of selected changes to this specification since the last issue, C 932 – 03, that may impact the use of this standard. (Approved May 1, 2005)

(*1*) Revised 12.6.

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Designation: C 933 – 09

Standard Specification for Welded Wire Lath[1]

This standard is issued under the fixed designation C 933; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope*

1.1 This specification covers welded wire lath, flat or self-furring, with or without backing, designed for use as a base to receive portland cement-based interior plaster and exterior stucco.

1.2 The values stated in inch-pound units are to be regarded as standard. The values given in parentheses are mathematical conversions to SI units that are provided for information only and are not considered standard.

2. Referenced Documents

2.1 *ASTM Standards:*[2]

A 641/A 641M Specification for Zinc–Coated (Galvanized) Carbon Steel Wire

C 11 Terminology Relating to Gypsum and Related Building Materials and Systems

2.2 *Federal Specifications:*

UU-B-790 Building Paper, Vegetable Fiber: (Kraft, Waterproofed, Water Repellent and Fire Resistant)[3]

3. Terminology

3.1 Definitions of terms used in this standard shall be in accordance with Terminology C 11.

4. Materials and Manufacture

4.1 Welded wire lath shall be fabricated from not less than 0.0625 in. (1.588 mm), cold-drawn, galvanized steel wire, conforming to Specification A 641/A 641M.

4.1.1 The wire shall be zinc-coated (galvanized) in accordance with Specification A 641/A 641M.

4.1.2 The backing shall conform to Federal Specification UU-B-790. The backing shall be either absorptive or water resistant. The backing shall have a bursting strength of not less than that required to maintain integrity under normal hand- or machine-application pressures.

4.1.3 The backing shall be attached to the lath to prevent accidental removal during shipping, handling or installation. Attachment of the backing shall allow lapping of wire-to-wire and backing-to-backing of not less than one mesh at ends and edges and shall permit full embedment, in not less than ¼ in. (6 mm) of plaster, of not less than one-half of the total length and width of the wire.

4.1.4 The thickness of the embedment of the lath and plaster shall be measured from the back plane of the back wire, exclusive of furring, to the backing or surface of the substrate.

5. Dimensions and Permissible Variations

5.1 *Openings and Stiffening*:

5.1.1 Lath shall be welded at all intersections of wire to form openings not more than 2 in. (51 mm) by 2 in. (51 mm).

5.1.2 Heavy-duty lath shall be stiffened continuously and parallel to the long dimension of the lath at intervals of not more than 6 in. (152 mm). Wire stiffeners used for this purpose shall range from 15-gauge (0.072 in.) to 11-gauge (0.1205 in.). The weight per square yard shall range from 1.14 to 1.95 lb/yd^2 (0.618 to 1.058 kg/m^2) for the heavy-duty lath.

5.1.3 Self-furring crimps on self-furring lath shall project not less than ¼ in. (6.4 mm) from the plane of the back of the lath.

5.2 *Thickness*—The nominal thickness shall be ⅛ in. (3.2 mm), exclusive of self-furring crimps, with a permissible variation of ±1/32 in. (0.8 mm).

5.3 *Width*—The nominal width shall be 28 in. (710 mm) to 54 in. (1370 mm), with a permissible variation of ±¾ in. (19 mm).

5.4 *Length*—The minimum length shall be 48 in. (1220 mm) for sheets or a maximum of 150 ft (45.720 m) for rolls with a permissible variation of ± ¾ in. (19 mm) for sheets or rolls.

5.5 *Weight*—The nominal weight, exclusive of backing, shall be from 1.14 to 1.95 lb/yd^2 (0.618 to 1.058 kg/m^2). Permissible variation in percentage over and under the nominal weights shall be in accordance with mill tolerances.

[1] This specification is under the jurisdiction of ASTM Committee C11 on Gypsum and Related Building Materials and Systems and is the direct responsibility of Subcommittee C11.02 on Specifications and Test Methods for Accessories and Related Products.

Current edition approved July 15, 2009. Published August 2009. Originally approved in 1980. Last previous edition approved in 2007 as C 933 – 07b.

[2] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

[3] Available from Standardization Documents Order Desk, Bldg. 4 Section D, 700 Robbins Ave., Philadelphia, PA 19111-5094, Attn: NPODS.

***A Summary of Changes section appears at the end of this standard.**

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6. Sampling

6.1 When specified by the purchase agreement, samples of welded wire lath shall be taken at the place of manufacture or at the place of destination. If samples are taken at the destination, such samples shall be taken within 24 h of the receipt of the material.

6.2 At least 0.25 % of the number of sheets of welded wire lath in a shipment, but not less than three sheets, shall be so selected as to be representative of the shipment and shall constitute a sample for the purpose of tests by the purchaser or user.

7. Inspection

7.1 Inspection of the welded wire lath shall be agreed upon between the purchaser and the producer or supplier as part of the purchase agreement.

8. Rejection

8.1 Rejection of welded wire lath that fails to conform to the requirements of the specification shall be reported to the producer or supplier promptly and in writing. The notice of rejection shall contain a statement documenting how the welded wire lath has failed to conform to the requirements of the specification.

9. Packaging and Package Marking

9.1 Welded wire lath shall be packaged in bundles or rolls.

9.2 Unless otherwise required by the purchase agreement, lath shall have legibly marked thereon the following: the product description; the name of the producer or seller; the brand name (if any); and the ASTM designation for the product.

9.2.1 Each bundle or roll of lath with no backing shall be marked with metal or paper tags securely attached to the bundles or rolls.

9.2.2 Each sheet of lath with backing shall be marked on the backing material.

10. Keywords

10.1 lath; metal plaster base; plaster; self-furring lath; stucco; wire lath

SUMMARY OF CHANGES

Committee C11 has identified the location of selected changes to this specification since the last issue, C 933 – 07b, that may impact the use of this specification. (Approved July 15, 2009)

(*1*) Revised 4.1.3 to change the embedment depth from ⅛ in. to ¼ in.

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Designation: C 937 – 02

Standard Specification for Grout Fluidifier for Preplaced-Aggregate Concrete[1]

This standard is issued under the fixed designation C 937; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

This standard has been approved for use by agencies of the Department of Defense.

1. Scope

1.1 This specification covers fluidifier for grout used for preplaced-aggregate (PA) concrete.

1.2 The values stated in SI units are to be regarded as the standard. The values given in parentheses are for information purposes only.

1.3 The following precautionary caveat pertains only to the test method portion, Section 8, of this standard: *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

2. Referenced Documents

2.1 *ASTM Standards:*

C 33 Specification for Concrete Aggregates[2]

C 150 Specification for Portland Cement[3]

C 618 Specification for Coal Fly Ash and Raw or Calcined Natural Pozzolan for Use in Concrete[2]

C 637 Specification for Aggregates for Radiation-Shielding Concrete[2]

C 938 Practice for Proportioning Grout Mixtures for Preplaced-Aggregate Concrete[2]

C 939 Test Method for Flow of Grout for Preplaced-Aggregate Concrete (Flow Cone Method)[2]

C 940 Test Method for Expansion and Bleeding of Freshly Mixed Grouts for Preplaced-Aggregate Concrete in the Laboratory[2]

C 941 Test Method for Water Retentivity of Grout Mixtures for Preplaced-Aggregate Concrete in the Laboratory[2]

C 942 Test Method for Compressive Strength of Grouts for Preplaced-Aggregate Concrete in the Laboratory[2]

C 943 Practice for Making Test Cylinders and Prisms for Determining Strength and Density of Preplaced-Aggregate Concrete in the Laboratory[2]

C 953 Test Method for Time of Setting of Grouts for Preplaced-Aggregate Concrete in the Laboratory[2]

TABLE 1 Expansion Limits

Alkali Content of Cement, % Expressed as Na_2O	Expansion Limits, %
0.80 or more	7 to 14
0.40 to 0.79	5 to 12
0.39 or less	3 to 9

3. Ordering Information

3.1 The purchaser shall specify the material desired as "grout fluidifier for preplaced-aggregate concrete." The material shall meet the requirements of this specification.

4. Materials

4.1 Grout ingredients shall conform to the following requirements:

4.1.1 Portland cement shall meet the requirements of Specification C 150 for the type to be used.

4.1.2 Pozzolan shall meet the requirements of Specification C 618.

4.1.3 Fine aggregate shall meet the requirements of Specification C 33 except that grading shall conform to Specification C 637, Table number 2, Grading 1 for Fine Aggregate.

5. Physical Requirements

5.1 The fluidifier, when tested in grout as specified herein, shall conform to the following requirements:

Reduction in mixing water, min, % of control (Test Method C 941)	3
Expansion, 3 h after mixing, (Test Method C 940)	See Table 1
Bleeding, 3 h after mixing, (Test Method C 940), max, %	2
Increase in water retentivity (Test Method C 941), min, % of control	60
Initial setting time, min, h (Test Method C 953)	4
Final setting time, max, h (Test Method C 953)	24

[1] This specification is under the jurisdiction of ASTM Committee C09 on Concrete and Concrete Aggregates and is the direct responsibility of Subcommittee C9.41 on Concrete for Radiation Shielding.

Current edition approved Dec. 10, 2002. Published February 2003. Originally approved in 1980. Last previous edition approved in 1997 as C 937–97.

[2] *Annual Book of ASTM Standards*, Vol 04.02.

[3] *Annual Book of ASTM Standards*, Vol 14.01.

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Compressive strength at 7 days and 28 days, (Test Method C 942), min, % of control	90

6. Composition

6.1 The fluidifier shall be composed of materials that will yield a product having the properties stipulated under Physical Requirements when tested in accordance with this specification.

7. Sampling

7.1 The test sample of fluidifier shall have a mass of at least 225 g (½ lb) and shall be representative of the material supplied. When feasible, the test sample shall be composited from grab samples taken from not fewer than four packages selected at random.

8. Test Method

8.1 *Summary of Method*—Physical properties of grout containing fluidifier are determined and compared with corresponding properties of grout made without fluidifier.

8.2 *Significance and Use*—The effects of adding fluidifier to a standard grout mixture are determined in order to evaluate its ability to reduce mixing water, prevent early stiffening, hold solid constituents in suspension, produce controlled expansion prior to initial setting, and maintain or increase compressive strength.

8.3 *Procedure*:

8.3.1 Have all grout materials including mixing water at 23.0 ± 2.0°C (73.5 ± 3.5°F) at the start of the test.

8.3.2 Maintain the laboratory and curing room at 23.0 ± 2.0°C (73.5 ± 3.5°F) at all times during testing.

8.3.3 *Grout Preparation*:

8.3.3.1 Proportion two grout mixtures, one a control mixture without and one a test mixture with the grout fluidifier under consideration, each containing equal parts, by weight, of cementitious material and fine aggregate, with sufficient water to produce a grout efflux time by Test Method C 939 of 21 ± 2 s. The cementitious material shall consist of two parts portland cement to one part of pozzolan, by weight.

8.3.3.2 The test mixture shall contain grout fluidifier equal to 1% of the combined weight of portland cement plus pozzolan; unless otherwise recommended by the manufacturer. The control mixture shall contain no fluidifier.

8.3.3.3 The volume of each batch shall be approximately 0.03 m^3(1 ft^3).

8.3.3.4 Mix grout in a mixer of the type shown in Fig. 1 of Practice C 938. Dampen the inside of the drum, start the mixer and charge ingredients within a period of 2 min in the following order: water, fluidifier (if used), pozzolan, cement, and fine aggregate. Mix for 3 to 3¼ min.

8.3.3.5 Determine time of efflux by Test Method C 939. If within acceptable range, proceed with tests to provide data required for the calculations.

8.4 *Calculations*—Calculate the following items:

8.4.1 Reduction in water requirement (R_w):

$$R_w = \frac{(W_c - W_t) \times 100}{W_c} \quad (1)$$

where:

R_w = reduction in water requirement, %,
W_c = mass of water required in grout mixture without fluidifier, and
W_t = mass of water required in grout mixture with fluidifier.

8.4.2 Increase in water retentivity (I_r):

$$I_r = \frac{(R_t - R_c) \times 100}{R_c} \quad (2)$$

where:

I_r = increase in water retentivity, %,
R_c = time required to extract 60 mL of water from the control sample without fluidifier, s, and
R_t = time required to extract 60 mL of water from the test sample with fluidifier.

8.5 *Report*—For each grout mixture, the following test data shall be reported:

8.5.1 Description and source of materials used,
8.5.2 Material proportions by mass,
8.5.3 Average time of grout efflux, s,
8.5.4 Expansion and bleeding, %,
8.5.5 Water retentivity, s,
8.5.6 Initial setting time, h,
8.5.7 Final setting time, h,
8.5.8 Compressive strength at 7 days, psi or MPa, and
8.5.9 Compressive strength at 28 days, psi or MPa.
8.5.10 The following computed values shall also be reported:
8.5.11 Reduction in water requirement, R_w %,
8.5.12 Increase in water retentivity, I_r %, and
8.5.13 Compressive strength at 7 days, expressed as percentage of control specimens, %.

9. Rejection

9.1 The fluidifier shall be rejected if it fails to meet any of the requirements of this specification.

10. Packaging and Marking

10.1 Grout fluidifier shall be packaged in moisture-resistant containers and stored in a dry covered area to prevent deterioration.

10.2 Containers shall be marked to provide at least the following information:

10.2.1 A statement to the effect that the contained material meets the requirements of this specification.
10.2.2 Weight of the contained material.
10.2.3 Basic instructions for use of the material.
10.2.4 Manufacturer's lot number and date of manufacture.

11. Keywords

11.1 efflux time; fluidifier; grout; pre-placed aggregate; water demand; water retentivity

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Designation: C 938 – 02

Standard Practice for Proportioning Grout Mixtures for Preplaced-Aggregate Concrete[1]

This standard is issued under the fixed designation C 938; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

This standard has been approved for use by agencies of the Department of Defense.

1. Scope

1.1 This practice describes the laboratory procedure for selecting proportions for grout mixtures required in the production of preplaced-aggregate (PA) concrete.

1.2 The values stated in SI units are to be regarded as the standard. The values given in parentheses are provided for information purposes only.

1.3 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

2. Referenced Documents

2.1 *ASTM Standards:*

C 39/C 39M Test Method for Compressive Strength of Cylindrical Concrete Specimens[2]

C 109/C 109M Test Method for Compressive Strength of Hydraulic Cement Mortars (Using 2-in. or [50-mm] Cube Specimens)[3]

C 150 Specification for Portland Cement[3]

C 185 Test Method for Air Content of Hydraulic Cement Mortar[3]

C 192/C 192M Practice for Making and Curing Concrete Test Specimens in the Laboratory[2]

C 618 Specification for Coal Fly Ash and Raw or Calcined Natural Pozzolan for Use in Concrete[2]

C 637 Specification for Aggregates for Radiation-Shielding Concrete[2]

C 937 Specification for Grout Fluidifier for Preplaced-Aggregate Concrete[2]

C 939 Test Method for Flow of Grout for Preplaced-Aggregate Concrete (Flow-Cone Method)[2]

C 940 Test Method for Expansion and Bleeding of Freshly Mixed Grouts for Preplaced-Aggregate Concrete in the Laboratory[2]

C 941 Test Method for Water Retentivity of Grout Mixtures for Preplaced-Aggregate Concrete in the Laboratory[2]

C 942 Test Method for Compressive Strength of Grouts for Preplaced-Aggregate Concrete in the Laboratory[2]

C 943 Practice for Making Test Cylinders and Prisms for Determining Strength and Density of Preplaced-Aggregate Concrete in the Laboratory[2]

3. Summary of Practice

3.1 Grouts at fluid consistency are prepared from one or more mixtures of cement, pozzolan, fine aggregate, grout fluidifier, with or without other chemical admixtures, and water, and tested to determine:

3.1.1 The properties of the grout, and

3.1.2 The properties of PA concrete made with the grout when the grout is intended for such use.

3.2 The procedure and equipment required for mixing this grout are prescribed in this practice.

4. Significance and Use

4.1 This practice provides a standard procedure for selecting proportions for mixtures of grout to be used at fluid consistency in the production of PA concrete meeting applicable criteria for strength, density, and other properties.

4.2 This practice is also useful for determining the composition of grout mixed at fluid consistency and meeting specified requirements for filling voids, cavities, and spaces in rock, foundations, and concrete structures.

5. Apparatus

5.1 *Mixer*, constructed as shown in Fig. 1. The three mixer blades shall be made of steel plate, 3-mm (⅛-in.) thick, with a 100 by 125-mm (4 by 5-in.) elliptical shape. Each blade shall have two 25 by 75-mm (1 by 3-in.) slots centered on the major axis, and shall be welded to the shaft at an angle of approximately 23° with the horizontal in such a way as to force grout

[1] This practice is under the jurisdiction of ASTM Committee C09 on Concrete and Concrete Aggregates and is the direct responsibility of Subcommittee C09.41 on Concrete for Radiation Shielding.

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[2] *Annual Book of ASTM Standards*, Vol 04.02.

[3] *Annual Book of ASTM Standards*, Vol 04.01.

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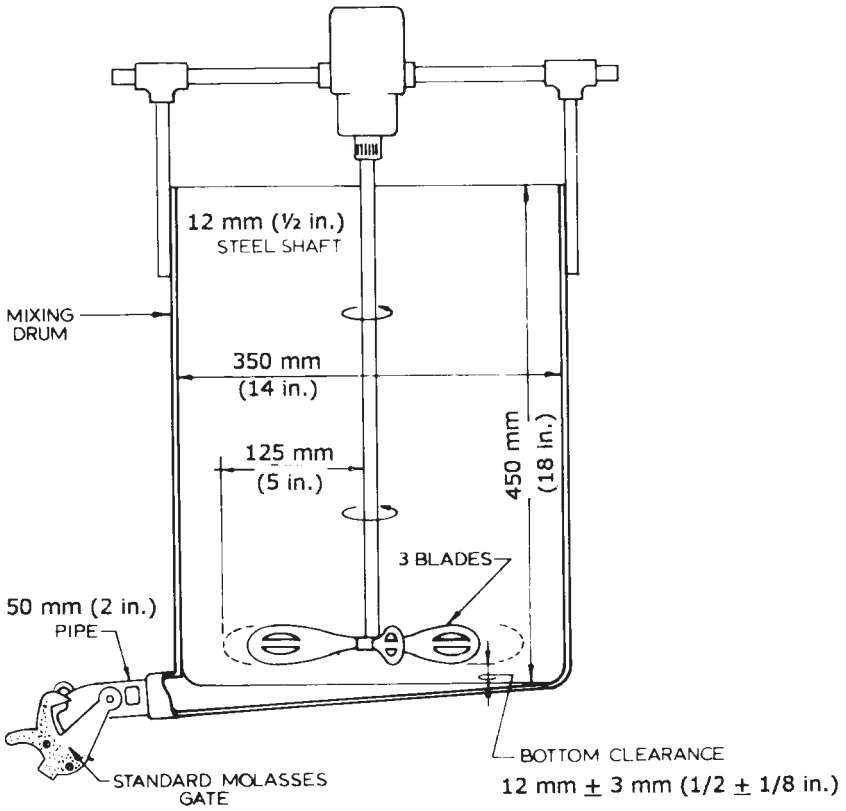

FIG. 1 Grout Mixer

to the bottom of the mixer during rotation. The mixer blades shall be powered to rotate at approximately 275 r/min under load.

5.2 *Scales or Balance*, accurate to within 0.3 % of the test mass at any point within range of use.

6. Materials

6.1 Materials for test purposes, except mixing water, shall meet the following requirements unless otherwise specified in project documents:

6.1.1 Portland cement, Specification C 150, nonair-entraining,

6.1.2 Pozzolan, if used, Specification C 618,

6.1.3 Fluidifier, Specification C 937, and

6.1.4 Fine aggregate, Specification C 637, Table number 2, Grading 1 for specific gravity under 3.0 and Grading 2 for specific activity 3.0 or heavier.

6.2 Where grout is being proportioned for use on a specific project, materials for test purposes shall be from and representative of the same source or type and description as will be used or is being considered for use on the project.

6.3 *Mixing water*, if clean and potable, is acceptable for normal test purposes.

7. Sampling

7.1 Samples of mixed grout for testing shall be representative of the batch from which they are drawn.

7.2 Agitation of the batch shall be continuous until all samples required from that batch have been drawn.

7.3 Grout in the mixer shall not be retempered by the addition of water. If mixing water is added in increments to adjust fluidity, a new batch shall be prepared for testing.

7.4 Samples shall be drawn for testing in the following order: (*1*) consistency, (*2*) expansion and bleeding, and (*3*), other requirements.

8. Conditioning

8.1 Maintain laboratory at and bring all grout materials to 23.0 ± 2.0°C (73.5 ± 3.5°F) unless otherwise specified.

9. Procedure

9.1 Prebatch grout ingredients by mass to provide a batch volume after mixing of approximately 0.03 m^3 (1 ft^3).

9.2 The first trial mixture, unless otherwise specified, shall contain equal parts, by mass, of cementitious material and fine aggregate, fluidifier in amount 1 % mass of cementitious material, unless otherwise recommended by manufacturer, and sufficient water to produce a flow of 21 ± 2 s. The cementitious material shall consist of two parts of portland cement to one part of pozzolan by mass.

9.3 In subsequent trial mixtures, the proportions of materials shall be varied as needed to satisfy design criteria. Adjusted mixtures may contain a cementitious ratio of portland cement to pozzolan other than as stipulated for the first trial mixture.

9.4 Dampen the inside of the mixer drum, turn the mixer on and charge the ingredients within 2 min in the following order: (*1*) water, (*2*) fluidifier, (*3*) pozzolan (if used), (*4*) portland

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cement, and (5) fine aggregate. After all materials have been added, mix for 3 to 3¼ min.

9.5 Determine the following fluid grout properties in the order shown of each trial mixture:

Property	Test Method
Flow (time of efflux)	C 939
Expansion and bleeding	C 940
Water retentivity	C 941, if required
Unit mass	see 9.5.1
Other	as required

9.5.1 Determine the unit mass of the fluid grout using the measure described in the Apparatus section under "Measure" in Test Method C 185. Pour the grout into a container, tap the side lightly five times with a tapping stick as described in Test Method C 185, strike off, then measure mass.

9.6 Determine the following hardened grout and PA concrete properties:

Property	Test Method
Compressive strength of grout	C 942
Compressive strength of PA concrete	C 943, if required
Unit mass of grout	see 9.6.1
Unit mass of PA concrete	see 9.6.1, if required

9.6.1 To determine the unit mass of grout or PA concrete, measure mass of the specimen to an accuracy of at least one part in 250. Divide the masses by volumes determined as follows:

9.6.1.1 *Cubes*—Take two measurements of each dimension to nearest 0.25 mm (0.01 in.). Compute the volume from average measurements.

9.6.1.2 *PA Cylinders*—Take measurements of two diameters at right angles at approximate mid-height. Measure the length of the cylinder at opposite ends of a diameter. Make all measurements to nearest 0.25 mm (0.01 in.). Compute the volume from average measurements.

10. Report

10.1 For each mixture, including the final mixture, the following shall be reported:

10.1.1 A description of all materials used including type and alkali content of portland cement, type of pozzolan, source and name of fluidifier, and sieve analysis and specific gravity of fine and coarse aggregate.

10.2 For each trial mixture the following fluid grout properties shall be reported: (*1*) time of efflux, (*2*) expansion and free water, (*3*) water retentivity (if required), (*4*) and other specified data.

10.3 For final mixture(s) selected, the report shall include compressive strength of grout at ages of 7, 28, and 90 days, and unit mass unless otherwise required.

10.4 For PA concrete cylinders, the report shall include compressive strengths at ages of 7, 28, and 90 days, and unit mass unless otherwise required.

11. Keywords

11.1 concrete; grouts; pre-placed aggregate

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Designation: C 939 – 02

Standard Test Method for Flow of Grout for Preplaced-Aggregate Concrete (Flow Cone Method)[1]

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This standard has been approved for use by agencies of the Department of Defense.

1. Scope

1.1 This test method covers a procedure, used both in the laboratory and in the field, for determining the time of efflux of a specified volume of fluid hydraulic cement grout through a standardized flow cone and used for preplaced-aggregate (PA) concrete; however, the test method may also be used for other fluid grouts.

1.2 It is for use with neat grout and with grouts containing fine aggregate all passing a 2.36-mm (No. 8) sieve.

1.3 This test method is intended for use with grout having an efflux time of 35 s or less.

1.4 When efflux time exceeds 35 s, flowability is better determined by flow table, found in Test Method C 109/C 109M, using 5 drops in 3 s.

1.5 The values stated in SI units are to be regarded as the standard. The values given in parentheses are for information only.

1.6 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

2. Referenced Documents

2.1 *ASTM Standards:*

C 109/C 109M Test Method for Compressive Strength of Hydraulic Cement Mortars (Using 2-in. or [50-mm] Cube Specimens)[2]

C 938 Practice for Proportioning Grout Mixtures for Preplaced-Aggregate Concrete[3]

3. Summary of Test Method

3.1 The time of efflux of a specified volume of grout from a standardized flow cone is measured.

4. Significance and Use

4.1 This test method is applicable to the determination of the fluidity of various fluid grout mixtures.

5. Interferences

5.1 The presence of solid particles retained on the 2.36-mm (No. 8) sieve or lumps of unmixed material in the grout may cause the grout to flow unevenly through the discharge tube of the flow cone or stop the flow completely. Uneven flow will result in slower transit of the grout, thereby indicating a false consistency.

6. Apparatus

6.1 *Flow Cone*, with dimensions as shown in Fig. 1. The discharge tube shall be stainless steel. The body can be stainless steel, cast aluminum, or other essentially noncorroding metal.

NOTE 1—Cones with high-density polyethylene bodies are acceptable for field use in situations where precision as described in this test method is not required.

6.2 *Receiving Container*, capacity 2000 mL, minimum.

6.3 *Ring Stand* or other device, capable of supporting the flow cone in a vertical, steady position over the receiving container.

6.4 *Level*, carpenter's or similar.

6.5 *Stop Watch*, least reading of not more than 0.2 s.

6.6 *Grout Mixer*, conforming to Practice C 938.

7. Test Sample

7.1 The grout test sample shall be in excess of 1725 mL and shall be representative of the grout in the mixer.

7.2 When sampling and testing is being done for the purpose of proportioning or comparing mixes or for qualifying materials, the temperature of the dry materials and mixing

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[3] *Annual Book of ASTM Standards*, Vol 04.02.

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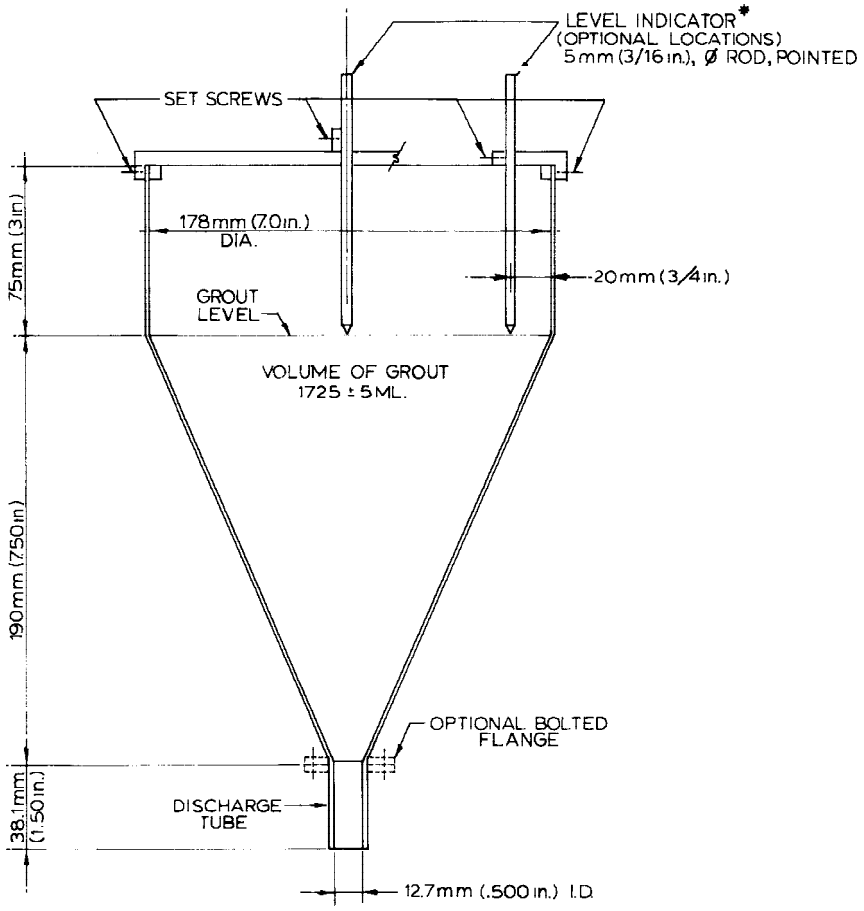

NOTE 1—Other means of indicating grout level may be used as long as accurate indication of grout level on volume is obtained.

FIG. 1 Cross Section of Flow Cone

water shall be such that the temperature of the freshly mixed grout is 23.0 ± 2.0°C (73.5 ± 3.5°F), unless otherwise specified.

8. Calibration of Apparatus

8.1 Mount the flow cone firmly in such a manner that it is free of vibration. Level the top to assure verticality. Close the outlet of the discharge tube with a finger or a stopper. Introduce 1725 ± 5 mL of water into the cone. Adjust the point gage to indicate the level of the water surface. Then allow the water to drain.

8.2 Before first use of the flow cone with grout and periodically thereafter, check the accuracy of the cone by filling it with water as described in 8.1. After checking or adjusting the point gage, start the stop watch and simultaneously remove the finger. Stop the watch at the first break in the continuous flow of water. The time indicated by the stop watch is the time of efflux of water. If this time is 8.0 ± 0.2 s, the cone may be used for determining the time of efflux of grout.

9. Procedure

9.1 Moisten the inside of the flow cone by filling the cone with water and, 1 min before introducing the grout sample, allow the water to drain from the cone. Close the outlet of the discharge tube with a finger or a stopper. Introduce the grout into the cone until the grout surface rises to contact the point gage, start the stop watch, and simultaneously remove the finger or stopper. Stop the watch at the first break in the continuous flow of grout from the discharge tube, then look into the top of the cone; if the grout has passed sufficiently, such that light is visible through the discharge tube, the time indicated by the stop watch is the time of efflux of the grout. If light is not visible through the discharge tube, then the use of the flow cone is not applicable for grout of this consistency. At least two tests having times of efflux within 1.8 s of their average shall be made for each grout mixture.

9.2 The test for time of efflux shall be made within 1 min of drawing of the grout from the mixer or transmission line. When grout is being placed over a significant period of time, the time of efflux may be determined at selected intervals to demonstrate that the consistency is suitable for the work.

10. Report

10.1 Report the following information:

10.1.1 Identification of sample,

10.1.2 Identification of materials in the sample, the proportions, and whether laboratory-prepared or taken from the field production mix,

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10.1.3 Average time of efflux to nearest 0.2 s and time interval from completion of mixing at which the test was made, and

10.1.4 Temperature, ambient and of the sample at the time of test.

11. Precision and Bias

11.1 *Precision*—The following within-laboratory, multiple-operator precision applies. The single laboratory standard deviation has been found to be 0.88 s. Therefore, results from two properly conducted tests on the same material should not differ by more than 2.49 s.

11.2 *Bias*—No statement on bias can be prepared because there are no standard reference materials.

12. Keywords

12.1 flow cone; grout; preplaced—aggregate concrete; time of efflux

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Designation: C 939 – 02

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This standard has been approved for use by agencies of the Department of Defense.

1. Scope

1.1 This test method covers a procedure, used both in the laboratory and in the field, for determining the time of efflux of a specified volume of fluid hydraulic cement grout through a standardized flow cone and used for preplaced-aggregate (PA) concrete; however, the test method may also be used for other fluid grouts.

1.2 It is for use with neat grout and with grouts containing fine aggregate all passing a 2.36-mm (No. 8) sieve.

1.3 This test method is intended for use with grout having an efflux time of 35 s or less.

1.4 When efflux time exceeds 35 s, flowability is better determined by flow table, found in Test Method C 109/C 109M, using 5 drops in 3 s.

1.5 The values stated in SI units are to be regarded as the standard. The values given in parentheses are for information only.

1.6 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

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C 938 Practice for Proportioning Grout Mixtures for Preplaced-Aggregate Concrete[3]

3. Summary of Test Method

3.1 The time of efflux of a specified volume of grout from a standardized flow cone is measured.

4. Significance and Use

4.1 This test method is applicable to the determination of the fluidity of various fluid grout mixtures.

5. Interferences

5.1 The presence of solid particles retained on the 2.36-mm (No. 8) sieve or lumps of unmixed material in the grout may cause the grout to flow unevenly through the discharge tube of the flow cone or stop the flow completely. Uneven flow will result in slower transit of the grout, thereby indicating a false consistency.

6. Apparatus

6.1 *Flow Cone*, with dimensions as shown in Fig. 1. The discharge tube shall be stainless steel. The body can be stainless steel, cast aluminum, or other essentially noncorroding metal.

NOTE 1—Cones with high-density polyethylene bodies are acceptable for field use in situations where precision as described in this test method is not required.

6.2 *Receiving Container*, capacity 2000 mL, minimum.

6.3 *Ring Stand* or other device, capable of supporting the flow cone in a vertical, steady position over the receiving container.

6.4 *Level*, carpenter's or similar.

6.5 *Stop Watch*, least reading of not more than 0.2 s.

6.6 *Grout Mixer*, conforming to Practice C 938.

7. Test Sample

7.1 The grout test sample shall be in excess of 1725 mL and shall be representative of the grout in the mixer.

7.2 When sampling and testing is being done for the purpose of proportioning or comparing mixes or for qualifying materials, the temperature of the dry materials and mixing

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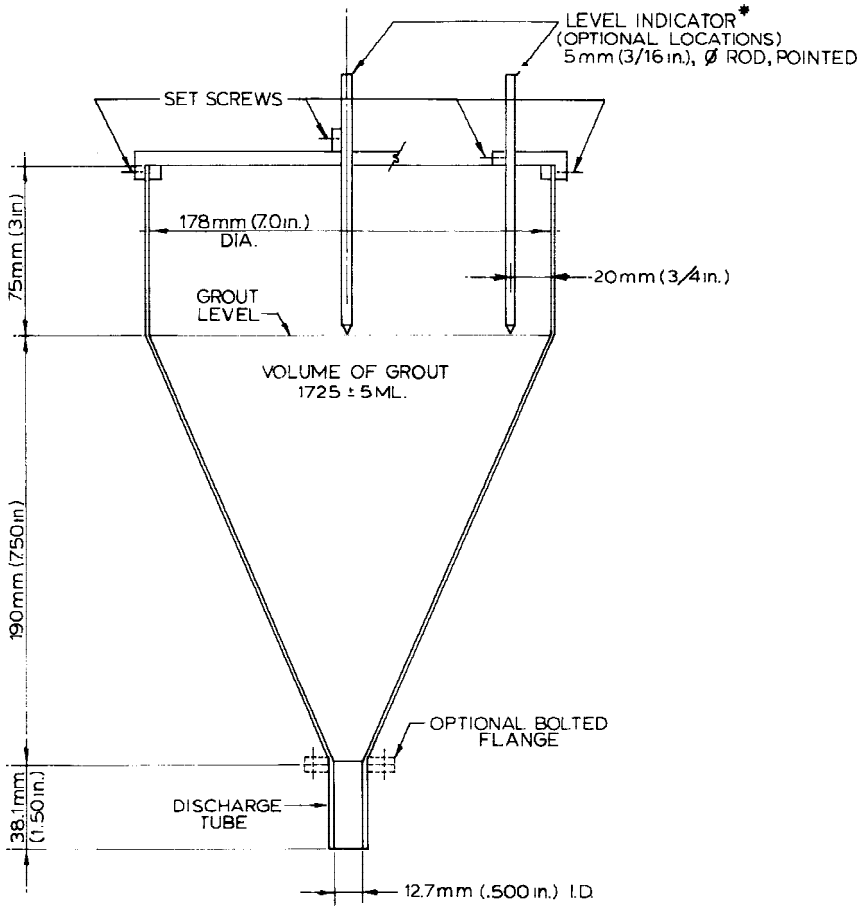

NOTE 1—Other means of indicating grout level may be used as long as accurate indication of grout level on volume is obtained.

FIG. 1 Cross Section of Flow Cone

water shall be such that the temperature of the freshly mixed grout is 23.0 ± 2.0°C (73.5 ± 3.5°F), unless otherwise specified.

8. Calibration of Apparatus

8.1 Mount the flow cone firmly in such a manner that it is free of vibration. Level the top to assure verticality. Close the outlet of the discharge tube with a finger or a stopper. Introduce 1725 ± 5 mL of water into the cone. Adjust the point gage to indicate the level of the water surface. Then allow the water to drain.

8.2 Before first use of the flow cone with grout and periodically thereafter, check the accuracy of the cone by filling it with water as described in 8.1. After checking or adjusting the point gage, start the stop watch and simultaneously remove the finger. Stop the watch at the first break in the continuous flow of water. The time indicated by the stop watch is the time of efflux of water. If this time is 8.0 ± 0.2 s, the cone may be used for determining the time of efflux of grout.

9. Procedure

9.1 Moisten the inside of the flow cone by filling the cone with water and, 1 min before introducing the grout sample, allow the water to drain from the cone. Close the outlet of the discharge tube with a finger or a stopper. Introduce the grout into the cone until the grout surface rises to contact the point gage, start the stop watch, and simultaneously remove the finger or stopper. Stop the watch at the first break in the continuous flow of grout from the discharge tube, then look into the top of the cone; if the grout has passed sufficiently, such that light is visible through the discharge tube, the time indicated by the stop watch is the time of efflux of the grout. If light is not visible through the discharge tube, then the use of the flow cone is not applicable for grout of this consistency. At least two tests having times of efflux within 1.8 s of their average shall be made for each grout mixture.

9.2 The test for time of efflux shall be made within 1 min of drawing of the grout from the mixer or transmission line. When grout is being placed over a significant period of time, the time of efflux may be determined at selected intervals to demonstrate that the consistency is suitable for the work.

10. Report

10.1 Report the following information:

10.1.1 Identification of sample,

10.1.2 Identification of materials in the sample, the proportions, and whether laboratory-prepared or taken from the field production mix,

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10.1.3 Average time of efflux to nearest 0.2 s and time interval from completion of mixing at which the test was made, and

10.1.4 Temperature, ambient and of the sample at the time of test.

11. Precision and Bias

11.1 *Precision*—The following within-laboratory, multiple-operator precision applies. The single laboratory standard deviation has been found to be 0.88 s. Therefore, results from two properly conducted tests on the same material should not differ by more than 2.49 s.

11.2 *Bias*—No statement on bias can be prepared because there are no standard reference materials.

12. Keywords

12.1 flow cone; grout; preplaced—aggregate concrete; time of efflux

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Designation: C 940 – 98a (Reapproved 2003)

Standard Test Method for Expansion and Bleeding of Freshly Mixed Grouts for Preplaced-Aggregate Concrete in the Laboratory[1]

This standard is issued under the fixed designation C 940; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope

1.1 This test method determines the amount of expansion and accumulation of bleed water at the surface of freshly mixed hydraulic-cement grout used in the production of preplaced-aggregate (PA) concrete.

1.2 It is for use with cement grout whether or not it includes fine aggregate or mineral admixtures or both.

1.3 The values stated in SI units are to be regarded as standard.

1.4 *This standard may involve hazardous materials, operations, and equipment. This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

2. Referenced Documents

2.1 *ASTM Standards:* [2]

C 125 Terminology Relating to Concrete and Concrete Aggregates

C 937 Specification for Grout Fluidifier for Preplaced-Aggregate Concrete

3. Terminology

3.1 *Definition of Terms*—Terms used in this test method are defined in Terminology C 125 or in this section.

3.1.1 *bleeding*—This term is defined as stated in Terminology C 125, with the exception that it pertains to grout in this test method.

3.1.2 *expansion*—increase in the volume of a grout, expressed as a percentage of the original volume of the grout.

4. Summary of Test Method

4.1 Grout is placed in a graduated cylinder. Changes in total volume and accumulation of bleed water, if any, on the surface of the grout are observed over a period of time.

5. Significance and Use

5.1 This method is useful for determining the expansion and bleeding characteristics of freshly mixed fluid grout used in PA concrete.

6. Interferences

6.1 Failure to obtain a uniformly smooth mixture, free of lumps, will cause excessive bleeding and may result in reduced expansion.

6.2 The capability of most admixtures to produce expansion and the tendency to bleed is related to the temperature of the grout during the period of test.

7. Apparatus

7.1 *Glass Graduate*, 1000 mL, reading to 10 mL.

7.2 *Glass Graduate*, 25 mL, reading to 1 mL.

7.3 *Thermometer*, accurate to 0.5°C (1°F) for measuring grout and air temperature.

8. Test Sample

8.1 The grout test sample shall consist of approximately 1500 mL and shall be representative of the grout in the mixer.

9. Procedure

9.1 When sampling and testing are being performed in the laboratory for the purpose of designing or comparing mixtures or for qualifying admixtures including grout fluidifiers proceed in the following manner:

9.1.1 Maintain the ambient temperature of the room in which the test is performed at 23.0 ± 2°C (73.4 ± 3°F), unless otherwise specified.

9.1.2 Bring the temperature of all dry materials and mixing water to a constant temperature of 23.0 ± 2°C (73.4 ± 3°F) before mixing, unless otherwise specified.

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[1] This test method is under the jurisdiction of ASTM Committee C09 on Concrete and Concrete Aggregates and is the direct responsibility of Subcommittee C09.41 on Concrete for Radiation Shielding.

Current edition approved May 10, 1998. Published December 1998. Originally approved in 1981. Last previous edition approved in 1998 as C 940 – 98a.

[2] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

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9.1.3 Start volume measurements within 3 min of completion of mixing.

9.2 When sampling and testing are being performed in the field, record the temperature of the grout sample and the ambient temperature of the area in which the test readings are made. Record the time interval between completion of mixing and start of test.

9.3 Immediately after the completion of mixing, measure the temperature of the grout. Then introduce the grout into a 1000-mL graduated cylinder until the volume of the sample is 800 ± 10 mL. Record the volume of the sample and the time at which the reading was made. Place the graduated cylinder on a level surface free of vibration. Cover to prevent evaporation of the bleed water.

9.4 Take and record the readings, estimated to the nearest 1 mL, of the upper surfaces of the grout and bleed water, if any, of the sample in the graduate at 15-min intervals for the first 60 min and thereafter at hourly intervals until two successive readings show no further expansion or bleeding. When the test for expansion and bleeding is used in connection with Specification C 937, it shall be discontinued 3 h after the initial reading.

9.5 At the conclusion of the test, decant the bleed water into a 25-mL graduate by tilting the specimen and drawing the water off with a pipet or large medicine dropper. Record the final volume of bleed water to the nearest 0.5 mL.

10. Calculation

10.1 Calculate the expansion of the grout, and its bleeding and the combined expansion of grout plus bleed water as percentages of the initial volume of the grout, as follows:

$$\text{Expansion, \%} = \frac{V_g - V_1}{V_1} \times 100$$

$$\text{Bleeding, \%} = \frac{V_2 - V_g}{V_1} \times 100 \text{ at prescribed intervals}$$

$$\text{Combined Expansion, \%} = \frac{V_2 - V_1}{V_1} \times 100$$

$$\text{Final bleeding, \%} = \frac{V_w}{V_1} \times 100$$

where:

V_1 = volume of sample at beginning of test, mL,
V_2 = volume of sample at prescribed intervals, measured at upper surface of water layer, mL,
V_g = volume of grout portion of sample at prescribed intervals, at upper surface of grout, mL, and
V_w = volume of decanted bleed water, mL.

11. Report

11.1 The report shall include the following:

11.1.1 Identification of the grout sample.

11.1.2 Expansion of grout to the nearest 0.2 % for each prescribed interval.

11.1.3 Bleeding of grout to the nearest 0.2 % for each prescribed interval.

11.1.4 Combined expansion of grout plus bleed water to the nearest 0.2 % for each prescribed interval.

11.1.5 Final bleeding to nearest 0.2 %.

11.1.6 Temperature of grout sample at start of test.

11.1.7 Ambient temperature of laboratory or testing area at the beginning and end of test.

12. Precision and Bias

12.1 *Precision*:

12.1.1 *Bleeding*—The single laboratory, three operators, standard deviation has been found to be 0.06 %. Therefore, results from two properly conducted tests (by the same operator) on the same material should not differ by more than 0.17 %.

12.1.2 *Combined Expansion*—The single laboratory, three operators, standard deviation has been found to be 0.37 %. Therefore, results from two properly conducted tests (by the same operator) on the same material should not differ by more than 1.04 %.

12.2 *Bias*—No statements on bias can be prepared because there are no standard reference materials.

13. Keywords

13.1 bleeding; concrete; expansion; grouts; preplaced-aggregate; preplaced-aggregate concrete

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Designation: C 941 – 02

Standard Test Method for Water Retentivity of Grout Mixtures for Preplaced-Aggregate Concrete in the Laboratory[1]

This standard is issued under the fixed designation C 941; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope

1.1 This test method covers the procedure for determining the water retentivity of freshly mixed hydraulic cement grout mixtures for preplaced-aggregate (PA) concrete.

1.2 The values stated in SI units are to be regarded as the standard. The values given in parentheses are for information only.

1.3 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

2. Referenced Documents

2.1 *ASTM Standards:*

E 832 Specification for Laboratory Filter Papers[2]

3. Summary of Test Method

3.1 The time required for the extraction of a standard amount of water by vacuum from a grout sample is measured.

4. Significance and Use

4.1 This test method measures the ability of a grout mixture to retain its mixing water.

4.2 It is used for qualifying grout fluidifiers to be used in the production of PA concrete.

4.3 It may be used to compare the effects of various admixtures or materials combinations on the water retentivity properties of any cement-water grout.

5. Apparatus

5.1 *Extraction Apparatus*, assembled as in Fig. 1, including the following:

5.1.1 *Funnel*, porcelain Büchner filtering, 111 mm inside diameter at the perforated plate and 500 mL in volume.

5.1.2 *Filter Paper*, Specification E 832, Type 2, Class G, disk, 11-cm diameter filter paper.

5.1.3 *Graduated Cylinder*, 250 mL cut down to about 130 mL.

5.1.4 *Vacuum Gage* or manometer graduated in increments of 1 kPa to 100 kPa (30-in. Hg) vacuum.

5.1.5 *Vacuum Pump* or other source of reduced pressure, capable of maintaining a minimum vacuum of 95 kPa (28 in. Hg) on a system having a volume of not less than 1 L.

5.2 *Stop Watch*, having a least reading of not more than 0.2 s.

5.3 *Thermometer*, accurate to 0.5°C (1.0°F), for measuring ambient and grout temperatures.

6. Sampling

6.1 The test sample shall consist of at least 500 mL of freshly mixed grout representative of grout in the mixer. The temperature of the laboratory sample of grout shall be 23.0 ± 2.0°C (73.5 ± 3.5°F).

7. Procedure

7.1 Dampen a single filter paper disk and place it on the perforated plate of the filtering funnel (see Fig. 1). Keep the top of the filtering funnel level. Apply to and maintain a minimum vacuum in the system below the stopcock of 95 kPa (28 in. Hg) for the duration of the test. Introduce grout into the funnel until it is filled flush with the top. Open the stopcock between the filtering funnel and the graduated cylinder and at the same time start the stop watch. Perform these operations not more than 1 min after taking the grout sample from the mixer.

7.2 When 60 mL of water have been removed from the sample, stop the stop watch.

7.3 When using this method for acceptance testing of a grout fluidifier, take the test sample within 1 min after completion of 3 to 3¼ min mixing.

8. Report

8.1 Report the following information:

8.1.1 Identification of the grout sample,

8.1.2 Required time to extract 60 mL of water from the sample, to the nearest 1 s,

[1] This test method is under the jurisdiction of ASTM Committee C09 on Concrete and Concrete Aggregates and is the direct responsibility of Subcommittee C09.41on Concrete for Radiation Shielding.

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[2] *Annual Book of ASTM Standards*, Vol 14.02.

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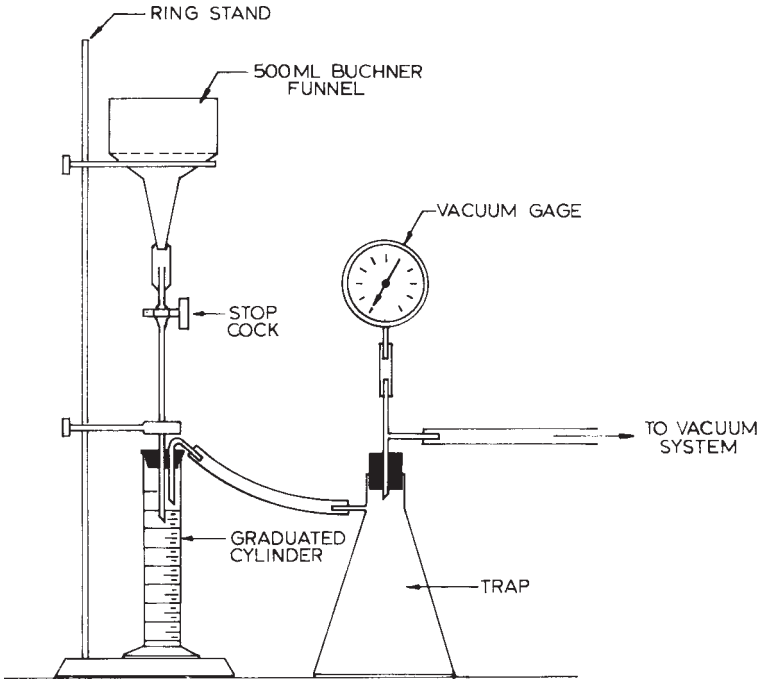

FIG. 1 Extraction Apparatus

8.1.3 Temperature of the grout sample at the beginning of the test, and

8.1.4 Ambient temperature during the test.

9. Precision and Bias

9.1 *Precision*—The single laboratory, three operators standard deviation has been found to be 11 s. Therefore, results from two properly conducted tets (by the same operator) on the same material should not differ by more than 31 s.

9.2 *Bias*—No statement on bias can be prepared because there are no standard reference materials.

10. Keywords

10.1 grout fluidifier; preplaced-aggregate concrete; water retentivity

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Designation: C 942 – 99 (Reapproved 2004)

Standard Test Method for Compressive Strength of Grouts for Preplaced-Aggregate Concrete in the Laboratory[1]

This standard is issued under the fixed designation C 942; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

This standard has been approved for use by agencies of the Department of Defense.

1. Scope

1.1 This test method covers the determination of the compressive strength of hydraulic cement grout for preplaced-aggregate (PA) concrete.

1.2 The values stated in SI units are to be regarded as standard.

1.3 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

2. Referenced Documents

2.1 *ASTM Standards:* [2]

C 31/C 31M Practice for Making and Curing Concrete Test Specimens in the Field

C 109/C 109M Test Method for Compressive Strength of Hydraulic Cement Mortars (Using 2-in. or [50-mm] Cube Specimens)

C 937 Specification for Grout Fluidifier for Preplaced-Aggregate Concrete

C 938 Practice for Proportioning Grout Mixtures for Preplaced-Aggregate Concrete

C 939 Test Method for Flow of Grout for Preplaced-Aggregate Concrete (Flow Cone Method)

3. Summary of Test Method

3.1 Compressive strength of hardened grout is determined using top-restrained cubes as defined in Test Method C 109/C 109M.

4. Significance and Use

4.1 This test method affords a means for determining the compressive strength of grouts that expand and, in use, harden under conditions of partial to total restraint.

4.2 It is particularly applicable for determining the effect on compressive strength of grout fluidifier to be used with grout for PA concrete (See Specification C 937).

5. Apparatus

5.1 *Scales, masses, sieves, glass graduates, and three-gang molds*, for 2-in. (or 50-mm) cube specimens, baseplates, trowel, and testing machine as specified in Test Method C 109/C 109M.

5.2 *Plates*, to cover specimen molds, capable of supporting the weight or being held down by C-clamps, as described in 9.3.

5.3 *Mass of 7 kg (or 15 lb) or C-clamps*, for holding down the cover plates.

6. Temperature and Humidity

6.1 Temperature and humidity conditions for tests performed in the laboratory shall be in accordance with Test Method C 109/C 109M unless otherwise specified.

6.2 Temperature and humidity conditions for tests performed in the field shall be as prescribed for curing cylinders in Practice C 31/C 31M.

7. Sampling

7.1 The test sample shall consist of approximately 1500 mL of grout and shall be representative of the material in the mixer.

7.2 Grout proportioned at the mixer from hydraulic cement(s) with or without other materials shall be mixed in accordance with Specification C 937.

7.3 Packaged grouts requiring only the addition of water or other fluid shall be mixed in accordance with the manufacturer's printed recommendations.

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[1] This test method is under the jurisdiction of ASTM Committee C09 on Concrete and Concrete Aggregates and is the direct responsibility of Subcommittee C09.41 on Concrete for Radiation Shielding.

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[2] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

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8. Preparation of Specimen Molds

8.1 Prepare the molds as specified in Test Method C 109/C 109M.

9. Procedure

9.1 Determine the consistency of grout as follows:

9.1.1 Use the flow cone, Test Method C 939, for grout to be used for PA concrete or whenever the consistency is less than 35 s.

9.1.2 For grouts at consistencies thicker than above, determine the consistency on the flow table, Test Method C 109/C 109M, using 5 drops of the table in 3 s. When placing grout in the mold, puddle each layer five times with the gloved finger.

9.2 Measure the temperature of the grout.

9.3 Mold sets of cube specimens for testing in compression.

9.3.1 A three-gang cube mold shall constitute one test set. Provide at least one test set for each age at which the strength is to be determined, but not less than two sets.

9.3.2 Fill each mold in the set halfway. Puddle each with a gloved finger five times to release entrapped air. Fill the mold and puddle again. Bring the excess grout to the center and finish the surface by cutting off the excess with the straight edge of a trowel held vertically and drawn across the top of the mold with a sawing motion.

9.3.3 Place the cover plate over the mold (three-gang), taking care that the grout or loose grains of sand do not prevent seating of the plate.

9.3.4 Place a mass of 7 kg (or 15 lb) on each cover plate or fix the cover plates to the molds with C-clamps, finger tightened.

10. Storage and Curing

10.1 Immediately upon completion of molding:

10.1.1 Place laboratory specimens in the moist room and cure in accordance with the applicable portions of Test Method C 109/C 109M.

10.1.2 Store field specimens and cure in accordance with Curing Cylinders of Practice C 31/ 31M.

10.2 *Stripping*—With grouts that expand prior to hardening, do not strip molds before age 24 h or final set, whichever occurs later.

10.2.1 Do not strip molds from grouts containing expansive-cement systems before age 3 days.

11. Determination of Compressive Strength

11.1 Determine the compressive strength at ages 7 and 28 days, unless otherwise specified, in accordance with Test Method C 109/C 109M.

12. Report

12.1 The report shall include the following:

12.1.1 Identification, date of mixing, and whether laboratory or field tested.

12.1.1.1 If field tested, include description of curing procedure and temperature.

12.1.2 Average compressive strength for each set of grout specimens to nearest 0.1 MPa (or 10 psi) at 7 and 28 days of age, unless otherwise specified.

13. Precision and Bias

13.1 *Precision*—The single-operator coefficient of variation has been found to be 1.6 %. Therefore, results of two properly conducted tests by the same operator on the same sample using proper equipment should not differ from each other by more than 4.5 % of their average.[3]

13.2 *Bias*—No statement on bias has been made since there are no standard reference materials.

[3] The precision data are based on testing results available from ASTM. Request RR: C08-1014.

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Designation: C 943 – 02

Standard Practice for Making Test Cylinders and Prisms for Determining Strength and Density of Preplaced-Aggregate Concrete in the Laboratory[1]

This standard is issued under the fixed designation C 943; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope

1.1 This practice covers procedures for making standard test cylinders used to determine the compressive strength and density of preplaced-aggregate (PA) concrete.

1.2 The values stated in SI units are to be regarded as the standard. The values given in parentheses are for information only.

1.3 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

2. Referenced Documents

2.1 *ASTM Standards:*

C 192/C 192M Practice for Making and Curing Concrete Test Specimens in the Laboratory[2]

C 637 Specification for Aggregates for Radiation-Shielding Concrete[2]

C 937 Specification for Grout Fluidifier for Preplaced-Aggregate Concrete[2]

C 938 Practice for Proportioning Grout Mixtures for Preplaced-Aggregate Concrete[2]

C 939 Test Method for Flow of Grout for Preplaced-Aggregate Concrete (Flow Cone Method)[2]

C 940 Test Method for Expansion and Bleeding of Freshly Mixed Grouts for Preplaced-Aggregate Concrete in the Laboratory[2]

3. Summary of Practice

3.1 Coarse aggregate is placed in a standard cylinder mold having end plates to which pipe fittings have been attached. Grout is pumped into the mold until full. The test cylinder, demolded after hardening, may be cured and used for determination of strength or cut into prisms for the determination of unit weight.

4. Significance and Use

4.1 This practice is used for making test cylinders or prisms of PA concrete. Cylinders are used for determining compressive strength and approximate density. Prisms, cut from cylinders, eliminate the surface effect and thus more accurately represent the actual density of PA concrete in place.

5. Apparatus

5.1 *Cylinder Molds* (Fig. 1), cast iron or steel, for making 150 by 300-mm (6 by 12-in.) cylinders. Base and top plates shall be arranged for tight assembly to the cylinder. All mating and inside surfaces shall be machined smooth such that the assembled mold will be essentially watertight. End plates shall be drilled and tapped at their centers for standard 19 mm (¾-in.) pipe nipples. The top end plate shall also be perforated, as shown in Fig. 2.

5.2 *Venting Fabric*, white cotton cloth, free of oil and grease.

5.3 *Grouting Apparatus* (Fig. 3), capable of delivering grout at a uniform rate of 1.4 to 2.8 L (0.05 to 0.10 ft^3)/min at pressures up to 345 kPa (50 psi).

5.4 *Mallet*, with rubber or rawhide head weighing approximately ¼ kg (½ lb).

5.5 *Platform Scales*, accurate to within 0.3 % of the test load at any point within the range of use.

5.6 *Stop Watch*, least reading not more than 0.2 s.

5.7 *Flow Cone*—See Test Method C 939.

5.8 *Thermometer*, accurate to 0.5°C (1°F), for measuring ambient and grout temperatures.

6. Materials

6.1 *Coarse Aggregate*—Except when tests are made for specific projects, coarse aggregate shall conform to the requirements of Specification C 637, Table number 2, Coarse Aggregate, Grading 1, unless Grading 2 is specified.

[1] This practice is under the jurisdiction of ASTM Committee C09 on Concrete and Concrete Aggregates and is the direct responsibility of Subcommittee C09.41 on Concrete for Radiation Shielding.

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[2] *Annual Book of ASTM Standards*, Vol 04.02.

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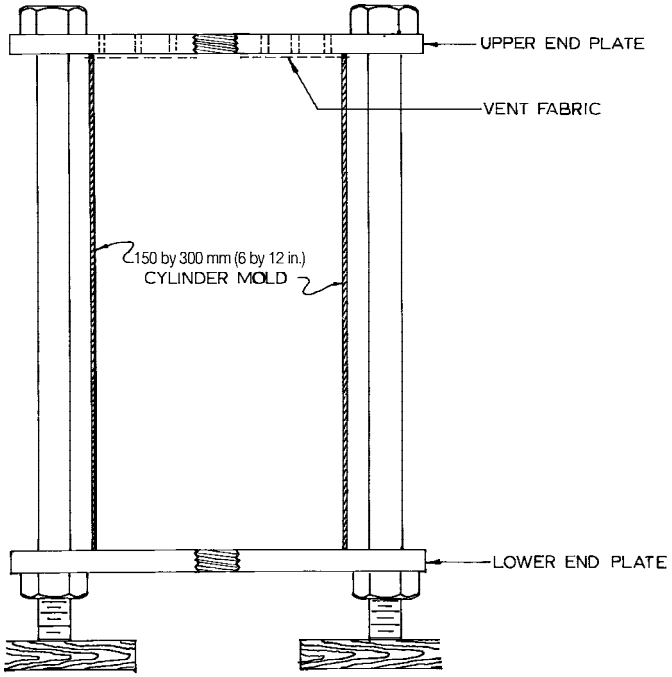

FIG. 1 Cylinder Mold Assembly Cross Section

6.2 *Grout*—Except when tests are made for specific projects, grout ingredients, proportioning, and mixing shall be in accordance with Practice C 938.

6.3 *Tests for Specific Projects*—When tests are to be made for specific projects, materials shall be representative of those in use or proposed for use in the work.

6.3.1 If not taken from project-mixed grout being used in the work, grout materials shall be mixed in the laboratory using the procedure described in Specification C 937.

7. Sampling

7.1 Coarse aggregate shall be representative of material used or to be used in the work or of that tested and stockpiled for test work.

7.2 Grout to be used in making PA concrete cylinders shall be typical of the batch from which it is drawn.

8. Preparation and Measurement of Prisms

8.1 When the determination of unit weight is required, prisms shall be cut from the central portions of the cylinders to dimensions as close as feasible to 101 by 101 by 254 mm (4 by 4 by 10 in.). Weigh the specimen to an accuracy of at least 1 part in 250. Compute the volume from the averages of two measurements of each dimension, taken to the nearest 0.25 mm (0.01 in.).

9. Procedure

9.1 *Temperature*:

9.1.1 When test cylinders are prepared in the laboratory, bring all materials to and maintain the laboratory in a temperature range of 23.0 ± 2.0°C (73.5 ± 3.5°F).

9.1.2 When test cylinders are prepared in the field, record ambient temperature in the vicinity of test operation.

9.2 Place each cylinder mold upright on its bottom plate on a firm, level surface.

9.3 Place the coarse aggregate in the mold in three approximately equal layers. Consolidate each layer by striking the mold ten times around its periphery with the mallet. When the mold has been filled, strike off the contents so that no aggregate particle projects above the plane of the top of the mold.

9.4 Place a single layer of venting fabric, in which a hole has been cut to match the 19-mm (¾-in.) hole in the top end plate, over the aggregate. Place the top plate on the mold, install bolts, and tighten. Attach the top and bottom valve assemblies and prepare to connect to hose from grout pump, as shown in Fig. 3.

9.5 Measure flow (Test Method C 939) and temperature of the representative sample of grout. Pour 800 ± 10 mL into a 1000-mL graduate for observation of expansion and bleeding, Test Method C 940.

9.6 If grout consistency is satisfactory, charge grout hopper and pump to waste until all water and diluted grout in the pump system has been expelled. Divert the grout flow to recirculation (to hopper) and make the connection to the bottom of the cylinder mold at valve *3*, shown in Fig. 3.

9.7 With valves *2*, *3*, and *4* open, fill the cylinder slowly by partially closing bypass valve *1*. When grout flows freely through upper plug valve *4*, open bypass and close valves *2* and *4*. Apply 70 to 100 kPa (10 to 15 psi) air pressure on the sample for 30 ± 5 s through air valve *5*; then close valve *3*. Move the grout supply line to succeeding cylinders in turn and repeat the above procedure for each.

9.7.1 The total elapsed time for intruding and pressurizing a cylinder mold shall be between 1½ and 3 min.

9.7.2 Grout, if continually agitated, may be used for intruding PA cylinders for as long as 30 min after original mixing provided no additional water is added and fluidity remains under 35 s, flow cone, Test Method C 939.

9.8 After grout expansion is complete, as determined by observation of the specimen set aside for the purpose, 9.5, remove the upper valve assembly and install a pipe plug in the center hole of the upper plate. Using care to avoid jarring the specimen, invert the cylinder, remove valve *3* assembly, and install a pipe plug in the center hole of the lower plate. Carefully turn the assembly back to its original position. Clean valves and fittings immediately upon removal from end plates.

10. Handling and Curing

10.1 Do not disturb the specimen after removal of valve assemblies for at least 24 h. Then strip molds and cure cylinders in accordance with the section on Curing of Practice C 192/C 192M.

10.2 Protect field-made specimens during initial storage period in the molds from direct sunlight or freezing temperatures. When large amounts of pozzolan are used in the grout mixture or in cool curing conditions, delay stripping of cylinders to avoid damaging the specimens.

11. Report

11.1 Report the following information:

11.1.1 Identification of specimens, date cast, and whether done in laboratory or field.

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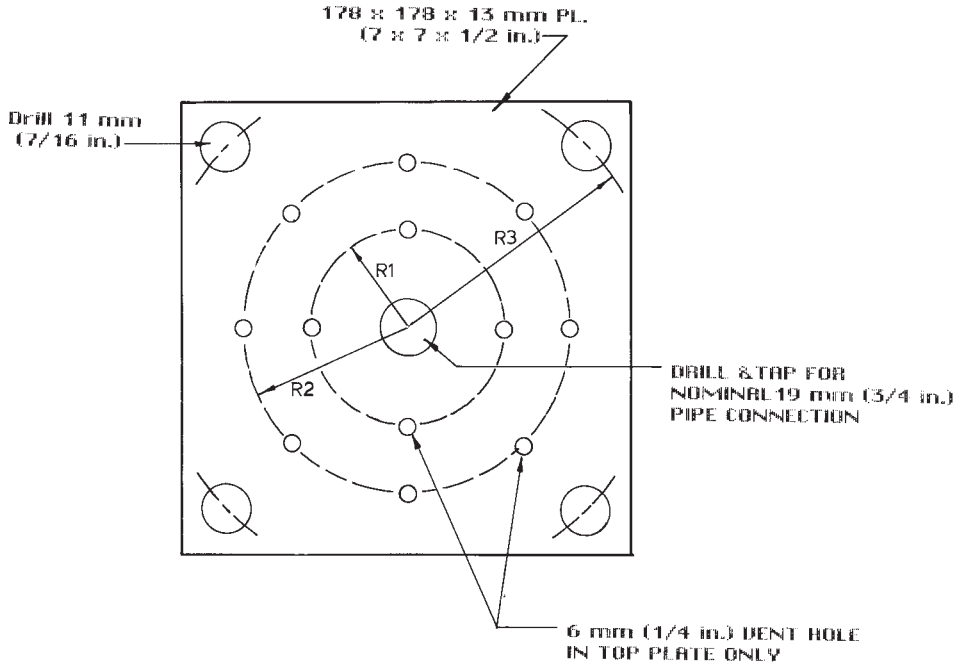
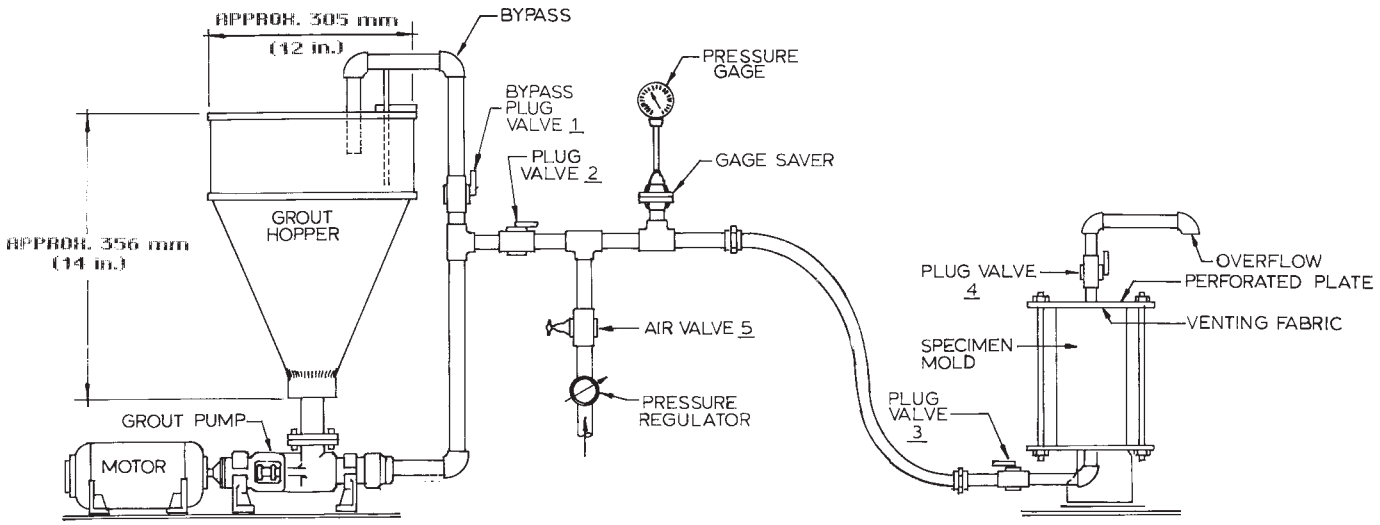


FIG. 2 End Plate Details



NOTE 1—Grout hose pipe and fittings 25 mm (1 in.) nominal.

FIG. 3 Typical Grouting Apparatus

11.1.2 Description of fine and coarse aggregate.

11.1.3 Identification of cementing materials and admixtures.

11.1.4 Description of grout including proportions, flow, temperature, expansion, and bleeding.

11.1.5 Temperatures at which the specimens were made and cured.

12. Keywords

12.1 cylinders; density; flow cone; grout; grouting apparatus; preplaced-aggregate; prisms; strength

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Designation: C 944 – 99 (Reapproved 2005)

Standard Test Method for Abrasion Resistance of Concrete or Mortar Surfaces by the Rotating-Cutter Method[1]

This standard is issued under the fixed designation C 944; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope

1.1 This test method covers a procedure for determining the resistance of either concrete or mortar to abrasion. This test method is similar to Procedure B of Test Method C 779/C 779M.

1.2 The values stated in SI units or inch–pound units are to be regarded separately as standard. The values stated in each system may not be exact equivalents; therefore, each system shall be used independently of the other. Combining values from the two systems may result in non–conformance with the standard.

1.3 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

2. Referenced Documents

2.1 *ASTM Standards:* [2]

C 42 Test Method for Obtaining and Testing Drilled Cores and Sawed Beams of Concrete

C 418 Test Method for Abrasion Resistance of Concrete by Sandblasting

C 779/C 779M Test Method for Abrasion Resistance of Horizontal Concrete Surfaces

3. Significance and Use

3.1 This test method gives an indication of the relative wear resistance of mortar and concrete based on testing of cored or fabricated specimens. This test method has been successfully used in the quality control of highway and bridge concrete subject to traffic. Primarily intended for use on the top ends of 152-mm [6-in.] diameter concrete cores, mortar specimens, or other samples of concrete of insufficient test area to permit the conduct of tests by Test Method C 418 or C 779/C 779M, this test method is also applicable on concrete surfaces in place by measuring the abrasion loss as described in Section 9, Procedure B, of Test Method C 779/C 779M.

4. Apparatus

4.1 *Abrasion Device*—A drill press or similar device with a chuck capable of holding and rotating the abrading cutter at a speed of 200 r/min and exerting a force of either a normal load of 98 ± 1 N [22 ± 0.2 lbf] or a double load of 197 ± 2 N [44 ± 0.4 lbf] on the test specimen surface. Fig. 1 shows a commercial drill press and Fig. 2 illustrates details of the rotating cutter. The difficulty in maintaining a constant load on the abrading cutter when using the lever, gear, and spring system of a drill press has been eliminated by placing the desired load directly upon the spindle that turns the cutter. The machine consists essentially of a frame that supports the drive motor, stepped pulley, and spindle. A clamping device to hold the specimen is built into the base.

4.2 *Rotating Cutter*—A rotating cutter similar to that shown in Fig. 2 and Fig. 3 shall be used in which 22 37.5 mm [1.5 in.] diameter dressing wheels and 24 25.4 to 31.75 mm [1 to 1.25 in.] diameter washers are mounted. The washers as received shall be stacked and locked on a bolt for the purpose of reducing their diameter to the specified range to avoid restricting abrasion of the concrete by the washers. Cutter assembly, including washers, shall be locked onto horizontal rods such that individual dressing wheels are free to turn independently. The overall diameter of the cutter or the diameter of the circular area abraded is 82.5 mm [3¼ in.]. Care shall be taken to achieve constant contact between the rotating cutter and the entire test surface of the sample. This can be better accomplished if the cutters have a swivel connection allowing some vertical movement. If the dressing wheels have one rounded edge, they shall be mounted with the rounded edge toward the vertical shaft. The individual grinding wheel dressers on the horizontal shaft of the cutter shall be repositioned whenever a

[1] This test method is under the jurisdiction of ASTM Committee C09 on Concrete and Concrete Aggregates and is the direct responsibility of Subcommittee C09.62 on Abrasion Testing of Concrete.

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[2] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

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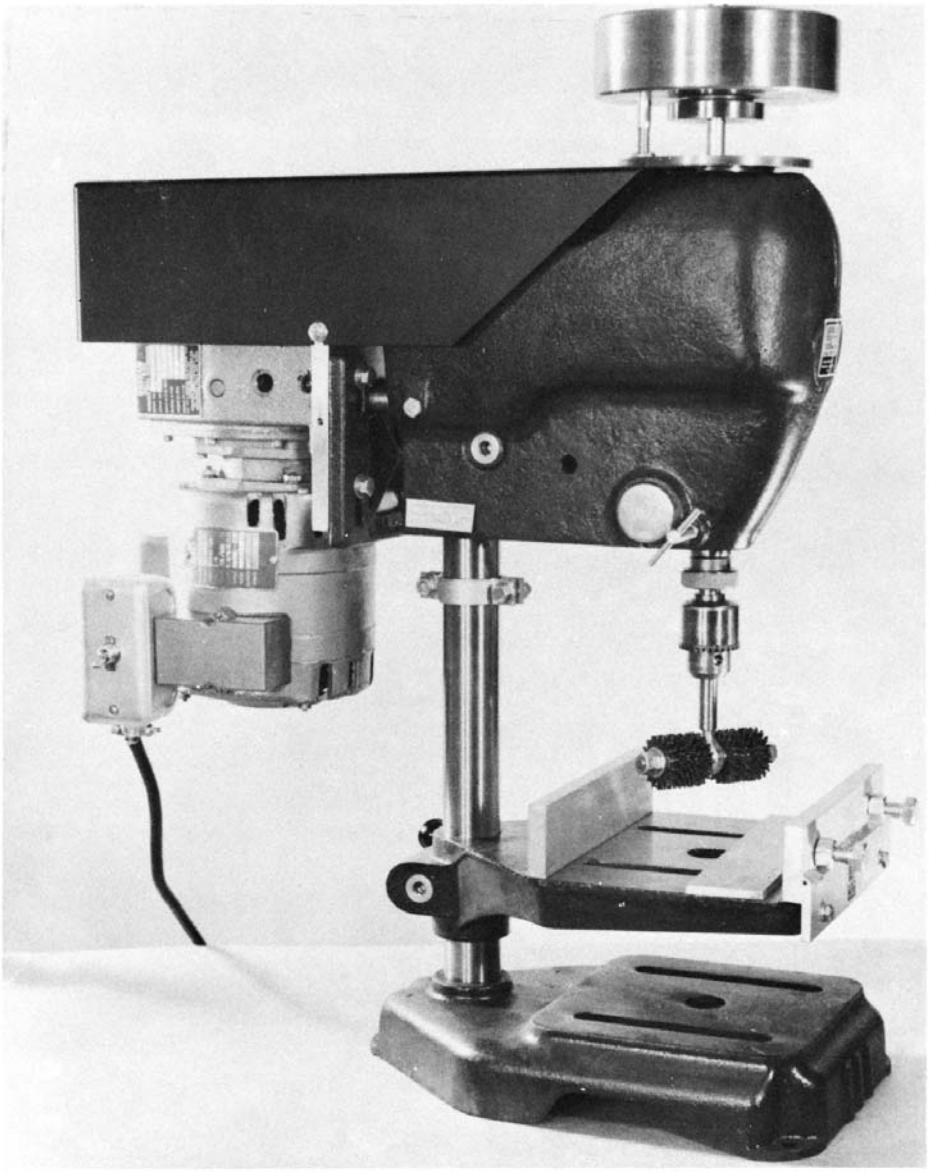

FIG. 1 Rotating-Cutter Drill Press

change in the diameter of the outer cutters becomes apparent. This is accomplished by reversing each set of dressing wheels to bring the smaller diameter cutters toward the vertical shaft.

4.2.1 In making a test, the rotating cutter is held in a raised position by means of the rod provided, the specimen clamped securely in position, and motor started. The rotating cutter is then lowered into contact with the specimen for a specified time, after which the cutter is raised.

4.2.2 A set of dressing wheels shall be replaced periodically, preferably after each 90 min of use. The washers may be ground or replaced to maintain the proper diameter.

4.3 *Balance*—A balance having a capacity of at least 4 kg, and accurate to at least 0.1 g.

4.4 *Leveling Plate*—The base plate upon which the specimen rests shall be capable of rotating in the horizontal plane so that the specimens when placed thereon can be positioned to secure maximum contact with the rotating cutter throughout the full test area.

5. Sampling

5.1 Cores shall be taken in accordance with Test Method C 42.

6. Specimens

6.1 The specimens used in this test shall be of any size and shape that can be accommodated by the abrasion device and the balance provided. The surface to be tested shall be either formed or finished and shall be positioned in the plane of contact of the cutter.

7. Procedure

7.1 Determine the mass of the specimen to the nearest 0.1 g.

7.2 Fasten the specimens securely in the abrasion device so that the surface to be tested is normal to the shaft.

7.3 Mount the rotating cutter device in the abrasion device.

7.4 Start the motor and lower the cutter slowly until just in contact with the surface of the specimen.

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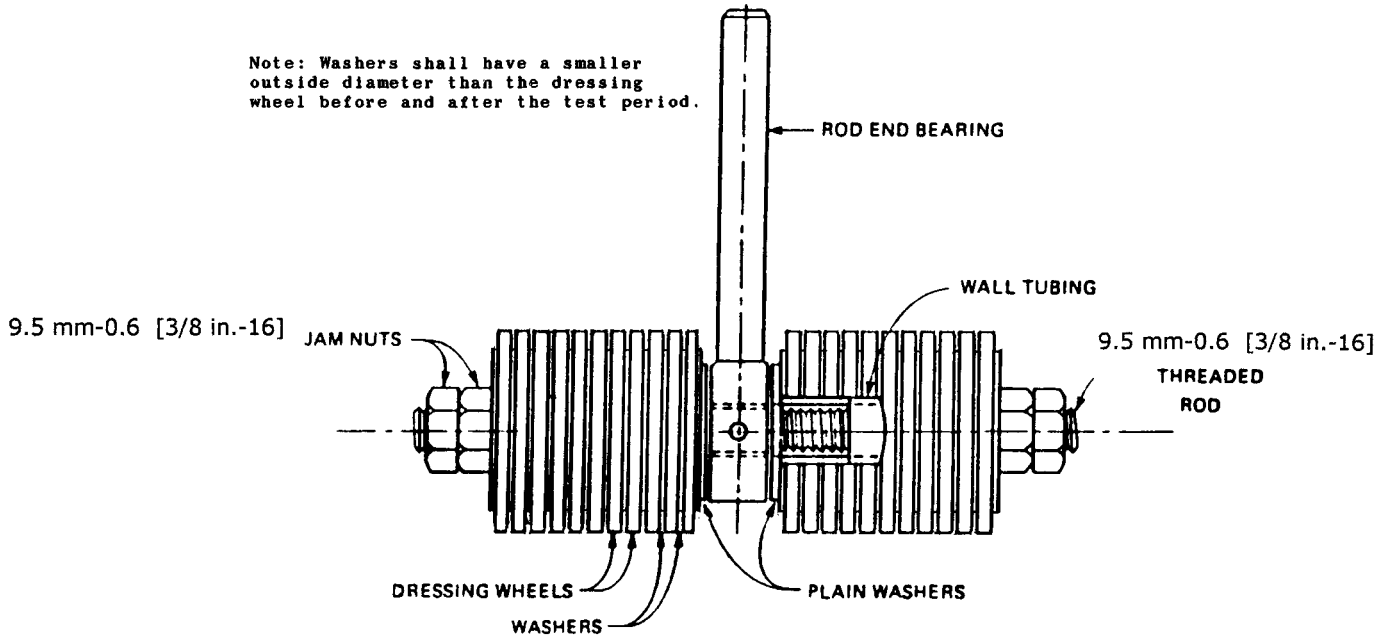

FIG. 2 Typical Rotating Cutters

7.5 Continue abrasion with a normal or a double load on the specimen for 2 min after contact between the cutter and the surface. At the end of each 2-min abrasion period, remove the test specimen from the device and clean surfaces to remove debris using a soft brush or blow the surface with air. Determine the specimen mass to the nearest 0.1 g. The minimum test schedule shall involve three 2-min periods conducted on three separate areas of representative surfaces of the concrete or mortar.

7.6 For concrete that is highly resistant to abrasion additional testing may be required. Doubling the applied load, or the time, or both, as shown in the following chart, should provide more comprehensive information on such concrete.

Abrasion Cycle		Load, N (lbf)	Test Frequency/Period
A	Normal	98 (22)	3 × 2 min
B	Double load	197 (44)	3 × 2 min

7.7 When testing surfaces in place, or when the depth of wear is to be determined due to significant differences in surface density, refer to Test Method C 779/C 779M Procedure B, to determine abraded depth using the apparatus in this test method.

8. Report

8.1 Report the following information on:

8.1.1 Description of surface,

8.1.2 Size of specimen,

8.1.3 Type of finish,

8.1.4 Concrete compaction, age, and strength,

8.1.5 Applied surface treatment,

8.1.6 Time of abrasion and load used (normal or double),

8.1.7 Average loss in grams or depth of wear in millimetres and,

8.1.8 Loss in mass and time abraded.

9. Precision and Bias

9.1 *Precision*—Criteria for judging the acceptability of abrasion resistance test results obtained by this test method are as follows:

9.1.1 *Normal Load Condition*—The single-operator coefficient of variation has been found to be 21 %. Therefore, the results of two properly conducted tests by the same operator on similar samples should not differ from each other by more than 59 % of the average.

9.1.2 *Double Load Condition*—The single-operator coefficient of variation has been found to be 12.6 %. Therefore, the results of two properly conducted tests by the same operator on similar samples should not differ from each other by more than 36 % of their average.

9.2 *Bias*—The procedure in this test method has no bias because the value of abrasion resistance of concrete surfaces can be only defined in terms of a test method.

10. Keywords

10.1 abrasion; concrete; impact; mortar; wear

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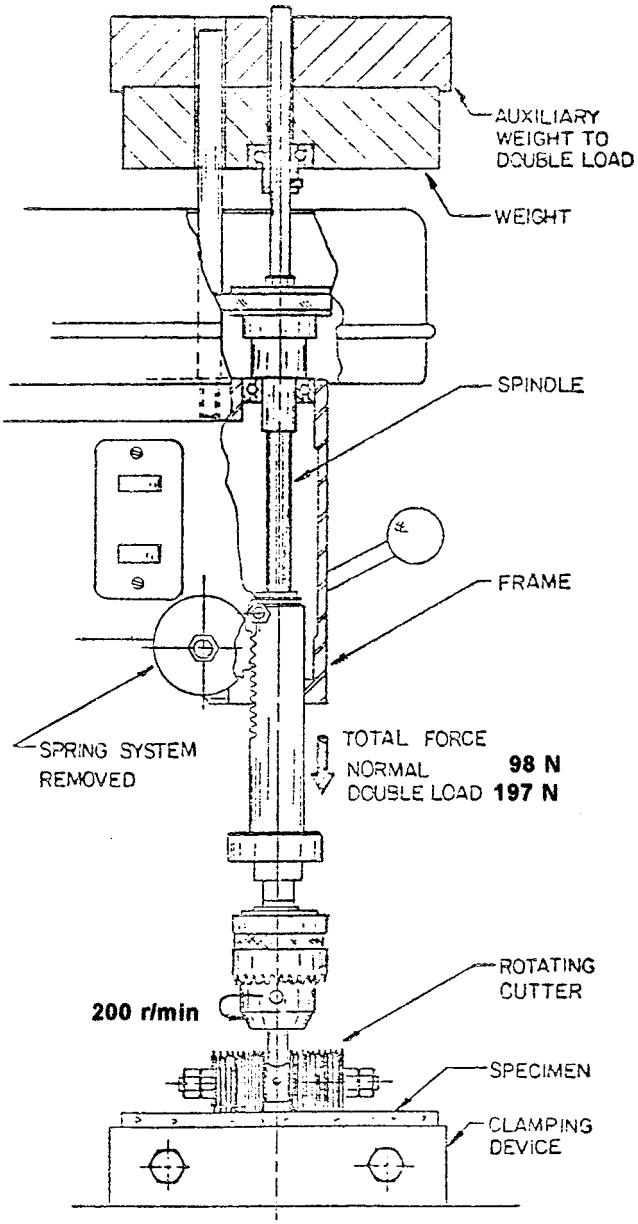

FIG. 3 Design Details of Rotating-Cutter Drill Press

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Designation: C 953 – 06

Standard Test Method for Time of Setting of Grouts for Preplaced-Aggregate Concrete in the Laboratory[1]

This standard is issued under the fixed designation C 953; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope*

1.1 This method covers the determination test of time of setting of hydraulic cement grout mixtures used in preplaced-aggregate (PA) concrete using the vicat apparatus.

1.2 The values stated in SI units are to be regarded as the standard.

1.3 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

2. Referenced Documents

2.1 *ASTM Standards:* [2]

C 191 Test Methods for Time of Setting of Hydraulic Cement by Vicat Needle

C 938 Practice for Proportioning Grout Mixtures for Preplaced-Aggregate Concrete

C 511 Specification for Mixing Rooms, Moist Cabinets, Moist Rooms, and Water Storage Tanks Used in the Testing of Hydraulic Cements and Concretes

3. Summary of Method

3.1 The time of setting, initial and final, of a sample of fluid grout is determined using the Vicat apparatus.

4. Significance and Use

4.1 This test method determines the setting time of grout mixed to the fluid consistency required for its use in PA concrete.

4.2 The time of setting is also useful in determining the acceptability of components of grout that must be mixed to the fluid consistency required for production of PA concrete.

5. Apparatus

5.1 *Vicat Apparatus*, in accordance with Test Method C 191.

5.2 *Moist Room*, maintained in accordance with Specification C 511.

6. Test Sample

6.1 The test sample shall consist of at least 300 mL of grout taken from a freshly-mixed batch prepared in accordance with Practice C 938 obtained from a mixer at the laboratory or construction site.

7. Procedure

7.1 Warm the Vicat conical ring and base plate to approximately 100 °C.

7.2 Apply a thin film of paraffin wax to the base of the conical ring and place the waxed conical ring on the base plate. Place a weight on the conical ring to ensure intimate contact with the base plate and allow the conical ring and plate to cool to room temperature.

7.3 Fill the conical ring apparatus with grout flush with its top within 2 min after completion of mixing. Strike off the grout flush with the top of the conical ring by a single oblique stroke of a sharp-edged trowel held at a slight angle to the top of the ring. Smooth the top, if necessary, with a few light touches of the pointed end of the trowel. Take care not to compress the sample during these cutting and smoothing operations. The time of completion of molding shall be taken as the start of measurement of time of set.

7.4 Store the specimen in the moist room.

7.5 Determine the time of setting using the procedure described in Test Method C 191 except that the first reading shall be taken 3 h ± 15 min after pouring the specimen.

NOTE 1—Grouts used to evaluate grout fluidifier or for use in PA concrete will normally reach initial set in about 4 h.

8. Report

8.1 The report shall include the following:

8.1.1 Identification of the grout sample,

8.1.2 Time of initial setting and final setting in hours and minutes,

8.1.3 Temperature of group sample at the beginning of the test, and

[1] This test method is under the jurisdiction of ASTM Committee C09 on Concrete and Concrete Aggregates and is the direct responsibility of Subcommittee C09.41 on Concrete for Radiation Shielding.

Current edition approved Feb. 1, 2006. Published February 2006. Originally approved in 1981. Last previous edition approved in 1997 as C 953 – 87(1997).

[2] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

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8.1.4 Ambient temperature during the test.

9. Precision and Bias

9.1 *Precision*—When data have been compiled that are suitable for use in preparing a precision statement, such statement will be prepared.

9.2 *Bias*—No statement on Bias can be prepared because there are no standard reference materials.

10. Keywords

10.1 grout; preplaced-aggregate concrete; time of setting

SUMMARY OF CHANGES

Committee C09 has identified the location of selected changes to this test method since the last issue, C 953 – 87(1997), that may impact the use of this test method. (Approved February 1, 2006)

(*1*) Added new paragraph 1.2 and renumbered subsequent paragraphs.

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Designation: C 954 – 07

Standard Specification for Steel Drill Screws for the Application of Gypsum Panel Products or Metal Plaster Bases to Steel Studs from 0.033 in. (0.84 mm) to 0.112 in. (2.84 mm) in Thickness[1]

This standard is issued under the fixed designation C 954; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

This standard has been approved for use by agencies of the Department of Defense.

1. Scope*

1.1 This specification covers minimum requirements for steel drill screws for use in fastening gypsum panel products or metal plaster bases to steel members from 0.033 in. (0.84 mm) to 0.112 in. (2.84 mm) in thickness.

1.2 This specification also covers physical properties and test methods for determining performance requirements.

1.3 The values stated in inch-pound units are to be regarded as the standard. The values given in parentheses are for information only.

1.4 The following safety hazards caveat pertains only to the test methods described in this specification. *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

2. Referenced Documents

2.1 *ASTM Standards:* [2]

A 510 Specification for General Requirements for Wire Rods and Coarse Round Wire, Carbon Steel

C 11 Terminology Relating to Gypsum and Related Building Materials and Systems

C 1396/C 1396M Specification for Gypsum Board

C 1513 Specification for Steel Tapping Screws for Cold-Formed Steel Framing Connections

3. Terminology

3.1 *Definitions:*

3.1.1 For definitions relating to gypsum and related building materials and systems, see Terminology C 11.

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *steel drill screw*—self-drilling tapping screw with the ability to drill its own hole, form or cut mating threads without deforming its own threads or breaking during assembly.

4. Materials

4.1 Screws shall be manufactured from Grade 1018 to 1022 steel wire manufactured in accordance with Specification A 510.

5. Physical Properties

5.1 *Metallurgical Requirements*:

5.1.1 The surface of the screw shall be carbonitrided to a depth of 0.004 to 0.008 in. (0.10 to 0.20 mm).

5.1.2 The core hardness shall be 32 to 40 HRB after being drawn at a minimum temperature of 625 °F (330 °C).

5.1.3 The screw shall have no band of free ferrite between the case and core nor shall the case contain appreciable amounts of retained austenite or other soft constituents.

5.1.4 Surface hardness shall be determined by a micro hardness instrument at "the root of the thread profile," as exposed by removal of enough material to form a flat surface along the length of the screw.

5.1.5 *Ductility*—Screws shall have sufficient ductility to be able to withstand a 5° bend without visible signs of fracture when tested as specified in paragraph 8.2.1 of Specification C 1513.

5.2 *Dimensions and Permissible Variations*:

5.2.1 *General*:

5.2.1.1 *Head Diameter*— The head of the screw shall not be out of round more than 0.021 in. (0.51 mm) and have the following shape and dimensions:

5.2.1.2 *Screw Diameter*— Screws shall have a major diameter not less than 0.136 in. (3.45 mm).

5.2.1.3 *Points*, shall provide for self-drilling into steel studs from 0.333 in. (0.84 mm) to 0.112 in. (2.84 mm) in thickness and meet the performance tests in Section 6.

[1] This specification is under the jurisdiction of ASTM Committee C11 on Gypsum and Related Building Materials and Systems and is the direct responsibility of Subcommittee C11.02 on Specifications and Test Methods for Accessories and Related Products.

Current edition approved Aug. 1, 2007. Published August 2007. Originally approved in 1981. Last previous edition approved in 2004 as C 954 – 04.

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5.2.1.4 *Driving Recess*, shall be a No. 2 "Phillips" design with a minimum depth of 0.104 in. (2.64 mm) as determined with a "Phillips" penetration depth gage or a recess of equal performance.

5.2.1.5 *Length*—Nominal lengths shall be minimum length.

5.2.2 *Screws for Fastening Gypsum Board*:

5.2.2.1 Screw-head minimum diameter shall be 0.3145 in. (8.00 mm).

5.2.2.2 The top of the head shall be flat. The outer flange thickness shall be 0.025 ± 0.005 in. (0.64 ± 0.13 mm). The contour beneath the flange head shall be such that the screw head shall be able to be driven so that the head of the screw rests immediately below the surface of the gypsum panel products.

5.2.2.3 The threads shall extend to the lower edge of the head contour.

5.2.3 *Screws for Fastening Metal Plaster Bases*:

5.2.3.1 Screw head minimum diameter shall be 0.437 in. (11.1 mm).

5.2.3.2 The top of the head shall be flat or contoured. The underside of the head shall be flat.

5.2.3.3 The threads shall extend to the underside of the head.

6. Performance Requirements

6.1 *Spin-Out*:

6.1.1 Screws shall self-drill and drive into a stud 0.0598 in. (1.5 mm) thick with an approximate hardness of 65 HRB without spin-out.

6.1.2 Screws shall self drill and drive into a stud 0.105 in. (2.7 mm) thick, with a hardness of 80 HRB without spin-out.

6.2 *Performance*:

6.2.1 When tested in accordance with Section 10, screws shall meet the requirements as follows:

6.2.1.1 *Gypsum Panel Products*—Screw threads shall be adequate to pull the head of the screw below the surface of the gypsum panel through four layers of kraft paper placed over the gypsum panel products and a steel stud 0.033 in. (0.84 mm) thick when tested in accordance with 10.5.1.

6.2.1.2 *Metal Plaster Bases*—Screw threads shall be adequate to pull metal lath tight against the flange of a steel stud 0.033 in. (0.84 mm) thick so that when subjected to a steady pull, the lath will tear and not slip out from under the screw head when tested in accordance with 10.5.1.

7. Finish and Appearance

7.1 Screws shall be corrosion-resistant treated with a material which will not inhibit adhesion to joint compounds or plaster and will not bleed through decorative finishes.

7.2 Screws shall be straight, clean, smooth, neatly formed, and free of defects such as burrs and deformations.

8. Sampling

8.1 Obtain not less than 90 screws from not less than five containers.

9. Number of Tests and Retests

9.1 Test a minimum of five screws for each test. If any of the first lot fails, test 25 more screws.

9.2 If two or more of the second lot fail the second test, then the represented lot fails to meet the specified requirements.

10. Test Method

10.1 *Summary of Test Method*:

10.1.1 This test method utilizes steel screws designed for use to hold gypsum panel products and metal plaster base materials applied with power-driven screw guns of 2500 r/min maximum to steel studs.

10.2 *Significance and Use*:

10.2.1 This test method evaluates the ability of steel drill screws used to secure gypsum panel products and metal plaster bases to certain steel framing members.

10.2.2 The test shall be conducted in a laboratory or on-site.

10.3 *Apparatus*:

10.3.1 *Power-Driven Drill Screw Gun*, having the capacity of turning 2500 r/min maximum (free spindle speed).

10.3.2 A *Vice,* or similar device to support the stud during the test.

10.4 *Materials*:

10.4.1 *Kraft Paper*, 0.010 in. (0.25 mm) thick.

10.4.2 *Steel Stud*—One section of 0.033-in. thick stud (0.84-mm), 1 section of 0.0598-in. (1.5-mm) thick stud and with a hardness of 65 HRB, and 1 section of 0.105-in. (2.7-mm) thick stud and with a hardness of 80 HRB.

10.4.3 *Gypsum Wallboard*— Specification C 1396/C 1396M, Type X, ⅝ in. (16 mm) thick.

10.4.4 *Screw Specimens*, to be tested.

10.4.5 *Diamond Mesh Metal Lath*, 2.5/lb/yd^2.

10.5 *Procedure for Performance Tests*:

10.5.1 Using the screw specimen, attach gypsum board or metal lath to center of a flange of a steel stud which has been securely and rigidly supported.

10.5.1.1 Grasp the metal lath with locking pliers and pull steadily in a plane parallel to the plane of the lath. Observe whether the lath tears before it slips out from under the screw head.

10.5.1.2 With the drill propelling the screw at 2500 r/min maximum (free spindle speed), exert a total pressure of 30 lbf (135.5 N) (dead weight plus applied force).

10.6 *Precision and Bias*—No statement is made regarding the precision and bias of this test method, since the result of the test method is reported in nonnumerical terms.

11. Inspection

11.1 Inspection of steel drill screws shall be agreed upon by the purchaser and the producer or supplier as part of the purchase agreement.

12. Rejection and Rehearing

12.1 Rejection of steel drill screws that fail to conform to the requirements of this specification shall be reported to the producer or supplier promptly and in writing within 10 working days from receipt of shipment by the purchaser. Notice of rejection shall contain a specific statement as to the respects in which the screws have failed to conform to the requirements of this specification. In case of dissatisfaction with the results of the test, and at the request of the producer or

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supplier, such notice of rehearing shall be supported by results of a test conducted by a mutually agreeable independent laboratory.

13. Certification

13.1 When specified in the purchase agreement, the producer or supplier shall furnish a report certifying that, at time of shipment, the screws were in compliance with the requirements of this specification.

14. Packaging and Marking

14.1 Screws shall be packaged in substantial commercial containers constructed so as to preserve the contents in good condition and to ensure acceptance and safe delivery by common or other carriers, at the lowest rate, to the point of delivery.

14.2 The containers shall be so constructed that the contents can be partially removed without destroying the container's ability to serve as a receptacle for the remainder of the contents.

14.3 Individual packages and shipping containers shall be marked with the type and length of screw and the name of the manufacturer or distributor.

15. Keywords

15.1 steel drill screw; steel self-drilling tapping screw

SUMMARY OF CHANGES

Committee C11 has identified the location of selected changes to this specification since the last issue, C 954 – 04, that may impact the use of this specification. (Approved August 1, 2007)

(*1*) Replaced reference to Specification C 36 with Specification C 1396/C 1396M in 10.4.3 and Referenced Documents.

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Designation: C 955 – 09a

Standard Specification for Load-Bearing (Transverse and Axial) Steel Studs, Runners (Tracks), and Bracing or Bridging for Screw Application of Gypsum Panel Products and Metal Plaster Bases[1]

This standard is issued under the fixed designation C 955; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope*

1.1 This specification covers steel studs, runners (tracks), and bracing or bridging (with a base metal thickness range of not less than 0.0329 in. (0.836 mm)) for screw application of gypsum panel products and metal plaster bases in load-bearing (transverse and axial) construction assemblies. Steel of lesser thickness shall be permitted in additional engineered products.

1.2 The values stated in inch-pound units are to be regarded as standard. The values given in parentheses are mathematical conversions to SI units that are provided for information only and are not considered standard.

1.3 The following precautionary caveat pertains only to the test method portion, Section 8, of this specification: *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

2. Referenced Documents

2.1 *ASTM Standards:*[2]

A 653/A 653M Specification for Steel Sheet, Zinc-Coated (Galvanized) or Zinc-Iron Alloy-Coated (Galvannealed) by the Hot-Dip Process

A 792/A 792M Specification for Steel Sheet, 55 % Aluminum-Zinc Alloy-Coated by the Hot-Dip Process

A 875/A 875M Specification for Steel Sheet, Zinc-5 % Aluminum Alloy-Coated by the Hot-Dip Process

A 1003/A 1003M Specification for Steel Sheet, Carbon, Metallic- and Nonmetallic-Coated for Cold-Formed Framing Members

C 11 Terminology Relating to Gypsum and Related Building Materials and Systems

C 954 Specification for Steel Drill Screws for the Application of Gypsum Panel Products or Metal Plaster Bases to Steel Studs from 0.033 in. (0.84 mm) to 0.112 in. (2.84 mm) in Thickness

2.2 *AISI Standard:* [3]

Specification for the Design of Cold-Formed Steel Structural Members

AISI Code of Standard Practice for Cold-Formed Steel Structural Framing Committee on Framing Standards—2006 Edition

3. Terminology

3.1 *Definitions:* Definitions shall be in accordance with Terminology C 11.

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *members*, *n*—studs, runners, tracks, bracing, bridging, accessories or other items manufactured in accordance with this standard.

3.2.2 *structural member*, *n*—a member in a steel framed system in which the loading exceeds any of the following conditions: a transverse load of 20 lbf/ft (290 N/m) of member length, or an axial load, exclusive of sheathing, of 200 lbf (890 N) per member.

4. Materials and Manufacture

4.1 Members shall be manufactured from steel meeting the requirements of Specification A 1003/A 1003M.

4.2 The minimum steel thickness (base steel) shall be not less than 0.0329 in. (0.84 mm).

4.3 Individual measurements before the application of protective coating shall be not less than 95 % of the specified design thickness.

4.4 Members shall have a protective coating in accordance with Table 1, CP 60 minimum.

4.5 Edges of members shall be manufactured to minimize burrs and sharp edges.

4.6 Factory punch-outs, when provided, shall be located along the centerline of the webs of members and shall have

[1] This specification is under the jurisdiction of ASTM Committee C11 on Gypsum and Related Building Materials and Systems and is the direct responsibility of Subcommittee C11.02 on Specifications and Test Methods for Accessories and Related Products.

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[2] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

[3] Available from American Iron and Steel Institute (AISI), 1140 Connecticut Ave., NW, Suite 705, Washington, DC 20036, http://www.steel.org.

***A Summary of Changes section appears at the end of this standard.**

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TABLE 1 Coating Designations

Coating Classification	Coating Designator	Minimum Coating Requirements			
		Zinc-Coated[A] oz/ft² (g/m²)	Zinc Iron[B] oz/ft² (g/m²)	55 % Al-Zinc[C] oz/ft² (g/m²)	Zinc-5 %[D] oz/ft² (g/m²)
Metallic Coated	CP 60	G 60 (Z 180)	A 60 (ZF 180)	AZ 50 (AZM 150)	GF 30 (ZGF 90)
	CP 90	G 90 (Z 275)	Not Applicable	AZ 50 (AZM 150)	GF 45 (ZGF 135)
Painted Metallic	PM	The metallic coated substrate shall meet the requirements of metallic coated. In addition, the paint film shall have a minimum thickness of 0.5 mil (0.013 mm) per side (primer plus topcoat) with a minimum primer thickness of 0.1 mil (0.0002 mm) per side.[E]			

[A] Zinc-coated steel sheet as described in Specification A 653/A 653M.
[B] Zinc-iron alloy-coated steel sheet as described in Specification A 653/A 653M.
[C] 55 % Aluminum-zinc alloy-coated steel sheet as described in Specification A 792/A 792M.
[D] Zinc-5 % aluminum alloy-coated steel sheet as described in Specification A 875/A 875M.
[E] In accordance with the requirements of Specification A 1003/A 1003M.

center-to-center spacing of not less than 24 in. (610 mm). Web punch-outs maximum width shall be the lesser of 0.5 times the member depth, d, or 2½ in. (64 mm). Web punch-out length shall not exceed 4 ½ in. (114 mm). Minimum distance between the end of the member and the near edge of the web punch-out shall be 10 in. (254 mm). The size of the factory punch-outs shall not exceed the size used in design and the center-to-center spacing shall not be less than that used in design.

4.7 The properties and strength of members shall be computed in accordance with the AISI Specification for the Design of Cold-Formed Steel Structural Members.

5. Performance Requirements

5.1 When tested in accordance with Section 8, members shall be capable of pulling the head of the screw below the surface of the gypsum panel product without spin out (see Fig. 1).

6. Dimensions and Permissible Variations

6.1 Data for calculating design performance shall be supplied by the manufacturer.

6.2 The width of the surface to which the sheathing board is attached shall be not less than 1¼ in. (32 mm).

6.3 Runners (track) shall be formed in a U-shaped configuration, having a depth compatible with that of the studs of the same nominal size.

6.4 Minimum height of runner (track) flanges shall be ¾ in. (19 mm).

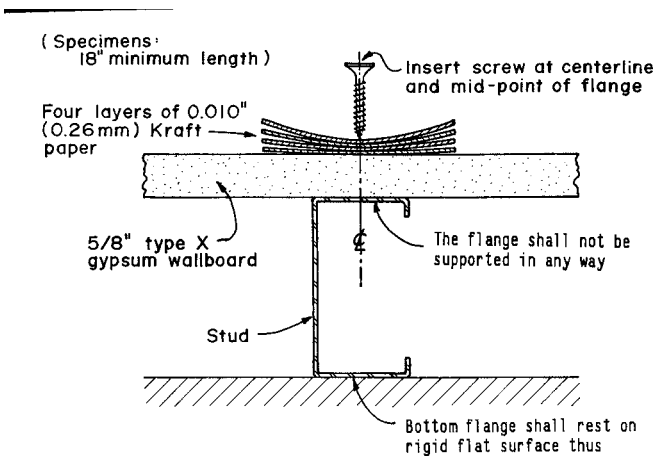

FIG. 1 Studs

6.5 Members shall be manufactured within the limits as shown in Table 2 and Fig. 2.

6.6 Bracing and bridging shall have configuration and steel thickness to provide secondary support for the studs in accordance with the AISI Specification for the Design of Cold-Formed Steel Structural Members.

7. Workmanship, Finish, and Appearance

7.1 The steel members shall be free of defects that interfere with the purpose for which they are intended.

8. Penetration Test

8.1 *Significance and Use*—This test method provides a procedure for evaluating the member's ability to pull the head of a screw below the surface of the gypsum panel product. It shall be used to determine compliance with this specification. The degree of performance of this test method with service performance has not been determined.

8.2 *Apparatus shall satisfy the following*:

TABLE 2 Manufacturing Tolerances

Dimension[A]	Item Checked	Structural Studs, in. (mm)	Structural Track, in. (mm)
A	length	+ 3/32 (2.38) – 3/32 (2.38)	+ ½ (12.7) – ¼ (6.35)
B[B]	web width	+ 1/32 (0.79) – 1/32 (0.79)	+ 1/32 (0.79) + ⅛ (3.18)
C	flare overbend	+ 1/16 (1.59) – 1/16 (1.59)	+ 0 (0) – 3/32 (2.38)
D	hole center width	+ 1/16 (1.59) – 1/16 (1.59)	NA
E	hole center length	+ ¼ (6.35) – ¼ (6.35)	NA
F	crown	+ 1/16 (1.59) – 1/16 (1.59)	+ 1/16 (1.59) – 1/16 (1.59)
G[C]	camber	⅛ (3.2) max per 10 ft	1/32 per ft (0.79) ½ max (12.7)
H[C]	bow	⅛ (3.2) max per 10 ft	1/32 per ft (0.79) ½ max (12.7)
I	twist	1/32 per ft (0.79) ½ max (12.7)	1/32 per ft (0.79) ½ max (12.7)

[A] All measurements shall be taken not less than 1 ft (305 mm) from the end.
[B] Outside dimension for stud; inside for track.
[C] ⅛ in. (3 mm) max per 10 ft (3000 mm) represents L/960 maximum for overall camber and bow. Thus a 20 ft (6000 mm) long member would have ¼ in. (6 mm) permissible maximum; a 5 ft (1500 mm) long member would have 1/16 in. (1.5 mm) permissible maximum.

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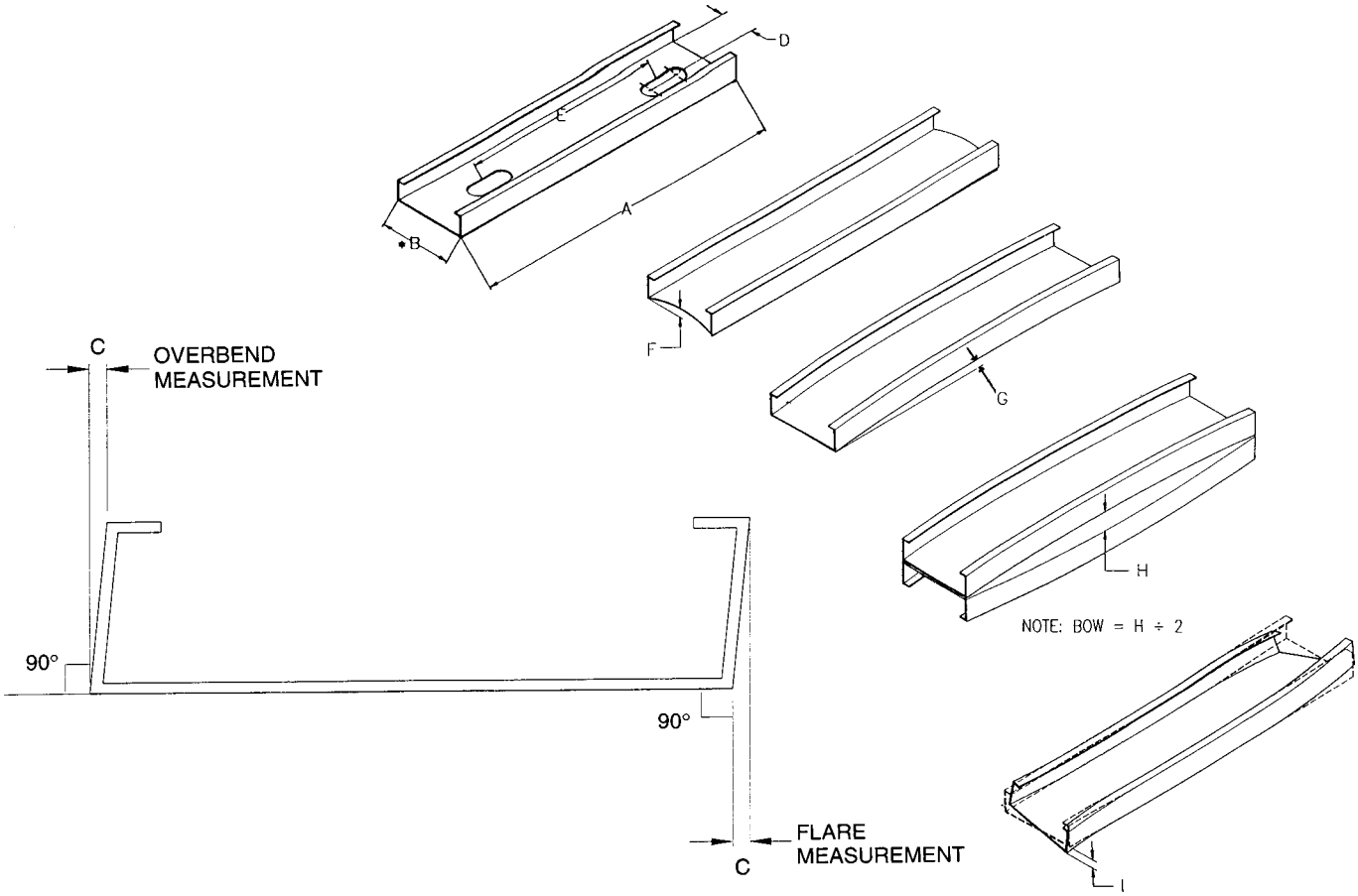

FIG. 2 Manufacturing Tolerances

8.2.1 *Electric Drill* capable of 2500 r/min (free spindle speed), supplied with a screw driving bit to fit the screw used in the test.

8.3 *Materials shall satisfy the following*:

8.3.1 *Gypsum Board*, Type X, ⅝ in. (16 mm) thick.

8.3.2 *Screws*—Specification C 954, 1 in. (25.4 mm) long.

8.3.3 *Kraft Paper*, 0.010 in. (0.25 mm) thick.

8.4 *Sampling*—One member shall be selected from each bundle or package but not more than ten from any one shipment for testing.

8.5 *Specimen Preparation*:

8.5.1 Each member to be tested shall be cut into test specimens not less than 18 in. (460 mm) long.

8.5.2 For each test, one piece of gypsum board, 6-in. (152-mm) square, shall be cut not less than 12 in. (305 mm) from the edge or end of the wallboard.

8.5.3 For each test, four pieces of kraft paper, 2-in. (51-mm) square shall be cut.

8.6 *Number of Tests and Retests*:

8.6.1 Five specimens of members shall be tested.

8.6.2 If more than one test specimen fails to meet the requirements, two more test specimens shall be chosen for retesting.

8.7 *Report*—Report shall indicate all specimens meeting the requirements of this specification if the screw penetrated the steel and the screw did not spin out; or shall indicate all specimens failing if the screw did not penetrate the steel, or the screw spun out.

8.8 *Precision and Bias*—No statement is made about either the precision or bias of this test method since the result merely states whether or not there is conformance to the criteria for success specified in the procedure.

9. Inspection

9.1 Inspection of the members shall be agreed upon between the purchaser and the producer or supplier as part of the purchase agreement.

10. Rejection

10.1 When specified in the purchase agreement, members that fail to conform to the requirements of this specification shall be rejected. Rejection shall be reported to the producer or supplier promptly and in writing. The notice of rejection shall contain a statement documenting how the member has failed to conform to the requirements of this specification and the purchase agreement.

11. Certification

11.1 When specified in the purchase agreement, a producer's or supplier's report shall be furnished at the time of shipment certifying that the product is in compliance with this specification.

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12. Marking and Identification

12.1 Groups of like members shall be marked with a label, or a tag attached thereto. Marking shall include the rollformer's identification (name, logo, or initials), length, quantity, and rollformer's member designator including member depth, flange size, and minimum steel thickness in mils or inches exclusive of protective coating.

12.2 In addition to the marking referenced in 12.1, individual members shall have a legible label, stencil, or embossment, at a maximum distance of 96 in. (2440 mm) on center, on the member, with the following minimum information:

12.2.1 The rollformer's identification (that is, name, logo, or initials).

12.2.2 The minimum steel thickness, in mils or inches, exclusive of protective coatings.

12.2.3 The minimum yield strength in kip per square inch (megapascals).

12.2.4 The minimum protective coating shall be indicated with the appropriate coating designator in accordance with Table 1.

12.3 Where color-coding of members or bundles of like members is employed, the standard color-coding in Table 3 shall be used.

13. Protection

13.1 Material shall be protected during shipment as required. When specified in the purchase order, the members shall be packaged in accordance with the purchaser's instructions.

13.2 Material shall be received and stored in accordance with AISI COSP, paragraph F3.

14. Keywords

14.1 runners; screws; section properties; studs; thickness

TABLE 3 Color Codes for Members

Color	Minimum Base Metal Thickness, mils	Minimum Decimal Equivalent,	
		in.	(mm)
White	33	0.0329	(0.836)
Yellow	43	0.0428	(1.087)
Green	54	0.0538	(1.367)
Orange	68	0.0677	(1.720)
Red	97	0.0966	(2.454)
Blue	118	0.1180	(2.997)

SUMMARY OF CHANGES

Committee C11 has identified the location of selected changes to this specification since the last issue, C 955 – 09, that may impact the use of this specification. (Approved September 1, 2009)

(*1*) Added metric equivalents to Table 1 for Painted Metallic Minimum Coating Requirements.

(*2*) Added metric equivalents to Footnote C of Table 2.

Committee C11 has identified the location of selected changes to this specification since the last issue, C 955 – 08a, that may impact the use of this specification. (Approved May 1, 2009)

(*1*) Revised camber and bow tolerances in Table 2.

(*2*) Added new Footnote C in Table 2.

Committee C11 has identified the location of selected changes to this specification since the last issue, C 955 – 08, that may impact the use of this specification. (Approved September 1, 2008)

(*1*) Deleted CP40 coatings, Painted coatings, and Footnote F from Table 1.

(*2*) Deleted ISO 9223 from Referenced Documents.

Committee C11 has identified the location of selected changes to this specification since the last issue, C 955 – 07, that may impact the use of this specification. (Approved March 1, 2008)

(*1*) Added metric equivalents in Table 1.

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Designation: C 956 – 04

Standard Specification for Installation of Cast-In-Place Reinforced Gypsum Concrete[1]

This standard is issued under the fixed designation C 956; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope

1.1 This specification covers the minimum requirements for the installation of cast-in-place reinforced gypsum concrete over permanent formboard.

1.2 The values stated in inch-pound units are to be regarded as the standard. The values given in parentheses are for information only.

1.3 The text of this standard references notes and footnotes which provide explanatory material. These notes and footnotes (excluding those in tables and figures) shall not be considered requirements of the standard.

2. Referenced Documents

2.1 *ASTM Standards:* [2]

A 82 Specification for Steel Wire, Plain, for Concrete Reinforcement

A 185 Specification for Steel Welded Wire Reinforcement, Plain, for Concrete

A 568 Specification for Steel, Sheet, Carbon, and High-Strength, Low-Alloy, Hot-Rolled and Cold-Rolled, General Requirements for

A 653/A 653M Specification for Steel Sheet, Zinc-Coated (Galvanized) or Zinc-Iron Alloy-Coated (Galvannealed) by the Hot-Dip Process

C 11 Terminology Relating to Gypsum and Related Building Materials and Systems

C 317 Specification for Gypsum Concrete

C 726 Specification for Mineral Fiber Roof Insulation Board

E 72 Test Methods of Conducting Strength Tests of Panels for Building Construction

2.2 *American Concrete Institute Standard:*

ACI 318 Building Code Requirements for Reinforced Concrete[3]

2.3 *American Welding Society Standard:*

D1.1 Structural Welding Code Steel[4]

3. Terminology

3.1 Definitions shall be in accordance with Terminology C 11.

3.2 *Definitions:*

3.2.1 *primary framing, n*—structural members provided to support the reinforced gypsum concrete roof deck assembly.

3.2.1.1 *purlin, n*—a secondary structural member that spans the primary framing members and provides support for subpurlins.

3.2.2 *subpurlin, n*—a steel member applied transversely to the primary framing and purlins to support the formboards and to transmit the dead and live loads from the gypsum concrete slab to the primary framing.

3.2.2.1 *bulb tee, n*—a subpurlin, hot-rolled formed steel, rail-shaped section.

3.2.2.2 *truss tee, n*—a subpurlin fabricated from steel wire and strip, tee-shaped section.

3.2.3 *cross tee, n*—a steel tee-shaped section used to support a formboard end at right angles to the subpurlins where a formboard end does not occur over the purlin or primary framing.

3.2.4 *formboard, n*—sheet material used as a permanent form to support the gypsum concrete.

3.2.5 *reinforcement, n*—steel wire mesh or fabric used within the gypsum concrete slab to provide longitudinal and transverse strength.

3.2.6 *double-pouring, n*—the application of gypsum concrete in more than one layer to complete the full slab thickness. See 8.7.4.3.

3.2.7 *ribbon-pouring or strip-pouring, n*—the application of narrow ribbons of gypsum concrete, about 10 to 12 in. (254 to

[1] This specification is under the jurisdiction of ASTM Committee C11 on Gypsum and Related Building Materials and Systems and is the direct responsibility of Subcommittee C11.03 on Specifications for the Application of Gypsum and Other Products in Assemblies.

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[2] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

[3] Available from the American Concrete Institute, P.O. Box 19150, Detroit, MI 48219.

[4] Available from the American Welding Society, 550 N.W. La Jeune Rd., P.O. Box 351040, Miami, FL 33135.

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305 mm) wide by 1 to 1½ in. (25.4 to 38.1 mm) deep, across the width of the formboard at center of span between purlins.

4. Delivery of Materials

4.1 Materials shall be delivered in original packages, containers, or bundles bearing the brand name and name of producer or seller. Bulk materials shall be delivered with the brand name and name of the producer or seller shown on the accompanying bills of lading.

5. Storage of Materials

5.1 All materials shall be stored in a manner that prevents damage before use. When stored under tarpaulins, ventilation shall be provided to prevent moisture accumulation under the tarpaulin.

5.2 Formboard shall be stored flat and off the ground. Handling and stacking shall be done in such a manner to prevent damage to face, ends, and edges and keep dry until use.

5.3 When it is necessary to store gypsum concrete at the job site, the gypsum concrete shall be stored off the ground and kept dry until use.

6. Environmental Conditions

6.1 The minimum temperature at which gypsum concrete is mixed and placed is not specified. Gypsum concrete shall not be mixed with water containing ice crystals.

NOTE 1—An exothermic reaction during setting ensures complete hydration before freezing.

7. Materials

7.1 *Subpurlins*:

7.1.1 Subpurlins shall be designed to support live and dead loads of the roof deck.

7.1.2 Hot-rolled and cold-rolled steel shapes other than bulb tees or truss tees shall meet the requirements of this specification for subpurlins.

7.2 *Cross Tees*, shall be not less than 1¼ in. (31.75 mm) wide by ½ in. (12.7 mm) high, fabricated from not less than 26 gage zinc-coated steel conforming to Specifications A 653/A 653M or A 568.

7.3 *Formboard*:

7.3.1 *Mineral Fiber Formboard*, Specification C 726, not less than ¾ in. (19.0 mm) thick nor more than 3 in. (76 mm) thick. It shall sustain a uniform load of 20 lb/ft^2(97 kg/m^2).

7.3.1.1 Mineral fiber formboard shall be tested in accordance with the transverse loading test of Test Methods E 72.

7.3.1.2 The test specimen shall be uniformly loaded and supported at both edges and ends. The test specimens shall be supported at the perimeter with a frame providing 1 in. (25.4 mm) bearing on ends and ½ in. (12.7 mm) bearing on edges and 7 in. (177.8 mm) nominal clearance from the bed of the apparatus.

7.3.1.3 For formboards ¾ in. (19.0 mm) thick, test specimens shall be 48 in. (1200 mm) long by 24 in. (600 mm) wide.

7.3.1.4 For formboards 1 in. (25.4 mm) thick or greater, test specimens shall be 48 in. (1200 mm) long by 32 in. (800 mm) wide.

7.4 *Reinforcement*, Specification A 82, shall be fabricated from zinc-coated (galvanized) welded or woven steel wire mesh or fabric having an effective cross-sectional area of not less than 0.026 in.^{2} (16.77 mm)^2 per foot of slab width. Reinforcement shall be free of rust, scale, or other materials that reduce bond to the gypsum concrete.

7.4.1 *Hexagonal Reinforcing Mesh*, shall be fabricated from 2 in. (50.8 mm) hexagonal mesh formed of not less than 0.0410 in. (1.04 mm) diameter wires with longitudinal wires not less than 0.0625 in. (1.59 mm) in diameter, spaced not more than 3 in. (76.2 mm) on centers. Steel wire for fabricating wire mesh and fabric—Specification A 82.

7.4.2 *Rectangular Reinforcing Fabric*, Specification A 185, shall be fabricated from longitudinal wires not less than 0.1055 in. (2.68 mm) in diameter spaced not more than 4 in. (102 mm) on centers and transverse wires not less than 0.0800 in. (2.03 mm) in diameter spaced not more than 8 in. (203 mm) on centers.

7.5 *Gypsum Concrete*, Specification C 317, Class A.

7.6 *Water*, shall be potable and free of substances that could adversely affect the gypsum concrete.

7.7 *Expansion Filler Strip*, shall be not less than ¾ in. (19 mm) thick and equal in height to the abutting gypsum concrete and of the type specified by the producer of the gypsum concrete.

8. Installation

8.1 *Installation of Subpurlins*:

8.1.1 *Installation, Normal*:

8.1.1.1 *Subpurlins*—The subpurlins shall be placed transversely to the purlins and primary framing and shall be spaced to suit the size of the formboards specified. Subpurlins shall be of sufficient length so that their joints occur over purlins or primary framing. Subpurlin joints shall be alternated so that the joints are staggered one purlin space.

8.1.1.2 Subpurlins shall be welded to purlins and steel primary framing with ⅛ in. (3.2 mm) fillet welds not less than ½ in. (12.7 mm) long on alternate sides of the subpurlin at each intersection with purlins. Except as otherwise specified, welding shall be in accordance with AWS D1.1. Where primary framing is of wood, nails not less than 16d shall be used on each side of the subpurlins at each intersection. The nails shall be bent over approximately ¾ in. (19 mm) to securely clinch the flange of the subpurlin.

8.1.2 *Installation Seismic*:

8.1.2.1 *Subpurlins*—The subpurlins shall be welded at each intersection with the purlins with ⅛-in. (3.2-mm) fillet welds not less than 1 in. (25.4 mm) long, on one side. Both sides of the subpurlin shall be welded with ⅛-in. fillet welds not less than 2 in. (50.8 mm) long where subpurlin joints occur over the purlin. Both sides of the subpurlin shall be welded with ⅛-in. fillet welds not less than 2 in. long at shear transfer points and at intersections with exterior frame.

8.1.3 *Maximum Spans*—Refer to X2.1.3.

8.2 *Cross Tees*—Cross tees shall be provided where formboard ends are supported by purlins or the primary framing.

8.3 *Formboards*—Formboards shall be located face down on the flanges of the supporting members and with the ends on top of the purlins.

8.3.1 Gypsum concrete shall not be poured over formboards which have been wetted by rain or snow.

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8.3.2 The gypsum concrete shall be poured on the same day the formboards are installed.

8.4 *Reinforcement*—The mesh of wire fabric shall be located with the main longitudinal wires at right angles to the subpurlins and adjacent to the formboard at midspan between the purlins. Ends of the reinforcement shall be lapped not less than 4 in. (102 mm) or one mesh, whichever is greater.

8.4.1 Edges shall be butted, not lapped, unless required for fire rated or horizontal diaphragm construction. Reinforcement shall be cut to fit at walls, curbs, and openings, folded over on to itself, and extended into all areas when gypsum concrete is to be placed.

8.5 *Expansion Filler Strips*—Expansion filler strips shall be placed continuously against the walls, curbs, nailers, or other rigid surfaces that gypsum concrete will abut.

8.6 *Expansion Joints*—Expansion joints shall be located at expansion joints found in the main structure, at a maximum of 200 ft (61 m) on center in a direction parallel to the subpurlins on large buildings, at intersections of wings on L-, U-, T-, and H-shaped buildings and, wherever the roof framing changes direction. See X1.5.5.

8.7 *Gypsum Concrete Mixing and Placement*:

8.7.1 *General*—All equipment, including mixers, pumps, hoses, tools, and screeds shall be kept clean and free of set gypsum concrete throughout the placement operation.

8.7.2 *Proportioning*—The ratio of water to gypsum concrete shall be that specified by the producer of the gypsum concrete; additional water is prohibited. Volumetric or metering devices shall be used to ensure accurate measurement.

8.7.3 *Mixing*—Mixing shall be thorough but not overmixed. The slurry shall be discharged into placement equipment immediately after completion of mixing to avoid buildup of set material.

8.7.3.1 Calcium chloride or other admixtures shall not be added to the gypsum concrete.

8.7.4 *Placement*:

8.7.4.1 *General*—To avoid exposure to inclement weather and physical abuse, gypsum concrete shall be placed the same day as the installation of the formboard and reinforcement materials.

8.7.4.1.1 The deck shall be poured in sections of similar size.

8.7.4.2 *Screeds Grounds*—Screeds, such as metal bars or wood strips, shall be spaced approximately 10 ft (3050 mm) apart at right angles on top of the subpurlins at a height that will allow the gypsum concrete slurry to be leveled at the specified thickness.

8.7.4.2.1 Gypsum concrete cants, curbs, and drainage slopes shall be placed to the design thickness. Curbs around openings shall be permitted to be formed with the formboard.

8.7.4.3 The gypsum concrete shall be discharged into placement equipment immediately after completion of mixing.

8.7.4.3.1 The slurry shall be poured or discharged not more than 24 in. (600 mm) off the formboard to minimize impact and allowed to build to full thickness in one continuous operation. Double pouring shall not be permitted.

8.7.4.3.2 As soon as the slurry has stiffened enough to hold a full level, it shall be screeded to a true, even surface using a smooth, rigid straight-edge.

8.7.4.4 Place gypsum concrete cants, curbs, and drainage slopes to the design thickness. Curbs around openings shall be permitted to be formed with the formboard.

8.8 *Roof Overhangs*—Gypsum concrete shall not be placed on roof overhangs, eaves, or other similar locations, on formboards unless the underside is protected against direct wetting by a suitable facia drip cap overhang.

8.9 *Drying*—Construction moisture shall be removed from the building to permit drying of completed gypsum concrete slab, providing heat and ventilation where required. See X1.3.

8.10 *Protection of Completed Slab*—Gypsum concrete is not a finished traffic or weather protective surface. The top side of the completed gypsum concrete slab shall be protected with a permanent waterproof covering.

9. Keywords

9.1 calculation of diaphragm shear; gypsum concrete; gypsum roof deck

APPENDIXES

(Nonmandatory Information)

X1. GENERAL INFORMATION

X1.1 Limitations of Use

X1.1.1 *Roof Shapes and Designs*—Gypsum roof decks meeting this specification can be installed on flat, warped, sawtooth, curved, or pitched roofs.

NOTE X1.1—On flat roofs, a minimum pitch of ⅛ in./ft (10.4 mm/m) is recommended.

X1.1.2 *Moisture Exposure*—Cast-in-place gypsum concrete is not recommended for general use in occupancies where it may be exposed to sustained relative humidity greater than 90 % or condensing moisture. The producer of the gypsum concrete should be consulted regarding limitations of use in high humidity occupancies.

X1.1.3 *Temperature Exposures*—Where intermittent or extended exposures to high temperatures are to be expected, such as in slabs directly exposed to radiant heat over furnace

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breachings, the gypsum concrete producer should be consulted for specific recommendations.

X1.1.4 *Acid Fumes*—If acid fumes are to be encountered, the producer of the gypsum concrete should be consulted for his specific recommendations.

X1.1.5 *Surface Protection*—Gypsum concrete decks shall not be used as a finished surface to bear traffic or other loads. Protective permanent waterproof coverings shall be installed as soon as possible after completion of the slab.

X1.1.6 *Welding Precautions*—Except as modified in the body of this specification, welding shall be in accordance with AWS D1.1. Welding will not be permitted when the temperature is lower than 0°F (−18°C), when steel surfaces are wet, or under other conditions not recommended by the American Welding Society.

X1.2 Support for Suspended Ceilings

X1.2.1 Suspended ceilings should be hung from the primary framing. Ceilings may be hung from the subpurlins. A design check shall be made in accordance with applicable building codes and regulations to verify that the structural adequacy of the subpurlins and the added weight of the ceiling will not cause the subpurlins to deflect more than that allowed by the roof deck or ceiling sign or that allowed by subpurlin design. Hangers should not be fastened into or through the gypsum concrete slab or the formboards. Similar precautions should be followed for the suspension of unit heaters, light troffers, and piping.

X1.3 Drying of Slabs

X1.3.1 Subsequent to the placing of gypsum concrete, ventilation accompanied by heat is recommended below the slabs to remove the excess construction moisture resulting from the slab pouring, placement of concrete floors, masonry plastering, and other similar construction work. Where natural ventilation is inadequate, mechanical ventilation is required to remove construction moisture from the building. When suspended ceilings are installed below the slabs, provisions should be made to permanently vent the enclosed space below the deck, particularly that space above a suspended ceiling, using sufficient gravity or mechanical ventilation to remove all construction moisture and excessive moisture vapor resulting from subsequent occupancy.

X1.4 Provisions for Expansion and Contraction

X1.4.1 Provision for relief of expansion and contraction should be considered for all cast-in-place roof decks. Wherever expansion joints have been provided in the main structure, they must also be provided in the roof deck and roof covering. The use of suitable expansion strips at the junction between roof slabs and parapets is recommended for further relief of expansion and contraction stresses in the slabs. Where subpurlins are used, edge expansion strips need be used only at walls where subpurlins abut walls at right angles.

X1.5 Roof Coverings

X1.5.1 Built-up or other suitable roof coverings should be specified over poured gypsum concrete roof slabs.

X1.5.2 The application of metal or other rigid types of roof covering over poured gypsum concrete decks is not generally recommended. If sheet metal roof coverings are required over portions of a poured gypsum concrete deck, their anchoring members must be attached either by the use of toggle bolts passing entirely through the slab and formboards or by suitable fastening to the primary members. Where shingle-type roof coverings are contemplated, the gypsum concrete producer's recommendations for attachment should be followed.

X1.5.3 Provisions for furnishing and installing roof sumps should be included in other sections of the specification.

X1.5.4 The application of roof covering should follow as promptly after the placing of gypsum concrete as possible. The top surface of the slab should be reasonably hard as indicated by the disappearance of visible moisture gloss from its surface.

X1.5.5 Expansion joints should be installed in the roofing wherever they are provided in the gypsum concrete and the main structure.

X1.6 Painting Undersides of Gypsum Concrete Roof Decks

X1.6.1 The underside of the gypsum deck is usually not further decorated. If painting is desired, it should be deferred until the formboard and the slab are thoroughly dry through their total thickness.

X1.7 Framing Requirements

X1.7.1 The primary framing to receive subpurlins and the primary framing spaced to directly receive the formboards for the gypsum concrete are not part of the gypsum concrete specifications. However, it is essential that the following provisions regarding such framing be incorporated in other sections.

X1.7.1.1 Spacing of primary structural supports to receive the subpurlins of the reinforced gypsum concrete assembly must be such that design stresses in the specified subpurlins are not exceeded.

X1.7.1.2 When subpurlins are not used, the following provisions should be made to anchor the slab to the primary framing members to resist uplift forces and movements due to temperature changes.

X1.7.1.2.1 Weld steel tee sections sized from 1 by 1 by ⅛ in. (25.4 by 25.4 by 3.2 mm) to 1½ by 1½ by 3⁄16 in. (38.1 by 38.1 by 4.7 mm) across the joists at approximately 32 in. (812.8 mm) to 48 in. (1219 mm) on center depending on type of formboard used. The reinforcing mat must then be wire tied to these tee sections.

X1.7.1.2.2 Wiring of formboard to the frame as a means of providing uplift resistance is not permissible.

X1.7.1.3 Heavy concentrated loads, such as water tanks, large fan bases, cooling towers, and flag poles, must not be imposed directly on the poured gypsum concrete roof deck. Details must provide for transmitting such loads directly to the walls, primary framing or structural supports.

X1.7.1.4 The architect or engineer should assign by specification the responsibility for furnishing and installing of roof nailers and for framing at openings and expansion joints, eaves and wall angles, and similar special items.

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X1.7.1.5 It is important that the gypsum concrete roof deck be designed with sufficient slope to provide adequate drainage and eliminate the possibility of free-standing water.

X1.8 Evaluation and Inspection

X1.8.1 Metal framing members should be of the sizes specified and have a factory applied coating to prevent rust.

X1.8.1.1 Welds should meet the requirements of AWS D1.1 and be correctly located and of the size specified.

X1.8.2 Formboards should be of the type, size, and thickness specified and should be free of damage rendering them unfit for their intended use.

X1.8.3 Reinforcement should have main longitudinal strands laid at right angles to subpurlins and near formboard at midspan.

X1.8.3.1 Edges should be butted. Edges should not be lapped unless required for fire rated or horizontal diaphragm construction.

X1.8.3.2 Ends should be lapped a minimum of 4 in. (101.6 mm). At slab edges, the fabric should be folded back to provide greater bond within the slab.

X1.8.4 Top surface of the gypsum concrete slab should be smooth and free of any protrusions.

X2. DESIGN

X2.1 General

X2.1.1 Reinforced gypsum concrete shall be designed to support the anticipated loads and to withstand the forces to which they may be subjected without exceeding the allowable stresses specified in X2.1.1.1. Except as otherwise specified, methods of design shall follow established principles of mechanics and principles of design for reinforced concrete in accordance with ACI 318.X2. The minimum ratio of area of reinforcement to area of portland cement concrete for shrinkage and temperature shall not apply to gypsum concrete.

X2.1.1.1 *Allowable Stresses*—not more than:

Compressive stress in bending	0.25 f_g(Note X2.1)
Axial compressive or bearing stress	0.20 f_g(Note X2.1)
Bond stress (plain reinforced bars)	0.02 f_g(Notes X2.1 and X2.2)
Bond stress (for deformed reinforced bars or electrically welded mesh)	0.03 f_g(Note X2.1)
Shear stress	0.02 f_g(Notes X2.1 and X2.2)

NOTE X2.1—f_g indicates the compressive strength of the gypsum concrete as determined in accordance with the requirements of Specification C 317, Class A.

NOTE X2.2—Gypsum concrete meets the bond and shear requirements of this section when reinforced with steel wire reinforcement conforming to the requirements of 7.4.

X2.1.2 *Minimum Thickness*—Not less than 2 in. (50.8 mm) measured at all points over the top surface of the formboard.

X2.1.3 *Maximum Spans*—Not more than 31 in. (787 mm) between supports when using subpurlins and formboards.

X2.1.4 *Maximum Spacing of Supports*—Not more than 36 in. (914 mm) for gypsum concrete slabs over formboards applied directly to primary framing members.

X2.2 *Seismic and Wind Conditions*—Where the gypsum concrete roof deck is used as a horizontal diaphragm to transmit seismic or wind loads, the subpurlins shall be installed in accordance with 9.1.2.

X2.2.1 *Diaphragm Shear*—Determine shear in poured gypsum concrete diaphragms as follows:

$$Q_e = [0.16\, f_g t C_1 + 1000\, (k_1 d_1 + k_2 d_2)] C_2 C_3 \quad \text{(X2.1)}$$

$$Q_m = [0.0000133\, f_g t C_1 + 0.175\, (k_1 d_1 + k_2 d_2)] C_2 C_3 \quad \text{(X2.2)}$$

where:

- Q_e = allowable shear on diaphragm in lb per linear ft which includes a one-third increase for short-term loading,
- Q_m = allowable shear on diaphragm in kN·m which includes a one-third increase for short-term loading,
- f_g = oven-dry compressive strength of gypsum in lbf/in.^{2}(kPa) as determined by tests conforming to this specification,
- C_1 = 1.0 for Class A gypsum concrete,
- t = thickness of gypsum concrete between subpurlins in inches (mm). For the purpose of computing diaphragm shear values, t shall be not more than 4 in. (101.6 mm),
- k_1 = number of mesh wires per ft (wires per m) passing over subpurlins,
- d_1 = diameter of mesh wires passing over subpurlins in inches (mm) except hexagonal mesh,
- k_2 = number of mesh wires per foot (wires per metre) parallel to subpurlins or 0.7 times the number of hexagonal wires,
- d_2 = diameter in inches of mesh wires parallel to subpurlins or of hexagonal wires,
- C_2 = 1.4 for Class A gypsum concrete using the truss tee and 1.0 for bulb tee, and
- C_3 = 0.85 for perlited gypsum concrete, 1.0 for gypsum concrete made with wood chips or wood shavings.

The allowable shear values are shown in Tables X2.1 and X2.2.

NOTE X2.3—k_1 = X2.5 for 2 in. (50.8 mm) hexagonal mesh woven of No. 19 gage galvanized wire with additional longitudinal No. 16 gage galvanized wires spaced every 3 in. (75.8 mm) across the width of the mesh.

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TABLE X2.1 Allowable Shear Values in Pounds per Foot Using Truss or Bulb Tee Subpurlins[A]

Perlited Gypsum Concrete—Class A (500 psi)						
Concrete Thickness, in.	Truss Tee Subpurlins, Mesh Type			Bulb Tee Subpurlins, Mesh Type		
	Galvanized			Galvanized		
	4 × 8 #12 × #14	6 × 6 #10 × #10	Hexagonal	4 × 8 #12 × #14	6 × 6 #10 × #10	Hexagonal
2	718	831	878	513	593	627
2.5	765	878	926	547	627	661
3	813	926	974	581	661	695
3.5	860	973	1021	615	695	729
4	908	1021	1069	649	729	763

Wood Chips or Wood Shavings Gypsum Concrete—Class A (500 psi)							
Concrete Thickness, in.	Truss Tee Subpurlins, Mesh Type			Bulb Tee Subpurlins, Mesh Type			Shear Values[B]
	Galvanized			Galvanized			
	4 × 8 #12 × #14	6 × 6 #10 × #10	Hexagonal	4 × 8 #12 × #14	6 × 6 #10 × #10	Hexagonal	
2	844	977	1033	603	698	738	840
2.5	900	1033	1089	643	738	778	
3	956	1089	1145	683	778	818	
3.5	1012	1145	1201	723	818	858	
4	1068	1201	1257	763	858	898	

[A] The tabulated shear values are for short-term loads due to wind or earthquake forces and are not permitted a one-third increase for duration of load.
[B] Recommended shear transfer provided such truss tees are embedded not less than ⅜ in. (9.5 mm) deep in gypsum concrete and are welded to the structural frame with not less than ⅛ in. (3.2 mm) fillet welds not less than 1½ in. (38.1 mm) long at 6 in. (152.4 mm) on centers both sides bottom flanges and the mesh is tied to top flange of such subpurlins.

TABLE X2.2 Allowable Shear Values in kiloNewtons per Meter Using Truss or Bulb Tee Subpurlins (Metric)[A]

Perlited Gypsum Concrete—Class A (3450 kPa)						
Concrete Thickness, mm	Truss Tee Subpurlins, Mesh Type			Bulb Tee Subpurlins, Mesh Type		
	4 × 8 #12 × #14	6 × 6 #10 × #10	Hexagonal	4 × 8 #12 × #14	6 × 6 #10 × #10	Hexagonal
50.8	10.5	12.1	12.8	7.47	8.65	9.15
63.5	11.2	12.8	13.5	7.97	9.15	9.64
76.2	11.8	13.5	14.2	8.46	9.64	10.1
88.9	12.5	14.2	14.9	8.96	10.1	10.6
101.6	13.2	14.9	15.6	9.45	10.6	11.1

Wood Chips or Wood Shavings Gypsum Concrete—Class A (3450 kPa)							
Concrete Thickness, mm	Truss Tee Subpurlins, Mesh Type			BulbTeeSubpurlins,MeshType			Shear Values[B]
	4 × 8 #12 × #14	6 × 6 #10 × #10	Hexagonal	4 × 8 #12 × #14	6 × 6 #10 × #10	Hexagonal	
50.8	12.3	14.2	15.1	8.79	10.2	10.8	12.3
63.5	13.1	15.1	15.9	9.37	10.8	11.3	
76.2	13.9	15.9	16.7	9.96	11.3	11.9	
88.9	14.8	16.7	17.5	10.5	11.9	12.5	
101.6	15.6	17.5	18.3	11.1	12.5	13.1	

[A] The tabulated shear values are for short-term loads due to wind or earthquake forces and are not permitted a one-third increase for duration of load.
[B] Recommended shear transfer provided such truss tees are embedded not less than 9.5 mm (⅜ in.) deep in gypsum concrete and are welded to the structural frame with not less than 3.2 mm (⅛ in.) fillet welds not less than 38.1 mm (1½ in.) long at 152.4 mm (6 in.) on centers both sides bottom flanges and the mesh is tied to top flange of such subpurlins.

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Designation: C 977 – 03

Standard Specification for Quicklime and Hydrated Lime for Soil Stabilization[1]

This standard is issued under the fixed designation C 977; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

This standard has been approved for use by agencies of the Department of Defense.

1. Scope

1.1 This specification pertains to quicklime and hydrated lime, either high calcium, dolomitic, or magnesian lime, for use in stabilization of soils (See Note 2).

NOTE 1—Quicklime and hydrated lime act upon clay soils and may render such soils suitable for highway construction and for other load-bearing applications. In most cases, lime causes finely divided clay particles to agglomerate into coarser particles which improves load-bearing properties and subsequently the lime-treated soil hardens by chemical reaction.

NOTE 2—No attempt is made to present requirements for by-product lime, commercial lime slurry, etc. Specification requirements for these materials could be better determined on a local basis.

1.2 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

2. Referenced Documents

2.1 *ASTM Standards:*

C 25 Test Methods for Chemical Analysis of Limestone, Quicklime, and Hydrated Lime[2]

C 50 Practice for Sampling, Sample Preparation, Packaging, and Marking of Lime and Limestone Products[2]

C 51 Terminology Relating to Lime and Limestone (as Used by the Industry)[2]

C 110 Test Methods for Physical Testing of Quicklime, Hydrated Lime, and Limestone[2]

D 6276 Test Method for Using pH to Estimate the Soil-Lime Proportion Requirement for Soil Stabilization[3]

3. Chemical Composition

3.1 Unless otherwise specified, for definitions of terms used in this specification, refer to Terminology C 51.

3.2 Quicklime and hydrated lime for soil stabilization shall conform to the following chemical composition:

Calcium and Magnesium Oxides (on a non-volatile basis, minimum %)	90.0
Carbon Dioxide (taken at point of manufacture, maximum %)	5.0
Free Moisture (taken at point of manufacture, maximum %)	2.0

4. Physical Properties

4.1 *Hydrated Lime*, shall have not more than 3 % retained on a No. 30 (590-µm) sieve and not more than 25 % retained on a No. 200 (75-µm) sieve.

4.2 *Quicklime*:

4.2.1 *Particle Size of Quicklime*—Quicklime shall all pass a 1.0-in. (24.4-mm) sieve.

4.2.2 Quicklime for soil stabilization shall have a temperature rise of a minimum of 30°C in 20 min as measured by Test Methods C 110.

4.2.3 *Residue of Quicklime*—Quicklime for soil stabilization shall have not more than 10 % residue as measured by Test Methods C 110.

5. Field Applications

5.1 When quicklimes are used, ensure that thorough mixing of the lime and soil is accomplished and all lime pebbles have been hydrated with additional water and distributed uniformly throughout the soil. There shall be no lime pebbles present before the compaction operation starts. Check by turning soil with a spade at representative intervals and inspect for visible lime pebbles. Care should be exercised on initial dry applications to minimize environmental dusting.

[1] This specification is under the jurisdiction of ASTM Committee C07 on Lime and is the direct responsibility of Subcommittee C07.02 on Specifications and Guidelines.

Current edition approved May 10, 2003. Published July 2003. Originally approved in 1983. Last previous edition approved in 2002 as C 977 – 02.

[2] *Annual Book of ASTM Standards*, Vol 04.01.

[3] *Annual Book of ASTM Standards*, Vol 04.09.

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5.2 For hydrated limes, additional water shall be added to the lime-soil mixture to facilitate mixing and uniform distribution of the hydrated lime in the soil layer. There shall be no lime clumps present before the compaction operation starts. Check by turning soil with a spade at representative intervals and inspect for visible lime clumps. Care should be exercised on initial dry applications to minimize environmental dusting.[4]

6. Test Method

6.1 The chemical analysis of quicklime and hydrated lime shall be conducted in accordance with Test Methods C 25.

6.2 The particle size of hydrated lime shall be determined in accordance with the sieve analysis of hydrated lime in Test Methods C 110.

6.3 The appendix of this specification contains a nonmandatory test to approximate the lime-soil proportion for stabilization. A more detailed version of this test appears in Test Method D 6276.

7. Sampling, Inspection, Packaging, and Marking

7.1 The sampling, inspection, rejection, retesting, packaging, and marking shall be done in accordance with Practice C 50.

8. Keywords

8.1 highway construction; hydrated lime; lime treated soils; load-bearing; quicklime; soil; stabilization

[4] Further information on soil stabilization construction technique is available from National Lime Association Bulletin No. 326, 200 N. Glebe Rd., Arlington, VA, 22203–3728. This information can be accessed online at www.lime.org.

APPENDIX

(Nonmandatory Information)

X1. EADES AND GRIM TEST METHOD FOR DETERMINING THE APPROXIMATE LIME/SOIL PROPORTION FOR STABILIZATION

X1.1 This test method usually provides a lime-soil proportion for stabilization. It gives an indication whether the soil in question can be stabilized. For most stabilization work, the results of this test should be verified by performance tests in a soil laboratory.

X1.2 Air dry a sufficient quantity of the soil to be tested and screen through a No. 40 (425-μm) sieve. Store in a closed container to maintain uniform moisture. Weigh to the nearest 0.1 g a series of 20-g samples of soil and place in separate 150-mL plastic containers with water-tight lids.

X1.3 In the case of quicklime, rapidly crush the lime to pass a No. 6 (3.35-mm) sieve.

X1.4 Weigh, to the nearest 0.01 g, a series of quantities of lime equivalent to 2, 3, 4, 5, and 6 % of the soil sample.

X1.5 Add the lime quantity to the soil sample, mark the container with the appropriate percentage, and mix the dry contents thoroughly.

X1.6 Add the 100 mL of 70°F carbon dioxide-free distilled water or, if possible, 70°F actual water to be used on the job to each container of soil and lime. Seal with screw-cap lid and mix the three components by shaking the bottles. Shake each bottle for 30 s every ten min for 1 h. After 1 h, shake vigorously and transfer part of the slurry into a beaker. Measure the pH with a low-sodium error glass electrode (previously standardized to pH 12.45 with an agitated calcium hydroxide slurry). Record the pH reading for each mixture.

X1.7 If the pH readings are 12.40 or higher, the lowest percentage that gives a pH of 12.40 is the % required to stabilize the soil. If the pH readings do not go beyond pH of 12.30 and two percentages give this reading, the lowest % to give a pH of 12.30 is the % required to stabilize the soil. If the highest pH reading is a pH of 12.30 and only the highest percentage lime used gives a pH of 12.30, additional testing is required using higher percentages of lime.

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Designation: C 979 – 05

Standard Specification for Pigments for Integrally Colored Concrete[1]

This standard is issued under the fixed designation C 979; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope

1.1 This specification covers the basic requirement for colored and white pigments in powder form to be used as admixtures in concrete for the purpose of producing integrally colored concrete. Where the pigments are a constituent of a multicomponent admixture, this specification applies to the pigment constituent of the admixture. This specification is not intended to establish compatibility of pigments with any other concrete admixtures unless they are tested in combination in accordance with 3.7.

1.2 This specification does not include the determination of pigment stability when elevated temperature using low-pressure (atmospheric) or high-pressure (autoclave) steam is used to accelerate the curing process.

1.3 In addition to tests defining the pigments themselves, a limited number of tests on concrete are included to define the effects on setting times, air content, and compressive strength. If more extensive information is required for a particular job, additional testing criteria and procedures should be agreed upon between the seller and user.

1.4 The maximum prescribed dosage rate of a pigment, established in accordance with 3.7, shall be equal to or less than 10 mass % of cement. When a combination of pigments is used to produce the desired color and color intensity, the total dosage rate of all pigments combined shall not exceed any of the individual maximum dosage rates of the component pigments.

1.5 The values stated in SI units are to be regarded as the standard. The inch-pound units in parentheses are for information purposes only.

2. Referenced Documents

2.1 *ASTM Standards:* [2]

C 33 Specification for Concrete Aggregates

C 39 Test Method for Compressive Strength of Cylindrical Concrete Specimens

C 143/C 143M Test Method for Slump of Hydraulic Cement Concrete

C 150 Specification for Portland Cement

C 173 Test Method for Air Content of Freshly Mixed Concrete by the Volumetric Method

C 192/C 192M Practice for Making and Curing Concrete Test Specimens in the Laboratory

C 231 Test Method for Air Content of Freshly Mixed Concrete by the Pressure Method

C 260 Specification for Air-Entraining Admixtures for Concrete

C 403/C 403M Test Method for Time of Setting of Concrete Mixtures by Penetration Resistance

D 50 Test Methods for Chemical Analysis of Yellow, Orange, Red, and Brown Pigments Containing Iron and Manganese

D 1208 Test Methods for Common Properties of Certain Pigments

D 1535 Practice for Specifying Color by the Munsell System

G 23 Practice for Operating Light-Exposure Apparatus (Carbon-Arc Type) With and Without Water for Exposure of Nonmetallic Materials[3]

2.2 *ACI Standards:*

211.1 Recommended Practice for Selecting Proportions for Normal and Heavyweight Concrete[4]

3. General Requirements

3.1 *Water Wettability*—The pigment shall be water wettable when tested in accordance with 7.1.

3.2 *Alkali Resistance*—The pigment treated with sodium hydroxide shall not show any significant (Note 1) change of color when tested in accordance with 7.2.

3.3 *Total Sulfates*—Calculated as SO_3, the sulfates shall not exceed 5.0 mass % of the original pigment sample when tested in accordance with 7.3.

3.4 *Water Solubility*—The total matter soluble in water shall not exceed 2.0 mass % of the original pigment sample when tested in accordance with 7.4.

[1] This specification is under the jurisdiction of ASTM Committee C09 on Concrete and Concrete Aggregates and is the direct responsibility of Subcommittee C09.23 on Chemical Admixtures.

Current edition approved Jan. 1, 2005. Published January 2005. Originally approved in 1982. Last previous edition approved in 2004 as C 979–04.

[2] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

[3] Withdrawn.

[4] Available from American Concrete Institute, 38800 Country Club Drive, Farmington Hills, MI 48331.

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3.5 *Atmospheric Curing Stability*—The magnitude of color differences between pigmented concrete specimens cured in dry air and those cured at high relative humidity when tested in accordance with 7.5 shall not be greater than the magnitude of the color difference between two unpigmented specimens cured under the same conditions.

3.6 *Light Resistance*—The exposed portions of the specimens shall show no significant differences (Note 1) in color from the unexposed portions when tested in accordance with 7.6. While a pigment that fails this test shall not be considered light resistant, a pigment that passes this test may still be subject to fading when exposed to natural weathering conditions.

NOTE 1—A significant difference is defined as one that is readily perceptible by visual observation without close examination. Lighting and viewing conditions as described in Practice D 1535, 6.1, may be used.

3.7 *Effects on Concrete*:

3.7.1 When compared with the control mixture, the concrete that is pigmented at the maximum prescribed dosage rate shall have a 28-day compressive strength of not less than 90 % and a water-cement ratio of not greater than 110 % of that of the control mixture when prepared and tested in accordance with 7.7 (Note 2).

3.7.2 The pigment, when added to a concrete mixture at the maximum prescribed dosage rate, shall neither accelerate the initial or final set by more than 1 h nor retard the initial or final set by more than 1½ h, as compared to the uncolored concrete control mixture when tested in accordance with 7.7 (Note 2).

3.7.3 Using the same quantity of air-entraining admixture, the pigments, when added to a concrete mixture at the maximum prescribed dosage rate, shall not change the air content by more than 1.0 %, as compared to the uncolored control mixture when tested in accordance with 7.7.

NOTE 2—These values include allowance for normal variations in test results. The object of the 90 % compressive-strength requirement is to require a level of performance of the pigmented concrete comparable to that of the reference concrete when tested in accordance with 7.7.

3.8 *Color Match of Shipment*—The color produced by the shipment of pigment shall not be significantly different (Note 1) from the color produced by the standard supplied by the pigment manufacturer when samples of both the shipment and the standard are tested in accordance with 7.8. New concrete specimens containing the standard sample of the particular pigment must be prepared whenever a new shipment is evaluated. This is necessary to eliminate color variations caused by any of the other mortar ingredients, specimen preparation, or curing.

4. Rejection

4.1 The purchaser has the right to reject material that does not conform to the requirements of this specification. Rejection shall be reported to the producer or supplier in writing.

4.2 Individual packages or containers varying more than 5 % from the stated mass may be rejected. If the average weight of 50 packages taken at random is less than that stated, the entire shipment may be rejected.

5. Packaging

5.1 Packages or containers shall be clearly marked as to color designation and the net mass.

5.2 The package or container for the pigment, only when so designated by the manufacturer, shall be added to the concrete batch, provided that it is composed of disintegrating paper or soluble material which, when tested as a unit (pigment and packaging), conforms to all requirements of this specification.

6. Materials for Tests

6.1 *Cement*—For the atmospheric curing stability and the light resistance tests, using white cement is suggested. The cement used in all other tests shall be either a Type I or Type II cement conforming to Specification C 150 or the cement proposed for specific work.

6.2 *Aggregates*—The aggregates used in all tests shall conform to Specification C 33 or shall be the aggregates proposed for specific work. For the atmospheric curing stability and the light resistance tests, clean silica sand shall be used. For both the reference and the pigmented mixtures, the aggregate grading shall be controlled by determining the mass of separate fractions.

6.3 *Admixtures*—If any of the test mixtures contain any admixtures in addition to pigment other than an air-entraining admixture complying with Specification C 260, the pigment shall be considered to comply with this specification only when used in conjunction with such other admixture(s).

7. Test Methods

7.1 *Water Wettability*—Add 10.0 g of the pigment to 150 mL of deionized water in a 250-mL beaker. If the pigment does not readily mix with the water when stirred with a spatula, but instead a substantial portion of the pigment floats on the surface of the water, the pigment is repellent and not water wettable.

7.2 *Alkali Resistance*—Add two 10.0 g-portions of the pigment to separate 250-mL beakers, each containing 150 mL of deionized water. Stir until thoroughly mixed. Add 10 mL of 10 mass % sodium hydroxide solution to one beaker, and stir thoroughly once more. Let the slurries stand 1 h, then remix and filter on separate Buchner funnels. Wash the filter cake with three replacement washes of hot deionized water. Dry the cake on the filter paper in an oven at 110 ± 3 °C (230 ± 5 °F) for 4 ± 0.5 h. Remove from the oven, cool, and crush the pigment into a fine powder in a mortar. Make two small adjacent piles of the pigment powders and press them flat with a spatula. Compare the color of the control and treated pigment powders.

7.3 *Percentage of SO_3*—Perform the sulfates soluble in hydrochloric acid test and determine the percentage in accordance with Test Methods D 50.

7.4 *Water Solubility*—Perform the matter soluble in water test in accordance with Test Methods D 1208.

7.5 *Atmospheric Curing Stability*—The composition and method of preparation of the test specimens shall be in accordance with Annex A1. Pigments shall be tested at both ½ % and 6 % levels (based on the cement mass). Two sets of specimens (designated as control specimens and test specimens) shall be prepared at the same time under identical

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conditions except for curing. Each set shall consist of two pigmented mortar specimens, one at each of the two levels of pigmentation, and one unpigmented specimen. If, for a particular pigment being tested, the specimens that contain the pigment at a dosage rate of ½ % of the cement mass do not provide a significant difference (Note 1) in color when compared to the corresponding unpigmented specimen, the pigment dosage rate shall be increased until but not beyond the rate at which the difference in color becomes significant. In addition, tests using the higher dosage rate of 6 % of the cement mass shall continue to be performed as specified. Compare for color the specimens that were cured under different conditions. For evaluating the color stability of the pigment tested, also compare the uncolored mortar specimens for color variations. Differences in the curing conditions or efflorescence, or both, can affect the color shade of any finished mortar or concrete, either colored or uncolored.

7.6 *Light Resistance*—The test shall be conducted in a Type E or EH exposure apparatus as described in Practice G 23. Type EH apparatus shall be operated without automatic humidity control. The exposure apparatus shall be operated in accordance with Practice G 23, except that no water spray or dark cycles shall be employed. The black panel temperature shall be 54± 3 °C (130 ± 5 °F). The composition and method of preparation of the test specimens shall be in accordance with Annex I. Pigments shall be tested at both ½ % (7.5) and 6 % levels (based on the cement mass). Half of each specimen shall be masked from light exposure by an aluminum foil covering. The other half of each specimen shall be exposed to light for 500 h after which time its color shall be compared to the unexposed half (3.6).

7.7 *Effects on Concrete*:

7.7.1 *Preparation of Mixtures*—Prepare concrete mixtures both with and without the pigment under test. Refer herein to the concrete mixture without the pigment as the reference or control mixture. The control mixture and the pigmented mixture shall be of the same composition and batched in the same proportions except that the pigmented mixture shall include the pigment addition at the maximum prescribed dosage rate (1.4), and the water content of each mixture shall be adjusted to produce a slump of 100 ± 13 mm (4 ± ½ in.), as determined by Test Method C 143/C 143M. Add the pigment to the first increment of coarse aggregate and water. The mixture shall be proportioned using ACI Practice 211.1. The cement content shall be either the cement content for specific work or 307 ± 3 kg/m^3(517 ± 5 lb/yd^3). If an air-entraining admixture complying with Specification C 260 is used, its dosage rate shall be the same for both the pigmented and the control mixtures.

7.7.2 *Making and Curing*—Specimens made from concrete with and without the pigment under test shall be molded and cured in accordance with Method C 192/C 192M. Three or more compression specimens shall be prepared for each mixture.

7.7.3 *Time of Setting*—Test Method C 403/C 403M shall be used. The temperature of each of the ingredients of the concrete mixtures, just prior to mixing, and the temperature at which the time of setting specimens are stored during the test period shall be 23.0± 2 °C (73 ± 3 °F).

7.7.4 *Air Content*—Test Methods C 173 or C 231 shall be used.

7.7.5 *Compressive Strength*—Test Method C 39 shall be used. Specimens shall be tested at 28 days and optionally also at 7 days. The 28-day compressive strength of the concrete containing the pigment under test shall be calculated as a percentage of the 28-day compressive strength of the reference concrete as follows: The average 28-day compressive strength of the specimens made from the concrete containing the pigment under test shall be divided by the average 28-day compressive strength of the specimens made from the reference concrete at the same age, and the quotient shall be multiplied by 100.

7.8 *Color Match of Shipment*—Samples of both the shipment of pigment and the standard supplied by the pigment manufacturer shall be prepared in concrete at both the ½ % (7.5) and 6 % levels (based on the cement mass) or at another dosage rate(s) agreed upon between the purchaser and seller. The composition and methods of preparation and color comparison of the specimens should be agreed upon between the purchaser and seller. A suggested method of specimen preparation is given in Annex I. Compare the colors of the concrete specimens. Do not compare the colors of the pigment powders as a test for color control.

8. Report

8.1 The report shall include the following:

8.1.1 The manufacturer, designation, and type of pigment,

8.1.2 Maximum prescribed dosage rate of pigment,

8.1.3 Description of additional admixtures that must be used in the concrete,

8.1.4 Water wettability of pigment,

8.1.5 Resistance to color change when treated with sodium hydroxide,

8.1.6 Percent total sulfates calculated as SO_3,

8.1.7 Percent total water-soluble matter contained in pigment,

8.1.8 Resistance to color change when concrete is cured in a high-relative-humidity atmosphere,

8.1.9 Light resistance of pigment,

8.1.10 Cement content of pigmented and control mixtures,

8.1.11 Water-cement ratios of pigmented and control mixtures and the relative percentage change due to the use of pigment,

8.1.12 Compressive strength (28-day) of pigmented concrete and control and the relative percentage change resulting from the use of pigment,

8.1.13 Initial and final setting times of pigmented and control mixtures and the changes resulting from the use of pigment,

8.1.14 Air contents of pigmented and control mixtures and the change resulting from the use of pigment, and

8.1.15 When individual shipments are tested, a color comparison of each shipment and control.

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9. Keywords

9.1 color match; integrally colored concrete; light resistance; pigment

ANNEX

(Mandatory Information)

A1. METHOD FOR PREPARING MORTAR TEST SPECIMENS

A1.1 *Apparatus*:

A1.1.1 *Wooden Mold*, to form specimens approximately 230 mm (9 in.) by 76 mm (3 in.) by 13 mm (½ in.) (Note A1.1). The mold shall be coated with a non-staining coating to prevent water absorption. The mold should be held together with C-clamps for easy removal.

NOTE A1.1—The dimensions may be modified, as long as finished specimen strength is maintained, to suit the individual weatherometer used for the light resistance test.

A1.1.2 *Wooden Tamping Block*, with a working surface area of approximately 50 mm (2 in.) by 100 mm (4 in.)

A1.1.3 *Metal or Ceramic Mixing Vessel*.

A1.1.4 *Stirring Device*, such as a large spoon or spatula.

A1.1.5 *Heated Drying Cabinet*.

A1.2 *Material*:

A1.2.1 *Clean Silica Sand*,

A1.2.2 *White Cement* (Note A1.2), and

A1.2.3 *Pigment to be Tested*.

NOTE A1.2—White cement is suggested to give maximum color discrimination in judging the pigment, but other cement may be used that is representative of the intended use.

A1.3 *Formulation*:

A1.3.1 Prepare the mortar mixtures at both ½ % (7.5) and 6 % pigment levels (based on the cement mass) in accordance with formulas below:

	Control[A]	½ %	6 %
Silica sand	480.0 g	480.0 g	480.0 g
White cement	160.0 g	159.2 g	151.0 g
Pigment	0.0 g	0.8 g	9.0 g
Water[B]	72 mL	72 mL	72 mL

[A] Control specimens are required for the atmospheric curing stability test but not for the light resistance test.

[B] In order to eliminate fluctuations in the moisture content (water/cement ratio) of the fresh and cured mortar specimens, it is advisable to dry the sand at 105 ± 3 °C (221 ± 5 °F) in an oven to constant weight. The amount of water should be adjusted such that a fairly dry, non-bleeding, mortar mix is obtained. However, the water content for all batches of the same mortar mix shall be identical.

A1.4 *Procedure*:

A1.4.1 In sequence, add the sand, cement, and pigment to the mixing vessel and mix thoroughly with the stirring device until the blend is uniform. Add the water and continue to mix until all the ingredients are thoroughly wetted.

A1.4.2 Place the mold on a glass slab, a steel plate, or any other flat, waterproof surface. Slightly overfill the mold with the mortar mixture. Using the wooden block, tamp the mixture firmly and evenly and with a screed, level it to the top of the mold.

A1.4.3 As soon as the mortar has set, loosen the C-clamps and carefully remove the sides of the mold.

A1.4.4 Place the mortar specimen on a table using spacers to permit ambient air to circulate around it, and let it dry in the air at room temperature for 12–24 h.

A1.4.5 Continue the curing process as follows: Transfer each specimen for the light resistance test and each control specimen for the atmospheric curing test to the heated cabinet, and finish curing at 49 ± 3 °C (120 ± 5 °F) for 24 h at 20 ± 10 % relative humidity. Transfer each test specimen for the atmospheric curing stability test to a 100 % relative humidity atmosphere at room temperature (Note A1.3) for at least 20 days, and then dry in the heated cabinet at 49 ± 3 °C (120 ± 5 °F) for 24 h at 20 ± 10 % relative humidity.

NOTE A1.3—A sealed plastic bag can be used for this purpose. Small amounts of water may be injected periodically into the bag to maintain a saturated atmosphere.

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APPENDIX

(Nonmandatory Information)

X1. TYPICAL PIGMENT TYPES MANUFACTURED FOR COLORING CONCRETE

X1.1 Typical pigment types manufactured for coloring concrete are as follows:

X1.1.1 Synthetic iron oxides, yellows, red, browns, and black,

X1.1.2 Some natural iron oxides,

X1.1.3 Chromium oxide,

X1.1.4 Cobalt blue,

X1.1.5 Titanium dioxide, and

X1.1.6 Carbon black (concrete grade).

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Designation: C 989 – 09a

Standard Specification for Slag Cement for Use in Concrete and Mortars[1]

This standard is issued under the fixed designation C 989; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

This standard has been approved for use by agencies of the Department of Defense.

1. Scope*

1.1 This specification covers three strength grades of slag cement for use as a cementitious material in concrete and mortar.

NOTE 1—The material described in this specification may be used for blending with portland cement to produce a cement meeting the requirements of Specification C 595 or as a separate ingredient in concrete or mortar mixtures. The material may also be useful in a variety of special grouts and mortars, and when used with an appropriate activator, as the principal cementitious material in some applications.

NOTE 2—Information on technical aspects of the use of the material described in this specification is contained in Appendix X1, Appendix X2, and Appendix X3. More detailed information on that subject is contained in ACI 233R-03, formerly ACI 226.1R.

1.2 The values stated in SI units are to be regarded as standard. No other units of measurement are included in this standard.

1.3 The following safety hazards caveat pertains only to the test methods described in this specification. *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

1.4 The text of this standard references notes and footnotes that provide explanatory information. These notes and footnotes (excluding those in tables) shall not be considered as requirements of this standard.

2. Referenced Documents

2.1 *ASTM Standards:*[2]

C 109/C 109M Test Method for Compressive Strength of Hydraulic Cement Mortars (Using 2-in. or [50-mm] Cube Specimens)

C 114 Test Methods for Chemical Analysis of Hydraulic Cement

C 125 Terminology Relating to Concrete and Concrete Aggregates

C 150 Specification for Portland Cement

C 185 Test Method for Air Content of Hydraulic Cement Mortar

C 188 Test Method for Density of Hydraulic Cement

C 204 Test Methods for Fineness of Hydraulic Cement by Air-Permeability Apparatus

C 430 Test Method for Fineness of Hydraulic Cement by the 45-μm (No. 325) Sieve

C 441 Test Method for Effectiveness of Pozzolans or Ground Blast-Furnace Slag in Preventing Excessive Expansion of Concrete Due to the Alkali-Silica Reaction

C 452 Test Method for Potential Expansion of Portland-Cement Mortars Exposed to Sulfate

C 465 Specification for Processing Additions for Use in the Manufacture of Hydraulic Cements

C 595 Specification for Blended Hydraulic Cements

C 1012 Test Method for Length Change of Hydraulic-Cement Mortars Exposed to a Sulfate Solution

C 1038 Test Method for Expansion of Hydraulic Cement Mortar Bars Stored in Water

D 3665 Practice for Random Sampling of Construction Materials

2.2 *American Concrete Institute Reports:*

226.1R Ground Granulated Blast-Furnace Slag as a Cementitious Constituent in Concrete[3]

233R-03 Slag Cement in Concrete and Mortar[3]

3. Terminology

3.1 Definition:

3.1.1 *blast-furnace slag*—the nonmetallic product, consisting essentially of silicates and aluminosilicates of calcium and other bases that is developed in a molten condition simultaneously with iron in a blast furnace (see Terminology C 125).

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *granulated blast-furnace slag*—the glassy granular material formed when molten blast-furnace slag is rapidly

[1] This specification is under the jurisdiction of ASTM Committee C09 on Concrete and Concrete Aggregates and is the direct responsibility of Subcommittee C09.27 on Ground Slag.

Current edition approved July 1, 2009. Published August 2009. Originally approved in 1982. Last previous edition approved in 2009 as C 989 – 09.

[2] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

[3] Available from American Concrete Institute (ACI), P.O. Box 9094, Farmington Hills, MI 48333.

***A Summary of Changes section appears at the end of this standard.**

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chilled as by immersion in water (see Terminology C 125), with or without compositional adjustments made while the blast-furnace slag is molten.

3.2.2 *slag cement*—granulated blast-furnace slag, as defined and described in 3.1.1 and 3.2.1, and ground to cement fineness with or without additions meeting the requirements of the section on additions.

4. Classification

4.1 Slag cement is classified by performance in the slag activity test in three grades: Grade 80, Grade 100, and Grade 120 (see Table 1).

5. Ordering Information

5.1 The purchaser shall specify the grade of slag cement desired and the optional chemical or physical data to be reported.

6. Additions

6.1 Slag cement covered by this specification shall contain no additions except as follows:

6.1.1 It is permissible to add calcium sulfate to slag cement provided it has been demonstrated by Test Method C 1038 that a test mixture will not develop expansion in water exceeding 0.020 % at 14 days. In the test mixture, 50 % of the mass of portland cement shall be replaced by an equal mass of slag cement. The portland cement used in the test mixture shall meet the requirements of Specification C 150. When the manufacturer supplies cement under this provision, upon request, supporting data shall be supplied to the purchaser.

6.1.2 When processing additions are used in the manufacture of slag cement, the maximum amount used shall comply with the requirements of Specification C 465 when tested using a 50-50 blend by mass and the portland cement.

7. Chemical Composition

7.1 Slag cement shall conform to the chemical requirements prescribed in Table 2.

TABLE 1 Physical Requirements

Item		
Fineness:		
amount retained when wet screened on a 45-μm (No. 325) sieve, max %		20
Specific surface by air permeability, Test Methods C 204 shall be determined and reported although no limits are required.		...
Air Content of Slag Mortar, max %		12
	Average of Last Five Consecutive Samples	Any Individual Sample
Slag Activity Index, min, %		
7-Day Index		
Grade 80	...	...
Grade 100	75	70
Grade 120	95	90
28-Day Index		
Grade 80	75	70
Grade 100	95	90
Grade 120	115	110

TABLE 2 Chemical Requirements

Sulfide sulfur (S), max, %	2.5

8. Physical Properties

8.1 Slag cement shall conform to the physical requirements of Table 1.

9. Sampling

9.1 The following sampling and testing procedures shall be used by the purchaser to verify compliance with this specification.

NOTE 3—Sulfur in granulated blast-furnace slag is present predominantly as sulfide sulfur. In most cases, instrumental analyses, such as x-ray fluorescence, cannot differentiate sulfide sulfur from sulfate. Determine and report the sulfide sulfur content separately, and do not include it in the SO_3 calculations.

9.2 Take random grab samples either from a delivery unit or at some point in the loading or unloading process so that no sample represents more than 115 Mg (125 tons) (Note 4). If samples are taken from rail cars or trucks, take at least two separate 2-kg (5-lb) portions and thoroughly mix them to obtain a test sample (Note 5). Sample by removing approximately a 300-mm (12-in.) layer of slag. Make a hole before obtaining a sample to avoid dust collector material that has discharged into the delivery unit after the predominant slag flow has ceased. Sample at a rate of one sample per month or one sample for each 2300 Mg (2500 tons) of shipments, whichever is more frequent.

NOTE 4—Standard statistical procedures are recommended for ensuring that samples are selected by a random procedure; see Practice D 3665. These procedures can be used to select the days within a month or within a week that samples will be taken. The delivery unit or time of day then should be chosen randomly.

NOTE 5—The quantity of sample specified is more than adequate for the testing required. A 2-kg (5-lb) portion should be retained in a sealed container for retesting if that is considered necessary to verify compliance.

10. Test Methods

10.1 *Slag-Activity Tests with Portland Cement*:

10.1.1 Slag activity shall be evaluated by determining the compressive strength of both portland-cement mortars and corresponding mortars made with the same mass of 50-50 mass combinations of slag cement and portland cement. Appendix X1 discusses the effects of cement, temperature, and amount of slag cement used on performance with portland cement.

10.1.2 *Reference Cement*—The portland cement used in the slag activity tests shall comply with the standard chemical and physical requirements of Specification C 150, Type 1 or Type II, and with the additional requirements of total alkali content and compressive strength limits as shown in Table 3. Sufficient cement shall be reserved to avoid changing reference cement more often than every two months. After the initial testing to determine compliance with the compressive strength requirement of Table 3, the reference cement shall be re-qualified at least every six months.

NOTE 6—Different reference cements may produce different Slag Activity Index results.

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TABLE 3 Alkali and Strength Limits of Reference Cement for Slag Activity Tests

Total Alkalies ($Na_2O + 0.658\ K_2O$)	min %	0.60
	max %	0.90
Compressive Strength, MPa, min, 28 days[A]		35 (5000 psi)

[A]The minimum strength limit is based solely on the strength of the Test Method C 109/C 109M mortar cubes, as required in Specification C 150, regardless of the strength of the flow-controlled Specification C 989 mortar cubes.

10.1.3 *Preparation of Specimens*—Prepare mortars in accordance with Test Method C 109/C 109M, except that sufficient water shall be used in each batch to produce a flow of 110± 5 %. The proportions shall be as follows:

Reference Cement Mortar:
500 g portland cement
1375 g graded standard sand

Slag Cement-Reference Cement Mortar:
250 g portland cement
250 g slag cement
1375 g graded standard sand

10.1.3.1 Mix a reference cement batch each day that a slag cement-reference cement batch is mixed until at least five batches have been mixed with the reference cement. Thereafter, reference cement batches need not be mixed more often than once a week whenever slag cement is being produced or shipped.

10.1.4 *Test Ages*—Determine the compressive strength of mortar specimens at 7 and 28 days age in accordance with Test Method C 109/C 109M.

10.1.5 *Calculation*—Calculate the slag activity index to the nearest percent for both 7 days and 28 days as follows:

$$\text{Slag activity index, \%} = (SP/P) \times 100 \quad (1)$$

SP = average compressive strength of slag cement-reference cement mortar cubes at designated ages, MPa (psi), and

P = average compressive strength of reference cement mortar cubes at designated age, MPa (psi).

The reference cement-mortar strength used to calculate a slag activity index shall, when a reference cement mortar is mixed on the same day as a slag cement-reference cement mortar, be the result for that batch. Otherwise, the average of tests of the five most recent reference cement-mortar batches shall be used.

10.1.6 *Report*—The report should include the following:

10.1.6.1 Slag activity index, %,

10.1.6.2 Compressive strength at 7 and 28 days, of slag cement-reference cement mortar,

10.1.6.3 Compressive strength at 7 and 28 days, of portland cement mortar,

10.1.6.4 Total alkalies of the reference cement ($Na_2O + 0.658\ K_2O$),

10.1.6.5 Fineness of reference cement, and

10.1.6.6 Potential compound composition of the reference portland cement.

10.1.7 *Precision*—The following precision statements are applicable when the slag activity index with portland cement is based on results of tests of two cubes from single batches of reference cement and 50-50 slag cement-reference cement mortars mixed on the same day. They are applicable to the slag activity index determined at 7 or 28 days.

10.1.7.1 The single-laboratory coefficient of variation has been found to be 4.1 %. Therefore, the slag activity indices of properly conducted tests based on single batches of mortar mixed on the same day should not differ by more than 11.6 % of their average.

10.1.7.2 The multilaboratory coefficient of variation has been found to be 5.7 %. Therefore, the slag activity indices of properly conducted tests of single batches by different laboratories should not differ by more than 16.1 %.

10.2 *Slag Cement Density*—Determine in accordance with Test Method C 188.

10.3 *Amount of Slag Cement Retained on a 45-μm (No. 325) Sieve*—Determine in accordance with Test Method C 430.

10.4 *Slag Cement Fineness by Air Permeability*—Determine in accordance with Test Methods C 204.

10.5 *Sulfate Ion in Slag Cement Reported as SO_3*—Determine as sulfur trioxide in accordance with Test Methods C 114, except the sample need not be completely decomposed by acid.

10.6 *Sulfide Sulfur in Slag Cement*—Determine in accordance with Test Methods C 114.

10.7 *Chloride Content of Slag*—Determine in accordance with Test Methods C 114.

10.8 *Air Content of Slag Cement Mortar*—Determine in accordance with Test Method C 185, except use 350 g of slag cement instead of cement in the standard mortar batch. Calculate using the appropriate density of the slag cement.

11. Rejection and Rehearing

11.1 The purchaser has the right to reject material that fails to conform to the requirements of this specification. Rejection shall be reported to the producer or supplier promptly and in writing. In case of dissatisfaction with the results of the tests, the producer or supplier is not prohibited from making a claim for retesting.

NOTE 7—In the event of a Slag Activity Index dispute, the purchaser should request a sample of the producer's reference cement for retest.

12. Certification

12.1 When specified in the purchase order or contract, the purchaser shall be furnished certification that samples representing each lot have been tested as directed in this specification and the specified requirements have been met. When specified in the purchase order or contract, a report of the test results shall be furnished.

12.2 When specified in the purchase order or contract, test data shall be furnished on the chloride ion content of the slag cement.

13. Manufacturer's Statement

13.1 At the request of the purchaser, the manufacturer shall state in writing the nature, amount, and identity of any processing or other additions made to the slag cement.

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14. Package Marking and Shipping Information

14.1 When the slag cement is delivered in packages, the classification of the slag cement, the name and brand of the manufacturer, and the weight of the slag cement contained therein shall be plainly marked on each package. Similar information shall be provided in the shipping invoices accompanying the shipment of packaged or bulk slag cement. All packages shall be in good condition at the time of inspection.

15. Storage

15.1 The slag cement shall be stored to permit easy access for proper inspection and identification of each shipment and in a suitable weather-tight building that will protect the slag cement from dampness and minimize quality deterioration.

16. Keywords

16.1 blast furnace slag; granulated blast furnace slag; slag activity index; slag cement

APPENDIXES

(Nonmandatory Information)

X1. CONTRIBUTION OF SLAG CEMENT TO CONCRETE STRENGTH

X1.1 When slag cement is used in concrete with portland cement, the levels and rate of strength development will depend importantly on the properties of the slag cement, the properties of the portland cement, the relative and total amounts of slag cement and portland cement, and the concrete curing temperatures.

X1.2 The reference cement used to test slag activity in this specification must have a minimum 28-day strength of 35 MPa (5000 psi) and an alkali content between 0.6 and 0.9 %. Performance of the slag cement with other portland cements may be significantly different. The slag-activity test also can be used to evaluate relative hydraulicity of different slag cements with a specific cement or of different shipments of the same slag cement. Such comparisons will be improved if all tests are made with a single sample of cement. To properly classify a slag cement, the reference portland cement must conform to the limits on strength and alkali content. Even within these limits performance will depend to some extent on the particular cement used. The percentages developed in the slag activity test do not provide quantitative predictions of strength performance in concrete. Performance in concrete will depend on a large number of factors including the properties and proportions of the slag cement, the portland cement, and other concrete ingredients, concrete temperatures, and curing conditions; and other conditions.

X1.3 Concrete strengths at 1, 3, and even 7 days may tend to be lower using slag cement-portland cement combinations, particularly at low temperatures or at high slag cement percentages. Concrete proportions will need to be established considering the importance of early strengths, the curing temperatures involved and the properties of the slag cement, the portland cement, and other concrete materials. Generally a higher numerical grade of slag cement can be used in larger amounts and will provide improved early strength performance; however, tests must be made using job materials under job conditions.

X2. SULFATE RESISTANCE

X2.1 *General*—Concrete manufactured with high percentages of slag cement is generally considered to have greater resistance to attack by sulfates than do portland cements, based largely upon comparisons of these mixtures with similar mixtures containing ordinary (Type I) portlands. These high volume slag cement mixtures (containing 60 % or more slag) are widely used for sulfate and sea-water resistant concretes throughout the world.

X2.2 *Sulfate Resistance of Portland Cements*—The sulfate resistance of concrete is dependent upon a number of factors, including mortar permeability and the type and concentration of the sulfate solutions involved. Others, directly related to the cement characteristics, include calcium hydroxide concentration and the tricalcium aluminate (C_3A) content. Specification C 150 provides limits on the C_3A for sulfate-resistant cements. Specification C 150 Type V requirements provide for a limit on the tetracalcium aluminoferrite (C_4AF) plus twice the C_3A. The C150 table of Optional Physical Requirements includes a maximum limit on expansion of Type V cement in mortar bars when tested by Test Method C 452. When this option is selected, the standard limits on tricalcium aluminate and on tetracalcium aluminoferrite plus twice the tricalcium aluminate do not apply. Test Method C 1012 can be used to measure the effects of exposure to external sulfate environments on mortar or concrete.

X2.3 *Effect of Slag Cement on Sulfate Resistance*—The use of slag cement will decrease the C_3A content of the cementing materials and decrease the permeability and calcium hydroxide

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content of the mortar or concrete. Tests have shown that the alumina content of the slag cement also influences sulfate resistance,[4,5] and that high alumina content can have a detrimental influence at low slag cement-replacement percentages. The data from these studies of laboratory exposure of mortars to sodium and magnesium sulfate solutions provide the following general conclusions.

X2.3.1 The combinations of slag cement and portland cement, in which the slag cement content was greater than 60 to 65 %, had high sulfate resistance, always better than the portland cement alone, irrespective of the Al_2O_3 content of the slag cement. The improvement in sulfate resistance was greatest for the cements with the higher C_3A contents.

X2.3.2 The low alumina (11 %) slag cement tested increased the sulfate resistance independently of the C_3A content of the cement. To obtain adequate sulfate resistance, higher slag cement percentages were necessary with the higher C_3A cements.

X2.3.3 The high alumina (18 %) slag cement tested, adversely affected the sulfate resistance of portland cements when blended in low percentages (50 % or less). Some tests indicated rapid decreases in resistance for cements in the 8 and 11 % C_3A ranges with slag cement percentages as low as 20 % or less in the blends.

X2.3.4 Tests on slag cement (7 to 8 % alumina) in Ontario[6] have shown that a 50:50 combination by mass with Type I portland cement (having up to about 12 % C_3A) is equivalent in sulfate resistance to the Type V cement used in that study.

X2.4 *Tests for Sulfate Resistance*—When the relative sulfate resistance of a specific cement-slag cement combination is desired, tests should be conducted in accordance with Test Method C 1012.[7] Studies by Subcommittee C01.29 on sulfate resistance using Test Method C 1012, as reported by Patzias [8], recommended the following limits for expansion of portland cement and slag cement combinations at six months of exposure:

Moderate sulfate resistance — 0.10 % max
High sulfate resistance — 0.05 % max

[4] Locher, F. W., "The Problems of the Sulfate Resistance of Slag Cements," *Zement-Kalk-Gips*, No. 9, September, 1966 .

[5] Van Aardt, J. H. P. and Visser, S., "The Behavior of Mixtures of Milled Granulated Blast-Furnace Slag and Portland Cement in Sulfate Solutions," *Bulletin 47*, National Building Research Institute, South Africa, 1967.

[6] Chojnacki, B., "Sulfate Resistance of Blended (Slag) Cement," *Report EM-52*, Ministry of Transport and Communications, Ontario, Canada 1981.

[7] Hooton, R. D. and Emery, J. J., "Sulfate Resistance of a Canadian Slag Cement," *ACI Materials Journal,* Vol *87* , No. 6, November-December 1990.

[8] Patzias, T., "The Development of ASTM Method C 1012 with Recommended Acceptance Limits for Sulfate Resistance of Hydraulic Cements", *Cement, Concrete, and Aggregates,* Vol 13, No. 1, ASTM, 1991.

X3. EFFECTIVENESS OF SLAG CEMENT IN PREVENTING EXCESSIVE EXPANSION OF CONCRETE DUE TO ALKALI-AGGREGATE REACTION

X3.1 Tests for effectiveness of slag cement in preventing excessive expansion due to alkali-aggregate reaction are not considered necessary unless the slag cement is to be used: (*a*) with a high-alkali portland cement ($Na_2O + 0.658\ K_20 \geq 0.6$ %) or the concrete contains added water-soluble alkalies (added as an activator to improve early strength); and (*b*) with an aggregate that is regarded as deleteriously reactive with alkalies.

X3.2 It should be expected that the effectiveness of the slag cement will depend upon the amount used and the reactivity of the slag cement itself. Data suggest that slag cements used as 40 % or more of the cementitious material will generally prevent excessive expansion with cements having alkali contents up to 1.0 %; however, definitive data are not available, and tests must be made in accordance with Test Method C 441.

X3.3 When the job cement and proportions of cement to slag cement are known, test mortars should be proportioned in accordance with the job mixture requirements of Test Method C 441, and the average expansion of mortar bars at 14 days should not exceed 0.020 %.

X3.4 When the job cement and proportions of slag cement to cement are not known, tests can be made for the reduction in mortar expansion in accordance with Test Method C 441. To be considered effective the slag cement must reduce 14-day expansions of mixtures made with the required high-alkali cement by 75 %. The slag cement should be considered effective only when the ratio of slag cement to cement equals or exceeds that found effective in the tests.

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SUMMARY OF CHANGES

Committee C09 has identified the location of selected changes to this specification since the last issue, C 989 – 09, that may impact the use of this specification. (Approved July 1, 2009)

(*1*) Revised 6.1.1 and Table 2.

Committee C09 has identified the location of selected changes to this specification since the last issue, C 989 – 08, that may impact the use of this specification. (Approved January 15, 2009)

(*1*) Revised terminology from "ground granulated blast furnace slag" to "slag cement" in the title of the standard and throughout the text.

Committee C09 has identified the location of selected changes to this specification since the last issue, C 989 – 06, that may impact the use of this specification. (Approved December 1, 2008)

(*1*) Revised 10.1.2.

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Designation: C 1002 – 07

Standard Specification for Steel Self-Piercing Tapping Screws for the Application of Gypsum Panel Products or Metal Plaster Bases to Wood Studs or Steel Studs[1]

This standard is issued under the fixed designation C 1002; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

This standard has been approved for use by agencies of the Department of Defense.

1. Scope*

1.1 This specification covers steel self-piercing tapping screws for use in fastening gypsum panel products and metal plaster bases to cold-formed steel studs less than 0.033 in. (0.84 mm) in thickness and wood members and for fastening gypsum panel products to gypsum board.

1.2 This specification also covers test methods for determining performance requirements and physical properties.

1.3 The values stated in inch-pound units are to be regarded as the standard. The SI (metric) values given in parentheses are approximate and are for information only.

1.4 The following safety hazards caveat pertains only to the test methods described in this specification: *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

2. Referenced Documents

2.1 *ASTM Standards:* [2]

A 548 Specification for Steel Wire, Carbon, Cold-Heading Quality for Tapping or Sheet Metal Screws[3]

A 568/A 568M Specification for Steel, Sheet, Carbon, Structural, and High-Strength, Low-Alloy, Hot-Rolled and Cold-Rolled, General Requirements for

C 11 Terminology Relating to Gypsum and Related Building Materials and Systems

C 1396/C 1396M Specification for Gypsum Board

C 645 Specification for Nonstructural Steel Framing Members

C 847 Specification for Metal Lath

3. Terminology

3.1 *Definitions:* For definitions relating to gypsum and related building materials and systems, see Terminology C 11.

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *self-piercing*, *v*—the ability to penetrate without benefit of a pre-drilled hole with sharp-point angles of not more than 30°.

3.2.2 *spin-out*, *v*—for a screw, the continued rotation of a screw without further penetration into the substrate.

4. Classification

4.1 Steel screws covered by this specification are of four types of thread configurations:

4.1.1 *Type G*, course-pitch high-thread self-piercing screws for fastening gypsum board to gypsum board.

4.1.2 *Type S*, fine-thread screw for fastening gypsum board to cold formed steel members.

4.1.3 *Type W*, course-thread screw for fastening gypsum board to wood members.

4.1.4 *Type A*, course-pitch tapping screw thread for fastening metal plaster bases to wood or cold-formed steel.

5. Materials

5.1 *Steel Wire*, for manufacturing screws, Specification A 548, Grades 1013 to 1022 for Type G and Type W screws.

5.2 *Steel Wire*, for manufacturing screws, Specification A 568/A 568M, Grades 1018 to 1022 for Type S and Type A screws.

6. Physical Properties

6.1 *Hardness*:

6.1.1 The surface of Type S, Type W, and Type A screws shall be case hardened to a depth of not less than 0.002 in. (0.05 mm) with case hardness not less than 45 HRC.

[1] This specification is under the jurisdiction of ASTM Committee C11 on Gypsum and Related Building Materials and Systems and is the direct responsibility of Subcommittee C11.02 on Specifications and Test Methods for Accessories and Related Products.

Current edition approved Aug. 1, 2007. Published August 2007. Originally approved in 1983. Last previous edition approved in 2004 as C 1002 – 04.

[2] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

[3] Withdrawn

***A Summary of Changes section appears at the end of this standard.**

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6.1.2 The surface of Type G screws is not required to be case hardened.

6.2 *Ductility*—The screws shall have sufficient ductility to be able to withstand a 10° bend without visible signs of fracture when tested as specified in 12.6.7.

7. Performance Requirements

7.1 *Type G Screws*:

7.1.1 Screws shall be able to self-pierce and drive into gypsum panel products.

7.1.2 Screw threads shall be adequate to pull the head of the screw below the surface of the gypsum panel product when tested as specified in 12.6.2.

7.2 *Type S Screws*:

7.2.1 *General*—Screws shall be able to self-pierce and drive into cold-formed steel members in less than 2 s, when tested as specified in 12.6.3.1.

7.2.2 *Screws for Fastening Gypsum Panel Products*—Screw threads shall be adequate to pull the head of the screw below the surface of the gypsum panel product, without spin-out, when tested as specified in 12.6.3.1.

7.3 *Type W Screws*:

7.3.1 *General*—Screw threads shall be able to self-pierce and drive into wood members.

7.3.2 *Screws for Fastening Gypsum Panel Products*—Screw threads shall be adequate to pull the head of the screw below the surface of the gypsum panel product, without spin-out when tested as specified in 12.6.4.1.

7.4 *Type A Screws*:

7.4.1 *General*—Screw shall be able to pierce and drive into wood or cold-formed steel members.

7.4.2 *Screws for Fastening Metal Plaster Bases*—Screw threads shall be adequate to pull a metal plaster base tightly enough against the face of a wood or steel stud, without spin-out, so that when subjected to a steady pull, the plaster base will tear before slipping out from under the screw head, when tested in accordance with 12.6.5.1 or 12.6.5.2.

8. Dimensions and Permissible Variations

8.1 *Head Diameter*:

8.1.1 *General*—Heads shall be permitted to be out of round not more than 0.02 in. (0.51 mm).

8.1.2 *Screws for Fastening Gypsum Board*—Not less than 0.315 in. (8 mm).

8.1.3 *Screws for Fastening Metal Plaster Bases*—Not less than 0.437 in. (11.1 mm).

8.2 *Head Contour*:

8.2.1 *Screws for Fastening Gypsum Panel Products*—The top of the head shall be flat. The outer flange thickness shall be 0.025 ± 0.005 in. (0.64 ± 0.13 mm). The contour beneath the flange head shall be such that the screw head shall be able to be driven so that the head of the screw rests immediately below the surface of the gypsum panel product.

8.2.2 *Screws for Fastening Metal Plaster Bases*—The top of the screw shall be either flat or contoured. The underside of the head shall be flat or near flat. The threads shall extend to the underside of the head.

8.3 *Driving Recess*:

8.3.1 *Screws for Fastening Gypsum Board*—No. 2 "Phillips" design, depth of recess, not less than 0.104 in. (2.64 mm).

8.3.2 *Screws for Fastening Metal Plaster Bases*—No. 2 "Phillips" design, depth of recess, not less than 0.077 in. (1.95 mm).

8.3.3 Determine depth of recess with a Phillips penetration depth gage.

8.3.4 Other types of screw-driving recesses having performance values equal to those of the recesses specified are acceptable.

8.4 *Shank Diameter*—Not less than No. 6, with major diameter not less than 0.136 in. (3.45 mm).

8.5 *Length*:

8.5.1 *Nominal Length*—The nominal length shall be the minimum length.

8.5.2 Type W and Type A screws shall be long enough to penetrate wood members not less than ⅝ in. (15.9 mm).

8.6 *Threads*—Either single or multiple thread design.

8.7 *Points*—Self-piercing design.

9. Finish and Appearance

9.1 *Form*—The form shall be straight and neatly formed.

9.2 *Threads*—The threads shall be clean and smooth.

9.3 *Finish*—Screws shall have a corrosion-resistant treatment. The treatment shall not inhibit adhesion to finishing compounds nor bleed through field-applied decoration.

10. Sampling

10.1 Obtain not less than 90 screws from not less than five containers.

11. Number of Tests and Retests

11.1 Test a minimum of five screws for each test. If any of the first lot fails, test 25 more screws.

11.2 If two or more of the second lot fail the second test, then the represented lot fails to meet the specified requirements.

12. Test Methods

12.1 The following test methods set forth procedures used to determine the ability of the screws to pierce through gypsum panel and metal plaster base and into the backup material without spin-out.

12.1.1 The test methods can also be used to determine whether or not alternate screw driving recesses will have performance values equal to those of the "Phillips" recess specified.

12.2 *Significance and Use*—The test methods provide procedures for evaluating the physical properties and performance requirements of steel self-piercing screws. The degree of correlation between these tests and service performance has not been determined.

12.3 *Apparatus*:

12.3.1 *Screw Gun*—Standard manufacture electric screw gun, turning at a minimum of 2500 r/min.

12.3.2 *Timing Device*—Standard stopwatch, calibrated in ⅒ s.

12.3.3 *Vice*—Standard machinists vice, not less than 3 in. (76 mm).

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12.3.4 *Clamp*—Locking pliers ("Vice-Grip"), 6 in. (152 mm).

12.4 *Materials*:

12.4.1 *Gypsum Wallboard*—Specification C 1396/C 1396M, Type X, 5⁄8 in. (16 mm) thick.

12.4.2 *Metal Lath*—As in Specification C 847, diamond mesh, weight 2.5 lb/yd^2(1.4 kg/m^2).

12.4.3 *Steel Stud*—As in Specification C 645, 0.0179 in. (0.455 mm) thick, hardness not less than 52 HRB, size 3 5⁄8 in. (92.1 mm).

12.4.4 *Wood Stud*—Douglas fir, construction grade, 2 by 4 or 2 by 6, nominal, containing not less than 16 % nor more than 19 % free moisture as determined by a suitable moisture meter.

12.4.5 *Kraft Paper*—0.01 in. (0.25 mm) thick, 2 in. (51 mm) square.

12.5 *Specimen Preparation*:

12.5.1 Cut 6-in. (152-mm) square specimens from a sheet of gypsum wallboard not less than 12 in. (305 mm) away from the edge or end.

12.5.1.1 Weigh the specimens to within 1 g, and then condition at a temperature of 85 ± 15 °F (29.5 ± 5.5 °C) in an atmosphere having a relative humidity of 50 ± 2 %. Individually test the specimens after constant weight is reached.

12.5.2 Cut 6 in. (152 mm) square specimens from a sheet of metal lath not less than 4 in. (102 mm) away from the edge or end.

12.5.3 Cut 12 in. (305 mm) long specimens from a length of a steel stud.

12.5.4 Cut 12 in. (305 mm) long specimens from a length of wood stud.

12.6 *Procedure*:

12.6.1 *General:* Drive the screws not closer than 5⁄8 in. (16 mm) from the edges of the gypsum wallboard and not closer than 2 in. (50 mm) from the edges of the metal lath.

12.6.2 *Type G Screw Test*—Rigidly support two pieces of gypsum board sandwiched together. With a screw gun, drive the screw specimen into the gypsum boards, so that the head of the screw is below the surface of the gypsum board.

12.6.2.1 When driving Type G screw specimens, use the force of less than 20 lbf (89 N).

12.6.2.2 *Interpretation of Results*—Observe if the screws are pulled below the surface of the gypsum board. If any of the five screws fail, the lot has failed the test. Retest in accordance with Section 11.

12.6.2.3 *Report*—Report whether the lot has passed or failed the test.

12.6.2.4 *Precision and Bias*—No information is presented about either the precision or the bias for the Type G screw test for pulling the screw head below the surface of the gypsum board because the test result is non-quantitative.

12.6.3 *Type "S" Screws Test for Fastening Board to Steel*:

12.6.3.1 When driving Type S screws use a force of 30 lbf (133N).

12.6.3.2 Rigidly support a piece of gypsum wallboard as described in 12.4.1 over a length of steel stud as described in 12.4.3. With a screw gun as described in 12.3, drive five screw specimens through the wallboard and into the steel. Measure the length of time it takes to drive each screw so that the screw head is below the surface of the gypsum board and observe if there was spin-out.

12.6.3.3 *Interpretation of Results*—Calculate the average time to drive the five screw specimens through the wallboard and into the steel. If any of the five specimens fail to pull the screw head below the surface of the gypsum board or spins out, or if the average time is more than 2 s, the lot has failed. Retest in accordance with Section 11.

12.6.3.4 *Report*—Report whether the lot has passed or failed the test and the reason for failure.

12.6.3.5 *Precision and Bias*—No information is presented about either the precision or the bias for the Type S screw test for measuring spin-out or pulling the screw head below the surface of the gypsum board, because the test result in non-quantitative. No information is presented about either the precision or the bias for the Type S screw test for measuring the time to drive the screw because no material having an acceptable reference value is available.

12.6.4 *Type A Screws for Fastening Metal Lath to Steel*:

12.6.4.1 When driving Type A screws, use a force of 30 lbf (133 N).

12.6.4.2 Rigidly support a piece of metal lath over a steel stud specimen. With a screw gun, as described in 12.3, drive the five screw specimens through each of the five pieces of metal lath, and into the steel. Measure the length of time it takes to drive the screws and observe if there was spin-out. Grasp the metal lath with the locking pliers and pull steadily in a plane parallel to the plane of the lath. Observe whether the lath tears before it slips out from under the screw head.

12.6.4.3 *Interpretation of Results*—Calculate the average time to drive the five screw specimens through the metal lath into the steel. If any of the five specimens fails to pull the screw head through the metal lath and into the steel, or spins out, or if the average time is more than 2 s, or if the metal lath fails to tear when pulled, the lot has failed.

12.6.4.4 *Precision and Bias*—No information is presented about either the precision or the bias for the Type A screw test for measuring spin-out or pulling the screw head below the surface of the gypsum board, because the test result is non-quantitative. No information is presented about either the precision or the bias for the Type A screw test for measuring the time to drive the screw because no material having an acceptable reference value is available.

12.6.5 *Type A Screws for Fastening Metal Lath to Wood*:

12.6.5.1 When driving Type A screws, use a force of 30 lbf (133 N).

12.6.5.2 Rigidly support a piece of metal lath over a length of wood stud as described in 12.4.4. With a screw gun as described is 12.3, drive the five screw specimens through each of the five pieces of metal lath and into the wood stud. Observe if there was spin-out. Grasp the metal lath with the locking pliers and pull steadily in a plane parallel to the plane of the lath. Observe whether the lath tears before it slips out from under the screw head.

12.6.5.3 *Interpretation of Results*—If any of the five specimens fails to pull the screw head through the metal lath and

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into the wood, or spins out, or if the metal lath fails to tear when pulled, the lot has failed. Retest in accordance with Section 11.

12.6.5.4 *Precision and Bias*—No information is presented about either the precision or the bias for the Type A screw test for pulling the screw head through the metal lath and into the wood, or spin-out, or tearing of the metal lath, because the test results are non-quantitative.

12.6.6 *Type W Screw Test for Fastening Gypsum Board to Wood*:

12.6.6.1 When driving Type W screws, use a force of 30 lbf (133 N).

12.6.6.2 Rigidly support a piece of gypsum wallboard as described in 12.4.1 over a length of wood as described in 12.4.4. With a screw gun as described in 12.3, drive five screw specimens through the wallboard and into the wood so that the head of the screw is below the surface of the wallboard, and observe if there was spin-out.

12.6.6.3 *Interpretation of Results*—If any of the five specimens fails to pull the head of the screw below the surface of the wallboard or spins out, the lot has failed the test. Retest in accordance with Section 11.

12.6.6.4 *Precision and Bias*—No information is presented about either the precision or the bias for the Type G screw test for pulling the screw head below the surface of the gypsum board because the test result is non-quantitative.

12.6.7 *Ductility Test*:

12.6.7.1 Place a screw specimen into a specified hole in a hardened block having a 10° angle on its face, then strike the part on the head with a hammer. If the head separates completely from the body, the part is either too hard in its core, the case hardness is too deep, the thread has cut the underhead radius, or the recess is too deep. Any of these problems can result in screws that break during assembly. If any of the five specimens fail, retest in accordance with Section 11.

12.6.7.2 *Interpretation of Results*—If any of the five screw specimens shows signs of fracture or complications as noted in 12.6.7.1, the lot has failed. Retest in accordance with Section 11.

12.6.7.3 *Report*—Report whether the lot has passed or failed the test and the reason for failure.

12.6.7.4 *Precision and Bias*—No information is presented about either the precision or the bias of the ductility test because the test results are non-quantitative.

13. Inspection

13.1 Inspection of the screws shall be agreed upon between the purchaser and the producer or the supplier as part of the purchase agreement.

14. Rejection

14.1 Rejection of screws that fail to conform to the requirements of this specification shall be reported to the producer or supplier promptly and in writing. The notice of rejection shall contain a statement documenting how the screws have failed to conform to the specification requirements.

15. Certification

15.1 When specified in the purchase agreement, a producer's or supplier's report shall be furnished at the time of shipment, certifying that the screws are in compliance with this specification.

16. Packaging and Marking

16.1 *Packaging*:

16.1.1 Screws shall be packaged in substantial commercial shipping containers, constructed so as to preserve the contents in good condition and to ensure acceptance and safe delivery by common or other carriers, to the point of delivery.

16.1.2 Individual packages shall be so constructed that the contents shall be able to be partially removed without destroying the container's ability to serve as a receptacle for the remainder of the contents.

16.2 *Marking*—Individual packages and shipping containers shall be marked with the type, size, use, and quantity of screws contained therein, the name, brand, or trademark of the producer or supplier, and the ASTM designation.

17. Keywords

17.1 drill screw; gypsum board; lath; metal plaster base; self-pierce; self-piercing screw

SUMMARY OF CHANGES

Committee C11 has identified the location of selected changes to this specification since the last issue, C 1002 – 04, that may impact the use of this specification. (Approved August 1, 2007)

(*1*) Replaced Specification C 36/C 36M with Specification C 1396/C 1396M in 12.4.1 and Referenced Documents.

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Designation: C 1005 – 05

Standard Specification for Reference Masses and Devices for Determining Mass and Volume for Use in the Physical Testing of Hydraulic Cements[1]

This standard is issued under the fixed designation C 1005; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope

1.1 This specification covers the minimum requirements for scales, balances, reference masses, and glass graduates used in the physical testing of hydraulic cements.

1.2 Requirements for analytical reference masses and balances are not included in this specification, but are to be found in Test Methods C 114. The use of restrictive terminology, classes, ranges, etc. has been intentionally avoided to allow the use of this specification by other standards-writing bodies with similar requirements for reference masses and devices for determining mass, if desired.

1.3 These requirements are not sufficiently descriptive to be used as the sole specifications for the purchase of reference masses or devices for determining mass without amplification.

1.4 Values in SI units shall be obtained by measurement in SI units or by appropriate conversion, using the Rules for Conversion and Rounding given in IEEE/ASTM SI–10, of measurement made in other units.

2. Referenced Documents

2.1 *ASTM Standards:* [2]

C 114 Test Methods for Chemical Analysis of Hydraulic Cement

E 617 Specification for Laboratory Weights and Precision Mass Standards

IEEE/ASTM SI–10 Standard for Use of the International System of Units (SI): The Modern Metric System

3. Terminology

3.1 *Definitions:*

3.1.1 *accuracy*, *n*—degree of conformity of the indication of a device for determining mass to the true value of an applied mass.

3.1.2 *balance*, *n*—a device for determining mass that compares a mass with standard masses.

3.1.3 *precision*, *n*—reproducibility of the readings of a device for determining mass when a given test mass is applied.

3.1.4 *range of mass determination*, *n*—the range of indications of a device from the minimum test load plus any aids or containers on the load-receiving elements to the maximum test load with the same aids or containers, as specified by the particular method of test being used.

3.1.5 *readability*, *n*—the smallest fraction of a division to which the index scale of a device for determining mass can be read with ease either by estimation or by use of a vernier.

3.1.6 *reference mass*, *n*—a piece of material of known specified mass for use in comparing or measuring the mass of other masses (See Note 1).

3.1.6.1 *Discussion*—The definition of "reference mass" was formerly incorrectly designated "weight;" weight is a force (See IEEE/ASTM SI–10).

3.1.7 *scale*, *n*—a device for determining mass having a load-receiving element and an index scale (possibly in combination with the use of internal masses or proportional masses), almost always calibrated to indicate mass; generally of lesser accuracy than a balance.

3.1.8 *sensitivity*, *n*—the minimum change of applied mass required to perceptibly move the indicating element of a device for determining mass.

3.1.9 *sensitivity requirement*, *n*—the minimum change in position of rest of the indicating element of a device for determining mass in response to a specified change of mass load on the load-receiving element.

3.1.10 *test load*, *n*—the mass to be determined in a single determination, exclusive of aids or containers, as specified in the test method being followed.

3.1.11 *tolerance*, *n*—precision and accuracy criteria for reference masses or devices for determining mass.

acceptance tolerance—the maximum permissible deviation from correct indication for new or newly reconditioned or adjusted reference masses or devices for determining mass; equal to ½ the maintenance tolerance.

adjustment tolerance—acceptance tolerance.

maintenance tolerance—maximum permissible deviation

[1] This specification is under the jurisdiction of ASTM Committee C01 on Cement and is the direct responsibility of Subcommittee C01.95 on Coordination of Standards.

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[2] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

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from correct indication for reference masses and devices for determining mass in service.

3.1.12 *total load*, *n*—the sum of the masses of materials and aids or containers applied to the load-receiving element at any one time.

4. Reference Masses

4.1 Reference masses for use in the methods of physical testing of hydraulic cement and related and similar materials shall conform at least to the requirements of Class 6 reference masses in Specification E 617, except that the maintenance tolerances given in Specification E 617 for Class 6 reference masses are to be considered acceptance tolerances for purposes of this specification and the maintenance tolerances twice these values. See Table 1. (See Note 1)

NOTE 1—Former NBS Class P and F reference masses meet this specification as do OIML Class M1 reference masses. Former NBS Class T reference masses of 100 mg and less, Class C reference masses of 1 kg and greater, and OIML Class M2 reference masses of 200 g and greater meet the specification.

4.2 A mass used strictly as a mass, whose actual value need not be known, need not meet the requirements of 4.1 (See Note 2).

NOTE 2—A tare mass for a container used in mass determination is in this category. The actual value of its mass need not be known, but it must be equal in mass to that of the container.

5. *Requirements for Scales and Balances* Requirements for Scales and Balances

5.1 *Capacity*—The capacity of a device for mass determination shall be at least equal to the maximum total load to be applied to the load-receiving element at any one time (See Note 3).

NOTE 3—In general, the capacity of a device for mass determination should not greatly exceed twice the maximum total load required for a given test because of the reduced accuracy, readability, and sensitivity with higher capacity weighing devices. There are exceptions to this generality as, for example, the high quality substitution balances.

TABLE 1 Tolerances for Reference Masses[A,B]

Mass, g	Acceptance Tolerance, ±mg	Maintenance Tolerance, ±mg
10 000	1 000	2 000
5 000	500	1 000
3 000	300	600
2 000	200	400
1 000	100	200
500	50	100
300	30	60
200	20	40
100	10	20
50	7	14
30	5	10
20	3	6
10	2	4
5	2	4
3	2	4
2	2	4
1	2	4

[A] Values from Table 1 of Specification E 617 for Class 6 metric reference masses.

[B] For reference masses with unlisted nominal values, the tolerance shall be that for the next lower denomination listed.

5.2 *Precision and Accuracy*—The maintenance tolerance for a device for mass determination shall be no greater than 0.05 % of the test load throughout the range. For balances with a capacity of 3000 g or more, the range of the test load shall be 300 to 3000 g. For balances with a capacity of less than 3000 g, the range of the test load shall be 10 % of the capacity up to the capacity of the balance. The device for mass determination shall be capable of reproducing readings with the same test mass to within at least the maintenance tolerance.

5.3 *Readability*—The index scale of a device for mass determination shall be easily readable to 0.1 g.

5.4 *Sensitivity Requirement*—The indicating element of the device for determination of mass shall show a change of at least one of the smallest divisions of the index scale for a change of 0.1 % of the test load within the range.

6. Requirements for Glass Graduates

6.1 *Glass Graduates*, of suitable capacities (large enough to measure the mixing water for paste and mortar mixtures in a single operation) shall be made to deliver the indicated volume at 20°C (68°F).

6.1.1 The permissible variation for graduates of 100 to 150-mL capacities shall be ±1.0 mL, for graduates of 200 to 300-mL capacities ±2.0 mL, and for all larger graduates ±0.5 % of the rated capacity.

6.1.2 These graduates shall be subdivided to at least 5 mL with the following exceptions:

6.1.2.1 The graduation lines may be omitted for the lowest 15 mL for a 150-mL graduate,

6.1.2.2 The graduation lines may be omitted for the lowest 25 mL for a 250-mL graduate, and

6.1.2.3 The graduation lines may be omitted for the lowest 50 mL for a 500-mL graduate.

6.1.3 The main graduation lines shall extend at least three quarters of the way around the graduate and shall be numbered (Note 4).

NOTE 4—Some graduates are manufactured with two numbering systems; one on each side of the main graduation lines. In reading from bottom to top, one system is increasing while on the other side the numbers are decreasing. Care should be taken since this could create confusion in reading the volume.

7. Rejection

7.1 New or newly reconditioned or adjusted reference masses and devices for determination of mass shall not be placed in service if they do not meet the acceptance tolerances specified in this standard.

7.2 Reference masses and devices for determination of mass in service shall be checked annually and shall be removed from service if they exceed the maintenance tolerances specified in this standard.

8. Keywords

8.1 devices for determining mass; devices for measuring volume; glass graduate; reference masses

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Designation: C 1007 – 08a

Standard Specification for Installation of Load Bearing (Transverse and Axial) Steel Studs and Related Accessories[1]

This standard is issued under the fixed designation C 1007; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope*

1.1 This specification covers the installation and erection requirements for load bearing (transverse and axial) steel studs and related accessories 0.0329 in. (0.836 mm) to 0.1120 in. (2.845 mm) thick.

1.2 The values stated in inch-pound units are to be regarded as standard. The values given in parentheses are mathematical conversions to SI units that are provided for information only and are not considered standard.

1.3 The text of this standard references notes and footnotes which provide explanatory material. These notes and footnotes (excluding those in tables and figures) shall not be considered as requirements of the standard.

2. Referenced Documents

2.1 *ASTM Standards:*[2]

C 11 Terminology Relating to Gypsum and Related Building Materials and Systems

C 841 Specification for Installation of Interior Lathing and Furring

C 954 Specification for Steel Drill Screws for the Application of Gypsum Panel Products or Metal Plaster Bases to Steel Studs from 0.033 in. (0.84 mm) to 0.112 in. (2.84 mm) in Thickness

C 955 Specification for Load-Bearing (Transverse and Axial) Steel Studs, Runners (Tracks), and Bracing or Bridging for Screw Application of Gypsum Panel Products and Metal Plaster Bases

C 1063 Specification for Installation of Lathing and Furring to Receive Interior and Exterior Portland Cement-Based Plaster

2.2 *American Iron and Steel Institute Publication (AISI):*

Cold-Formed Steel Design Manual: Specifications for the Design of Cold-Formed Steel Structural Members, 1986 Revision and 1989 addendum[3]

2.3 *American Welding Society Documents (AWS):*

D1.3 Specification for Welding Sheet Steel in Structures[4]

2.4 *Military Specification:*

MIL-P-21035 Paint, High Zinc Dust Content, Galvanizing Repair[5]

2.5 *Federal Specification:*

FF-P-395 Pin, Drive, Guided and Pin Drive, Power Actuated Fasteners for Power Actuated and Hand Actuated Fastening Tools[5]

3. Terminology

3.1 Definitions shall be in accordance with Terminology C 11.

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *axial loads*, *n*—those loads applied to a member in the same plane as its major centroidal axis.

3.2.2 *cripple studs*, *n*—less than full height studs above a header or below a sill.

3.2.3 *framing members*, *n*—studs joist, runners (tracks), bridging and bracing and related accessories.

3.2.4 *header*, *n*—the stud assembly or the track assembly, or both, placed at a right angle to supporting studs that creates the top of a framed opening.

3.2.5 *jack stud*, *n*—a framing member which provides support at the end of a header.

3.2.6 *panelized construction*, *n*—fabrication of framing members into an assembly prior to erection.

3.2.7 *sill*, *n*—the stud assembly or the track assembly, or both, placed at a right angle to supporting studs that creates the bottom of a framed opening.

[1] This specification is under the jurisdiction of ASTM Committee C11 on Gypsum and Related Building Materials and Systems and is the direct responsibility of Subcommittee C11.03 on Specifications for the Application of Gypsum and Other Products in Assemblies.

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[2] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

[3] Available from American Iron and Steel Institute (AISI), 1140 Connecticut Ave., NW, Suite 705, Washington, DC 20036, http://www.steel.org.

[4] Available from American Welding Society (AWS), 550 NW LeJeune Rd., Miami, FL 33126, http://www.aws.org.

[5] Available from Standardization Documents Order Desk, Bldg. 4 Section D, 700 Robbins Ave., Philadelphia, PA 19111-5094, Attn: NPODS.

***A Summary of Changes section appears at the end of this standard.**

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3.2.8 *transverse loads*, *n*—those loads applied to a member in a plane perpendicular to its major centroidal axis.

4. Storage of Materials

4.1 Products shall be protected from adverse weather and job site conditions that will cause any physical damage.

4.2 Materials shall be stored on a flat plane.

4.3 Any damaged materials shall be removed from the job site immediately.

5. Materials

5.1 *Framing members*—Specification C 955.

5.2 *Zinc-rich paint*—MIL-P-21035.

5.3 *Steel drill screws*—Specification C 954. Screws shall have rust inhibitive coating suitable for the intended installation.

5.4 *Power actuated drive pins*—FF-P-395.

6. Fastenings and Attachments

6.1 Anchorage of the tracks to the structure shall be with methods designed for the specific application of sheet steel to that surface. Size, penetration, type, and spacing shall be determined by design.

6.2 Welds shall conform to the requirements of AWS D1.3, and AISI Manual, section E 2. Welds shall be butt, fillet, spot, or groove type, the appropriateness of which shall be determined by, and within, the design calculations. All welds shall be touched-up using zinc rich paint.

6.3 Steel drill screws shall be of the minimum diameter indicated by the design of that particular attachment detail. Penetration through joined materials shall not be less than three exposed threads.

6.4 Wire tying in structural applications shall not be permitted.

7. Tolerances

7.1 Vertical alignment (plumbness) of studs shall be within 1/960 (⅛ in. in 10 ft 0 in.) of the span.

7.2 Horizontal alignment (levelness) of walls shall be within 1/960 (⅛ in. in 10 ft 0 in.) of their respective lengths.

7.3 Spacing of the framing members shall not be more than ±⅛ in. (3 mm) from the designed spacing, provided that the cumulative error does not exceed the requirements of the finishing materials.

7.4 Squareness of the prefabricated panels shall be not more than ⅛ in. (3 mm) out of square within the length of that panel.

INSTALLATION

8. General Installation

8.1 Methods of construction shall be either stickbuilt or panelized.

8.2 Stud to track connections shall be designed to meet or exceed the design loads required.

8.3 Allowance for vertical deflection of the structure shall be as required by the designer.

8.4 Transversely loaded studs shall not be required to sit squarely in tracks, but shall be attached to the tracks.

8.5 Axially loaded studs shall be fabricated with the studs seated squarely within ⅛ in. (3 mm) of the web portion of the top and bottom tracks and shall be attached to the tracks.

8.6 All axially loaded members shall be aligned vertically to allow for full transfer of the loads down to the foundation. Vertical alignment shall be maintained at floor/wall intersections.

8.7 Bearing shall be provided under tracks to provide for load transfer in axially loaded assembles.

8.8 Additional corrosion protection shall not be required on edges of metallic coated steel framing members, shop or field cut, punched or drilled.

8.9 *Cutting and Splicing of Members*:

8.9.1 Cutting of steel framing members shall be accomplished with a saw or shear.

8.9.2 Torch cutting of framing members shall not be permitted.

8.9.3 Splicing of axially loaded framing members shall not be permitted.

8.9.4 Cutting of flanges in stud and joist framing members shall not be permitted.

8.9.5 Cutting of additional holes other than those provided by the manufacturer in framing members shall not be permitted.

8.10 Temporary bracing shall be provided and left in place until the work is permanently stabilized.

8.11 Bridging shall be of the size and type shown on the shop drawings and as called for in the design calculations. For further description of the shop drawings see Annex A3.

8.12 *Header and Jack Stud Installation*:

8.12.1 Headers shall be installed in all openings in axially loaded walls that are larger than the stud spacing in that wall.

8.12.1.1 Headers shall be installed so that they lie wholly within the width of the stud wall.

8.12.1.2 Insulation (equal to the job requirements) shall be placed in all jamb and header type conditions that will be in accessible after their installation into the wall.

8.12.2 Jack studs shall be securely connected to the header and must seat squarely in the lower track of the wall in accordance with 8.4.

8.12.3 If the header is designed to be installed immediately above the wall opening the cripple studs that occur over the header shall be designed to carry all superimposed loads.

8.13 Wall track (runners) shall not be used to support any load unless specifically designed for that purpose.

9. Panelized Construction

9.1 Panels shall be designed to resist all construction and handling loads as well as live loads.

9.2 Handling and lifting of prefabricated panels shall not cause permanent distortion in any member or collateral material.

9.3 All stud-to-track connections shall be installed prior to hoisting the panel.

9.4 Where splicing of the track is necessary between stud spacings, a piece of stud not less than 12 in. (305 mm) long shall be placed in the track fastened with not less than two screws per flange to each piece of track or welds shall be provided as required.

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NOTE 1—Claddings may be permitted to be attached prior to panel installation.

9.5 Attachment of the panel to the structure shall be as shown on the design drawings.

9.6 All panels shall be aligned to provide continuity of any wall/floor surface.

10. Stick Built (Non-Panelized) Members

10.1 Tracks shall be aligned accurately at supporting structure and shall be fastened to the structure.

10.2 Track intersections shall butt evenly.

10.3 Doors, windows, and other items installed in the wall shall be securely anchored to the wall by means of clips, angles, screws, bolts, etc.

11. Keywords

11.1 axial; loadbearing; runners; steel; studs; tracks; transverse

ANNEXES

(Mandatory Information)

A1. DESIGN REQUIREMENTS

A1.1 Physical properties and allowable load capabilities of materials shall be developed in accordance with AISI Design Manual, as provided by Specification C 955.

A1.2 Studs shall be spaced to suit the design requirements and limitations of collateral materials.

A1.3 All applicable loads, strains, deflections, shear and web crippling, and bending of all sections shall be examined.

A1.4 All connections (member-to-member and member-to-structure) shall be examined taking into account all relevant physical strengths and properties.

A1.5 Selected walls shall be designed to provide frame stability and lateral load resistance. Diagonal steel strapping or other engineered methods shall be used to provide frame stability and lateral load resistance. Diagonal steel strapping shall be used to transfer lateral loads to the structure and foundation. Additional studs shall be provided to resist the vertical component of the loads from the diagonal bracing.

A1.6 Wall bridging shall be designed to provide resistance to minor axis bending and rotation of wall studs.

A2. INSTALLATION REQUIREMENTS

A2.1 Gypsum board shall be attached to the steel studs in accordance with the appropriate specification.

A2.2 Metal plaster bases shall be attached in accordance with Specification C 841 or Specification C 1063, except screw heads shall be of a size and type suitable for positive (no movement) attachment.

A2.3 When diaphragm rated components are substituted for bridging, they shall be installed prior to loading of the wall. If components are installed on one side of the wall only, then the other stud flanges shall be bridged with suitable bridging. Bridging is not required to be removed when diaphragm rated components are installed.

A2.4 Care shall be taken to allow for additional studs at panel intersections, corners, doors, window, control joints, etc.

A2.5 Provision for structure movement shall be provided as indicated and necessary by design or code requirements.

A2.6 Properly designed splices, cutting of flanges, and holes other than those provided by the manufacturer shall be approved in writing by the engineer of record.

A2.7 Care shall be taken to properly distribute construction materials so that they do not exceed the project design loads.

A3. SUBMITTALS

A3.1 The following items shall be considered for approval prior to delivery of materials to the site:

A3.1.1 *Shop Drawings*—Drawings shall illustrate materials; shop coatings; steel thickness; details of fabrication; details of attachment to adjoining work; size, location, spacing of fasteners for attaching framing to itself; details of attachment to the structure; accessories and their installation; and critical installation procedures. Drawings shall include plans, elevations, sections and details.

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A3.1.2 *Samples*—Samples shall be representative pieces of all framing component parts and accessories.

A3.1.3 *Certification*—Certification shall be a statement from the manufacturer certifying that the materials conform to the appropriate requirements as outlined in the contract documents.

A3.1.4 *Calculations*—Engineering calculations shall be prepared verifying the assembly's ability to meet or exceed design requirements as required by local codes and authorities.

A3.1.5 *Descriptive Literature*—Manufacturer's literature shall contain product and installation specifications and details.

SUMMARY OF CHANGES

Committee C11 has identified the location of selected changes to this specification since the last issue, C 1007 – 08, that may impact the use of this specification. (Approved November 1, 2008)

(*1*) Revised 6.2.

Committee C11 has identified the location of selected changes to this specification since the last issue, C 1007 – 04, that may impact the use of this specification. (Approved September 1, 2008)

(*1*) Revised 8.8.

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Designation: C1012/C1012M – 09

Standard Test Method for Length Change of Hydraulic-Cement Mortars Exposed to a Sulfate Solution[1]

This standard is issued under the fixed designation C1012/C1012M; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope*

1.1 This test method covers the determination of length change of mortar bars immersed in a sulfate solution. Mortar bars made using mortar described in Test Method C109/C109M are cured until they attain a compressive strength of 20.0 ± 1.0 MPa [3000 ± 150 psi], as measured using cubes made of the same mortar, before the bars are immersed.

1.2 The values stated in either SI units or inch-pound units are to be regarded separately as standard. Within the text, the inch-pound units are shown in brackets. The values stated in each system may not be exact equivalents; therefore, each system shall be used independently of the other. Combining values from the two systems may result in non-conformance with the standard.

1.3 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

2. Referenced Documents

2.1 *ASTM Standards:*[2]

C109/C109M Test Method for Compressive Strength of Hydraulic Cement Mortars (Using 2-in. or [50-mm] Cube Specimens)
C114 Test Methods for Chemical Analysis of Hydraulic Cement
C150 Specification for Portland Cement
C157/C157M Test Method for Length Change of Hardened Hydraulic-Cement Mortar and Concrete
C215 Test Method for Fundamental Transverse, Longitudinal, and Torsional Resonant Frequencies of Concrete Specimens
C305 Practice for Mechanical Mixing of Hydraulic Cement Pastes and Mortars of Plastic Consistency
C348 Test Method for Flexural Strength of Hydraulic-Cement Mortars
C349 Test Method for Compressive Strength of Hydraulic-Cement Mortars (Using Portions of Prisms Broken in Flexure)
C452 Test Method for Potential Expansion of Portland-Cement Mortars Exposed to Sulfate
C490 Practice for Use of Apparatus for the Determination of Length Change of Hardened Cement Paste, Mortar, and Concrete
C511 Specification for Mixing Rooms, Moist Cabinets, Moist Rooms, and Water Storage Tanks Used in the Testing of Hydraulic Cements and Concretes
C595 Specification for Blended Hydraulic Cements
C597 Test Method for Pulse Velocity Through Concrete
C618 Specification for Coal Fly Ash and Raw or Calcined Natural Pozzolan for Use in Concrete
C684 Test Method for Making, Accelerated Curing, and Testing Concrete Compression Test Specimens
C778 Specification for Standard Sand
C917 Test Method for Evaluation of Cement Strength Uniformity From a Single Source
C989 Specification for Slag Cement for Use in Concrete and Mortars
D1193 Specification for Reagent Water
E18 Test Methods for Rockwell Hardness of Metallic Materials

2.2 *American Concrete Institute Reports:*

ACI C201-2R-01 Guide to Durable Concrete[3]

3. Significance and Use

3.1 This test method provides a means of assessing the sulfate resistance of mortars made using portland cement, blends of portland cement with pozzolans or slags, and blended hydraulic cements. Method C452 is suitable for evaluating portland cements but not blended cements or blends of portland cement with pozzolans or slags.

3.2 The standard exposure solution used in this test method, unless otherwise directed, contains 352 moles of Na_2SO_4 per

[1] This test method is under the jurisdiction of ASTM Committee C01 on Cement and is the direct responsibility of Subcommittee C01.29 on Sulfate Resistance.

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[2] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

[3] Available from American Concrete Institute (ACI), P.O. Box 9094, Farmington Hills, MI 48333-9094, http://www.concrete.org.

***A Summary of Changes section appears at the end of this standard.**

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m^3 [50 g/L]. Other sulfate concentrations or other sulfates such as $MgSO_4$ may be used to simulate the environmental exposure of interest. Further discussion of these and other technical issues is given in the Appendix.

4. Apparatus

4.1 *Mixer*, conforming to the requirements of Practice C305.

4.2 *Cube Molds*, conforming to the requirements of Test Method C109/C109M.

4.3 *Bar Molds*, conforming to the requirements of Specification C490.

4.4 *Comparator*, conforming to the requirements of Specification C490.

4.5 *Containers*—The containers in which the bars are immersed shall be corrosion resistent such as plastic, glass, or ceramic. Support the bars so that no end or side of a bar rests against the container. Seal the container with a lid so that the sulfate solution cannot evaporate.

4.6 *Curing Tank*, conforming to the requirements of Test Method C684.

5. Reagents and Materials

5.1 *Purity of Reagents*—USP or technical grade chemicals may be used, provided it is established that any reagent used is of sufficiently high purity to permit its use without lessening the accuracy of the determination. When tests are made that are expected to produce results that are close to an acceptance-rejection value, it is recommended that reagent grade chemicals be used. Such chemicals shall conform to the specifications of the Committee on Analytical Reagents for the American Chemical Society where such specifications are available.[4]

5.2 *Purity of Water*—Unless otherwise indicated, references to water shall be understood to mean reagent water conforming to Type IV of Specification D1193.

5.3 *Sodium Sulfate (Na_2SO_4)*—Check the water content by loss on ignition each time the solution is prepared. Any anhydrous or hydrated sodium sulfate may be used if the water content of the salt is checked by loss on ignition and proper corrections made to account for the specified sulfate concentration.

5.4 *Sulfate Solution*—Each litre of solution shall contain 50.0 g of Na_2SO_4 dissolved in 900 mL of water, and shall be diluted with additional distilled or deionized water to obtain 1.0 L of solution. Mix the solution on the day before use, cover, and store at 23.0 ± 2.0 °C [73.5 ± 3.5 °F]. Determine the pH of the solution before use; reject the solution if the pH range is outside 6.0 to 8.0. Maintain the volume proportion of sulfate solution to mortar bars in a storage container at 4.0 ± 0.5 volumes of solution to 1 volume of mortar bars. For mortar bars 1 by 1 by 11¼ in. (volume of 184 mL [11.25 $in.^3$]), this is 645 to 830 mL of solution per mortar bar in the storage container. For mortar bars 25 by 25 by 285 mm (volume 178 mL), this is 625 to 800 mL of solution per mortar bar in the storage container.

5.5 *Materials*:

5.5.1 *Graded Standard Sand*, as specified in Specification C778.

5.5.2 *Stainless Steel Gauge Studs*, as specified in Specification C490.

6. Hazards

6.1 **Warning—**Fresh hydraulic cementitious mixtures are caustic and may cause chemical burns to skin and tissue upon prolonged exposure.[5]

7. Preparing Mortars

7.1 Make mortars as described in Test Method C109/C109M, that is, 1 part cement to 2.75 parts of sand by mass. Use a water-cement ratio by mass of 0.485 for all non-air-entraining portland cements and 0.460 for all air-entraining portland cements. Use a water-cement ratio by mass of 0.485 for non-air-entraining portland-pozzolan (IP) and portland-blast furnace slag (IS) cements. For blends of portland cement with a pozzolan or slag, use a water-cement ratio that develops a flow within ±5 of that of the portland-cement mortar at a water-cement ratio of 0.485.

8. Specimen Molds

8.1 Prepare the specimen molds in accordance with the requirements of Specification C490 except the interior surfaces of the mold shall be covered with a release agent. A release agent will be acceptable if it serves as a parting agent without affecting the setting of the cement and without leaving any residue that will inhibit the penetration of water into the specimen.

NOTE 1—TFE-fluorocarbon tape complies with the requirements for a mold release agent.

9. Procedure

9.1 *Molding and Initial Curing of Specimens*—Mold the test bars in accordance with Test Method C157/C157M. Mold the cubes in accordance with Test Method C109/C109M. A set of specimens to test one cement consists of 6 bars and up to 21 cubes (Note 2). Immediately after molding, cover the molds with a rigid steel, glass, or plastic plate, seal the plate to the mold so as to be watertight, and place the mold in the curing tank in water at 35 ± 3 °C [95 ± 5 °F] for 23½ h ± 30 min, as in Test Method C684, Procedure A (Warm-Water Method). Place the sealed molds in the curing tank with the bottom of the bars as cast down, that is, in the same relative position in which the bars were cast. At 23½ h ± 30 min, remove molds from tank and demold the specimens.

NOTE 2—The set of cubes consists of 21 cubes to be tested as described herein when significant information on the strength development rate is not available. When information is available (as for example, from the use

[4] *Reagent Chemicals, American Chemical Society Specifications* , American Chemical Society, Washington, DC. For Suggestions on the testing of reagents not listed by the American Chemical Society, see *Annual Standards for Laboratory Chemicals,* BDH Ltd., Poole, Dorset, U.K., and the *United States Pharmacopeia and National Formulary,* U.S. Pharmacopeial Convention, Inc. (USPC), Rockville, MD.

[5] See *Manual of Cement Testing*, Section on Safety, *Annual Book of ASTM Standards*, Vol 04.01.

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of the procedures of Test Method C917) that would justify making fewer cubes, only those needed to confirm the time the mortar achieves 20.0 ± 1.0 MPa [3000 ± 150 psi] are needed.

9.2 *Subsequent Curing and Preparation for Test*—After demolding, store all bars and cubes, except the two to be broken, in a curing tank of saturated limewater at 23.0 ± 2.0 °C [73.5 ± 3.5 °F]. Break two cubes in compression in accordance with Test Method C109/C109M after demolding when the specimens have cooled to ambient temperature under moist cloths. If the mean strength of the two cubes is 20 MPa [2850 psi] or more, observe and record comparator readings in accordance with Specification C490 and as prescribed in the section on Measurements of Length Change and place all the bars in the sulfate solution. If 20 MPa [2850 psi] is not achieved, store the demolded cubes and mortar bars in the curing tank and test additional cubes. Predict from the first two cubes when a compressive strength of at least 20 MPa [2850 psi] will be reached. Verify the prediction, and at that time observe and record comparator readings and place all the bars in the sulfate solution (Note 3). This measurement is designated as the initial length. The storage temperature and test temperature shall be 23.0 ± 2.0 °C [73.5 ± 3.5°F].

NOTE 3—If the value for strength at 24 h is less than 20.0 MPa [2850 psi] and additional testing on the same day is not possible, or, is unlikely to yield a value over 20.0 MPa [2850 psi] and the strength is over 21 MPa [3150 psi] when tested early the next day, it is not necessary to remake the batch.

9.3 *Storage of Test Bars during Exposure to Test Solution*—Cover the container of the bars and test solution, and seal it to prevent evaporation from the inside, or dilution with water from the outside. (See Note 4.) The storage temperature and test temperature shall be 23.0 ± 2.0 °C [73.5 ± 3.5 °C]. (See Note 5.)

NOTE 4—Gaffers tape or duct tape has been found to be suitable for sealing the container.

NOTE 5—This is the same temperature and temperature range as that specified for moist rooms in Specification C511.

9.4 *Measurements of Length Change*—At 1, 2, 3, 4, 8, 13, and 15 weeks after the bars are placed in the sulfate solution, test them for length change using the length comparator in accordance with Specification C490. Review the data at 15 weeks. Make the subsequent measurements at a minimum of 4, 6, 9, and 12 months. If at any time the rate of change between readings is great, insert other readings as needed to ensure the intervals are short enough to permit observing and reporting the behavior of the bars. If compliance with ACI C201-2R-01 Class 3 exposure is required, measure the bars at 4, 6, 9, 12, 15, and 18 months (Note 6).

NOTE 6—ACI C201-2R-01 requires an 18-month limit for Class 3 exposure.

9.4.1 *Details of Measurement of Bars for Length Change*:

9.4.1.1 Clean the hole in the base of the comparator into which the gauge stud on the lower end of the bar fits (this hole tends to collect water and sand and should be cleaned after every reading). Read and record the comparator indication of the length of the reference bar. Take one bar out of immersion, blot the pins, put the bar in the comparator, read, and record the indication. Return the bar to immersion and clean the hole in the base of the comparator. Take out the second bar and treat it in a like manner. Return the second bar to immersion, record the reading, and clean the hole in the base of the comparator. Continue the procedure until all bars have been read, returned to immersion, and the readings recorded, cleaning the hole in the bottom of the comparator each time. After reading the last bar, clean the hole in the comparator base and read and record the reference-bar indication.

9.4.1.2 When the required strength of the mortar is achieved in accordance with 9.2, store the bars in fresh sulfate solution. At subsequent readings for length change, proceed as described in 9.4.1.1; cleaning the socket in the base of the comparator before reading the reference bar initially and after reading each mortar bar. Record reference bar and mortar bar readings. Read and record the reference bar again after measurement of the last bar. Blot only around the pins (Note 7). Return each bar to the used sulfate solution after reading. When all the bars have been measured, discard the used solution. Rinse the container once with water, pouring out water and debris. Replace the frame holding the bars in the container, fill the container with enough new sulfate solution to immerse bars, and secure the lid on the container.

NOTE 7—The purpose of the minimal blotting of the pins and no blotting of the bars is to avoid drying and shrinkage of the bars. It has been observed that if the pins are blotted, and the bar placed in the comparator and the dial read, and the bar is then wiped gently with a dry cloth, the bar will shrink measurably. Therefore, drying should be minimized.

9.4.2 *Examination of Specimens After Measuring Length Change*—When the bars seem to have behaved in an unusual way or when the test is part of a research study, test the specimens for warping by placing them on a plane surface so that the ends are curved down and the maximum bowing measured. Note cracking (presence, location, type); also note surface deposits, mottling, exudations (nature, thickness, type).

9.5 *Tolerance on Time*—All references to elapsed time in 9.4 are intended to have a tolerance of ±2 %.

TABLE 1 Maximum Permissible Range of Values

Remaining No. of Specimens	Blended Cements	Portland Cement
3	0.034	0.010
4	0.037	0.011
5	0.039	0.012
6	0.041	0.012

10. Calculation

10.1 Calculate the length change at any age as follows:

$$\Delta L = \frac{L_x - L_i}{Lg} \times 100 \quad (1)$$

where:

ΔL = change in length at x age, %,

L_x = comparator reading of specimen at x age—reference bar comparator reading at x age, and

L_i = initial comparator reading of specimen-reference bar comparator reading, at the same time

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Lg = nominal gauge length, or 250 mm [10 in.] as applicable. (See C490).

10.2 Calculate length change values for each bar to the nearest 0.001 % and report averages to the nearest 0.01 %.

11. Report

11.1 Report type of cement, and, if blending material is used, its identification and amount and whether cement and blending material, if used, meet the applicable specifications. Report the initial comparator reading of each bar at the time of immersion in sulfate solution; this is the base value for calculation of length changes. Report the subsequent length changes in percent of base value to the nearest 0.001 % for individual bars and the nearest 0.01 % for averages. Comment on the visual condition of bars at end of the test. With each report of mean length change of bars at a particular age, report number of bars (*n*), standard deviation of length change, and coefficient of variation of length change. Data from at least three bars must be available at any age to constitute a valid test at that age. Depending upon how many remaining specimens there are, the maximum permissible range of the values must not exceed the values of length change in percent in Table 1.

11.2 Report any variation from the procedure outlined in the text as it relates to solution composition, concentration, or temperature, mortar proportions, age, or maturity, and so forth.

12. Precision and Bias

12.1 The precision of this test method has been evaluated by cooperative testing and found to vary with the type of cement studied, hence separate precision statements are given.[6]

12.1.1 *Blended Cements*—The single-operator standard deviation has been found to be 0.010 % for expansions between 0.04 % and 0.07 %. Therefore, results of two properly conducted tests by the same operator on the same blended cement Type IP or IS, should not differ from each other by more than 0.028 %. The multi-laboratory standard deviation has been found to be 0.020 % for expansions between 0.04 %, and 0.07 %. Therefore, results of two properly conducted tests on the same blended cement Type IP or IS in two different laboratories, should not differ from each other by more than 0.056 %.

12.1.2 *Type II Cement*—The single-operator standard deviation has been found to be 0.005 %, for expansions between 0.04 % and 0.07 %. Therefore, results of two properly conducted tests by the same operator on the same cement, should not differ from each other by more than 0.014 %. The multi-laboratory standard deviation has been found to be 0.020 % for expansions between 0.04 % and 0.07 %. Therefore, results of two properly conducted tests on the same cement in two different laboratories, should not differ from each other by more than 0.056 %.

12.1.3 *Type V Cement*—The single-operator standard deviation has been found to be 0.003 % for expansions between 0.04 % and 0.07 %. Therefore, results of two properly conducted tests by the same operator on the same cement, should not differ from each other by more than 0.009 %. The multi-laboratory standard deviation has been found to be 0.010 % for expansions between 0.04 % and 0.07 %. Therefore, results of two properly conducted tests on the same cement in two different laboratories should not differ from each other by more than 0.028 %.

12.2 *Bias*—Since there is no accepted reference material suitable for determining the bias for the procedure in this test method, no statement on bias is being made.

13. Keywords

13.1 acceptability; expansion; fly ash; mortars; pozzolans; precision; search report; slag; sulfate attack; sulfate-resisting cements; tests

[6] Supporting data have been filed at ASTM International Headquarters and may be obtained by requesting Research Report RR: RR:C01-1003.

ANNEX

(Mandatory Information)

A1. Determination of Water Content of Sodium Sulfate

A1.1 *Apparatus*

A1.1.1 Porcelain crucible, 15mL,

A1.1.2 Oven, drying capable of maintaining 110 ± 5 °C

A1.1.3 Desiccator with a good desiccant, such as magnesium percholrate, or activated alumina. Calcium sulfate treated with a color-change indicator that shows when it has lost its effectiveness is also suitable.

A1.1.4 Balance as described in Section 4 of Test Method C114.

A1.2 *Determining the water content*

Determine the mass of approximately 1 g of the sodium sulfate in a tared porcelain crucible to the nearest 0.0001 g. Dry the crucible and its contents for 1 ± 0.25 h in an oven at a temperature of 110 ± 5 °C [230 ± 10 °F]. Remove the crucible and its contents from the oven and cool in a dessicator until they are at room temperature. (See Note A1.1) Record the mass of the crucible and sodium sulfate after heating.

NOTE A1.1—15-30 minutes are usually sufficient. A small Pyrex beaker could be used as long as the mass can accurately be weighed (e.g. 50 ml beaker).

A1.3 *Calculation*

Calculate the water content of the sodium sulfate to the nearest 0.1%:

$$\% \text{ WC} = \frac{(M_i - M_f) \times 100}{M_{ss}} \quad \text{(A1.1)}$$

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where:

% WC = water content, %
M_i = mass of sodium sulfate + crucible before heating, g
M_f = mass of sodium sulfate + crucible after heating, g
M_{ss} = mass of sodium sulfate before heating, g

Use the % WC to correct the mass of sodium sulfate used in Section 5.4 (see Note A1.2).

NOTE A1.2—Example: Water content was determined to be 5.0 %. Thus, the corrected mass of anhydrous sodium sulfate present would be:

$$\frac{\text{Mass sodium sulfate uncorrected} \times (100 - \%\ \text{WC})}{100} \quad \text{(A1.2)}$$

or:

$$\frac{50\ \text{g}\ Na_2SO_4 \bullet \text{x}\ H_2O \times (100 - 5)}{100} = 47.5\ \text{g} \quad \text{(A1.3)}$$

or in reverse:

$$\frac{50\ \text{g}\ Na_2SO_4 \times 100}{(100 - 5)} = 52.6\ \text{g}\ Na_2SO_4 \bullet \text{x}\ H_2O \quad \text{(A1.4)}$$

APPENDIX

(Nonmandatory Information)

X1. Technical Background

X1.1 Test Method C1012 was developed to explore the suitability of a test method for sulfate resistance based on length-change measurements of molded prisms immersed in sulfate solution. This approach was taken after it was established that Test Method C452, in which the sulfate is added to the mortar as it is mixed, and the prisms stored in fresh water, was not able properly to evaluate sulfate resistance of blended cements and blends of portland cement with pozzolan or slag.

X1.2 This test method has been subjected to two rounds of cooperative testing. The first program involved five cements (Types I, II, and V of Specification C150, and Types IS and IP of Specification C595). The test solution contained both sodium sulfate and magnesium sulfate, each in the amount of 0.176 mol/L. A report of this work is available. A paper giving results using this test method has been published **(1)**.[7] The second program involved eight blends using a Type I and a Type II cement with 50 and 70 % slag, 25 % Class F, and 35 % Class C fly ash (Specification C618). Two test solutions were used: one contained 0.303 mol/L sodium sulfate and 0.049 % magnesium sulfate; the other contained 0.352 mol/L sodium sulfate only.

X1.3 This test method involves length change of hydraulic-cement mortar bars immersed in a sulfate solution. Mortar bars are placed in the sulfate solution after companion mortar cubes have reached a compressive strength of 20.0 ± 1.0 MPa [3000 ± 150 psi]. Attempts to use Test Method C452 for blended cements and blends of portland cement and slag (Specification C989) or pozzolan (Specification C618) with portland cement failed to yield results that correlate with field and laboratory experience where the mortar or concrete developed some maturity prior to being exposed to external sulfate solution **(2)**. Since some blended cements and some blends of slag and pozzolan with portland cement have been successfully used where sulfate resistance was needed, they are tested under circumstances which permit comparisons to be based on results obtained when all the sulfate exposures are begun at equivalent strength since, in practice, it is likely that the concrete will be at about the same strength when sulfate attack begins regardless of the type of cementitious medium employed. This test method is also applicable for use in evaluating portland cements.

X1.4 The solution of 0.176 mol/L of each of the two sulfates (magnesium and sodium) studied in the first cooperative program, is believed likely to adversely affect blends or blended cements containing slag, due to a magnesium ion **(3, 4)** attack, this attack being unrelated to sulfate attack. Therefore, this solution should not be used to evaluate such systems unless they are to be exposed in service to attack in which the magnesium ion (Mg^{++}) is present in amounts approaching that of the test solution (4200 ppm).

X1.5 This test method does not simulate the mechanism of sulfate attack by solutions of sulfate compositions other than that used. If evaluation of behavior due to exposure to a given sulfate solution is desired, that solution should be used.

X1.6 The user may therefore modify this test method to use any relevant compositions or concentrations of aggressive solutions, other ages or degrees of maturity as the basis for beginning the exposure, mortars of different proportions, or different or additional means of assessing the influence of the aggressive solution on the specimens. Much work was done using mortar bars of lower strength (higher porosity) in previous cooperative tests sponsored by Committee C01 **(5-7)**. A procedure in which sodium sulfate is kept at constant alkalinity/acidity has been proposed **(8)**. Other methods of assessing the influence of the aggressive solutions that have been used or proposed include (*a*) change in pulse velocity (Test Method C597), (*b*) change in resonant frequency (Test Method C215), (*c*) change in compressive strength (Test Methods C109/C109M and C349), (*d*) change in flexural strength (Test Method C348), (*e*) change in mass, and (*f*) change in hardness (Test Methods E18).

X1.7 Work reported by Polivka and Brown **(9)** in 1958 and by Mehta and Polivka in 1975 **(10)** included tests of concrete

[7] The boldface numbers in parentheses refer to the list of references at the end of this test method.

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exposed to a mixed sulfate solution containing 5 % each of sodium and magnesium sulfate. Other relevant work is cited in the references (**1-19**).

X1.8 The second cooperative study used both a mixed sodium/magnesium sulfate solution and a sodium sulfate solution. Precision of the results and the ranking of the cements did not differ between the solutions. Hence, the simpler test, using sodium sulfate, was selected as the standard.

REFERENCES

(**1**) Rosnerl, J. C., Chehovits, J. G., and Wharburton, R. G., "Sulfate Resistance of Mortars Using Fly Ash as a Partial Replacement for Portland Cement," *Proceedings*, Sixth International Conference on Utilization of Fly Ash, Reno, March 1982.

(**2**) Mather, Bryant, "Laboratory Tests of Portland Blast-Furnace Slag Cements," *Journal of the American Concrete Institute*, Proceedings, Vol 54, 1957, pp 205–232.

(**3**) Biczok, I. *Concrete Corrosion, Concrete Protection,* Chemical Publishing Company, New York, 1967, p 178.

(**4**) Miller, D. G., and Snyder, C. G., "Report on Comparative Short-Time Tests for Sulfate Resistance of 121 Commercial Cements," Report of Committee C-1 on Cement, Appendix III, *Proceedings*, ASTM, Vol 45, 1945, pp 165–194.

(**5**) Wolochow, D., "Determination of the Sulfate Resistance of Portland Cement," Report of Committee C-1 on Cement, Appendix, *Proceedings*, ASTM, Vol 52, 1952, pp. 250–363.

(**6**) Wolochow, D., "A Lean Mortar Bar Expansion Test for Sulfate Resistance of Portland Cements," Appendix A, *Proceedings*, ASTM, Vol 52, 1952, pp 264–265.

(**7**) Mather, Katharine, "Tests and Evaluation of Portland and Blended Cements for Resistance to Sulfate Attack," *ASTM STP 663*, 1978, pp 74–86.

(**8**) Mehta, P. K., "Evaluation of Sulfate-Resisting Cements by a New Test Method," *Proceedings of the American Concrete Institute*, Vol 72, Oct. 1975, pp 573–575.

(**9**) Polivka, M., and Brown, E. H., "Influence of Various Factors on Sulfate Resistance of Concretes Containing Pozzolan," *Proceedings*, ASTM, Vol 58, 1958, pp 1077–1100.

(**10**) Mehta, P. K., and Polivka, M., "Sulfate Resistance of Expansive Cement Concretes," American Concrete Inst SP-47, 1975, pp 367–379.

(**11**) Regourd, M., "The Action of Sea Water on Cements," *Annales de L'Institut Technique du Batiment et des Travaux Publics*, Vol 329, 1975, pp 86–102.

(**12**) Mehta, P. K., and Haynes, H. H., "Durability of Concrete in Sea Water," *Proceedings of the American Society for Civil Engineers*, Vol 101, No. ST 8, 1975, pp 1679–1686.

(**13**) Campus, F., "Essais de resistance des Mortiers et Betons à la Mer (1934–1964)," Silicates Industriel, Vol 28, 1963, pp 79–88.

(**14**) Bakker, R., "On the Cause of Increased Resistance of Concrete Made From Blast Furnace Cement to the Alkali Silica Reaction and to Sulfate Corrosion," (English Translation of doctoral thesis at RWTH 1980), Maastricht, 1981, 144 pp.

(**15**) Miller, D. G., and Manson, P. W., "Tests of 106 Commercial Cements for Sulfate Resistance," *Proceedings*, ASTM, Vol 40, 1940, pp 988–1001.

(**16**) Lea, F. M., *The Chemistry of Cement and Concrete*, Third Edition, Chemical Publishing Co., Inc., New York, NY, 1970, pp 727.

(**17**) Brown, P. W., "An Evaluation of the Sulfate Resistance of Cements in a Controlled Environment," Cement and Concrete Research. Vol 11, 1981, pp 719–727.

(**18**) Patzias, Terry, "Evaluation of Sulfate Resistance of Hydraulic-Cement Mortars by the ASTM C1012 Test Method. *Concrete Durability*, Katharine and Bryant Mather International Conference, American Concrete Institute SP-100, Vol 2, 1987, pp 2103–2120.

(**19**) Patzias, T., "The Development of ASTM C1012 with Recommended Acceptance Limits for Sulfate Resistance of Hydraulic Cement," Cement, Concrete, and Aggregates, CCA GDP, Vol 13, No. 1, Summer 1991, pp. 50–57.

SUMMARY OF CHANGES

Committee C01 has identified the location of selected changes to this test method since the last issue, C1012–04, that may impact the use of this test method. (Approved December 15, 2009)

(*1*) Revised the standard as a dual units test method.

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Designation: C 1017/C 1017M – 07

Standard Specification for Chemical Admixtures for Use in Producing Flowing Concrete[1]

This standard is issued under the fixed designation C 1017/C 1017M; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

This standard has been approved for use by agencies of the Department of Defense.

1. Scope*

1.1 This specification covers two types of chemical admixtures to be added to hydraulic cement concrete mixtures for the purpose of producing flowing concrete. The types are as follows:

1.1.1 *Type I*—Plasticizing, and

1.1.2 *Type II*—Plasticizing and retarding.

1.2 This specification stipulates tests of a chemical admixture with reference concreting materials or with concrete-making materials proposed for specific work. Unless otherwise specified by the purchaser, the tests shall be made using reference concreting materials.

1.3 If a chemical admixture has been tested and found to comply with the provisions of this specification using reference materials, and is being considered for use with other materials for specific work, additional tests for such use are allowed if agreed upon between the purchaser and the supplier and are allowed to consist of a portion of the tests described herein.

1.4 This specification provides for three levels of testing.

1.4.1 *Level 1*—During the initial approval stage, proof of compliance with the performance requirements defined in Table 1 demonstrates that the admixture meets the requirements of this specification. Uniformity and equivalence tests of the section on Lot Uniformity and Equivalence shall be carried out to provide results against which later comparisons can be made.

1.4.2 *Level 2*—Limited retesting described in the section relating to general requirements may be requested at intervals by the purchaser. Proof of compliance with the requirements of Table 1 demonstrates continued conformity of the admixture with the requirements of the specification.

1.4.3 *Level 3*—For acceptance of a lot or for measuring uniformity within or between lots, when specified by the purchaser, the uniformity and equivalence tests of the section on Lot Uniformity and Equivalence shall be used.

1.5 The values stated in SI units are to be regarded as standard. The values in inch-pound units shown in parentheses are provided for information purposes only.

NOTE 1—It is recommended that, whenever practicable, tests be made using the concrete-making materials (cement, pozzolan, slag, aggregates, air-entraining admixture), the mixture proportions, and the batching sequence and other physical conditions proposed for the specific work. The specific effects produced by chemical admixtures may vary with the properties and proportions of the other ingredients of the concrete.

NOTE 2—Temperature has a pronounced effect on time of setting of concrete. This may be exaggerated by the use of admixture Types I and II. If concrete temperatures to be expected on a particular job differ significantly from the conditions set forth in this specification, further testing may be desirable.

NOTE 3—An unusually rapid loss of workability with time, sometimes termed "slump loss", can be experienced with these admixtures. The rate of slump loss will vary with the particular concreting materials and proportions, mixing equipment and procedures, and temperatures experienced on any particular job. At elevated temperatures, the slump may be retained for a longer period if a Type II admixture is used.

NOTE 4—Admixtures that contain relatively large amounts of chloride may accelerate corrosion of prestressing steel. Compliance with the requirements of this specification does not constitute assurance of acceptability of the admixture for use in prestressed concrete (see ACI 318).

NOTE 5—Admixtures that contain relatively large amounts of alkali ($Na_2O + 0.658\ K_2O$) may contribute to reaction with some aggregates. Compliance with the requirements of this specification does not assure acceptability when used with alkali-reactive aggregates and some cements.

1.6 The text of this standard references notes and footnotes which provide explanatory material. These notes and footnotes (excluding those in tables and figures) shall not be considered as requirements of the standard.

1.7 The following precautionary caveat pertains only to the test method sections of this specification: *This standard does not purport to address all of the safety concerns, if any,*

[1] This specification is under the jurisdiction of ASTM Committee C09 on Concrete and Concrete Aggregates and is the direct responsibility of Subcommittee C09.23 on Chemical Admixtures.

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***A Summary of Changes section appears at the end of this standard.**

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associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.

2. Referenced Documents

2.1 *ASTM Standards:* [2]

C 33 Specification for Concrete Aggregates
C 39/C 39M Test Method for Compressive Strength of Cylindrical Concrete Specimens
C 78 Test Method for Flexural Strength of Concrete (Using Simple Beam with Third-Point Loading)
C 136 Test Method for Sieve Analysis of Fine and Coarse Aggregates
C 138/C 138M Test Method for Density (Unit Weight), Yield, and Air Content (Gravimetric) of Concrete
C 143/C 143M Test Method for Slump of Hydraulic-Cement Concrete
C 150 Specification for Portland Cement
C 157/C 157M Test Method for Length Change of Hardened Hydraulic-Cement Mortar and Concrete
C 173/C 173M Test Method for Air Content of Freshly Mixed Concrete by the Volumetric Method
C 183 Practice for Sampling and the Amount of Testing of Hydraulic Cement
C 192/C 192M Practice for Making and Curing Concrete Test Specimens in the Laboratory
C 231 Test Method for Air Content of Freshly Mixed Concrete by the Pressure Method
C 260 Specification for Air-Entraining Admixtures for Concrete
C 403/C 403M Test Method for Time of Setting of Concrete Mixtures by Penetration Resistance
C 666/C 666M Test Method for Resistance of Concrete to Rapid Freezing and Thawing
C 778 Specification for Standard Sand
D 75 Practice for Sampling Aggregates
D 1193 Specification for Reagent Water
E 100 Specification for ASTM Hydrometers
Manual of Aggregate and Concrete Testing

2.2 *American Concrete Institute Standard:*[3]

ACI 211.1-81 Recommended Practice for Selecting Proportions for Normal and Heavyweight Concrete
ACI 318-83 Building Code Requirements for Reinforced Concrete

3. Terminology

3.1 *Definitions of Terms Specific to This Standard:*

3.1.1 *flowing concrete*—concrete that is characterized by a slump greater than 7½ in. (190 mm) while maintaining a cohesive nature, and which otherwise meets the requirements of Table 1.

TABLE 1 Physical Requirements[A]

	Type I Plasticizing	Type II Plasticizing and Retarding
Time of setting, allowable deviation from Reference, h		
Initial: at least not more than	...	1 later
	1 earlier nor 1½ later	3½ later
Final: at least not more than	...	...
	1 earlier nor 1½ later	3½ later
Increase in slump, min.	90 mm (3.5 in.)	90 mm (3.5 in.)
Compressive strength, min., % of reference		
3 days	90	90
7 days	90	90
28 days	90	90
6 months	90	90
1 year	90	90
Flexural strength, min., % of reference		
3 days	90	90
7 days	90	90
28 days	90	90
Length change after 14 days drying, max. shrinkage (alternative requirements):[B]		
% of reference	135	135
Increase over reference, in.	0.010	0.010
Relative durability factor, min.[C]	80	80

[A] The values in the table include allowance for normal variation in the test results. The object of the 90 % strength requirements is to require a level of performance comparable to that of the reference concrete.

[B] *Alternative Requirements*—Percent of reference limit applies when length change of reference is 0.030 % or greater; increase over reference limit applies when length change of reference is less than 0.030 %.

[C] The requirement is applicable only when the admixture is to be used in air-entrained concrete which may be exposed to freezing and thawing while wet.

3.1.2 *plasticizing admixture*— a chemical admixture which, when added to concrete, produces flowing concrete without further addition of water and does not retard the setting of the concrete.

3.1.3 *plasticizing and retarding admixture*—a chemical admixture which, when added to concrete, produces flowing concrete without further addition of water and retards the setting of concrete.

3.1.4 *reference concrete*—concrete which contains the same amounts of cement, aggregates, water, and other concreting materials, but no plasticizing admixture.

3.1.5 *test concrete*—concrete which has a plasticizing admixture added.

4. Ordering Information

4.1 When the purchaser specifies flowing concrete, he shall also specify the type of chemical admixture desired. If not specified, the requirements of Type I will apply.

5. General Requirements

5.1 For initial compliance with this specification, test concrete in which each type of admixture shown in 1.1 is used shall conform to the respective requirements prescribed in Table 1.

5.2 The purchaser is allowed to require a limited retesting to confirm current compliance of the admixture to specification requirements. The limited retesting will cover physical properties and performance of the admixture.

[2] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

[3] Available from American Concrete Institute (ACI), P.O. Box 9094, Farmington Hills, MI 48333-9094, http://www.aci-int.org.

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5.2.1 The physical properties retesting shall consist of uniformity and equivalence tests for infrared analysis, residue by oven drying and specific gravity.

5.2.2 The performance property retesting shall consist of water content of fresh concrete, setting time and compressive strength at 3, 7 and 28 days.

NOTE 6—Additional performance tests currently in this standard may be required by users having special requirements.

5.3 At the request of the purchaser, the manufacturer shall state in writing that the admixture supplied for use in the work is identical in all essential respects, including concentration, to the admixture tested for conformance under this specification.

5.4 At the request of the purchaser, when the chemical admixture is to be used in prestressed concrete, the manufacturer shall state in writing the chloride content of the admixture and whether or not chloride has been added during its manufacture.

5.5 Tests for uniformity and equivalence shall be made on the initial sample and the results retained for reference and comparison, with the results of tests of samples taken from elsewhere within the lot or subsequent lots of admixture supplied for use in the work.

6. Lot Uniformity and Equivalence

6.1 When specified by the purchaser, the uniformity of a lot, or the equivalence of different lots from the same source, shall be established by the use of the following requirements:

6.1.1 *Infrared Analysis*—The absorption spectra of the initial sample and the test sample, obtained as specified, shall be essentially similar.

6.1.2 *Residue by Oven Drying (Liquid Admixtures)*—When dried as specified, the oven-dried residues of the initial sample and of subsequent samples shall be within a range of variation of not greater than five percentage points.

6.1.3 *Residue by Oven Drying (Nonliquid Admixtures)*—When dried as specified, the oven-dried residues of the initial sample and of the subsequent samples shall be within a range of variation not greater than four percentage points.

6.1.4 *Specific Gravity (Liquid Admixtures)*—When tested as specified, the specific gravity of subsequent test samples shall not differ from the specific gravity of the initial sample by more than 10 % of the difference between the specific gravity of the initial sample and that of reagent water at the same temperature. If 10 % of the difference between the specific gravity of the initial sample and water is less than 0.01, use the value 0.01 as the maximum allowable difference. Reagent water conforming to Specification D 1193, Types III or IV, and prepared by distillation, ion exchange, reverse osmosis, electrodialysis, or a combination of these procedures is adequate.

6.2 When the nature of the admixture or the analytical capability of the purchaser make some or all of these procedures unsuitable, other requirements for uniformity and equivalence from lot to lot or within a lot shall be established by agreement between the purchaser and the manufacturer.

7. Sampling and Inspection

7.1 Every facility shall be provided the purchaser for careful sampling and inspection, either at the point of manufacture or at the site of the work, as specified by the purchaser.

7.2 Samples shall be either grab or composite samples, as specified or required by this specification. A grab sample is one obtained in a single operation. A composite sample is one obtained by combining three or more grab samples.

7.3 Samples will be taken for two reasons:

7.3.1 *Quality Tests*—A sample taken for the purpose of evaluating the quality of a source or lot of admixture will be required to meet all the applicable requirements of this specification. Samples used to determine conformance with the requirements of this specification shall be composites of grab samples taken from sufficient locations to ensure that the composite sample will be representative of the lot.

7.3.2 *Uniformity and Equivalence Tests*— When specified by the purchaser, a sample taken for the purpose of evaluating the uniformity of a single lot, or equivalence of different lots from one source, shall be tested as provided in Section 6. Such samples shall be composite samples from individual lots when different lots from the same source are being compared. When the uniformity of a single lot is being determined, grab samples shall be used.

7.4 *Liquid Admixtures*—Liquid admixtures shall be agitated thoroughly immediately prior to sampling. Grab samples taken for quality or uniformity tests shall represent not more than 2500 gal (9500 L) of admixture and shall have a volume of at least 1 qt (1 L). A minimum of three grab samples shall be taken. Composite samples shall be prepared by thoroughly mixing the grab samples selected and the resultant mixture sampled to provide at least 1 gal (4 L) for quality tests. Grab samples shall be taken from different locations well distributed throughout the quantity to be represented.

7.4.1 Admixtures in bulk storage tanks shall be sampled equally from the upper, intermediate, and lower levels by means of drain cocks in the sides of the tanks or a weighted sampling bottle fitted with a stopper that can be removed after the bottle is lowered to the desired depth.

7.4.2 Samples shall be packaged in impermeable, airtight containers which are resistant to corrosion.

7.5 *Nonliquid Admixtures*—Grab samples taken for quality or uniformity tests shall represent not more than 2 tons (1800 kg) of admixture and shall weigh at least 2 lb (1 kg). A minimum of four grab samples shall be taken. Composite samples shall be prepared by thoroughly mixing the grab samples selected and the resultant mixture sampled to provide at least 5 lb (2.3 kg) for the composite sample. Grab samples shall be taken from different locations well distributed throughout the quantity to be represented.

7.5.1 Samples of packaged admixtures shall be obtained by means of a tube sampler as described in Practice C 183.

7.5.2 Samples shall be packaged in moisture-proof, airtight containers.

7.6 Samples shall be thoroughly mixed before testing to ensure uniformity. When recommended by the manufacturer,

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the entire sample of a nonliquid admixture shall be dissolved in water prior to testing.

TEST METHODS

8. Scope

8.1 These test methods are based on arbitrary stipulations which make possible highly standardized testing in the laboratory and are not intended to simulate actual job conditions.

9. Apparatus

9.1 *Infrared Spectrophotometer*.

9.2 *Hydrometers*, Nos. 112H through 117H in accordance with Specification E 100.

9.3 *Water Bath*, capable of maintaining 25 ± 1 °C.

10. Reagents and Materials

10.1 *Reagents*:

10.1.1 *Purity of Water*—Unless otherwise indicated, references to water shall be understood to mean reagent water as defined by Types III or IV of Specification D 1193.

10.1.2 *Potassium Bromide*, of a grade suitable for infrared analysis.

10.2 *Materials*:

10.2.1 *Cement*—The cement used in any series of tests shall be either the cement proposed for specific work or a cement conforming to the requirements of Specification C 150, Type I or Type II. If, when using a cement other than that proposed for specific work, the air content of the concrete made without admixture is more than 3.0 %, select a different cement so that the air content of the concrete will be 3.0 % or less.

10.2.2 *Aggregates*—Except when tests are made using the aggregates proposed for specific work, the fine and coarse aggregates used in any series of tests shall come from single lots of well-graded, sound materials that conform to the requirements of Specification C 33, except that the grading of the aggregates shall conform to the following requirements:

10.2.3 *Fine Aggregate*—The fine aggregate grading shall be as follows:

Sieve	Weight Percent Passing
4.75-mm (No. 4)	100
1.18-mm (No. 16)	65 to 75
300-µm (No. 50)	12 to 20
150-µm (No. 100)	2 to 5

10.2.4 *Coarse Aggregate*—The coarse aggregate grading shall meet the requirements for Size 57 grading requirements of Specification C 33. Take care in loading and delivery to avoid segregation.

10.2.4.1 Coarse aggregate used for reference concrete and test concrete shall be essentially the same. Provide sufficient coarse aggregate for the reference concrete, the test concrete, and for grading analysis.

10.2.4.2 Prepare required quantities of coarse aggregate (See Note 7) as follows: Fill tared containers, one for sieve analysis, one for a batch of reference concrete, and one for a batch of test concrete, to the required mass from the aggregate stockpile. Accomplish this by placing equal quantities into each container, successively, and repeat the procedure until all the containers have their required mass.

NOTE 7—Refer to the section on Sampling Aggregates in the Manual of Aggregate and Concrete Testing for guidance on sampling from stockpiles.

10.2.4.3 Perform sieve analyses on the coarse aggregate prepared in 10.2.4.2 by Test Method C 136. Discard any set for which the sample does not comply with Size 57. Average test results for samples that comply with Size 57 for each sieve size. Discard any set for which the sample deviates from this average by more than the amount shown in column 3 of the tabulated values shown below. Continue the process of preparation, testing, and averaging until sufficient sets of aggregate within tolerances are obtained.

Sieve	Specification C 33, No. 57 Percent Passing	Maximum variation from average/passing
37.5-mm (1.5 in.)	100	0.0
25.0-mm (1.0 in.)	95 to 100	1.0
12.5-mm (0.5 in.)	25 to 60	4.0
4.75-mm (No. 4)	0 to 10	4.0
2.36-mm (No. 8)	0 to 5	1.0

NOTE 8—All of the results required for demonstrating compliance under this specification are dependent on the uniformity of the aggregate samples prepared and used. Careful, skilled and well-supervised work is essential.

10.2.5 *20-30 Sand*—As specified in Specification C 778.

10.2.6 *Air-Entraining Admixture*—Except when tests are made using the air-entraining admixture proposed for specific work, the air-entraining admixture used, if needed in the concrete mixtures, shall be a material which when used to entrain the specified amount of air in the reference concrete mixture will give concrete of satisfactory resistance to freezing and thawing. The material to be so used will be designated by the person, or agency, for whom the testing is to be performed. If no material is designated, neutralized Vinsol resin shall be used.

NOTE 9—If unneutralized Vinsol resin is purchased, neutralization may be accomplished by treating 100 parts of Vinsol resin with 9 to 15 parts of NaOH by mass. In an aqueous solution, the ratio of water to the resinate should not exceed 12 to 1 by mass.

10.2.7 *Materials for Tests for Specific Uses*—To test a chemical admixture for use in specific work, the concreting materials used shall be representative of those proposed for use in the work. Add the chemical admixture in the same manner and at the same time during the batching and mixing sequence as it will be added on the job. Proportion the concrete mixtures to have the cement content specified for use in the work. If the maximum size of coarse aggregate is greater than 25.0 mm (1 in.), screen the concrete over a 25.0-mm (1-in.) sieve prior to fabricating the test specimens.

10.2.7.1 *Other Use Conditions*—At times, other conditions affect the overall suitability of the concrete mixture for specific intended uses. These include the temperature of the materials or the surroundings, the humidity, the length of time between mixing and placing, the amount of mixing activity and other factors. These physical conditions are allowed to be incorporated into the tests with intention for indicating the potential interactions. These tests would be only for guidance. After incorporation of such test conditions it would not be suitable to expect compliance with this specification requirement.

10.2.8 *Preparation and Weighing*—Prepare all material and make all weighings as prescribed in Practice C 192/C 192M.

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11. Proportioning of Concrete Mixtures

11.1 *Proportions*—Except when tests are being made for specific uses, all concrete shall be proportioned using ACI 211.19 to conform to the requirements described below.

NOTE 10—The effects of a chemical admixture on the time of setting and water requirement of concrete may vary with the time of its addition. Consequently, specifications for particular work should require that the admixture be added in the same manner and at the same time as it will be added on the job, or as recommended by the manufacturer, within the restrictions imposed by the specified mixing sequence.

11.1.1 The cement content shall be 335 ± 3 kg/m ^{3}(564 ± 5 lb/yd^3).

11.1.2 For the first trial mixture, refer to the table on volume of coarse aggregate per unit volume of concrete in ACI 211.1 for guidance on the amount of coarse aggregate to use, for the nominal maximum size of aggregate, and for the fineness modulus of the fine aggregate being used (Note 11).

NOTE 11—Values in the referenced table in ACI 211.1 are intended to ensure workable mixtures with the least favorable combinations of aggregate likely to be used.

11.1.3 For the non-air-entrained mixtures, the air content used in calculating the proportions shall be 1.5 %, as shown in Table 5.3.3 of ACI 211.1-81. For the air-entrained mixtures, the air content used for this purpose shall be 5.5 %.

11.1.4 Adjust the water content of both the reference concrete and the test concrete to obtain an initial slump of 90 ± 15 mm (3½ ± ½ in.). The workability of the concrete mixtures shall be suitable for consolidation by hand rodding, and the concrete mixtures shall have the minimum water content possible. Achieve these conditions by final adjustments in the proportion of fine aggregate to total aggregate, or in the amount of total aggregate, or both, while maintaining the yield and slump in the required range.

11.2 *Conditions*—Prepare batches of the final trial mixture, one of test concrete and one of reference concrete, which are identical prior to addition of the plasticizer. Add the admixture to the test concrete in the manner recommended by the manufacturer and in the amount necessary to obtain a slump of 215 ± 25 mm (8½ ± 1 in.).

11.2.1 *Non-Air-Entrained Concrete*—When the admixture is to be tested for use only in non-air-entrained concrete, the air content of both the test concrete mixture and the reference concrete mixture shall be 3.0 % or less, and the difference between the air contents of the two mixtures shall not exceed 0.5 %. If necessary, the air-entraining admixture shall be added to the reference concrete mixtures.

11.2.2 *Air-Entrained Concrete*—When the admixture is to be tested for use only in air-entrained concrete requiring resistance to freezing and thawing, the air-entraining admixture shall be added to reference and test concrete mixtures to produce air contents in the range of 5.0 to 7.0 %. When entrained air is to be used for workability or other purposes, air contents are adjusted to 3.5 to 7.0 %. In either case, the difference between the air content of the reference concrete and that of the test concrete shall not exceed 0.5 %.

12. Mixing

12.1 Machine mix the reference concrete mixture as prescribed in Practice C 192/C 192M.

12.2 Machine mix the test concrete mixture as prescribed in Practice C 192/C 192M, except that the admixture shall be added according to the manufacturer's instructions. In the absence of such instructions, add the admixture at the start of the 2 min final mixing period described in Practice C 192/C 192M.

13. Tests and Properties of Freshly Mixed Concrete

13.1 Samples of freshly mixed concrete from at least three separate batches for each condition of concrete shall be tested in accordance with the following methods:

13.1.1 *Slump*—Test Method C 143/C 143M.

13.1.2 *Air Content*—Test Method C 231 or Test Method C 173/C 173M.

13.1.3 *Time of Setting*—Test Method C 403/C 403M, except that the temperature of each of the ingredients of the concrete mixtures just prior to mixing and the temperature at which the time of setting specimens are stored during the test period shall be 23.0 ± 2.0 °C (73 ± 3 °F).

13.1.4 *Water Content and Unit Weight*— Determine the net water content of the batch as the weight of water in the batch in excess of that present as absorbed water in the aggregates. Measure the unit weight and compute the yield, cement content, and water content as prescribed in Test Method C 138/C 138M. Determine the water–cement ratio to the nearest 0.01 by dividing the net weight of water by the weight of cement in the batch.

14. Test Specimens of Hardened Concrete

14.1 Make specimens for tests of hardened concrete from at least three separate batches representing each test and age of test from each condition of concrete being compared. The minimum number of specimens shall be as prescribed in Table 2. On a given day, make at least one specimen for each test and age of test from each condition of concrete, except make at least two specimens for the freezing and thawing test from each condition of concrete. Complete the preparation of all specimens in three days of mixing.

14.2 *Manifestly Faulty Specimens*—Visually examine each group of specimens representing a given test or a given age of test, including tests of freshly mixed concrete, before or during the test, or both, whichever is appropriate. Discard without

TABLE 2 Types and Minimum Number of Specimens and Tests

	Number of Types of Specimens	Number of Test Ages	Number of Conditions of Concrete	Number of Specimens, min.
Slump	1	1	2	[A]
Air content	1	1	2	[A]
Time of setting	1	[B]	2	6
Compressive strength	1	5	2	30
Flexural strength	1	3	2	18
Freezing and thawing	2	1	2	12
Length change	1	1	2	6

[A] Determined on each batch of concrete mixed.
[B] As prescribed in the text.

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testing any specimen found to be manifestly faulty by such examination. Visually examine all specimens representing a given test at a given age after testing. Should any specimen be found to be manifestly faulty, the test results thereof shall be disregarded. Should more than one specimen representing a given test at a given age be found manifestly faulty either before or after testing, the entire test shall be disregarded and repeated. The test result reported shall be the average of the individual test results of the specimens tested or, in the event that one specimen or one result has been discarded, it shall be the average of the test results of the remaining specimens.

14.3 *Number of Specimens*—Six or more test specimens for the freezing and thawing test, and three or more test specimens for each other type of test and age of test specified in Table 2 shall be made for each condition of concrete to be compared.

14.4 *Types of Specimens*—Specimens made from concrete with and without chemical admixture under test shall be prepared in accordance with the following:

14.4.1 *Compressive Strength*—Make and cure test specimens in accordance with Practice C 192/C 192M.

14.4.2 *Flexural Strength*—Make and cure test specimens in accordance with Practice C 192/C 192M.

14.4.3 *Resistance to Freezing and Thawing*— Test specimens shall consist of prisms made and cured in accordance with the applicable requirements of Practice C 192/C 192M. The prisms shall be not less than 75 mm (3 in.) nor more than 130 mm (5 in.) in width and depth, and not less than 275 mm (11 in.) nor more than 410 mm (16 in.) in length. Make one set of specimens from the test concrete mixture and one from the reference concrete mixture, the air content of each mixture being as specified.

14.4.4 *Length Change*—Make and cure test specimens in accordance with Test Method C 157/C 157M. The moist-curing period, including the period in the molds, shall be 14 days.

15. Tests on Hardened Concrete

15.1 Test the specimens of hardened concrete in accordance with the following methods:

15.1.1 *Compressive Strength*—Test Method C 39/C 39M. Test specimens at ages 3 days, 7 days, 28 days, 6 months, and 1 year. Calculate the compressive strength of the concrete containing the admixture under test as a percentage of the compressive strength of the reference concrete as follows:

15.1.1.1 Divide the average compressive strength of the specimens made from the test concrete at a given age of test by the average compressive strength of the specimens made from the reference concrete at the same age of test and multiply the quotient by 100. Requirements are shown in Table 1.

NOTE 12—When tests are conducted with materials representative of those proposed for use in specific work, and if the results of the tests are required in a period of time that will not permit curing of specimens to ages of 6 months and 1 year, the tests at those ages as required in 14.1.1 may be waived.

15.1.2 *Flexural Strength*—Test Method C 78. Test specimens at ages 3, 7, and 28 days. Calculate the flexural strength of the test concrete as a percentage of the flexural strength of the reference concrete.

15.1.3 *Resistance to Freezing and Thawing*— Procedure A of Test Method C 666/C 666M. Place specimens under test at the age of 14 days unless durability at some later age is desired for specific work. Calculate the relative durability factors as shown in Specification C 260. Only air-entrained concrete designed for resistance to freezing and thawing shall be tested for resistance to freezing and thawing.

15.1.4 *Length Change*—Test specimens shall consist of molded prisms made and tested in accordance with Test Method C 157/C 157M, except that the moist curing period, including the period in the molds, shall be 14 days. Then store the specimens in air under conditions specified in Test Method C 157/C 157M for a period of 14 days, at which time determine the length change of the specimen. Consider the drying shrinkage to be the length change during the 14 day drying period, based on an initial measurement at the time of removal of the specimen from the mold, and express it as percent to the nearest 0.001 % based on the specimen gage length. Alternative requirements for length change, based on reference concrete length change, are shown in Table 1.

NOTE 13—Since the specific effects produced by chemical admixtures may vary with the properties of the other ingredients of the concrete, results of length change tests using aggregates of such a nature that the length change on drying is low may not accurately indicate relative performance to be expected from other aggregates having properties that produce concrete of high length change on drying.

16. Infrared Analysis

16.1 *Scope*—This test method is intended to compare qualitatively the composition of different samples; results should not be not interpreted quantitatively. A general procedure for the infrared analysis of admixtures is given.

NOTE 14—It is important that the same procedures be used on all samples to be compared with each other and it is preferable that they be conducted by the same analyst. Major changes in infrared spectra may result from: (*a*) water content differences due to drying variations, (*b*) water picked up by hygroscopic materials, (*c*) reaction between the potassium bromide and some other compound present, and (*d*) differences in time between formation of the disk and its use. Also, the threshold for detection of individual components by infrared absorption varies widely, depending upon the identity and concentration of accompanying substances. For example, significant amounts of saccharides may be present in a lignosulfonate admixture without their presence being indicated by this test method.

16.2 *Procedure*:

16.2.1 *Liquid Admixtures*—Determine the residue by oven drying by 17.1 and dilute an aliquot of the liquid admixture sample with distilled water to yield a dissolved solids concentration of about 0.015 g/mL: for example, a 5-mL aliquot diluted to 200 mL. Pipet 5 mL of above solution and add it to a petri dish containing 2.5 g of potassium bromide and 5 mL of distilled water. Stir and mix to dissolve. Place in a drying oven and dry for 17 ± ¼ h at 105 ± 3 °C. Cool and transfer the dried residue to a mortar and grind to a fine powder. Work quickly to avoid moisture pick-up. Weigh 0.1 g of the powder and 0.4 g of potassium bromide. Mix in an electric amalgamator for 30 s using stainless steel capsule and balls. Proceed in accordance with 16.2.3.

16.2.2 *Nonliquid Admixture*—Grind 10 g to a fine powder with mortar and pestle. Transfer the sample to a petri dish,

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place in a drying oven and dry for 17 ± ¼ h at 105 ± 3 °C. Weigh approximately 0.005 g of the dried powder and 0.995 g of potassium bromide. Mix in an electric amalgamator for 30 s using stainless steel capsule and balls. Proceed in accordance with 16.2.3.

16.2.3 To prepare a disk for infrared analysis, weigh 0.300 g of the mixture prepared in 16.2.1 or 16.2.2 and transfer into a suitable die. If an evacuable die is used, apply vacuum for 2 min prior to pressing. Continue vacuum and press at a suitable force for 3 min, producing a disk about 1-mm thick. Remove the disk from the die, insert into the infrared spectrophotometer, and obtain infrared absorption spectra.

17. Residue by Oven Drying

17.1 *Liquid Admixtures*:

17.1.1 Place 25 to 30 g of 20–30 sand (Specification C 778) in a wide-mouth, low-form (about 60 mm inside diameter and 30 mm in height) glass weighing bottle provided with a ground-glass stopper. Place the weighing bottle and stopper, with stopper removed, in a drying oven and dry for 17 ± ¼ h at 105 ± 3 °C (Note 15). The drying oven must be either a forced circulation type or one with provision for free access of air. Precise control of temperature and time of drying is essential so that the degree of volatilization of the material other than water from sample will not vary. Transfer to a desiccator, cool to room temperature, insert the stopper in the weighing bottle, and weigh to the nearest 0.001 g. Remove the stopper and, using a pipet, evenly distribute 4 mL of the liquid admixture over the sand. Immediately insert the stopper to avoid loss by evaporation and weigh to the nearest 0.001 g. Remove the stopper and place both the bottle and stopper in a drying oven. Dry for 17 ± ¼ h at 105 ± 3 °C. At the end of the drying period, transfer to a desiccator, cool to room temperature, stopper the weighing bottle, and weigh to the nearest 0.001 g.

NOTE 15—For laboratories conducting this test as a routine operation, previously dried sand and weighing bottles can be maintained in desiccators so that they are immediately available for use when a sample is to be tested.

17.1.2 *Calculation*:

17.1.2.1 Record the following masses:

M_1 = mass of stoppered bottle with sand and sample,
M_2 = mass of stoppered bottle with sand,
M_3 = $M_1 - M_2$ = mass of sample,
M_4 = mass of stoppered bottle with sand and dried residue, and
M_5 = $M_4 - M_2$ = mass of dried residue.

17.1.2.2 Calculate the residue by using the following equation.

$$\text{Residue by oven drying (percent by mass)} = (M_5 \times 100)/M_3 \quad (1)$$

17.1.3 *Precision*—The maximum multilaboratory coefficient of variation for residue by oven drying (liquid admixtures) has been found to be 1.25 %. Therefore, results of tests by two different laboratories on identical samples of an admixture are not expected to differ from each other by more than 3.5 % of their average (Note 16). The maximum single-operator coefficient of variation has been found to be 0.6 %. Therefore, results of two properly conducted tests by the same operator on the same material are not expected to differ by more than 1.7 %.

NOTE 16—The precision statements are based on the maximum variation of tests made in 18 laboratories on sets of three duplicate samples of two different admixtures.

17.2 *Nonliquid Admixtures*:

17.2.1 Place about 3 g of the nonliquid admixture into a dried and tared glass-stoppered weighing bottle. Stopper and weigh bottle and contents to the nearest 0.001 g. Remove the stopper and immediately place both bottle and stopper in a drying oven. Dry for 17 ± ¼ h at 105 ± 3°C. At the end of the drying period, transfer to the desiccator, cool to room temperature, stopper the weighing bottle, and weigh to the nearest 0.001 g.

17.2.2 *Calculation*:

17.2.2.1 Record the following masses:

M_1 = mass of tared stoppered weighing bottle and sample before drying,
M_2 = mass of empty, stoppered weighing bottle,
M_3 = $(M_1 - M_2)$ = mass of sample,
M_4 = mass of tared stoppered weighing bottle and sample after drying, and
M_5 = $(M_4 - M_2)$ = mass of oven-dried residue.

17.2.2.2 Calculate the oven dried residue by using the following equation:

$$\text{Residue by oven drying (mass percent)} = (M_5 \times 100)/M_3 \quad (2)$$

17.2.3 *Precision*—The maximum multilaboratory coefficient of variation for residue by oven drying (nonliquid admixtures) has been found to be 1.40 %. Therefore, results of tests by two different laboratories on identical samples of an admixture are not expected to differ from each other by more than 4.0 % of their average. The maximum single-operator coefficient of variation for residue by oven drying (nonliquid admixture) has been found to be 0.48 %. Therefore, results of two properly conducted tests by the same operator on the same material are not expected to differ by more than 1.4 % of their average (Note 16).

18. Specific Gravity (Liquid Admixtures)

18.1 Determine the specific gravity at 25 ± 1 °C of a liquid admixture using hydrometers complying with Specification E 100. Hydrometers Nos. 112H through 117H will cover the range for most determinations. A250-mL graduated cylinder, and a water bath capable of maintaining 25 ± 1 °C will also be required.

18.2 Place a sample in the 250-mL graduated cylinder and put in the hydrometer in such a manner that it floats free and does not touch the side of the cylinder. Place the cylinder with sample and hydrometer in the constant-temperature bath until the temperature of the cylinder, hydrometer, and sample is uniform at 25 ± 1°C. If all are at the proper temperature prior to insertion of the hydrometer, approximately 10 min shall be

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allowed for equilibrium. If the sample shows evidence of foaming, hydrometer reading shall be continued until constant readings are obtained. Read the hydrometer at the base of the meniscus to the nearest 0.005.

NOTE 17—If foaming is encountered during transfer of the admixture to the cylinder, sufficient time should be allowed for the foam to dissipate or rise to the surface, or both, so that it will be removed before inserting the hydrometer. Crusting of the admixture on the hydrometer stem due to evaporation during temperature adjustment should be avoided.

18.3 *Precision*—The maximum multilaboratory coefficient of variation for specific gravity (liquid admixtures) has been found to be 0.316 %. Therefore, results of tests by two different laboratories on identical samples of an admixture are not expected to differ from each other by more than 0.9 % of their average (Note 16). The maximum single-operator coefficient of variation has been found to be 0.09 %. Therefore, results of two properly conducted tests by the same operator on the same material are not expected to differ by more than 0.275 %.

19. Rejection

19.1 For initial compliance testing, the purchaser is allowed to reject the admixture if it fails to meet any of the applicable requirements of this specification.

19.2 For limited retesting, the purchaser is allowed to reject the admixture if it fails to meet any of the requirements of the Uniformity and Equivalence Section and of the applicable parts of Table 1.

19.3 An admixture stored at the point of manufacture for more than 6 months prior to shipment, or an admixture in local storage in the hands of a vendor for more than 6 months after completion of tests, shall be retested if requested by the purchaser and is allowed to be rejected if it fails to conform to any of the applicable requirements of this specification.

19.4 Packages or containers varying more than 5 % from the specified weight or volume are allowed to be rejected. If the average weight or volume of 50 packages taken at random is less than that specified, the entire shipment is allowed to be rejected.

19.5 The admixture shall be rejected when the purchaser desires if the test concrete containing it has an air content greater than 3.0 % in non-air-entraining concrete; when the admixture is to be used in air-entrained concrete, it shall be rejected when the purchaser desires if the test concrete containing it has an air content greater than 7.0 %. Except when testing in accordance with 10.2.4, other concrete materials are allowed to be chosen for reference and test concretes in order to conform to these requirements.

20. Certification and Report

20.1 When specified in the purchase order or contract, the manufacturer's or supplier's certification shall be furnished to the purchaser stating that samples representing each lot have been manufactured, tested, and inspected in accordance with this specification and the requirements have been met. When specified in the purchase order or contract, a report of the test results shall be furnished.

20.2 Report the following:

20.2.1 Results of the specified tests and the relevant specification requirements with which they are compared,

20.2.2 Brand name, manufacturer's name, and lot number, character of the material, and quantity represented by the sample of the admixture under test,

20.2.3 Brand name, manufacturer's name, and other pertinent data on the material used as the air-entraining admixture,

20.2.4 Brand name, manufacturer's name, type, and test data on the portland cement or cements used,

20.2.5 Description of, and test data on, the fine and coarse aggregates used,

20.2.6 Detailed data on the concrete mixtures used, including amounts and proportions of admixtures used, actual cement contents, water-cement ratios, densities (unit weights), ratios of fine to total aggregate, slumps, and air contents, and

20.2.7 In the event that, in accordance with the provisions of Note 12, some of the tests have been waived, the circumstances under which such action was taken shall be stated.

21. Packaging and Package Marking

21.1 When the admixture is delivered in packages or containers, the proprietary name of the admixture, the type under this specification, and the net weight or volume shall be plainly marked thereon. Similar information shall be provided in the shipping documents accompanying packages or bulk shipments of admixtures.

22. Storage

22.1 The admixture shall be stored in such a manner as to permit easy access for proper inspection and identification of each shipment and adequate protection for the admixture.

23. Keywords

23.1 admixture; concrete; flowing concrete; plasticizing admixtures; plasticizing and retarding admixtures; water-reducing admixtures; water-reducing and retarding admixtures

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SUMMARY OF CHANGES

Committee C09 has identified the location of selected changes to this specification since the last issue, C 1017/C 1017M – 03, that may impact the use of this specification. (Approved June 1, 2007)

(*1*) Revised 10.2.4, 10.2.4.1, 10.2.4.2 and 10.2.4.3 to clarifying wording.

(*2*) Added new Note 7 and renumbered subsequent notes.

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Designation: C 1032 – 06

Standard Specification for Woven Wire Plaster Base[1]

This standard is issued under the fixed designation C 1032; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope*

1.1 This specification covers woven wire plaster base, flat or self-furring, with or without stiffener wires, and with or without backing, designed for use as a base to receive gypsum or portland cement based plaster.

1.2 The values stated in inch-pound units are to be regarded as the standard. The SI equivalents of inch-pound units are approximate.

1.3 The text of this standard references notes and footnotes which provide explanatory material. These notes and footnotes (excluding those in tables and figures) shall not be considered as requirements of the standard.

2. Referenced Documents

2.1 *ASTM Standards:* [2]

A 641/A 641M Specification for Zinc–Coated (Galvanized) Carbon Steel Wire

C 11 Terminology Relating to Gypsum and Related Building Materials and Systems

2.2 *Federal Specifications:*

UU-B-790a Building Paper, Vegetable Fiber: Kraft, Waterproofed, Water Repellent and Fire Resistant[3]

UU-P-31 B/171 Tensile Breaking Strength (Dry)[3]

3. Terminology

3.1 *Definitions*—Definitions shall be in accordance with Terminology C 11.

4. Material

4.1 In accordance with Specification A 641/A 641M and Table 1.

4.2 *Kraft Building Paper*, Federal Specification UU-B-790a.

TABLE 1 Nominal Diameter and Minimum Weight for Size of Opening

Opening Size, in. (mm)	Diameter, in. (mm)	Weight, lb/yd^2 (kg/m^2)[A]
1 (25.4)	0.035 (0.89)	0.86 (0.466)
1½ (38.0)	0.051 (1.30)	1.40 (0.760)

[A] The weight of attached backing is not included.

5. Physical Properties

5.1 *Backing*:

5.1.1 Factory attached backing shall provide a one mesh wire to wire lap joint at one end and one edge of each flat sheet or roll. Attachment of the backing shall allow lapping of wire-to-wire and backing-to-backing of one mesh at ends and edges and shall permit full embedment in not less than ¼ in. (6.4 mm) of plaster of not less than one half the total length and width of the wire.

5.1.2 Backing shall have a minimum tensile breaking strength (dry) of 20 lbf/in. (3.5 kN/m) width, as tested in accordance with Federal Specification UU-P-31 B, Method 171.

6. Dimensions, Weight, and Permissible Variations

6.1 *Openings*:

6.1.1 Woven wire plaster base shall be fabricated to provide the size of openings in accordance with Table 1, except that any single opening shall be not more than 3.0 in.^{2} (1935.5 mm^2).

6.1.2 Wire diameter for opening size shall be in accordance with Table 1.

6.2 Diameter tolerance for galvanized wire shall be in accordance with Specification A 641/A 641M.

6.3 The wire shall be zinc-coated (galvanized) in accordance with Specification A 641/A 641M.

6.4 Weight for woven wire plaster base shall be in accordance with Table 1.

6.5 When included as part of the woven wire plaster base, factory fabricated stiffener wires shall have a diameter not less than that specified in Table 1 and shall be continuous, parallel to the long dimension of the plaster base, and shall occur at not more than 6-in. (154.4-mm) intervals.

6.6 Factory fabricated crimps for self-furring woven wire plaster base shall provide a nominal ¼-in. (6.4-mm) separation between the back plane of the plaster base and the surface of solid backing to permit embedment in both directions.

[1] This specification is under the jurisdiction of ASTM Committee C11 on Gypsum and Related Building Materials and Systems and is the direct responsibility of Subcommittee C11.02 on Specifications and Test Methods for Accessories and Related Products.

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[2] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

[3] Available from U.S. Government Printing Office Superintendent of Documents, 732 N. Capitol St., NW, Mail Stop: SDE, Washington, DC 20401.

***A Summary of Changes section appears at the end of this standard.**

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6.7 Width of woven wire plaster base shall be not less than 36 in. (914 mm).

6.8 Length of woven wire plaster base shall be in accordance with Table 2.

7. Inspection

7.1 Inspection of the material shall be agreed upon between the purchaser and the producer or supplier as part of the purchase agreement.

8. Rejection and Rehearing

8.1 Material that fails to conform to the requirements of this specification shall be reported to the producer or supplier promptly and in writing. The notice of rejection shall contain a statement documenting how the product has failed to conform to the requirements of the specification.

TABLE 2 Minimum Length of Flat Sheets and Rolls[A]

Flat Sheets	100 linear in. (2.540 m)
Rolls	150 linear ft. (45.72 m)
Rolls, with backing	100 linear ft. (30.48 m)

[A] Allowable variations shall be not more than – ¾ in. (–19.0 mm) in width or length.

9. Certification

9.1 When specified in the purchase order or contract, the producer or supplier shall furnish a report certifying that at the time of shipment, the materials were in compliance with the requirements of this specification.

10. Packaging and Package Marking

10.1 *Packaging*—Woven wire plaster base shall be packaged in bundles, rolls or pallets.

10.2 *Marking*—When shipped for sale or resale, the name of the producer or the supplier and the brand and description of the contents shall be legibly marked on each pallet, bundle or roll. The quantity for bundles shall be square yards and number of sheet per bundle. The quantity for pallets, bundles or rolls shall indicate the mesh-opening size and wire thickness.

11. Keywords

11.1 backing; base; cement plaster; flat; gypsum plaster; plaster; self-furning; woven wire

SUMMARY OF CHANGES

Committee C11 has identified the location of selected changes to this specification since the last issue, C 1032 – 04, that may impact the use of this specification. (Approved June 1, 2006)

(*1*) Combined Tables 1 and 2 into new Table 1.

(*2*) Changed references to old Tables 1 and 2 to new Table 1 within the text of the specification.

(*3*) Renumbered Table 3 as Table 2.

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Designation: C 1038 – 04

Standard Test Method for Expansion of Hydraulic Cement Mortar Bars Stored in Water[1]

This standard is issued under the fixed designation C 1038; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope

1.1 This test method covers the determination of the expansion of mortar bars made using hydraulic cement, of which sulfate is an integral part.

1.1.1 **Warning**—Fresh hydraulic cementitious mixtures are caustic and may cause chemical burns to skin and tissue upon prolonged exposure.

1.2 The values stated in SI units are to be regarded as the standard. Values in parentheses are for information only.

1.3 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

2. Referenced Documents

2.1 *ASTM Standards:* [2]

C 109/C 109M Test Method for Compressive Strength of Hydraulic Cement Mortars (Using 2-in. or [50-mm] Cube Specimens)

C 305 Practice for Mechanical Mixing of Hydraulic Cement Pastes and Mortars of Plastic Consistency

C 490 Practice for Use of Apparatus for the Determination of Length Change of Hardened Cement Paste, Mortar, and Concrete

C 511 Specification for Mixing Rooms, Moist Cabinets, Moist Rooms, and Water Storage Tanks Used in the Testing of Hydraulic Cements and Concretes

C 778 Specification for Standard Sand

C 1005 Specification for Reference Masses and Devices for Determining Mass and Volume for Use in the Physical Testing of Hydraulic Cements

C 1437 Test Method for Flow of Hydraulic Cement Mortar

D 1193 Specification for Reagent Water

3. Significance and Use

3.1 This test method is used to determine the amount of expansion of a mortar bar when it is stored in water. The amount of mortar-bar expansion may relate to the amount of sulfate in the cement; expansion may become excessive when the cement contains too much sulfate.

3.2 Some cement specifications limit the amount of sulfate contained in hydraulic cement by requiring that the amount of expansion in water not exceed a specified value.

4. Apparatus

4.1 *Reference Masses and Mass-Determining Devices*, conforming to the requirements of Specification C 1005. Evaluate the device for precision and bias at a total load of 2 Kg.

4.2 *Glass Graduates, Molds, and Length Comparator*, conforming to the requirements of Specification C 490.

4.3 *Moist Cabinet or Room*, conforming to the requirements of Specification C 511.

4.4 *Mixer, Bowl, and Paddle*, conforming to the requirements of Practice C 305.

4.5 *Trowel and Tamper*, conforming to the requirements of Test Method C 109.

5. Temperature and Relative Humidity

5.1 *Molding Room, Dry Materials, and Mixing Water*—Maintain the temperature of the molding room, dry materials, and mixing water at 23.0 ± 4.0 °C, and maintain the relative humidity of the molding room at not less than 50 %.

6. Reagents and Materials

6.1 *Mixing Water*—Potable water is satisfactory for routine tests. For all cooperative tests and in case of dispute, use reagent water conforming to the numerical limits of Type III of Specification D 1193.

6.2 *Graded Sand*—Sand for making the test specimens shall conform to the requirements for graded standard sand in Specification C 778.

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[1] This test method is under the jurisdiction of ASTM Committee C01 on Cement and is the direct responsibility of Subcommittee C01.28 on Sulfate Content.

Current edition approved July 1, 2004. Published August 2004. Originally approved in 1985. Last previous edition approved in 2001 as C 1038 – 01ε1.

[2] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

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7. Procedure

7.1 *Number and Dimensions of Test Specimens*—Make four 25 by 25 by 285-mm, or 1 by 1 by 11¼-in. test specimens for each cement. The effective gage length of these specimens is 250 mm (10 in.).

NOTE 1—In routine tests, 25 by 25 by 160-mm, or 1 by 1 by 6¼-in. specimens may be used; however, in case of dispute, results obtained with 25 by 25 by 285-mm, or 1 by 1 by 11¼-in. specimens shall govern. The effective gage length of this specimen is 125 mm (5 in.).

7.2 *Specimen Molds*—Prepare the specimen molds in accordance with the requirements of Specification C 490, except cover the interior surfaces of the mold with a release agent. A release agent will be acceptable if it serves as a parting agent without affecting the setting of the cement and without leaving any residue which will reduce the penetration of water into the specimen.

NOTE 2—TFE-fluorocarbon tape complies with the requirements for a mold release agent.

7.3 *Proportioning, Consistency, and Mixing of Mortar*:

7.3.1 The quantity of dry materials required to prepare four 25 by 25 by 285-mm or 1 by 1 by 11¼-in. specimens is 500 g of cement and 1375 g of graded sand. Use an amount of mixing water that produces a flow of 110 ± 5 as determined by the flow table after 25 drops in 15 s as described in Test Method C 1437. Record the amount of water used to the nearest millilitre.

7.3.2 Mix the mortar in accordance with the procedure described in Practice C 305.

7.4 *Molding Test Specimens*—Immediately upon completion of mixing, remove the paddle and the bowl from the mixer and shake the excess mortar from the paddle into the bowl. Fill the mold in two layers, compacting each layer with the tamper. Work the mortar into the corners, around the gage studs, and along the surfaces of the mold with the tamper until a homogeneous specimen is obtained. After the top layer has been compacted, cut the mortar off flush with the top of the mold and smooth the surface with a few strokes of the trowel.

8. Storage of Test Specimens

8.1 *Initial Storage*—Immediately upon completion of molding, place the test specimens in the moist cabinet or moist room. Keep all test specimens in the molds in the moist cabinet or moist room for 22.5 ± 0.5 h with upper surfaces exposed to the moist air but protected from dripping water. After this time, remove the specimens from the molds, properly identify, and place in water or saturated lime water maintained at 23.0 ± 2.0 °C for at least 30 min prior to making the initial measurement.

8.2 *Subsequent Storage*—After the initial measurement, store the test specimens in saturated lime water in a tank in the moist cabinet or moist room. Cover the specimens with at least 5-mm (¼-in.) of water during storage. Keep the storage water clean by changing as necessary. Use a tank and lime water conforming to the requirements of Specification C 511.

9. Length Change Measurement

9.1 Remove the specimens from water storage, one at a time, and wipe only the gage studs with a damp cloth before measuring. Make length-comparator readings. The effective gage length of specimens is 250 mm or 10 in. for the standard mold size.

9.2 Make the first reading at the age of 24 h ± 15 min from the time the cement and water are mixed together. Make additional length-comparator readings at the age of 14 days.

NOTE 3—Additional information of value may be obtained by making length-comparator readings of the specimens at ages earlier and later than 14 days.

10. Calculation and Report

10.1 Calculate the change in length of the specimen at 24 h and at 14 days to the nearest 0.001 % of the effective gage length and report as the expansion of the specimen at that period. Report the average length of change of the four specimens to the nearest 0.001 %.

11. Precision and Bias

11.1 *Precision*—The following precision statements are applicable when replicate samples are made using the same portland cement at fixed water content.

11.1.1 The single-operator standard deviation has been found to be 0.00165 % for expansions between 0.0075 and 0.011 %. Therefore, results of two properly conducted tests by the same operator on the same material should not differ from each other by more than 0.005 %.

11.1.2 The multi-laboratory standard deviation has been found to be 0.00287 % for expansions between 0.0075 and 0.0115 %. Therefore, results of two properly conducted tests on the same material in two different laboratories should not differ from each by more than 0.008 %.

11.2 *Bias*—Since there is no accepted reference material suitable for determining the bias for the procedure in Test Method C 1038 for measuring the expansion of the bar specimens, no statement on bias is being made.

12. Keywords

12.1 hydraulic cement; mortar-bar expansion; sulfate; sulfate content

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Designation: C 1040/C 1040M – 08

Standard Test Methods for In-Place Density of Unhardened and Hardened Concrete, Including Roller Compacted Concrete, By Nuclear Methods[1]

This standard is issued under the fixed designation C 1040/C 1040M; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope*

1.1 These test methods cover the determination of the in-place density of unhardened and hardened concrete, including roller compacted concrete, by gamma radiation. For notes on the nuclear test see Appendix X1.

1.2 Two test methods are described, as follows:

	Section
Test Method A—Direct Transmission	7
Test Method B—Backscatter	8

1.3 The values stated in either SI units or inch-pound units are to be regarded separately as standard. The values stated in each system may not be exact equivalents; therefore, each system shall be used independently of the other. Combining values from the two systems may result in non-conformance with the standard.

1.4 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

2. Referenced Documents

2.1 *ASTM Standards:* [2]

C 29/C 29M Test Method for Bulk Density ("Unit Weight") and Voids in Aggregate

C 138/C 138M Test Method for Density (Unit Weight), Yield, and Air Content (Gravimetric) of Concrete

C 670 Practice for Preparing Precision and Bias Statements for Test Methods for Construction Materials

3. Significance and Use

3.1 These test methods are useful as rapid, nondestructive techniques for the in-place determination of the density of unhardened concrete. The backscatter test method is also useful for the same purpose on hardened concrete. The fundamental assumptions inherent in the test methods are that Compton scattering is the dominant interaction and that the material under test is homogeneous.

3.2 These test methods are suitable for control and for assisting in acceptance testing during construction, for evaluation of concrete quality subsequent to construction, and for research and development.

NOTE 1—Care must be taken when using these test methods in monitoring the degree of consolidation, which is the ratio of the actual density achieved to the maximum density attainable with a particular concrete. The test methods presented here are used to determine the actual density. A density measurement, by any test method, is a function of the components of the concrete and may vary, to some extent, in response to the normal, acceptable variability of those components.

3.3 Test results may be affected by reinforcing steel, by the chemical composition of concrete constituents, and by sample heterogeneity. The variations resulting from these influences are minimized by instrument design and by the user's compliance with appropriate sections of the test procedure. Results of tests by the backscatter test method may also be affected by the density of underlying material. The backscatter test method exhibits spatial bias in that the apparatus's sensitivity to the material under it decreases with distance from the surface of the concrete.

NOTE 2—Typically, backscatter gauge readings represent the density in the top 75 to 100 mm [3 to 4 in.] of material.

4. Apparatus

4.1 The exact details of construction of the apparatus may vary, but the apparatus as a whole shall satisfy the requirements for system precision stated in Annex A1. The system shall consist of the following:

4.1.1 *Gamma Source*—An encapsulated and sealed radioisotopic source, such as cesium-137 (see X1.2).

[1] These test methods are under the jurisdiction of ASTM Committee C09 on Concrete and Concrete Aggregates and are the direct responsibility of Subcommittee C09.45 on Roller-Compacted Concrete.

Current edition approved Oct. 1, 2008. Published November 2008. Originally approved in 1985. Last previous edition approved in 2005 as C 1040 – 05.

[2] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

***A Summary of Changes section appears at the end of this standard.**

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4.1.2 *Detector*—Any type of gamma detector, such as a Geiger-Müller tube, scintillation crystal, or proportional counter.

4.1.3 *Probe*—For direct transmission measurements, either the gamma source or the detector shall be housed in a probe for inserting in a preformed hole in the material to be tested. The probe shall be marked in increments of 50 mm [2 in.] for tests with probe depths from 50 to 300 mm [2 to 12 in.]. The probe shall be so made mechanically, that when moved manually to the marked depth desired, it will be held securely in position at that depth.

4.1.4 *Readout Instrument*—A suitable scaler or direct readout meter.

4.1.5 *Gauge Housing*—The source, detector, readout instrument and appropriate power supplies shall be in housings of rugged construction that are moisture and dust proof.

4.1.6 *Reference Standard*—A block of uniform, unchanging density provided for checking equipment operation, background count, and count-rate reproducibility.

4.1.7 *Guide Plate and Hole-Forming-Device*—For direct transmission measurements, a guide plate and a device, such as a pin or drill rod, having a nominal diameter slightly larger than the probe, for forming a hole normal to the concrete surface are required.

4.1.8 *Calibration Adjustment Container*— The container shall be rigid and watertight, with minimum inside dimensions large enough to allow the calibration curve adjustment procedure (5.2) to be followed with no effect of the finite size of the container on the instrument's responses. The volume of the container shall be established following the procedure outlined in Test Method C 29/C 29M.

NOTE 3—For backscatter measurements, a container 450 by 450 by 150 mm [18 by 18 by 6 in.] will meet this requirement for most equipment currently available commercially. For 50-mm [2-in.] depth direct transmission measurements, a container 600 by 600 by 100 mm [24 by 24 by 4 in.] will meet this requirement.

4.1.9 *Scale*—The scale shall be accurate to within 0.2 kg [0.5 lb] of the test load at any point within the range of use. The range of use shall be considered to extend from the weight of the calibration adjustment container empty, to the weight of the measure plus the contents at 2600 kg/m^3 [160 lb/ft^3].

4.1.10 *Strike-Off Plate or Bar*—This shall be a flat metal or glass plate or metal bar with a length at least 50 mm [2 in.] greater than the length, width, or diameter of the calibration adjustment container. The strike-off must be rigid, straight, and smooth enough to finish the concrete surface flat and flush with the edges of the calibration adjustment container.

5. Calibration

5.1 Calibration curves are established by determining the nuclear count rate of each of several materials at different and known densities, plotting the count rate (or count ratio) versus each known density, and placing a curve through the resulting points. The method used to establish the curve must be the same as that used to determine the density. The materials used for calibration must be of uniform density.

NOTE 4—Calibration curves are supplied by gauge manufacturers, or can be established using blocks of known density or prepared containers of uniform, unchanging material compacted to known densities. Materials considered satisfactory for use in blocks include granite, aluminum, chalk, limestone, and magnesium.

5.2 *Adjusting Calibration Curves*—Prior to use, adjust the instrument's calibration curve, if necessary, to compensate for chemical composition effects. Such an adjustment is necessary whenever the chemical composition of the concrete to be tested differs significantly from that for which the calibration curve was established. An adjustment is also necessary if the testing equipment has been changed. Adjustment is particularly important for backscatter test method measurements. Determine the necessary adjustments using the same mode of operation and at the same depth (if using direct transmission) as that intended for testing. A recommended procedure for making this adjustment is as follows:

5.2.1 Prepare a concrete mix similar in composition to the material to be tested subsequently.

5.2.2 Fill the calibration adjustment container with concrete and consolidate to produce a uniform, homogeneous material with approximately the density that will be achieved in the construction.

NOTE 5—Consolidation may be achieved by the procedure used for unit weight testing (Test Method C 138/C 138M) or by other methods, such as spading the concrete and then dropping the ends of the container alternately on a rigid surface.

5.2.3 Strike off the container with strike-off plate or bar. Take care to make the concrete surface flat and flush with the container edges.

NOTE 6—A 2 mm [1⁄16 in.] average difference between the concrete surface and the container edges in a 150 mm [6 in.] deep container will produce a 1 to 2 % error in the weighed density of the concrete.

5.2.4 Weigh the concrete in the container to the nearest 0.2 kg [0.5 lb] and determine the weighed density as follows:

$$W = \frac{W_c}{V} \quad (1)$$

where:

W = weighed density of concrete, kg/m^3 [lb/ft^3],
W_c = mass of the concrete, kg [lb], and
V = volume of the container, m^3 [ft^3].

5.2.5 Immediately take three automatically timed direct transmission or backscatter readings with the instrument centered on the surface of the concrete in the container. Rotate the base of the instrument 90° around the vertical axis, with subsequent rotations of 180 and 270° from the original position. Obtain three additional automatically timed counts at each position. The instrument must be centered over the surface of the concrete in each rotated position to prevent edge effects on the instrument reading.

5.2.6 Using the applicable calibration curve, determine the density from the average of the 12 counts obtained in 5.2.5.

5.2.7 Determine the difference between the two density readings obtained in 5.2.4 and 5.2.6.

5.2.8 Repeat 5.2.2-5.2.7 on two additional concrete mixes of the same proportions. Determine the adjustment factor by averaging the three values obtained in 5.2.7 and 5.2.8. If one of the three values differs from the average by more than 25

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kg/m^3 [1.5 lb/ft^3], discard it as a statistical outlier and recalculate the adjustment factor as the average of the remaining two values.

5.2.9 Use the adjustment factor determined in 5.2.8 to plot a corrected count-rate calibration curve which shall be parallel to the original calibration curve and offset by the amount indicated in 5.2.8. Alternatively, the value of the adjustment factor shall be attached to the instrument and applied to all density determinations arrived at from an original (unadjusted) calibration curve.

NOTE 7—In some circumstances, for example, where chemical composition changes are minimal, calibration curve adjustments may be established on permanent, uniform, hardened concrete blocks.

6. Standardization

6.1 Standardization of the equipment on the reference standard is required at the start of each day and whenever test measurements are suspect.

NOTE 8—In some older instrument models, count rates are strongly influenced by the ambient temperature; frequent standardization may be necessary.

6.2 Warm-up time shall be in accordance with the manufacturer's recommendations.

6.3 Take at least five readings on the reference standard, more if recommended by the manufacturer, or take one 4 min or longer count if the instrument is equipped with automatic standard count storage.

6.4 If more than one of the individual readings is outside the limit set by Eq 2, repeat the standardization. If the second attempt does not satisfy Eq 2, check the system for a malfunction. If no malfunction is found, establish a new N_o(average count) by taking the average of a minimum of 10 counts on the reference standard.

$$|N_s - N_o| < 1.96\sqrt{N_o} \quad (2)$$

where:

N_s = count currently measured in checking the instrument operation, and

N_o = average count previously established on the reference standard.

In instruments where the count has been prescaled, that is, divided by a constant factor k before it is displayed, Eq 2 shall be replaced by the following:

$$|N_s - N_o| < 1.96\sqrt{N_o/k} \quad (3)$$

6.4.1 If automatic standard count storage is used and the newly established count is outside the limit set by Eq 2, repeat the standardization.

6.4.2 If the second attempt does not satisfy Eq 2, check the system for a malfunction.

6.4.3 If no malfunction is found, establish a new N_o equal to the average count found in 6.4.2.

6.5 If a new N_o differs by more than 10 % from the standard count at which the calibration curve (5.1) was established, recalibrate the instrument.

TEST METHOD A—DIRECT TRANSMISSION (FOR UNHARDENED CONCRETE)

7. Procedure

7.1 Select a test location such that, when the gauge is placed in test position:

7.1.1 Any point on the source-detector axis shall be at least 230 mm [9 in.] from any pavement edge or object.

7.1.2 Reinforcing steel shall not be present in the volume bounded by the extended probe and the detector tubes.

7.1.3 The test location shall contain concrete to a depth 25 mm [1 in.] greater than that to which the probe will be inserted. In thin concrete overlay projects, this may require the removal of the underlying (original) concrete 25 to 50 mm [1 to 2 in.] down over a small area before placement of the overlay.

7.2 Smooth the surface with a wood float. If necessary, use the guide plate and hole-forming device (4.1.7) to make a hole slightly larger than the probe and perpendicular to the surface. In some concretes, the probe may be inserted directly into the concrete without the use of the guide plate and hole-forming device.

7.3 Insert the probe so that the side of the probe facing the center of the gauge is in intimate contact with the side of the hole. Keep all other radioactive sources at such a distance from the gauge that the readings will not be affected.

NOTE 9—The recommended minimum distance from other nuclear density gauges is 10 m [30 ft].

7.4 Use the same warm-up time as in standardization. Take automatically timed readings, for a minimum of 1 min, and determine the in-place density from the adjusted calibration curve. Alternatively, determine the in-place density from the unadjusted calibration curve and then apply the calibration adjustment factor (5.2.9). If the instrument has a direct reading display which is not programmed to apply the calibration adjustment factor (5.2.8), correct the displayed density by applying that factor.

TEST METHOD B—BACKSCATTER (FOR UNHARDENED OR HARDENED CONCRETE)

8. Procedure

8.1 Select a test location such that, when the gauge is placed in test position:

8.1.1 Any point on the source-detector axis shall be at least 230 mm [9 in.] from any pavement edge or object, and

8.1.2 No reinforcing steel with less than 75 mm [3 in.] of concrete cover shall lie directly under the source - detector axis, except as indicated in Note 10.

NOTE 10—The user may find that certain instrument models and operating modes allow gauges to operate over steel with as little as 40 mm [1½ in.] of concrete cover.

8.2 Prepare the test site in the following manner:

8.2.1 On unhardened concrete, smooth the surface with a wood float.

8.2.2 For best results on hardened concrete, find as smooth a surface as possible. Remove all loose material. The maximum void beneath the gauge shall not exceed 3 mm [⅛ in.].

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Use fine sand to fill these voids and smooth the surface with a rigid plate or other suitable tool.

8.3 Seat the gauge firmly. Keep all other radioactive sources at such a distance from the gauge that the readings will not be affected (Note 9).

8.4 Use the same warm-up time as in standardization. Take automatically timed readings, for a minimum of 1 min, and determine the in-place density from the adjusted calibration curve (5.2.9). Alternatively, determine the in-place density from the unadjusted calibration curve and then apply the calibration adjustment factor. If the instrument has a direct reading display which is not programmed to apply the calibration adjustment factor (5.2.8), correct the displayed density by applying that factor.

NOTE 11—On lifts less than 75 mm [3 in.] thick, readings may be erroneous if the density of the underlying material differs significantly from that of the concrete being placed. Correction procedures are available for some gauge models.

9. Report

9.1 Report the following information:

9.1.1 Test method (direct transmission or backscatter),

9.1.2 Nature of concrete (hardened or unhardened),

9.1.3 Depth of probe, if using direct transmission,

9.1.4 Thickness of layer tested,

9.1.5 Identification of raw materials,

9.1.6 Mixture proportions,

9.1.7 Count rate for standardization, and

9.1.8 Count rate for each test reading and the converted mean density value, or the corrected direct reading density value, in kg/m^3 [lb/ft^3].

10. Precision and Bias

10.1 *Precision*:

10.1.1 *Round Robin Test Program*—A round robin program was executed involving five instruments and five operators. All tests were done on a single placement of RCC. Twelve sites were prepared for measurements, relying on the natural variation in the as-placed material among the sites to generate twelve different material properties. Each instrument-operator combination determined the density at each location three times. The instrument was removed and re-inserted before each new determination. The study resulted in 60 sets of three determinations. All instruments were of the same manufacture. A report of results and calculations is on file at ASTM.[3] The data used to develop the precision statement were obtained using the inch-pound version of this test method. The precision indices shown in SI units are exact conversions of the values in parentheses.

10.1.2 *Single-Operator, Single-Instrument Precision*—The single-instrument and single-operator standard deviation was found to be 8.0 kg/m^3 [0.5 lb/ft^3].[4] Therefore, results of two properly conducted tests by the same operator are not expected to differ by more than 22.4 kg/m^3 [1.4 lb/ft^3].[4]

10.1.3 *Multi-Operator, Multi-Instrument Precision*—The multi-operator and multi-instrument standard deviation was found to be 16.0 kg/m^3 [1.0 lb/ft^3].[4] Therefore, results of two properly conducted tests by the same operator are not expected to differ by more than 44.9 kg/m^3 [2.8 lb/ft^3].[4]

10.2 *Bias*—No statement on bias is being made because no standard reference concrete of known density is available.

11. Keywords

11.1 acceptance testing; backscatter measurement; concrete-density; density; direct transmission measurement; gamma radiation; in-place density; nuclear testing; roller-compacted concrete

[3] Supporting data have been filed at ASTM International Headquarters and may be obtained by requesting Research Report RR: C09-1031.

[4] These numbers represent, respectively, the (1s) and (d2s) limits as described in Practice C 670.

ANNEX

(Mandatory Information)

A1. DETERMINING PRECISION OF APPARATUS

A1.1 Instrument Count Precision:

A1.1.1 Instrument count precision is defined as the change in density that corresponds to a one standard deviation change in the count due to the random decay of the radioactive source. Instrument count precision is determined from the slope of the calibration curve and the statistical standard deviation of the count rate, as follows:

$$P = \sigma/S \quad \text{(A1.1)}$$

where:

P = instrument count precision, kg/m^3 [lb/ft^3],

σ = standard deviation, cpm (counts/minute), and

S = slope, cpm/kg/m^3 [cpm/lb/ft^3].

A1.1.2 The slope of the calibration curve is determined at the 2240 kg/m^3 [140 lb/ft^3] point and the standard deviation is calculated from ten individual automatically-timed readings taken on material with a density of 2240 ± 80 kg/m^3 [140 ± 5 lb/ft^3]. The gauge is not moved after seating for the first count. For a direct reading gauge, the instrument count precision, P, in kg/m^3 [lb/ft^3], is the standard deviation of ten individual automatically-timed density readings.

A1.1.3 The value of P shall be determined at least once every three months. The value of P shall be less than 16 kg/m^3 [1.0 lb/ft^3] for backscatter and less than 8 kg/m^3 [0.5 lb/ft^3] for direct transmission measurements.

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APPENDIX

(Nonmandatory Information)

X1. NOTES ON THE NUCLEAR TEST

X1.1 It should be noted that the volume of concrete represented in the measurements is indeterminate and will vary with (*1*) the source-detector geometry of the equipment used, and (*2*) with the characteristics of the material tested. In general, and with all other conditions constant, the denser the material, the smaller the volume involved in a backscatter measurement. The density so determined is not necessarily the average density within the volume involved in the measurement. Typically, backscatter gauge readings are influenced by 75 to 125 mm [3 to 5 in.] of material; the top 25 mm [1 in.] of the material determines 50 to 70 % of the measured count rate, and the top 50 mm [2 in.] determines 80 to 95 %. Where these materials are of uniform density, this characteristic of this test method is of no effect. However, reinforcing steel and underlying concrete are both often within the volume in which they may influence gauge readings. Also, the extent of the influence of vertical density variations, such as those caused by reinforcing steel, depends on the depth at which the steel is located.

X1.2 The use of cesium-137 and other radioisotope sources in density gauges is regulated and licensed by the U.S. Nuclear Regulatory Commission or, in agreement states, by state regulatory agencies. The primary objective of these regulations is the use of these materials in a manner safe to the operator, to other workers, and to the general public. While detailed safety procedures are beyond the scope of these test methods, the originating committee emphasized its support of these objectives. In order to meet regulatory agency requirements, gauge owners must establish effective operator instruction and use procedures, together with routine safety procedures, such as source leak tests, recording and evaluation of film badge data, the use of survey meters, etc., in connection with the operation of this type of equipment. Likewise, individual users of the equipment must complete a formal training program and must be familiar with possible safety hazards. Users should be particularly concerned about developing safe procedures for removing mortar while cleaning the source rod after direct transmission measurements.

X1.3 The determination of density in these test methods by the nuclear means is indirect. The relationship between nuclear gauge count rate and density necessarily is determined by correlation tests on materials at known average densities. Calibration curves established in this manner do not necessarily hold for all concretes because of differences in chemical composition. This effect is particularly significant for backscatter method measurements. Because of these considerations, provisions are included in these test methods for adjusting calibration curves on a project-by-project basis.

SUMMARY OF CHANGES

Committee C09 has identified the location of selected changes to these test methods since the last issue, C 1040 – 05, that may impact the use of these test methods. (Approved October 1, 2008)

(*1*) The standard was revised as a combined standard with SI units listed first.
(*2*) Revised 1.3.
(*3*) Added new Note 2 and renumbered subequent notes.
(*4*) Revised 10.1.1.

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Designation: C 1047 – 09

Standard Specification for Accessories for Gypsum Wallboard and Gypsum Veneer Base[1]

This standard is issued under the fixed designation C 1047; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

This standard has been approved for use by agencies of the Department of Defense.

1. Scope*

1.1 This specification covers accessories used in conjunction with assemblies of gypsum wallboard and gypsum veneer base to protect edges and corners and to provide architectural features (see Fig. 1).

1.2 The values stated in inch-pound units are to be regarded as standard. The values given in parentheses are mathematical conversions to SI units that are provided for information only and are not considered standard.

2. Referenced Documents

2.1 *ASTM Standards:*[2]

A 463/A 463M Specification for Steel Sheet, Aluminum-Coated, by the Hot-Dip Process

A 653/A 653M Specification for Steel Sheet, Zinc-Coated (Galvanized) or Zinc-Iron Alloy-Coated (Galvannealed) by the Hot-Dip Process

A 879/A 879M Specification for Steel Sheet, Zinc Coated by the Electrolytic Process for Applications Requiring Designation of the Coating Mass on Each Surface

B 69 Specification for Rolled Zinc

B 117 Practice for Operating Salt Spray (Fog) Apparatus

C 11 Terminology Relating to Gypsum and Related Building Materials and Systems

C 475/C 475M Specification for Joint Compound and Joint Tape for Finishing Gypsum Board

C 587 Specification for Gypsum Veneer Plaster

D 1788 Specification for Rigid Acrylonitrile-Butadiene-Styrene (ABS) Plastics[3]

D 2092 Guide for Preparation of Zinc-Coated (Galvanized) Steel Surfaces for Painting[3]

D 3678 Specification for Rigid Poly(Vinyl Chloride) (PVC) Interior-Profile Extrusions

3. Terminology

3.1 *Definitions:*

3.1.1 Definitions shall be in accordance with Terminology C 11.

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *accessories*, *n*—cornerbeads, edge trims, and control joints, such as casing beads, bull noses, and stops.

3.2.2 *control joint*, *n*—a formed product used for designed or required separations between adjacent surfaces of gypsum boards or gypsum veneer base.

3.2.3 *cornerbead*, *n*—a formed metal, plastic, or metal and paper angle for outside corners of gypsum boards or gypsum veneer base.

3.2.4 *edge trim*, *n*—typically "J"- or "L"-shaped strip, as shown in Fig. 1, formed of metal, plastic, or metal and paper to cover exposed ends or edges of gypsum board or gypsum veneer base.

3.2.5 *flange*, *n*—that portion of the accessory used for the attachment to gypsum wallboard, gypsum veneer base, or a framing member.

4. Materials and Manufacture

4.1 Steel accessories and steel components of accessories manufactured from steel and paper in combination shall be manufactured from zinc-coated cold-roll (coil or cut length) sheet steel not less than 0.012-in. (0.30-mm) thick before application of coating.

4.1.1 Sheet steel, zinc-coated by the hot-dip process, shall be in accordance with Specification A 653/A 653M, minimized spangle, minimum G-30 coating.

4.1.2 Sheet steel, zinc-coated by the electrolytic process shall be in accordance with Specification A 879/A 879M, minimum coating on surface side to be 0.000140 in. (0.00356 mm), minimum coating on reverse side to be 0.00010 in. (0.00254 mm).

[1] This specification is under the jurisdiction of ASTM Committee C11 on Gypsum and Related Building Materials and Systems and is the direct responsibility of Subcommittee C11.02 on Specifications and Test Methods for Accessories and Related Products.

Current edition approved May 1, 2009. Published May 2009. Originally approved in 1992. Last previous edition approved in 2005 as C 1047 – 05.

[2] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

[3] Withdrawn. The last approved version of this historical standard is referenced on www.astm.org.

***A Summary of Changes section appears at the end of this standard.**

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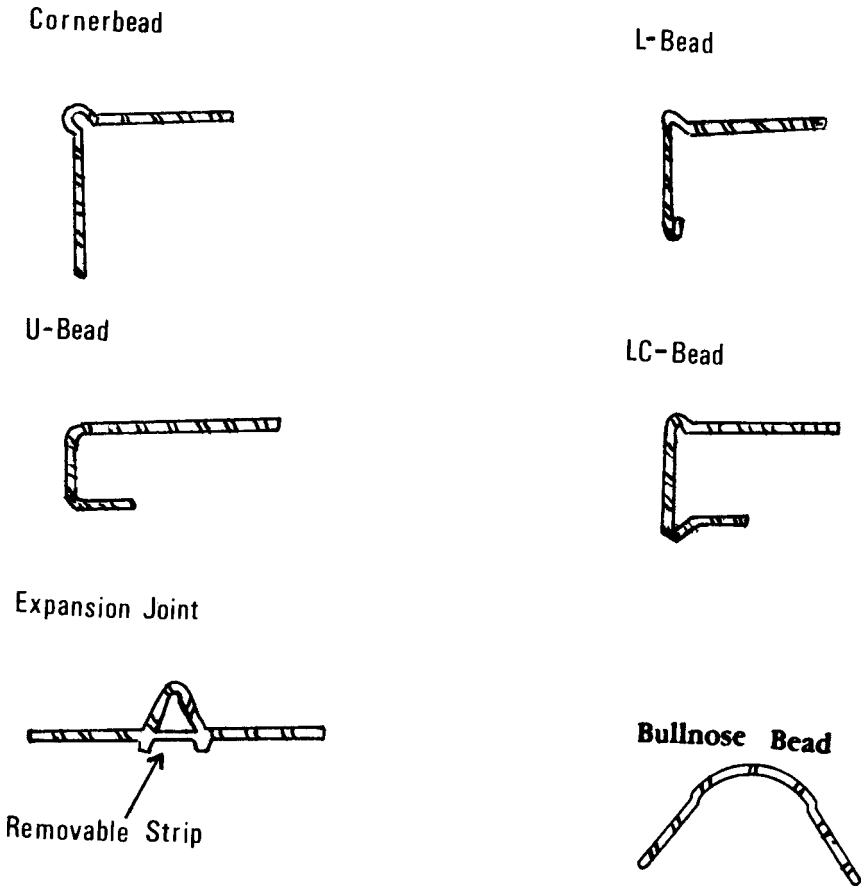

FIG. 1 Accessories for Gypsum Wallboard and Gypsum Veneer Base

4.1.3 Sheet steel, aluminum-coated, shall be in accordance with Specification A 463/A 463M minimum T1-40 coating.

4.1.4 Phosphatizing (as specified in Method A of Guide D 2092) or other surface treatments may be used to ensure compatibility and bond as specified in Section 5.

4.2 Zinc accessories shall be manufactured from rolled zinc in accordance with Specification B 69, Type I, not less than 0.012-in. (0.305-mm) thick.

4.3 Plastic for accessories shall be manufactured from rigid PVC or ABS plastic not less than 0.012 in. (0.305 mm).

4.3.1 PVC, Specification D 3678, Class II or III.

4.3.2 ABS, Specification D 1788 – 81, all limits 5-3-3-1-1.

4.4 Paper components of accessories manufactured from steel and paper in combination shall comply with requirements for thickness, tensile strength, dimensional stability, and bond of joint tape to joint compound as specified in Specification C 475/C 475M.

5. Physical Properties

5.1 *Compatibility and Bond*—Accessories shall be compatible with and provide a surface bond to the materials specified in Specifications C 475/C 475M and C 587.

5.2 *Test Performance*—Steel accessories and steel components of accessories shall not show any red oxidation when tested as specified in Practice B 117 for 192 h.

6. Dimensions and Permissible Variations

6.1 Cornerbeads shall have an interior angle between the flanges no greater than 89°.

6.2 Accessories shall be free of twist or camber of a degree that will prevent their use in the assembly for which they are intended.

6.3 Length tolerances shall be ±3⁄16 in. (±4.8 mm).

6.4 The size of the edge trim shall suit the thickness of the gypsum board used.

6.5 The minimum width of the flange shall be 7⁄8 ± 1⁄32 in. (22 ± 0.8 mm).

7. Appearance

7.1 Edges of accessories shall be free of burrs and sharp edges.

8. Configuration

8.1 Flanges of accessories, when required to be attached to framing members, shall have punch outs to accommodate fastening to the framing members. When required to meet performance requirements, the flanges shall be either knurled, made of mesh, deformed, expanded, or otherwise shaped to meet the performance requirements and intended use. Fig. 1 depicts the most commonly used shapes.

NOTE 1—Other types of accessories designed for special finish application (bull-nose, cove, and so forth) shall be manufactured in accordance

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with the general requirements of this specification.

9. Sampling

9.1 At least 0.25 % of the number of each type of accessory in a shipment, but not less than three pieces, shall be selected to represent the shipment and shall constitute a sample for the purpose of tests by the purchaser or user.

10. Inspection

10.1 Inspection of the accessories shall be agreed upon between the purchaser and the supplier as part of the purchase order.

11. Rejection and Rehearing

11.1 Rejection of accessories that fail to conform to the requirements of this specification shall be reported to the producer or supplier promptly and in writing within 10 working days from receipt of shipment by the purchaser. The notice of rejection shall contain a specific statement of the respect in which the accessories have failed to conform to the requirements of this specification. In case of dissatisfaction with the results of the test, at the request of the producer or supplier, such notice of rejection shall be supported by results of a test conducted by a mutually agreeable independent laboratory.

12. Certification

12.1 When specified in the purchase order, a producer's or supplier's certification that the product meets the requirements of this specification shall be furnished to the purchaser.

13. Packaging and Package Marking

13.1 Accessories shall be packaged to ensure safe delivery by common or other carriers.

13.2 When shipped for resale, the name of the manufacturer or seller and the brand and contents shall be legibly marked on each package.

14. Keywords

14.1 accessories; bead; corner; cornerbead; edge

SUMMARY OF CHANGES

Committee C11 has identified the location of selected changes to this specification since the last issue, C 1047 – 05, that may impact the use of this specification. (Approved May 1, 2009)

(*1*) Replaced reference to Specification A 591/A 591M with Specification A 879/A 879M in 4.1.2 and Referenced Documents.

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Designation: C 1059/C 1059M – 99 (Reapproved 2008)

Standard Specification for Latex Agents for Bonding Fresh To Hardened Concrete[1]

This standard is issued under the fixed designation C 1059/C 1059M; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope

1.1 This specification covers latex bonding agents, suitable for brush, broom, or spray application, to bond fresh concrete to hardened concrete.

1.2 These bonding agents are intended for bonding new concrete to old concrete such as interior surfaces, floors, roadways, bridge decks, ramps, runways, walks, and curbs.

1.3 The values stated in either inch-pound units or SI units shall be regarded separately as standard. Within the text, the SI units are shown in brackets. The values stated in each system may not be exact equivalents, therefore, each system must be used independently of the other without combining values in any way.

2. Referenced Documents

2.1 *ASTM Standards:* [2]

C 1042 Test Method for Bond Strength of Latex Systems Used With Concrete By Slant Shear

3. Classification and Use

3.1 This specification provides for the classification of the latex bonding agents in accordance with use.

3.1.1 *Type I (Redispersable)*, is restricted for use in interior work not subject to water immersion or high humidity.

3.1.2 *Type II (Non-redispersable)*, may be used for areas subject to high humidity or immersion in water and is suitable for use in other areas.

4. Ordering Information

4.1 Purchase orders for these materials shall identify:

4.1.1 The number of this specification and the required type, and

4.1.2 Supplementary requirements if necessary.

5. Physical Properties

5.1 The material shall conform to the requirements of Table 1 when tested in accordance with Test Method C 1042.

6. Sampling

6.1 For sampling of bulk quantities, a batch or lot shall be considered a unit of manufacture as prepared for shipment or may consist of a blend of two or more production runs of material. A composite sample shall be taken and it shall provide a volume of at least 1 gal [4 L].

6.2 When the bonding agent to be sampled is in containers, the sample shall be obtained by taking a portion out of the containers that is equal in number to the next integer larger than the cube root of the total number of containers in the lot. Grab samples shall be taken from each container and they shall have a volume of at least ½ pt. [0.25 L].

6.3 All the sample containers shall be sealed to prevent leakage or dilution and shall be properly marked for identification and correlation.

7. Rejection

7.1 The purchaser has the right to reject the bonding agent if it fails to meet the bond strength requirement, appears curdled or otherwise nonuniform, or if it has a rank odor.

8. Packaging and Package Marking

8.1 The proprietary name and type of the organic bonding agent and the net quantity in gallons or litres shall be plainly marked on the containers in which the material is delivered. Similar information shall be provided in the shipping advices accompanying packaged or bulk shipments of admixtures.

9. Keywords

9.1 adhesives; bonding agents; latex

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[1] This specification is under the jurisdiction of ASTM Committee C09 on Concrete and Concrete Aggregates and is the direct responsibility of Subcommittee C09.25 on Organic Materials for Bonding.

Current edition approved March 15, 2008. Published April 2008. Originally approved in 1986. Last previous edition approved in 1999 as C 1059/C 1059M – 99ε[1].

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TABLE 1 Physical Property Requirements of Latex Bonding Agents

Latex	Bond Strength min, psi [MPa]
Type I	400 [2.8] dry
Type II	1250 [8.6] after immersion

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1.2 These bonding agents are intended for bonding new concrete to old concrete such as interior surfaces, floors, roadways, bridge decks, ramps, runways, walks, and curbs.

1.3 The values stated in either inch-pound units or SI units shall be regarded separately as standard. Within the text, the SI units are shown in brackets. The values stated in each system may not be exact equivalents, therefore, each system must be used independently of the other without combining values in any way.

2. Referenced Documents

2.1 *ASTM Standards:* [2]

C 1042 Test Method for Bond Strength of Latex Systems Used With Concrete By Slant Shear

3. Classification and Use

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4.1.1 The number of this specification and the required type, and

4.1.2 Supplementary requirements if necessary.

5. Physical Properties

5.1 The material shall conform to the requirements of Table 1 when tested in accordance with Test Method C 1042.

6. Sampling

6.1 For sampling of bulk quantities, a batch or lot shall be considered a unit of manufacture as prepared for shipment or may consist of a blend of two or more production runs of material. A composite sample shall be taken and it shall provide a volume of at least 1 gal [4 L].

6.2 When the bonding agent to be sampled is in containers, the sample shall be obtained by taking a portion out of the containers that is equal in number to the next integer larger than the cube root of the total number of containers in the lot. Grab samples shall be taken from each container and they shall have a volume of at least ½ pt. [0.25 L].

6.3 All the sample containers shall be sealed to prevent leakage or dilution and shall be properly marked for identification and correlation.

7. Rejection

7.1 The purchaser has the right to reject the bonding agent if it fails to meet the bond strength requirement, appears curdled or otherwise nonuniform, or if it has a rank odor.

8. Packaging and Package Marking

8.1 The proprietary name and type of the organic bonding agent and the net quantity in gallons or litres shall be plainly marked on the containers in which the material is delivered. Similar information shall be provided in the shipping advices accompanying packaged or bulk shipments of admixtures.

9. Keywords

9.1 adhesives; bonding agents; latex

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[1] This specification is under the jurisdiction of ASTM Committee C09 on Concrete and Concrete Aggregates and is the direct responsibility of Subcommittee C09.25 on Organic Materials for Bonding.

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[2] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

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TABLE 1 Physical Property Requirements of Latex Bonding Agents

Latex	Bond Strength min, psi [MPa]
Type I	400 [2.8] dry
Type II	1250 [8.6] after immersion

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Designation: C 1063 – 08

Standard Specification for Installation of Lathing and Furring to Receive Interior and Exterior Portland Cement-Based Plaster[1]

This standard is issued under the fixed designation C 1063; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

This standard has been approved for use by agencies of the Department of Defense.

1. Scope*

1.1 This specification covers the minimum requirements for lathing and furring for the application of exterior and interior portland cement-based plaster as in Specification C 926 or Specification C 841.

1.2 Where a fire resistance rating is required for plastered assemblies and constructions, details of construction shall be in accordance with reports of fire tests of assemblies that have met the requirements of the fire rating imposed.

1.3 Where a specific degree of sound control is required for plastered assemblies and constructions, details of construction shall be in accordance with official reports of tests conducted in recognized testing laboratories in accordance with the applicable requirements of Test Method E 90.

1.4 The values stated in inch-pound units are to be regarded as standard. The values given in parentheses are mathematical conversions to SI units that are provided for information only and are not considered standard.

2. Referenced Documents

2.1 *ASTM Standards:* [2]

A 641/A 641M Specification for Zinc–Coated (Galvanized) Carbon Steel Wire

A 653/A 653M Specification for Steel Sheet, Zinc-Coated (Galvanized) or Zinc-Iron Alloy-Coated (Galvannealed) by the Hot-Dip Process

B 69 Specification for Rolled Zinc

B 221 Specification for Aluminum and Aluminum-Alloy Extruded Bars, Rods, Wire, Profiles, and Tubes

C 11 Terminology Relating to Gypsum and Related Building Materials and Systems

C 841 Specification for Installation of Interior Lathing and Furring

C 847 Specification for Metal Lath

C 926 Specification for Application of Portland Cement-Based Plaster

C 933 Specification for Welded Wire Lath

C 954 Specification for Steel Drill Screws for the Application of Gypsum Panel Products or Metal Plaster Bases to Steel Studs from 0.033 in. (0.84 mm) to 0.112 in. (2.84 mm) in Thickness

C 1002 Specification for Steel Self-Piercing Tapping Screws for the Application of Gypsum Panel Products or Metal Plaster Bases to Wood Studs or Steel Studs

C 1032 Specification for Woven Wire Plaster Base

D 1784 Specification for Rigid Poly(Vinyl Chloride) (PVC) Compounds and Chlorinated Poly(Vinyl Chloride) (CPVC) Compounds

D 4216 Specification for Rigid Poly(Vinyl Chloride) (PVC) and Related PVC and Chlorinated Poly(Vinyl Chloride) (CPVC) Building Products Compounds

E 90 Test Method for Laboratory Measurement of Airborne Sound Transmission Loss of Building Partitions and Elements

3. Terminology

3.1 *Definitions*—For definitions relating to Ceilings and Walls, see Terminology C 11.

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *control joint*, *n*—a joint that accommodates movement of plaster shrinkage and curing along predetermined, usually straight, lines.

3.2.2 *expansion joint*, *n*—a joint that accommodates movement beyond plaster shrinkage and curing.

[1] This specification is under the jurisdiction of ASTM Committee C11 on Gypsum and Related Building Materials and Systems and is the direct responsibility of Subcommittee C11.03 on Specifications for the Application of Gypsum and Other Products in Assemblies.

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[2] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

***A Summary of Changes section appears at the end of this standard.**

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NOTE 1—For design consideration of control and expansion joints, see Annex A2.3.1.2 of Specification C 926.

3.2.3 *hangers*, *n*—wires or steel rods or straps used to support main runners for suspended ceilings beneath floor or roof constructions.

3.2.4 *inserts*, *n*—devices embedded in concrete structural members to provide a loop or opening for attachment of hangers.

3.2.5 *saddle tie*, *n*—see Figs. 1 and 2.

3.2.6 *self-furring*, *adj*—a metal plaster base manufactured with evenly-spaced indentations that hold the body of the lath approximately ¼ in. (6.4 mm) away from solid surfaces to which it is applied.

3.2.7 *framing member*, *n*—studs, joist, runners (track), bridging, bracing, and related accessories manufactured or supplied in wood or light gauge steel.

4. Delivery of Materials

4.1 All materials shall be delivered in the original packages, containers, or bundles bearing the brand-name and manufacturer's (or supplier's) identification.

5. Storage of Materials

5.1 All materials shall be kept dry. Materials shall be stacked off the ground, supported on a level platform, and protected from the weather and surface contamination.

5.2 Materials shall be neatly stacked with care taken to avoid damage to edges, ends, or surfaces.

5.3 Paper backed metal plaster bases shall be handled carefully in delivery, storage, and erection to prevent puncturing or removal of paper.

6. Materials

6.1 *Metal Plaster Bases*:

6.1.1 *Expanded Metal Lath*—Specification C 847, galvanized.

6.1.2 *Wire Laths*:

6.1.2.1 *Welded Wire Lath*—Specification C 933.

6.1.2.2 *Woven Wire Lath*—Specification C 1032.

6.1.2.3 *Paper Backed Plaster Bases*—Specification C 847.

6.2 *Accessories*:

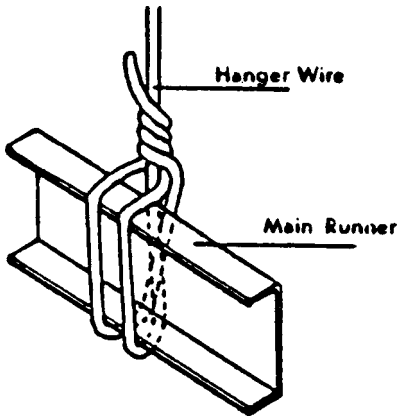

FIG. 1 Saddle Tie

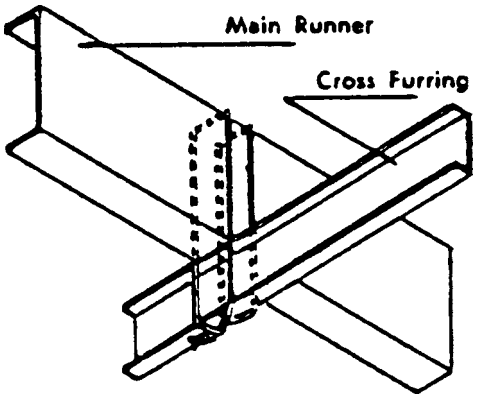

FIG. 2 Saddle Tie

6.2.1 *General*—All accessories shall have perforated or expanded flanges or clips shaped to permit complete embedment in the plaster, to provide means for accurate alignment, and to secure attachment of the accessory to the underlying surface. Accessories shall be designed to receive application of the specified plaster thickness.

6.2.2 Accessories shall be fabricated from Zinc Alloy (99 % pure zinc), galvanized (zinc coated) steel, rigid PVC or CPVC plastic, or anodized aluminum alloy. See Specification B 221. (See Table 1 for minimum allowable thicknesses).

NOTE 2—The selection of an appropriate type of material for accessories shall be determined by applicable surrounding climatic and environmental conditions specific to the project location, such as salt air, industrial pollution, high moisture, or humidity.

6.2.3 *Steel*—Specification A 653/A 653M and shall have a G60 coating.

6.2.4 *PVC Plastic*—Specification D 1784 or D 4216.

6.2.5 *Zinc Alloy*—Specification B 69, 99 % pure zinc.

6.2.6 Thickness of base material shall be as shown in Table 1.

6.2.7 *Cornerite*—1.75 lb/yd^2(0.059 kg/m^2), galvanized expanded metal lath, galvanized, 1.7 lb/yd^2(0.057 kg/m^2) galvanized woven or welded wire fabric of 0.0410 in. (1.04 mm) wire. When shaped for angle reinforcing, it shall have outstanding flanges (legs) of not less than 2 in. (51 mm).

6.3 *Channels*—Shall be cold-formed from steel with minimum 33 000 psi (228 MPa) yield strength and 0.0538 in. (1.37 mm) minimum bare steel thickness. Channel shall have a protective coating conforming to Specification A 653/A 653M–G60, or have a protective coating with an equivalent corrosion resistance for exterior applications, or shall be coated with a rust inhibitive paint, for interior applications, and shall have the following minimum weights in pounds per 1000 linear feet (kg/m).

TABLE 1 Minimum Thickness of Accessories

Accessory	Base Material, in. (mm)		
	Steel	Zinc Alloy	P.V.C.
Corner Beads	0.0172 (0.44)	0.0207 (0.53)	0.035 (0.89)
Casing Beads	0.0172 (0.44)	0.0207 (0.53)	0.035 (0.89)
Weep Screeds	0.0172 (0.44)	0.0207 (0.53)	0.050 (1.27)
Control Joints	0.0172 (0.44)	0.018 (0.46)	0.050 (1.27)

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Sizes, in. (mm)	Weight, lb/1000 ft (kg/m)	Flange Width, in. (mm)
¾ (19)	277 (0.412)	½ (13)
1½ (38)	414 (0.616)	½ (13)
2 (51)	506 (0.753)	½ (13)
2½ (64)	597 (0.888)	½ (13)

NOTE 3—Channels used in areas subject to corrosive action of salt air shall be hot-dipped galvanized, G60 coating.

6.3.1 *External Corner Reinforcement*—Expanded lath, welded wire, or woven wire mesh bent to approximately 90° used to reinforce portland cement stucco at external corners. This accessory shall be fully embedded in the stucco.

6.3.2 *Foundation Weep Screed*—Accessory used to terminate portland cement based stucco at the bottom of exterior walls. This accessory shall have a sloped, solid, or perforated, ground or screed flange to facilitate the removal of moisture from the wall cavity and a vertical attachment flange not less than 3½ in. (89 mm) long.

6.4 *Wire*—As specified in Specification A 641/A 641M with a Class I zinc coated (galvanized), soft temper steel. Wire diameters (uncoated) specified herein correspond with United States Steel Wire Gauge numbers as follows:

Wire Gauge (US Steel Wire Gauge)	Diameter (in.)	mm
No. 20	0.0348	.88
No. 19	0.0410	1.04
No. 18	0.0475	1.21
No. 17	0.0540	1.37
No. 16	0.0625	1.59
No. 14	0.0800	2.03
No. 13	0.0915	2.32
No. 12	0.1055	2.68
No. 11	0.1205	3.06
No. 10	0.1350	3.43
No. 9	0.1483	3.77
No. 8	0.1620	4.12

6.5 *Rod and Strap Hangers*—Mild steel, zinc or cadmium plated, or protected with a rust-inhibiting paint.

6.6 *Clips*—Form from steel wire, Specification A 641/A 641M zinc-coated (galvanized), Specification A 641/A 641M or steel sheet, Specification A 653/A 653M, depending on use and manufacturer's requirements.

6.7 *Fasteners*:

6.7.1 *Nails*—For attaching metal plaster bases to wood supports, 0.1205-in. 11 gauge (3.06-mm) diameter, 7/16-in. (11.1-mm) head, barbed, galvanized roofing nails or galvanized common nails.

6.7.1.1 Nails for attaching metal plaster bases to solid substrates shall be not less than ¾ in. (19 mm) long.

6.7.2 Screws for attaching metal plaster base shall be fabricated in accordance with either Specification C 954 or C 1002 and shall have a 7/16 in. (11.1 mm) diameter pan wafer head and a 0.120 in. (3.0 mm) diameter shank. Screws used for attachment to metal framing members shall be self-drilling and self-tapping. Screws used for attachment to wood framing members shall be sharp-point.

7. Installation

7.1 *Workmanship*—Metal furring and lathing shall be erected so that the finished plaster surfaces are true to line (allowable tolerance of ¼ in. [6.4 mm] in 10 ft [3.05 m]), level, plumb, square, or curved as required to receive the specified plaster thickness.

7.2 *Hangers and Inserts*:

7.2.1 Hangers shall be of ample length and shall conform to the requirements of Table 2 both as to size and maximum area to be supported, except as modified in this section.

7.2.2 When 1 by 3/16-in. (25 by 4.8-mm) flat inserts and hangers are used, 7/16-in. (11.1-mm) diameter holes shall be provided on the center line at the lower end of the insert and upper end of the hanger to permit the attachment of the hanger to the insert. The edge of the holes in both the inserts and the hangers shall be not less than 3/8 in. (9.5 mm) from the ends.

7.2.3 In concrete, hangers shall be attached to inserts embedded in the concrete or to other attachment devices designed for this purpose and able to develop full strength of the hanger.

7.2.4 Flat, steel hangers shall be bolted to 1 by 3/16-in. (25 by 4.8-mm) inserts with 3/8-in. (9.5-mm) diameter round-head stove bolts. (See Fig. 3.)

7.2.5 The nuts of the bolts shall be drawn up tight.

NOTE 4—Hangers required to withstand upward wind pressures shall be of a type to resist compression. Struts of formed channels shall be permitted.

7.3 *Installation of Hangers for Suspended Ceilings Under Wood Constructions*—Hangers shall be attached to supports by any of the following methods:

7.3.1 A hole shall be drilled through the wood member not less than 3 in. (76 mm) above the bottom with the upper end of the wire hanger passed through the hole and twisted three times around itself. See Fig. 4.

7.3.2 Three 12d nails shall be driven, on a downward slant, into the sides of the wood member with not less than 1¼ in. (31.8 mm) penetration and not less than 5 in. (127 mm) from the bottom edges, and not more than 36 in. (914 mm) on the center with the upper end of the wire hanger wrapped around the nails and twisted three times around itself. See Fig. 5.

7.3.3 A loop shall be formed in the upper end of the wire hanger and secured to the wood member by four 1½-in. (38.1-mm), not less than 9 gauge, 0.1483-in. (3.77-mm) diameter wire staples driven horizontally or on a downward slant into the sides of the wood members, three near the upper end of the loop and the fourth to fasten the loose end. See Fig. 6.

7.3.4 Where supports for flooring are thicker than 1½ in. (38.1 mm) and are spaced more than 4 ft (1.2 m) on center, 1½ in. (38.1-mm) No. 1/0 (0.3065 in.) (7.78 mm) eye screws, or equivalent, spaced not more than 3 ft (0.9 m) on centers shall be screwed into the flooring supports with the upper end of the wire hanger inserted through the eye screws and twisted three times around itself.

7.3.5 Two holes shall be drilled in the upper end of the flat hangers and nailed to the sides of the wood members with 12d nails driven through the holes and clinched. Nails shall be not less than 3 in. (76 mm) above the bottom edge of the framing member. See Fig. 7.

7.4 *Attachment of Hangers to Main Runners*:

7.4.1 Wire hangers shall be saddle-tied to the runners. See Fig. 1.

7.4.2 Smooth or threaded rod hangers shall be fastened to the runners with special attachments appropriate to the design.

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TABLE 2 Allowable Support or Hanger Wire Spacing ft-in. (mm) and Cold-Rolled Channel Main Runner Spans, ft-in. (mm)[1–10]

NOTE—1 in. = 25.4 mm; 1 ft^2 = 0.093 m^2

Member Size, in. (mm)	Member Weight, lb/1000 ft (kg/m)	Span Condition[9,10]	Uniform Load = 12 psf (0.479 kPa)				
			Member Spacing, in. (mm)				
			24 (610)	36 (914)	48 (1220)	60 (1520)	72 (1830)
			Allowable Hanger Wire or Support Spacing, ft-in. (mm)				
1½	414	Single	3-6 (1070)	3-1 (940)	2-9 (840)	2-9 (790)	2-5 (740)
(38.1)	(0.615)	2 or More	4-11 (1500)	4-2 (1270)	3-7 (1090)	3-2 (970)	2-11 (890)
2	506	Single	3-9 (1140)	3-3 (990)	3-0 (910)	2-9 (840)	2-8 (810)
(50.8)	(0.753)	2 or More	5-2 (1570)	4-6 (1370)	4-1 (1240)	3-10 (1170)	3-7 (1090)
2½	597	Single	3-11 (1190)	3-5 (1040)	3-2 (970)	2-11 (890)	2-9 (840)
(63.5)	(0.888)	2 or More	5-5 (1650)	4-9 (1450)	4-4 (1320)	4.0 (1220)	3-10 (1170)
Member Size, in. (mm)	Member Weight, lb/1000 ft (kg/m)	Span Condition[9,10]	Uniform Load = 15 psf (0.287 kPa)				
			Member Spacing, in. (mm)				
			24 (610)	36 (914)	48 (1220)	60 (1520)	72 (1830)
1½	414	Single	3-3 (990)	2-10 (860)	2-7 (790)	2-4 (710)	2-2 (660)
(38.1)	(0.616)	2 or More	4-6 (1370)	3-8 (1120)	3-2 (970)	2-10 (860)	2-7 (790)
2	506	Single	3-6 (1070)	3-1 (940)	2-10 (880)	2-7 (790)	2-5 (740)
(50.8)	(0.753)	2 or More	4-10 (1470)	4-3 (1300)	3-10 (1170)	3-6 (1070)	3-3 (990)
2½	597	Single	3-8 (1120)	3-3 (990)	2-11 (890)	2-9 (840)	2-7 (790)
(63.5)	(0.888)	2 or More	5-0 (1520)	4-5 (1350)	4-0 (1220)	3.9 (1140)	3-6 (1070)

Allowable Spans Notes:
[1] Bare metal thickness of cold-rolled main runners shall be not less than 0.0538 in. (1.367 mm).
[2] Inside corner radii shall not be greater than ⅛ in. (3.19 mm).
[3] Spans based on upper flange of main runners laterally unbraced.
[4] Maximum deflection limited to 1/360 of the span length.
[5] Steel yield stress, Fy, shall be not less than 33 000 psi (228 MPa).
[6] Uniform load 12 psf (dry density) shall be used for portland cement plaster ceilings with plaster thicknesses up to ⅞ in. (22 mm) and 15 psf shall be used for ceilings with plaster thicknesses over ⅞ in. (22 mm) and not more than 1-¼ in. (32 mm).
[7] "2 or More" spans refers to two or more continuous, equal spans.
[8] For the "2 or More" span condition, listed spans represent the center-to-center distance between adjacent supports.
[9] These tables are designed for dead loads. Specific conditions such as exterior installations in high wind areas require additional engineering.
[10] Where uplift resistance is required for suspended ceilings to resist negative forces, the architect or engineer of record shall select the method to be used.

7.4.3 The lower ends of flat hangers shall be bolted to the main runners, or bent tightly around the runners and carried up and above the runners and bolt to the main part of the hanger. Bolts shall be ⅜-in. (9.5-mm) diameter, round-head stove bolts. See Fig. 3.

7.5 *Installation of Main Runners*:

7.5.1 Minimum sizes and maximum spans and spacings of main runners for the various spans between hangers or other supports shall be in accordance with the requirements of Table 2.

7.5.2 A clearance of not less than 1 in. (25 mm) shall be maintained between the ends of the main runners and the abutting masonry or the concrete walls, partitions, and columns. Where special conditions require that main runners let into abutting masonry or concrete construction, within such constructions maintain a clearance of not less than 1 in. (25 mm) from the ends and not less than ¼ in. (6.4 mm) from the tops and sides of the runners.

7.5.3 A main runner shall be located within 6 in. (152 mm) of the paralleling walls to support the ends of the cross furring. The ends of main runners shall be supported by hangers located not more than 6 in. (152 mm) from the ends.

7.5.4 Where main runners are spliced, the ends shall be overlapped not less than 12 in. (305 mm) with flanges of channels interlocked and securely tied near each end of the splice with double loops of 0.0625 in. (1.59 mm) or double loops of twin strands of 0.0475-in. (1.21-mm) galvanized wire. However, when the splice occurs at an expansion/control joint, the channel shall be nested and loosely tied to hold together but still allow movement.

7.5.5 Hanger wires shall hang straight down. If an obstacle prevents this, a trapeze type device shall be used to allow hanger wires to hang straight.

7.6 *Installation of Cross Furring*:

7.6.1 Minimum size and maximum spans and spacings of various types of cross furring for various spans between main runners and supports shall conform to the requirements of Table 2.

7.6.2 Cross furring shall be saddle-tied to main runners with 0.0625-in. 16 gauge (1.59-mm) galvanized wire, or a double strand of 0.0475-in. 18 gauge (1.21-mm) galvanized wire or with special galvanized clips, or equivalent attachments. (See Fig. 2.)

7.6.3 Where cross furring members are spliced, the ends shall be overlapped not less than 8 in. (203 mm), with flanges of channels interlocked, and securely tied near each end of the splice with double loops of 0.0625-in. 16 gauge (1.59-mm) galvanized wire or twin strands of 0.0475-in. 18 gauge (1.21-mm) galvanized wire.

7.6.4 Cross furring shall not come into contact with abutting masonry or reinforced concrete walls or partitions except, where special conditions require that cross furring be let into abutting masonry or concrete construction, the applicable provisions of 7.5.2 shall apply.

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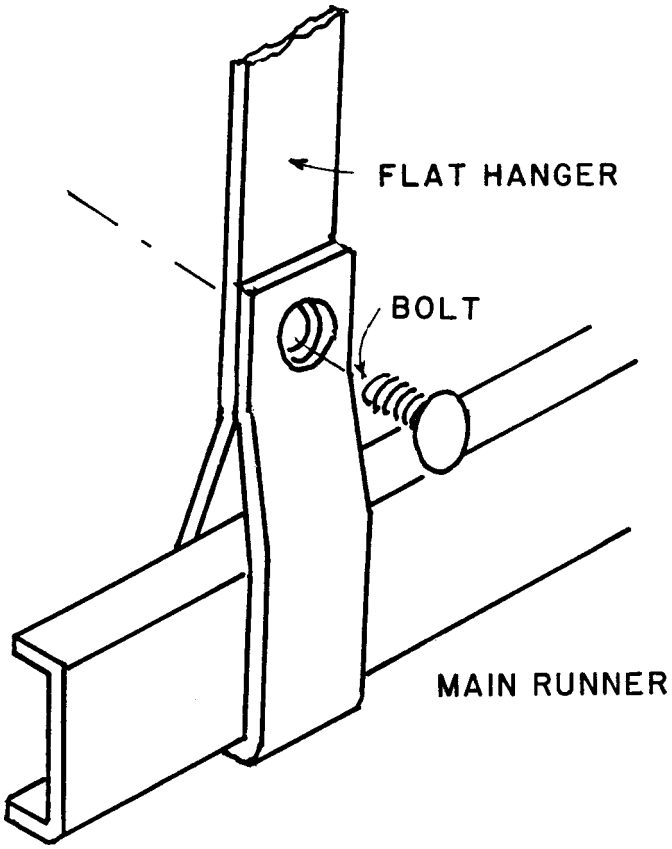

FIG. 3 Flat Hanger Attached to Main Runner Using Round-Head Stove Bolt

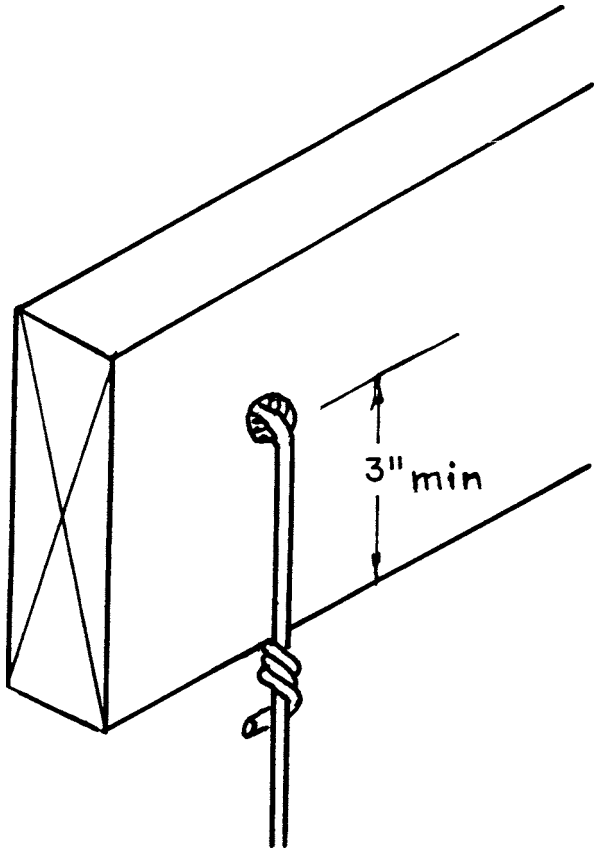

FIG. 4 Hanger Attached to Support Through a Drilled Hole

7.6.5 Main runners and cross running shall be interrupted at control (expansion) joints. However, when the splice occurs at an expansion/control joint, the channel shall be nested and loosely tied to hold together but still allow movement.

7.7 *Metal Furring for Walls*:

7.7.1 Attachments for furring shall be concrete nails driven securely into concrete or into masonry joints, short pieces of ¾-in. (19.1-mm) channels used as anchors driven into masonry joints, or other devices specifically designed as spacer elements, spaced horizontally not more than 2 ft (0.6 m) on centers. They shall be spaced vertically in accordance with horizontal stiffener spacing so that they project from the face of the wall in order for ties to be made.

7.7.2 Horizontal stiffeners shall be not less than ¾ in. (19.5-mm) cold-rolled channels, spaced not to exceed 54 in. (1372 mm) on centers vertically, with the lower and upper channels not more than 6 in. (152 mm) from the ends of vertical members and not less than ¼ in. (6.4 mm) clear from the wall face, securely tied to attachments with three loops of galvanized, soft-annealed wire, or equivalent devices. Approved furring is not prohibited from use in this application.

7.7.3 Vertical members shall be not less than ¾ in. (19.5-mm) cold-rolled channels in accordance with the requirements of Table 3. Vertical members shall be saddle-tied to horizontal stiffeners with three loops of 0.0475-in. (1.21-mm) galvanized soft-annealed wire, or equivalent devices, at each crossing, and securely anchored to the floor and ceiling constructions. Where furring is not in contact with the wall, channel braces shall be installed between horizontal stiffeners and the wall, spaced horizontally not more than 2 ft (600 mm) on centers.

7.7.4 Where dampproofing has been damaged during installation of attachments, the dampproofing shall be repaired with the same material before proceeding with the installation of the furring.

7.8 *Lapping of Metal Plaster Bases*:

7.8.1 Side laps of metal plaster bases shall be secured to framing members. They shall be tied between supports with 0.0475-in. (1.21-mm) wire at intervals not more than 9 in. (229 mm).

7.8.2 Metal lath shall be lapped ½ in. (12.7 mm) at the sides, or nest the edge ribs. Wire lath shall be lapped one mesh at the sides and the ends. Lap metal lath 1 in. (25 mm) at ends. Where end laps occur between the framing members, the ends of the sheets of all metal plaster bases shall be laced or wire tied with 0.0475-in. (1.21-mm) galvanized, annealed steel wire.

7.8.3 Where metal plaster base with backing is used, the vertical and horizontal lap joints shall be backing on backing and metal on metal.

7.8.3.1 Backing shall be lapped not less than 2 in. (50 mm). On walls, the backing shall be lapped so water will flow to the exterior. Backing shall not be placed between plaster base (lath) and flanges of accessories. Metal lath to metal flange contact shall be required to ensure that flanges are mechanically locked together.

7.9 *Spacing of Attachments for Metal Plaster Bases*—Attachments for securing metal plaster bases to framing

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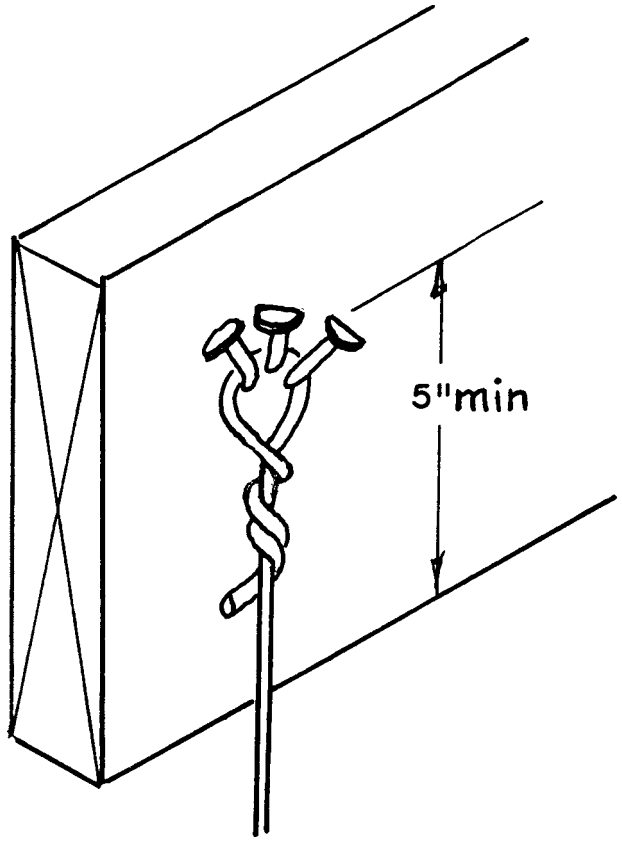

FIG. 5 Hanger Attached to Support Using Nails

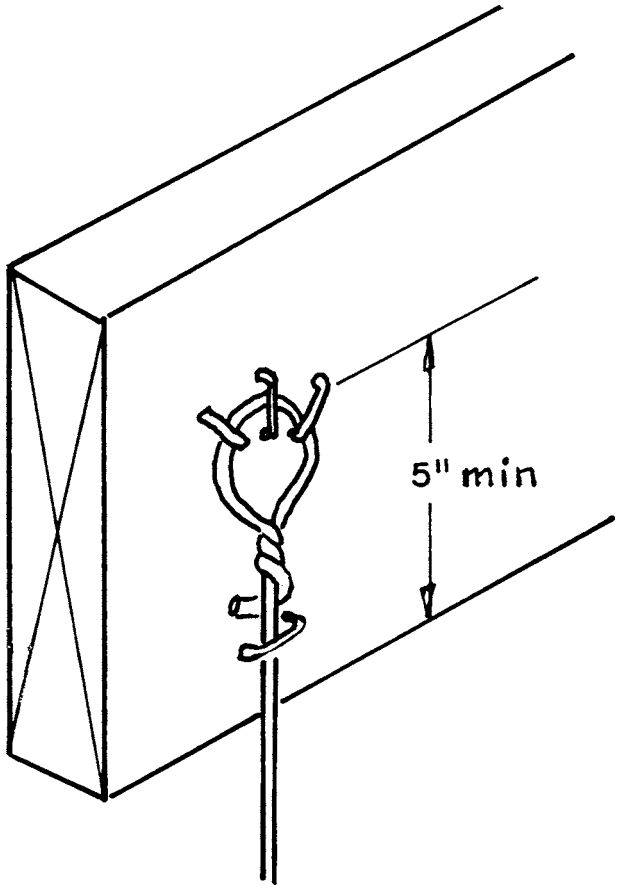

FIG. 6 Hanger Attached to Support Using Staples

members shall be spaced not more than 7 in. (178 mm) apart for diamond mesh and flat rib laths and at each rib for ⅜ in. (9.5-mm) rib lath.

7.10 *Application of Metal Plaster Bases*:

7.10.1 *General*:

7.10.1.1 The spacing of framing members for the type and weight of metal plaster base used shall conform to the requirements of Table 3. Metal plaster bases shall be attached to framing members at not more than 7 in. (178 mm) along framing members except for ⅜-in. (9.5-mm) rib metal lath that shall be attached at each rib.

7.10.1.2 Lath shall be applied with the long dimension at right angles to the supports, unless otherwise specified.

7.10.1.3 Ends of adjoining plaster bases shall be staggered.

7.10.1.4 Lath shall not be continuous through control joints but shall be stopped and tied at each side.

7.10.1.5 Where furred or suspended ceilings butt into or are penetrated by columns, walls, beams, or other elements, the edges and ends of the ceiling lath shall be terminated at the horizontal internal angles with a casing bead, control joint, or similar device designed to keep the edges and ends of the ceiling lath and plaster free of the adjoining vertically oriented, or penetrating elements. Cornerite shall not be used at these locations. A clearance of not less than ⅜ in. (9.5 mm) shall be maintained between the bead and all such elements.

7.10.1.6 Where load bearing walls or partitions butt into structural walls, columns, or floor or roof slabs, the sides or ends of the wall or partition lath shall be terminated at the internal angles with a casing bead, expansion/control joint, or similar device designed to keep the sides and ends of the wall or partition lath free of the adjoining elements. Cornerite shall not be used at these internal angles. A clearance of not less than ⅜ in. (9.5 mm) shall be maintained from all abutting walls, columns, or other vertical elements.

7.10.2 *Attachments for Metal Plaster Bases to Wood Framing Members*:

7.10.2.1 Lath shall be attached to framing members with attachments spaced not more than 7 in. (178 mm) on centers along supports.

7.10.2.2 Diamond-mesh expanded metal lath, flat-rib expanded metal lath, and wire lath shall be attached to horizontal wood framing members with 1½-in. (38.1-mm) roofing nails driven flush with the plaster base and attached to vertical wood framing members with 6d common nails, or 1-in. (25-mm) roofing nails driven to a penetration of not less than ¾ in. (19.1 mm), or 1-in. (25-mm) wire staples driven flush with the plaster base. Staples shall have crowns not less than ¾ in. (19.05 mm) and shall engage not less than three strands of lath and penetrate the wood framing members not less than ¾ in. (19.05 mm). When metal lath is applied over sheathing, use fasteners that will penetrate the structural members not less than ¾ in. (19 mm).

7.10.2.3 Expanded ⅜ in. (9.5 mm) rib lath shall be attached to horizontal and vertical wood framing members with nails or staples to provide not less than 1¾-in. (44.5-mm) penetration into horizontal wood framing members, and ¾-in. (19.1-mm) penetration into vertical wood framing members.

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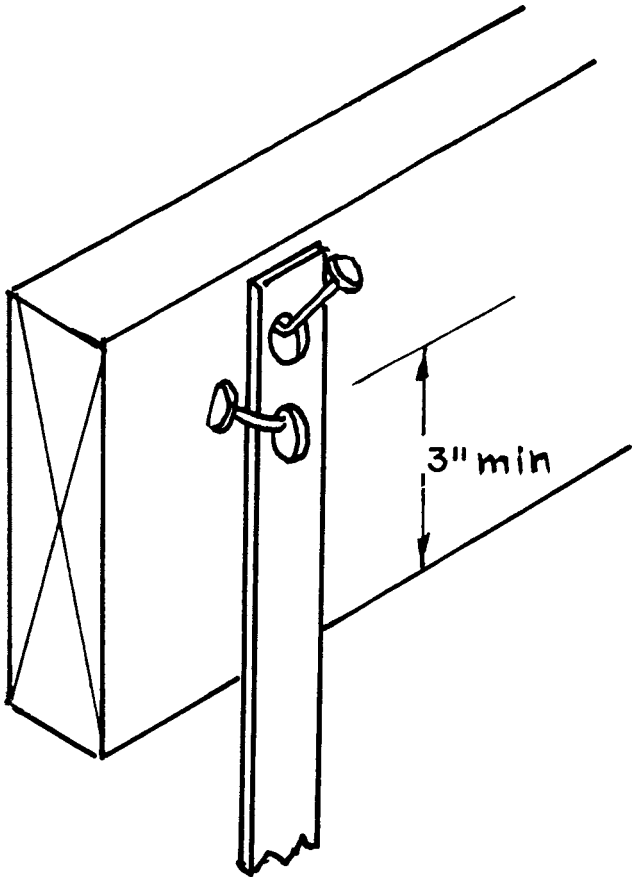

FIG. 7 Flat Hanger Attached to Support Using Nails

7.10.2.4 Common nails shall be bent over to engage not less than three strands of lath, or be bent over a rib when rib lath is installed.

7.10.2.5 Screws used to attach metal plaster base to horizontal and vertical wood framing members shall penetrate not less than ⅝ in. (15.9 mm) into the member when the lath is installed and shall engage not less than three strands of lath. When installing rib lath, the screw shall pass through, but not deform, the rib.

7.10.3 *Attachments for Metal Plaster Bases to Metal Framing Members*:

7.10.3.1 Except as described in 7.10.3.2, all metal plaster bases shall be securely attached to metal framing members with 0.0475-in. 18 gauge (1.21-mm) wire ties, clips or by other means of attachment which afford carrying strength and resistance to corrosion equal to or superior to that of the wire.

7.10.3.2 Rib metal lath shall be attached to open-web steel joists by single ties of galvanized, annealed steel wire, not less than 0.0475 in. (1.21 mm), with the ends of each tie twisted together 1½ times.

7.10.3.3 Screws used to attach metal plaster base to metal framing members shall project not less than ⅜ in. (9.5 mm) through the metal framing member when the lath is installed and shall engage not less than three strands of lath. When installing rib lath, the screw shall pass through, but not deform, the rib.

7.10.4 *Attachments for Metal Plaster Bases to Concrete Joists*—Rib metal lath shall be attached to concrete joists by loops of 0.0800-in. (2.03-mm) galvanized, annealed steel wire, with the ends of each loop twisted together.

7.10.5 Metal plaster bases shall be attached to masonry or concrete with power or powder actuated fasteners or a combination of power or powder actuated fasteners and hardened concrete stub nails. One power or powder actuated fastener shall be located at each corner and one at the mid point of the long dimension adjacent to the edge of the metal plaster base sheet. The balance of the sheet shall be fastened with power or powder actuated fasteners or hardened concrete stub nails. The fasteners shall be installed in rows not more than 16 in. (406 mm) on center and spaced vertically along each row not more 7 in. (178 mm) on center. All fasteners shall be corrosion resistant and shall be not less than ¾ in. (19 mm) long, with heads not less than ⅜ in. (9.5 mm) wide.

7.11 *Application of Accessories*:

7.11.1 *General*—All metal accessories shall be installed in such a manner than flanges and clips provided for their attachment are completely embedded in the plaster.

7.11.1.1 Accessories shall be attached to substrate in such a manner as to ensure proper alignment during application of plaster. Flanges of accessories shall be secured at not more than 7 in. (178 mm) intervals along supports.

7.11.2 *Corner Beads*—Corner beads shall be installed to protect all external corners and to establish grounds.

7.11.2.1 *External Corner Reinforcement*—External corner reinforcement shall be installed to reinforce all external corners where corner bead is not used. Where no external corner reinforcement or corner bead is used, lath shall be furred out and carried around corners not less than one support on frame construction.

7.11.3 *Casing Beads*—Nonload-bearing members shall be isolated from load-bearing members, and all penetrating elements, with casing beads or other suitable means, to avoid transfer of structural loads, and to separate from dissimilar materials.

7.11.4 *Control Joints-General*—Control joints shall be formed by using a single prefabricated member or fabricated by installing casing beads back to back with a flexible barrier membrane behind the casing beads. The separation spacing shall be not less than ⅛ in. (3.2 mm) or as required by the anticipated thermal exposure range and shall be in conformance with 7.10.1.4.

7.11.4.1 *Control Joints*—Control (expansion and contraction) joints shall be installed in walls to delineate areas not more than 144 ft^2(13.4 m^2) and to delineate areas not more than 100 ft^2(9.30 m^2) for all horizontal applications, that is, ceilings, curves, or angle type structures.

7.11.4.2 The distance between control joints shall not exceed 18 ft (5.5 m) in either direction or a length-to-width ratio of 2½ to 1. A control joint shall be installed where the ceiling framing or furring changes direction.

7.11.4.3 A control joint shall be installed where an expansion joint occurs in the base exterior wall.

7.11.4.4 Wall or partition height door frames shall be considered as control joints.

7.11.5 *Foundation Weep Screed*—Foundation weep screed shall be installed at the bottom of all steel or wood framed

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TABLE 3 Types and Weights of Metal Plaster Bases and Corresponding Maximum Permissible Spacing of Supports

Type of Metal Plaster Base	Minimum Weight of Metal Plaster Base, lb/yd^2(kg/m^2)	Maximum Permissible Spacing of Supports Center to Center, in. (mm)				
		Walls (Partitions)			Ceilings	
		Wood Studs or Furring	Solid Partitions[A]	Steel Studs or Furring	Wood or Concrete	Metal
U.S. Nominal Weights:						
Diamond Mesh[B]	2.5 (1.4)	16 (406)[C]	16 (406)	16 (406)[C]	12 (305)	12 (305)
	3.4 (1.8)	16 (406)[C]	16 (406)	16 (406)[C]	16 (406)	16 (406)
Flat Rib	2.75 (1.5)	16 (406)	16 (406)	16 (406)	16 (406)	16 (406)
	3.4 (1.8)	19 (482)	24 (610)	19 (482)	19 (482)	19 (482)
Flat Rib (large opening)	1.8 (0.95)	24 (610)	24 (610)	24 (610)	16 (406)	16 (406)
⅜ in. Rib	3.4 (1.8)	24 (610)	N/A[D]	24 (610)	24 (610)	24 (610)
	4.0 (2.1)	24 (610)	N/A	24 (610)	24 (610)	24 (610)
¾ in. Rib	5.4 (2.9)	24 (610)	N/A	24 (610)	36 (914)	36 (914)
Welded Wire[B]	1.14 (0.62)	16 (406)	16 (406)	16 (406)	16 (406)	16 (406)
	1.95 (1.1)	24 (610)	24 (610)	24 (610)	24 (610)	24 (610)
Woven Wire[B]	1.4 (0.6)	24 (610)	16 (406)	16 (406)	24 (610)	16 (406)
Canadian Nominal Weights:						
Diamond Mesh[B]	2.5 (1.4)	16 (406)	12 (305)	12 (305)	12 (305)	12 (305)
	3.0 (1.6)	16 (406)	12 (305)	12 (305)	12 (305)	12 (305)
	3.4 (1.8)	16 (406)	16 (406)	16 (406)	16 (406)	16 (406)
Flat Rib	2.5 (1.4)	16 (406)	12 (305)	12 (305)	12 (305)	12 (305)
	3.0 (1.6)	16 (406)	16 (406)	16 (406)	16 (406)	13½ (343)
⅜ in. Rib	3.0 (1.6)	19 (482)	N/A	16 (406)	16 (406)	16 (406)
	3.5 (1.9)	24 (610)	N/A	19 (482)	19 (482)	19 (482)
	4.0 (2.1)	24 (610)	N/A	24 (610)	24 (610)	24 (610)

[A] Where plywood is used for sheathing, a minimum of ⅛ in. (3.2 mm) separation shall be provided between adjoining sheets to allow for expansion.
[B] Metal plaster bases shall be furred away from vertical supports or solid surfaces at least ¼ in. Self-furring lath meets furring requirements; except, furring of expanded metal lath is not required on supports having a bearing surface of 1⅝ in. or less.
[C] These spacings are based on unsheathed walls. Where self-furring lath is placed over sheathing or a solid surface, the permissible spacing of supports shall be no more than 24 in. (610 mm).
[D] Not applicable.

TABLE 4 Spans and Spacing of Cold-Rolled Channel Cross-Furring Members[A, B, C, D, E, F]

Design Load, 12 psf (575 Pa)		Allowable Span, Main Runners or Supports Ft-in. (mm)	
Member Depth	Spacing, in. (mm)	Simple Span	Two or More Spans[G,H]
¾ (19)	13.5 (343)	2-9 (840)	3-5 (1040)
	16 (406)	2-7 (790)	3-3 (990)
	19 (483)	2-7 (740)	3-0 (910)
	24 (610)	2-3 (690)	2-10 (860)
1½ (38)	13.5 (343)	4-6 (1370)	5-8 (1730)
	16 (406)	4-3 (1300)	5-5 (1650)
	19 (483)	4-0 (1220)	5-1 (1550)
	24 (610)	3-8 (1120)	4-9 (1450)

[A] Bare metal thickness of cold-rolled members shall not be less than 0.0538 in. (1.367 mm).
[B] Inside corner radii shall not be greater than ⅛ in. (3.17 mm).
[C] Spans based on upper flange of cross-furring laterally unbraced.
[D] Maximum deflection limited to $1/360^{th}$ of span length unbraced.
[E] Steel yield stress, *Fy*, shall not be less than 33 000 psi (228 MPa).
[F] Tabulated spans apply only to cross-furring with webs oriented vertically.
[G] "Two or more" spans refers to two or more continuous, equal spans.
[H] For the "two or more" span conditions, listed spans represent the center-to-center distance between adjacent supports.

exterior walls to receive lath and plaster. Place the bottom edge of the foundation weep screed not less than 1 in. (25 mm) below the joint formed by the foundation and framing. The nose of the screed shall be placed not less than 4 in. (102 mm) above raw earth or 2 in. (51 mm) above paved surfaces. The weather resistive barrier and lath shall entirely cover the vertical attachment flange and terminate at the top edge of the nose or ground flange.

8. Keywords

8.1 ceiling; expansion control joints; lath; plaster; screed; suspended ceiling; walls

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ANNEX

(Mandatory Information)

A1. GENERAL INFORMATION

A1.1 All wood-based sheathing shall be installed with a minimum ⅛-in. (3.2-mm) gap around all panel edges and between openings for doors and windows.

NOTE A1.1—This ⅛-in. (3.2-mm) gap is intended to accommodate expansion. Linear expansion that is not accommodated by an expansion gap can cause stress on the stucco membrane resulting in stucco cracks.

A1.2 **Expansion Joints** shall be used to accommodate some degree of movement in the stucco membrane caused by movement of the building or its components to minimize damage to the stucco and weather resistive barrier. **Control Joints** shall be installed to minimize stress due to stucco curing and drying shrinkage and minor movement, along predetermined, usually straight lines and as a screed to aid in stucco thickness control.

SUMMARY OF CHANGES

Committee C11 has identified the location of selected changes to this specification since the last issue, C 1063 – 07, that may impact the use of this specification. (Approved May 15, 2008)

(*1*) Revised Table 3.
(*2*) Added new 3.2.1 and 3.2.2 and renumbered subsequent paragraphs. Added new Note 1 and renumbered subsequent notes.
(*3*) Added new Annex A1.2.

Committee C11 has identified the location of selected changes to this specification since the last issue, C 1063 – 06, that may impact the use of this specification. (Approved November 1, 2007)

(*1*) Added Annex A1.
(*2*) Replaced references to Specification A 526/A 526M with Specification A 653/A 653M throughout.

Committee C11 has identified the location of selected changes to this specification since the last issue, C 1063 – 03, that may impact the use of this specification. (Approved December 1, 2006)

(*1*) The minimum weights in Table 3 for Welded and Woven wire were changed to be brought in line with Specification C 933 and Specification C 1032, respectively.

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Designation: C 1064/C 1064M – 08

Standard Test Method for Temperature of Freshly Mixed Hydraulic-Cement Concrete[1]

This standard is issued under the fixed designation C 1064/C 1064M; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

This standard has been approved for use by agencies of the Department of Defense.

1. Scope*

1.1 This test method covers the determination of temperature of freshly mixed hydraulic-cement concrete.

1.2 The values stated in either SI or inch-pound units are to be regarded separately as standard. Within the text, SI units are shown in brackets. The values stated in each system may not be exact equivalents; therefore, each system shall be used independently of the other. Combining values from the two systems may result in non-conformance with the standard.

1.3 The text of this standard references notes and footnotes that provide explanatory information. These notes and footnotes (excluding those in tables and figures) shall not be considered as requirements of this standard.

1.4 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.* (**Warning**—Fresh hydraulic cementitious mixtures are caustic and may cause chemical burns to skin and tissue upon prolonged exposure.[2])

2. Referenced Documents

2.1 *ASTM Standards:* [3]

C 172 Practice for Sampling Freshly Mixed Concrete

C 670 Practice for Preparing Precision and Bias Statements for Test Methods for Construction Materials

3. Significance and Use

3.1 This test method provides a means for measuring the temperature of freshly mixed concrete. The measured temperature represents the temperature at the time of testing and may not be an indication of the temperature of the freshly mixed concrete at a later time. It may be used to verify conformance to a specified requirement for temperature of concrete.

3.2 Concrete containing aggregate of a nominal maximum size greater than 3 in. [75 mm] may require up to 20 min for the transfer of heat from aggregate to mortar. (See ACI Committee 207.1R Report.[4])

4. Apparatus

4.1 *Container*, shall be large enough to provide at least 3 in. [75 mm] of concrete in all directions around the sensor of the temperature measuring device; concrete cover must also be at least three times the nominal maximum size of the coarse aggregate.

4.2 *Temperature Measuring Device*, shall be capable of accurately measuring the temperature of the freshly mixed concrete to ±1 °F [± 0.5 °C] throughout a range of 30° to 120 °F [0° to 50 °C]. The design of the temperature measuring device shall be such that it allows 3 in. [75 mm] or more immersion during operation.

4.3 Partial immersion liquid-in-glass thermometers (and possibly other types) shall have a permanent mark to which the device must be immersed without applying a correction factor.

4.4 *Reference Temperature Measuring Device*, shall be readable and accurate to ± 0.5 °F [0.2 °C] at the verification points in 5.1. A certificate or report that verifies the accuracy shall be available in the laboratory for review. Accuracy of liquid-in-glass reference temperature measuring devices shall be verified once. Verification of direct-reading resistance reference temperature measuring devices shall be performed every twelve months. The certificate or report shall provide documentation that the reference standard used in the verification is traceable to the National Institute of Standards and Technology (NIST).

5. Calibration of Temperature Measuring Device

5.1 Each temperature measuring device used for determining temperature of freshly mixed concrete shall be calibrated

[1] This test method is under the jurisdiction of ASTM Committee C09 on Concrete and Concrete Aggregates and is the direct responsibility of Subcommittee C09.60 on Testing Fresh Concrete.

Current edition approved July 1, 2008. Published August 2008. Originally approved in 1986. Last previous edition approved in 2005 as C 1064 – 05.

[2] Section on Safety Precautions, Manual of Aggregate and Concrete Testing, *Annual Book of ASTM Standards*, Vol 04.02.

[3] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

[4] Available from American Concrete Institute (ACI), P.O. Box 9094, Farmington Hills, MI 48333-9094, http://www.concrete.org.

***A Summary of Changes section appears at the end of this standard.**

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annually, or whenever there is a question of accuracy. This calibration shall be performed by comparing the readings of the temperature measuring device at two temperatures at least 30 °F [15 °C] apart.

5.2 Calibration of the temperature measuring devices may be made in oil or other suitable baths having uniform density if provision is made to:

5.2.1 Maintain the bath temperature constant within 0.5 °F [0.2 °C] during the period of the test.

5.2.2 Have both the temperature and reference temperature measuring devices maintained in the bath for a minimum of 5 min before reading temperatures.

5.2.3 Continuously circulate the bath liquid to provide a uniform temperature.

5.2.4 Slightly tap thermometers containing liquid to avoid adhesion of the liquid to the glass if the temperature exposure is being reduced.

6. Sampling Concrete

6.1 It is acceptable to measure the temperature of freshly mixed concrete in either the transporting equipment or the forms after discharge provided the sensor of the temperature measuring device has at least 3 in. [75 mm] of concrete cover in all directions.

6.2 If the transporting equipment or placement forms are not used as the container, a sample shall be prepared as follows:

6.2.1 Immediately, prior to sampling the freshly mixed concrete, dampen (with water) the sample container.

6.2.2 Sample the freshly mixed concrete in accordance with Practice C 172, except that composite samples are not required if the only purpose for obtaining the sample is to determine temperature.

6.2.3 Place the freshly mixed concrete into the container.

7. Procedure

7.1 Position the temperature measuring device so that the end of the temperature sensing portion is submerged a minimum of 3 in. [75 mm] into the freshly mixed concrete. Close the void left by the placement by gently pressing the concrete around the temperature measuring device at the surface of the concrete to prevent ambient air temperature from affecting the reading.

7.2 Leave the temperature measuring device in the freshly mixed concrete for at least 2 min but not more than 5 min, then read and record the temperature to the nearest 1 °F [0.5 °C]. Do not remove the device from the concrete when reading the temperature.

8. Report

8.1 Report the measured temperature of the freshly mixed concrete to the nearest 1 °F [0.5 °C].

9. Precision and Bias

9.1 The single operator standard deviation for measurement of concrete temperature has been found to be 0.5 °F.[5] Therefore, results of two properly conducted tests by the same operator on the same sample of material should not differ by more than 1.3 °F.[5]

9.2 The multi-operator standard deviation for the measurement of concrete temperature on the same sample has been found to be 0.7 °F.[5] Therefore, two tests properly conducted by different operators but on the same material should not differ by more than 1.9 °F.[5]

9.3 The precision values given were derived from an interlaboratory study using 11 operators on two concrete batches at around 75 °F.[6]

9.4 Since there is no accepted reference material suitable for determining the bias of this test method, no statement on bias is being made.

10. Keywords

10.1 freshly mixed concrete; temperature; temperature measuring device

[5] These numbers represent, respectively, the (1s) and (d2s) limits as described in Practice C 670.

[6] Supporting data have been filed at ASTM International Headquarters and may be obtained by requesting Research Report RR: C09-1028.

SUMMARY OF CHANGES

Committee C09 has identified the location of selected changes to this specification since the last issue, C 1064/C 1064M – 05, that may impact the use of this specification. (Approved July 1, 2008)

(*1*) Revised 3.1 to clarify what the recorded temperature represents.

(*2*) Revised 7.2 and 8.1.

(*3*) Deleted 7.3 and Note 4.

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Designation: C 1067 – 00 (Reapproved 2007)

Standard Practice for Conducting A Ruggedness or Screening Program for Test Methods for Construction Materials[1]

This standard is issued under the fixed designation C 1067; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope

1.1 This practice covers a procedure for detecting sources of variation in a test method. The procedure should be used during the development of a test method, before the interlaboratory study is executed, such as those in Practices C 670, C 802, and E 691. Interlaboratory studies can be expensive to execute. Resources will probably be more efficiently used if sources of variation in a test method are eliminated prior to performing the interlaboratory study. The procedure also is useful for determining sources of variation in an existing test method that has been found to have poor precision.

1.2 This practice covers, in very general terms, techniques for planning, collecting data, and analyzing results from a few laboratories. Annex A1 provides the details of the procedure with an example and Annex A2 gives the theoretical background.

1.3 The practice does not give information pertinent to estimating within- or between-laboratory precision.

1.4 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

2. Referenced Documents

2.1 *ASTM Standards:* [2]

C 670 Practice for Preparing Precision and Bias Statements for Test Methods for Construction Materials

C 802 Practice for Conducting an Interlaboratory Test Program to Determine the Precision of Test Methods for Construction Materials

E 456 Terminology Relating to Quality and Statistics

E 691 Practice for Conducting an Interlaboratory Study to Determine the Precision of a Test Method

E 1169 Guide for Conducting Ruggedness Tests

3. Terminology

3.1 *Definitions:*

3.1.1 *determination value*, *n*—numerical quantity calculated as directed in the test method using direct measurements obtained in accordance with the procedures given in the test method.

3.1.2 *replication*, *n*—the act of obtaining two or more determination values under specified conditions. The number of replications must be finite and the scope of the replication operation may be narrow or broad, but must be specified.

3.1.3 For definitions of other statistical terms used in this standard, refer to Terminology E 456.

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *factor*, *n*—an element in the test procedure or laboratory environment that is a potential source of variation in test results.

3.2.2 *ruggedness*, *adj*—the characteristic of a test method that produces test results that are not influenced by small differences in the testing procedure or environment.

3.2.3 *screening*, *n*—the detection of significant sources of variation as compared to chance variation.

3.2.4 *variable*, *n*—a number or quantity that varies.

4. Summary of Practice

4.1 The practice requires that the user develop, from theoretical or practical knowledge, or both, a list of factors that plausibly would cause significant variation in test results if the factors were not controlled. The technique is limited to the analysis of the effects seven factors and requires considerably less effort than would be required to collected data for seven

[1] This practice is under the jurisdiction of ASTM Committee C09 on Concrete and Concrete Aggregates . This practice was developed jointly by ASTM Committees C01, C09, D04, and D18, and is endorsed by all four committees.

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[2] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

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factors in a full factorial study. Procedures exist for analysis of smaller and larger numbers of factors (see Guide E 1169), but seven is a convenient number for many test methods for construction materials. The seven-factor analysis requires 16 determinations by each laboratory. The procedure can be usefully executed by a single laboratory, but sometimes additional information can be obtained if it is repeated in one or two additional laboratories.

4.2 The procedure requires that two levels of each factor be identified, then 16 determinations be done on a prescribed combinations of factor levels. The levels assigned to a factor may be quantitative or qualitative (for example, brass versus steel).

4.3 The disadvantage of this type of analysis is that the method only estimates simple effects of each factor and does not detect interactive effects among factors.

5. Significance and Use

5.1 The purpose of a ruggedness evaluation is to determining how sensitive the test method is to changes in levels of pertinent operating factors. Normally, operating conditions for a test method are defined along with an allowable tolerance. A ruggedness analysis determines that effect of worst-case variation in operating conditions within this tolerance range. The method then can be revised with smaller tolerances on operating conditions to improve the precision.

5.2 A major reason for poor precision in test methods is the lack of adequate control over the sources of variation in testing procedures or testing environments. These sources of variation often are not controlled adequately because they were not identified during the development of the test procedures.

5.3 All new test methods must be subjected to an interlaboratory program for purposes of developing a precision and bias statement. These programs can be expensive and lengthy, and the result may be that the determination is made that the method is too variable to be published without further revision. Interlaboratory studies typically give the subcommittee an indication that the method is too variable, but they do not usually give a clear picture of what is causing the variation. Application of this ruggedness practice using one or a few laboratories may be a much more economical way to determine these causes.

5.4 Many existing test methods were published before there was a requirement that precision and bias statements be developed. Since this became a requirement, most of these test methods have developed precision and bias statements, and the result is that many have been found to suffer from relatively large amount of variation. Use of this practice represents a relatively simple way to investigate the causes of variation in test methods, so that a subcommittee will have some guidance as to which parts of the test method need to be studied further for revision.

5.5 The procedure can be used for a program within a single laboratory, but involvement of at least three laboratories is recommended, particularly if the single laboratory were to be the one in which the test method was developed. This is particularly important for new test methods. The originating laboratory is so much a part of the development of the test method that it is difficult for it to be objective in spotting any problems in the clarity of the test method directions. Two additional laboratories will probably contribute fresh critical review of the validity of the test method and provide assistance in clarifying the instructions of the test method when needed.

6. Materials

6.1 The number and types of material shall cover the range of material properties to which the test method is applicable. The test method does not apply to material types or property values outside the range evaluated. Three to five materials will usually be sufficient.

6.1.1 Some preliminary testing may help the laboratories involved determine the materials that shall be used in the screening program.

7. Procedure

7.1 Determine the number of laboratories that will participate in the program and which materials each will use in the program. The maximum amount of information is obtained if all laboratories include all materials in their part of the program, however cost can be reduced by each laboratory using a different material. Caution must be exercised in interpreting the results since laboratory-dependent cannot be separated from material-dependent effects.

7.2 Factors that are likely to have the greatest effect on the variability in the test results are selected for study. Levels of these factors are determined, selecting the minimum and maximum levels that would plausibly occur in the execution of the test method if there were no particular efforts to control them. Only two levels are allowed. Levels often represent quantitative properties, such as temperature, pressure, etc, but they may also represent nonquantitative values, such as old vs new, wet vs dry, etc. In this standard, factors are assigned letter designations, $A - G$, and the two levels of each factor are designated with upper and lower cases of these letters, as in Table 1.

7.3 Assign combinations of factor levels to experimental determinations according to Table 1. The 8 determinations will be done in duplicate, therefore, the full study on each material will require 16 determinations.

7.4 Construct a 16 row by 16 column results matrix from the 16 determinations values ($d_1 - d_{16}$) as shown in Table 2. The absolute values of the determinations in each row are identical, only the signs vary. Calculate Z and W statistics as shown in the equations below.

$$Z_r = \sum_1^{16} d_i, \text{ where } d_i\text{'s are the 16 results in each row (r).} \quad (1)$$

TABLE 1 Pattern of Assigning Levels to Seven Factors

	Determination Number							
Factor	1	2	3	4	5	6	7	8
A	a	a	a	a	A	A	A	A
B	b	b	B	B	b	b	B	B
C	C	c	C	c	C	c	C	c
D	D	D	d	d	d	d	D	D
E	e	E	e	E	E	e	E	e
F	F	f	f	F	F	f	f	F
G	G	g	g	G	g	G	G	g

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TABLE 2 Results Matrix of 16 Determinations ($d_1 - d_{16}$)

	Eight Determinations for Replicate Set 1								Eight Determinations for Replicate Set 2									
row	1	2	3	4	5	6	7	8	1	2	3	4	5	6	7	8	Z	W
1	d_1	d_2	d_3	d_4	d_5	d_6	d_7	d_8	d_9	d_{10}	d_{11}	d_{12}	d_{13}	d_{14}	d_{15}	d_{16}	Z_1	W_1
2	d_1	d_2	d_3	d_4	$-d_5$	$-d_6$	$-d_7$	$-d_8$	d_9	d_{10}	d_{11}	d_{12}	$-d_{13}$	$-d_{14}$	$-d_{15}$	$-d_{16}$	Z_2	W_2
3	d_1	d_2	$-d_3$	$-d_4$	d_5	d_6	$-d_7$	$-d_8$	d_9	d_{10}	$-d_{11}$	$-d_{12}$	d_{13}	d_{14}	$-d_{15}$	$-d_{16}$	Z_3	W_3
4	d_1	$-d_2$	d_3	$-d_4$	d_5	$-d_6$	d_7	$-d_8$	d_9	$-d_{10}$	d_{11}	$-d_{12}$	d_{13}	$-d_{14}$	d_{15}	$-d_{16}$	Z_4	W_4
5	d_1	d_2	$-d_3$	$-d_4$	$-d_5$	$-d_6$	d_7	d_8	d_9	d_{10}	$-d_{11}$	$-d_{12}$	$-d_{13}$	$-d_{14}$	d_{15}	d_{16}	Z_5	W_5
6	d_1	$-d_2$	d_3	$-d_4$	$-d_5$	d_6	$-d_7$	d_8	d_9	$-d_{10}$	d_{11}	$-d_{12}$	$-d_{13}$	d_{14}	$-d_{15}$	d_{16}	Z_6	W_6
7	d_1	$-d_2$	$-d_3$	d_4	d_5	$-d_6$	$-d_7$	d_8	d_9	$-d_{10}$	$-d_{11}$	d_{12}	d_{13}	$-d_{14}$	$-d_{15}$	d_{16}	Z_7	W_7
8	d_1	$-d_2$	$-d_3$	d_4	$-d_5$	d_6	d_7	$-d_8$	d_9	$-d_{10}$	$-d_{11}$	d_{12}	$-d_{13}$	d_{14}	d_{15}	$-d_{16}$	Z_8	W_8
9	d_1	d_2	d_3	d_4	d_5	d_6	d_7	d_8	$-d_9$	$-d_{10}$	$-d_{11}$	$-d_{12}$	$-d_{13}$	$-d_{14}$	$-d_{15}$	$-d_{16}$	Z_9	W_9
10	d_1	d_2	d_3	d_4	$-d_5$	$-d_6$	$-d_7$	$-d_8$	$-d_9$	$-d_{10}$	$-d_{11}$	$-d_{12}$	d_{13}	d_{14}	d_{15}	d_{16}	Z_{10}	W_{10}
11	d_1	d_2	$-d_3$	$-d_4$	d_5	d_6	$-d_7$	$-d_8$	$-d_9$	$-d_{10}$	d_{11}	d_{12}	$-d_{13}$	$-d_{14}$	d_{15}	d_{16}	Z_{11}	W_{11}
12	d_1	$-d_2$	d_3	$-d_4$	d_5	$-d_6$	d_7	$-d_8$	$-d_9$	d_{10}	$-d_{11}$	d_{12}	$-d_{13}$	d_{14}	$-d_{15}$	d_{16}	Z_{12}	W_{12}
13	d_1	d_2	$-d_3$	$-d_4$	$-d_5$	$-d_6$	d_7	d_8	$-d_9$	$-d_{10}$	d_{11}	d_{12}	d_{13}	d_{14}	$-d_{15}$	$-d_{16}$	Z_{13}	W_{13}
14	d_1	$-d_2$	d_3	$-d_4$	$-d_5$	d_6	$-d_7$	d_8	$-d_9$	d_{10}	$-d_{11}$	d_{12}	d_{13}	$-d_{14}$	d_{15}	$-d_{16}$	Z_{14}	W_{14}
15	d_1	$-d_2$	$-d_3$	d_4	d_5	$-d_6$	$-d_7$	d_8	$-d_9$	d_{10}	d_{11}	$-d_{12}$	$-d_{13}$	d_{14}	d_{15}	$-d_{16}$	Z_{15}	W_{15}
16	d_1	$-d_2$	$-d_3$	d_4	$-d_5$	d_6	d_7	$-d_8$	$-d_9$	d_{10}	d_{11}	$-d_{12}$	d_{13}	$-d_{14}$	$-d_{15}$	d_{16}	Z_{16}	W_{16}

$$W_r = \frac{Z_r^2}{16} \tag{2}$$

7.5 The W statistic for row 1 represents the simple sum of the determinations and are not used in this analysis. Statistics for rows 2–8 ($W_2 - W_8$) represent the effects of the seven factors. The statistic for row 9 (W_9) represent the total variation between the two replicate sets and is not used in this analysis. Statistics for rows 10 through 16 ($W_{10} - W_{16}$) are used to calculate the error variance (X), which then is used to calculate the test criterion (F) for each factor, as shown by the equations below. Calculations are summarized in Table 3.

$$X = (\sum_{r=10}^{16} W_r^2)/7 \tag{3}$$

$F_f = \frac{W_r^2}{X}$, where F_f is the F statistic for the effect of factor f (1–7, represented by $W_2 - W_8$, respectively)

7.6 A F value of ≥5.59 represents a significant effect for factor f at a probability of 5 % for drawing an erroneous conclusion.

TABLE 3 Summary of Statistics for Seven Factors and Random Error

Factor	W	F
A	W_2	W_2^2/X
B	W_3	W_3^2/X
C	W_4	W_4^2/X
E	W_5	W_5^2/X
F	W_6	W_6^2/X
G	W_7	W_7^2/X
H	W_8	W_8^2/X
	W_{10}	
	W_{11}	
	W_{12}	
	W_{13}	$X = \Sigma(W^2)/7$, for $W_{10\text{-}16}$
	W_{14}	
	W_{15}	
	W_{16}	

7.7 An example of an analysis of data representing results on 4 materials from 3 laboratories is shown in Annex A1.

8. Keywords

8.1 precision; ruggedness; test method; variation

ANNEXES

(Mandatory Information)

A1. EXAMPLE OF A RUGGEDNESS PROGRAM

A1.1 This annex describes the procedure for conducting a ruggedness evaluation using as an example a description of the ruggedness evaluation on a test method for the measurement of the viscosity of asphalt.

A1.2 As the first step in the ruggedness evaluation, each of the laboratories critically examined the procedure in the proposed test method. The objectives of the examination were as follows:

A1.2.1 To determine if the instructions are clear, concise, and complete,

A1.2.2 To decide which factors are likely to influence test results and therefore should be included in the study,

A1.2.3 To pick materials that cover the range of the property of interest for the range of physical forms of the materials to be tested, and

A1.2.4 To determine the proper levels to be evaluated for each of the chosen variables.

A1.3 In this example, representatives of the three laboratories, after familiarizing themselves with the test method as specified in A1.2, met and tried to improve the instructions for the viscosity method. They selected variables, materials, and levels that showed the effect of the variation. One of the laboratories measured viscosity at 24 °C, 25 °C, and 26 °C and found that there was about a 10 % variation with a change of

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1 °C. This was considered too large so 24.6 and 25.4 °C were selected as the lower and upper temperature levels for the ruggedness test. In the same manner, the effect of the other variables were evaluated and the two levels to be evaluated were determined.

NOTE A1.1—Seven variables were selected and placed in a systematic procedure called an incomplete Latin Square or a Youden Square (**1**).The variables are listed below and shown in a Youden Square in Table A1.1. This plan can evaluate the seven variables with eight determinations. Table A1.2 shows the variables and the levels selected for this example.

A1.4 Four materials were selected to cover the range of the test method and the viscosities were determined by each of the three laboratories with one replication. The results are displayed in Table A1.3. This plan required 16 determinations by each laboratory on each material or 64 determinations by each laboratory.

A1.5 Table A1.4 specifies the experimental plan for a Youden Square for seven factors. The theory of its use is covered in Annex A2. Table A1.4 consists of 16 rows and 16 columns of coefficients each equal to ±1 and arranged in a definite pattern.

A1.6 To obtain Table A1.5, first copy one row from Table A1.3 16 times in the general format of Table A1.5 and then multiply each entry in the new table by the corresponding entry in Table A1.4. Table A1.5 is just such a table derived from the data for Material 1 and Laboratory 1 in Table A1.3.

A1.7 To obtain Table A1.6, add, with due regard to sign, each row of Table A1.5 to obtain the first column of Table A1.6 containing Z_1–Z_{16}. Next, square each entry in column one of Table A1.6 to obtain the corresponding entry in column two and then divide each entry in column two of Table A1.6 by 16 to obtain the corresponding entry in column three. The first row, Z_1, represents the sum of all viscosities for the first row in Table A1.5 and will not be used in this analysis. The second row, Z_2, is the algebraic addition of the second row in Table A1.5 and measures the effect of temperature. In the same manner, the third row, Z_3, measures the effect of the age of the viscometer. The fourth row, Z_4, measures the effect of vacuum level. The fifth row, Z_5, measures the effect of stirring. The sixth row, Z_6, measures the effect of the viscometer being slanted. The seventh row, Z_7, measures the effect of variation in meniscus level. The eighth row, Z_8 measures the effect of variation in time in the bath of the viscometer prior to testing. The ninth row, Z_9, measures the variation between the first and second replication. Rows 10 through 16 (Z_{10}–Z_{16}) measure the factor differences that yield the estimate of error variance. By adding W_{10} through W_{16} we can estimate the error variance with seven degrees of freedom using Eq A1.1:

$$\chi = \sum_{i=10}^{16} W^2{}_i /7\sigma^2 \qquad \text{(A1.1)}$$

where:

χ = pooled sum of squares for error,
$W^2{}_i$ = sum of squares for error in ith row, and
σ^2 = true, but unknown error variance.

A1.7.1 By dividing χ into $W^2{}_j/\sigma^2$, representing the sums of squares for the main factors, we can test for the significance of the *j*th factor difference as shown in Eq A1.2:

$$F_j = W^2{}_j /\sigma^2 / \sum_{i=10}^{16} W^2{}_i /7\sigma^2 = W^2{}_j / \sum_{i=10}^{16} W^2{}_i /7 \qquad \text{(A1.2)}$$

A1.7.2 Eq A1.2 will have an *F*-distribution with 1 and 7 degrees of freedom.

A1.8 The pooled sum of squares for error was determined and compared with the sums of squares for each of the main factors or treatments. The ratio that is significant at the 0.05 level is 5.59.

A1.9 *F* values for each of the main factors were calculated for Tables A1.6-A1.17. The results of these calculations are shown for all factors in Table A1.18. All ratios that were less than 5.59 are shown in the table as NS to show that they are not significant. Z_2 or the effect of temperature was found highly significant for every material and every laboratory indicating the importance of improved control of temperature. Z_4 or the effect of variation in vacuum showed five significant values indicating a need for tightened controls on vacuum. Z_6 or the effect of the viscometer deviating from the vertical position was significant in six of the laboratory-material combinations indicating the need for tightened controls on the position of the viscometer. Z_3, Z_5, Z_7, and Z_8 showed some scattering of barely significant values but these were not judged to be of sufficient importance to require tighter controls.

TABLE A1.1 Pattern for Assigning Levels to Seven Factors

	Determination Number							
Variable	1	2	3	4	5	6	7	8
A or a	a	a	a	a	A	A	A	A
B or b	b	b	B	B	b	b	B	B
C or c	C	c	C	c	C	c	C	c
D or d	D	D	d	d	d	d	D	D
E or e	e	E	e	E	E	e	E	e
F or f	F	f	f	F	F	f	f	F
G or g	G	g	g	G	g	G	G	g

a = 24.6°, the lower level of temperature.
A = 25.4°, the higher level of temperature.
b = New viscometer tube.
B = Worn viscometer tube.
C = 290-mm Hg, lower vacuum.
c = 310-mm Hg, higher vacuum.
d = Charge viscometer without stirring sample.
D = Charge viscometer after stirring for 1 min.
e = Mount the viscometer vertically.
E = Mount the viscometer 3° from vertical.
f = Charge with meniscus 1 mm above line.
F = Charge with meniscus 1 mm below line.
g = Hold viscometer in bath 10 min less than normal before testing.
G = Hold viscometer in bath 10 min longer than normal before testing.

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TABLE A1.2 Conditions for Each Determination in, Experiment with Seven Factors, Asphalt Viscosity

	Determinaton Number							
Variable	1	2	3	4	5	6	7	8
Temperature °C	24.6	24.6	24.6	24.6	25.4	25.4	25.4	25.4
Age of Tube	New	New	Old	Old	New	New	Old	Old
Vacuum, mm Hg	310	290	310	290	310	290	310	290
Stirring	Yes	Yes	No	No	No	No	Yes	Yes
Angle with Horizontal Degree	90	87	90	87	87	90	87	90
Fill line, mm	4	6	6	4	4	6	6	4
Time in Bath, min	40	20	20	40	20	40	40	20

TABLE A1.3 Raw Data for Viscosity Example Seven Factors With Replication

Material	Viscosity															
	First Replicate Determination Number								Second Replicate Determination Number							
	1	2	3	4	5	6	7	8	1	2	3	4	5	6	7	8
	Laboratory 1															
1	2370	2258	2355	2185	1825	1845	1820	1830	2320	2275	2350	2380	1840	1850	1825	1820
2	520	495	519	480	401	404	398	402	492	516	490	522	390	408	402	395
3	4205	4006	4191	3846	3212	3284	3185	3221	4200	4160	4130	4020	3218	3180	3280	3280
4	1075	1061	1060	961	803	793	801	805	1050	1070	1015	1000	808	790	795	805
	Laboratory 2															
1	2350	2240	2335	2165	1805	1825	1800	1810	2280	2310	2400	2120	1825	1806	1809	1812
2	540	515	539	500	421	424	418	422	518	545	524	492	410	425	430	420
3	4235	4036	4121	3876	3242	3314	3117	3250	4250	4142	3960	4205	3310	3112	3240	3117
4	1102	1040	1085	980	820	811	824	828	1110	1125	1040	1050	825	804	816	835
	Laboratory 3															
1	2390	2278	2375	2205	1845	1865	1840	1850	2400	2268	2350	2250	1860	1850	1870	1845
2	510	485	509	470	391	394	388	392	505	482	510	480	395	390	385	392
3	4200	3975	4160	3816	3190	3246	3150	3200	4180	3990	4140	3890	3200	3180	3220	3195
4	1050	990	1035	930	786	766	775	780	1040	980	1050	970	780	760	785	782

TABLE A1.4 Pattern for Assigning Levels to Seven Factors with Replication

	Replicate 1								Replicate 2							
	1 X_1	2 X_2	3 X_3	4 X_4	5 X_5	6 X_6	7 X_7	8 X_8	1 X_9	2 X_{10}	3 X_{11}	4 X_{12}	5 X_{13}	6 X_{14}	7 X_{15}	8 X_{16}
Z_1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Z_2	1	1	1	1	−1	−1	−1	−1	1	1	1	1	−1	−1	−1	−1
Z_3	1	1	−1	−1	1	1	−1	−1	1	1	−1	−1	1	1	−1	−1
Z_4	1	−1	1	−1	1	−1	1	−1	1	−1	1	−1	1	−1	1	−1
Z_5	1	1	−1	−1	−1	−1	1	1	1	1	−1	−1	−1	−1	1	1
Z_6	1	−1	1	−1	−1	1	−1	1	1	−1	1	−1	−1	1	−1	1
Z_7	1	−1	−1	1	1	−1	−1	1	1	−1	−1	1	1	−1	−1	1
Z_8	1	−1	−1	1	−1	1	1	−1	1	−1	−1	1	−1	1	1	−1
Z_9	1	1	1	1	1	1	1	1	−1	−1	−1	−1	−1	−1	−1	−1
Z_{10}	1	1	1	1	−1	−1	−1	−1	−1	−1	−1	−1	1	1	1	1
Z_{11}	1	1	−1	−1	1	1	−1	−1	−1	−1	1	1	−1	−1	1	1
Z_{12}	1	−1	1	−1	1	−1	1	−1	−1	1	−1	1	−1	1	−1	1
Z_{13}	1	1	−1	−1	−1	−1	1	1	−1	−1	1	1	1	1	−1	−1
Z_{14}	1	−1	1	−1	−1	1	−1	1	−1	1	−1	1	1	−1	1	−1
Z_{15}	1	−1	−1	1	1	−1	−1	1	−1	1	1	−1	−1	1	1	−1
Z_{16}	1	−1	−1	1	−1	1	1	−1	−1	1	1	−1	1	−1	−1	1

A1.10 Representatives of the three laboratories met after completion of the laboratory work and the subsequent analysis. After discussion of the results, the decision was made that it was practical and desirable to control temperature, vacuum, and the angle of the viscosity tube to the following limits:

Temperature 25 ± 0.1, °C
Vacuum 300 ± 2, mm (Hg) and
Angle with Horizontal 90 ± 1°

With these changes an interlaboratory study was made on the method.

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TABLE A1.5 Matrix Based on Table A1.4 for Laboratory I, Material 1

NOTE 1—The data contained in Tables A1.7-A1.17 is derived from matrices constructed as illustrated by this table for each of the remaining eleven laboratory-material combinations from Table A1.3.

Replicate 1								Replicate 2							
X_1	X_2	X_3	X_4	X_5	X_6	X_7	X_8	X_9	X_{10}	X_{11}	X_{12}	X_{13}	X_{14}	X_{15}	X_{16}
2370	2258	2355	2185	1825	1845	1820	1830	2320	2275	2350	2380	1840	1850	1825	1820
2370	2258	2355	2185	−1825	−1845	−1820	−1830	2320	2275	2350	2380	−1840	−1850	−1825	−1820
2370	2258	−2355	−2185	1825	1845	−1820	−1830	2320	2275	−2350	−2380	1840	1850	−1825	−1820
2370	−2258	2355	−2185	1825	−1845	1820	−1830	2320	−2275	2350	−2380	1840	−1850	1825	−1820
2370	2258	−2355	−2185	−1825	−1845	1820	1830	2320	2275	−2350	−2380	−1840	−1850	1825	1820
2370	−2258	2355	−2185	−1825	1845	−1820	1830	2320	−2275	2350	−2380	−1840	1850	−1825	1820
2370	−2258	−2355	2185	1825	−1845	−1820	1830	2320	−2275	−2350	2380	1840	−1850	−1825	1820
2370	−2258	−2355	2185	−1825	1845	1820	−1830	2320	−2275	−2350	2380	−1840	1850	1825	−1820
2370	2258	2355	2185	1825	1845	1820	1830	−2320	−2275	−2350	−2380	−1840	−1850	−1825	−1820
2370	2258	2355	2185	−1825	−1845	−1820	−1830	−2320	−2275	−2350	−2380	1840	1850	1825	1820
2370	2258	−2355	−2185	1825	1845	−1820	−1830	−2320	−2275	2350	2380	−1840	−1850	1825	1820
2370	−2258	2355	−2185	1825	−1845	1820	−1830	−2320	2275	−2350	2380	−1840	1850	−1825	1820
2370	2258	−2355	−2185	−1825	−1845	1820	1830	−2320	−2275	2350	2380	1840	1850	−1825	−1820
2370	−2258	2355	−2185	−1825	1845	−1820	1830	−2320	2275	−2350	2380	1840	−1850	1825	−1820
2370	−2258	−2355	2185	1825	−1845	−1820	1830	−2320	2275	−2350	−2380	−1840	1850	1825	−1820
2370	−2258	−2355	2185	−1825	1845	1820	−1830	−2320	2275	−2350	−2380	1840	−1850	−1825	1820

TABLE A1.6 Results of Calculations for Matrix Due to Laboratory 1 and Material 1

Z_1 = 33 148	Z_1^2 = 1 098 789 904	W_1^2 = 68 674 369
Z_2 = 3 838	Z_2^2 = 14 730 244	W_2^2 = 920 640.25
Z_3 = 18	Z_3^2 = 324	W_3^2 = 20.25
Z_4 = 262	Z_4^2 = 68 644	W_4^2 = 4 290.25
Z_5 = −112	Z_5^2 = 12 544	W_5^2 = 784
Z_6 = 332	Z_6^2 = 110 224	W_6^2 = 6 889
Z_7 = −8	Z_7^2 = 64	W_7^2 = 4
Z_8 = 42	Z_8^2 = 1 764	W_8^2 = 110.25
Z_9 = −172	Z_9^2 = 29 584	W_9^2 = 1 849
Z_{10} = −142	Z_{10}^2 = 20 164	W_{10}^2 = 1 260.25
Z_{11} = 198	Z_{11}^2 = 39 204	W_{11}^2 = 2 450.25
Z_{12} = 242	Z_{12}^2 = 58 564	W_{12}^2 = 3 660.25
Z_{13} = 248	Z_{13}^2 = 61 504	W_{13}^2 = 3 844
Z_{14} = 292	Z_{14}^2 = 85 264	W_{14}^2 = 5 329
Z_{15} = −128	Z_{15}^2 = 16 384	W_{15}^2 = 1 024
Z_{16} = −138	Z_{16}^2 = 19 044	W_{16}^2 = 1 190.25

TABLE A1.7 Results of Calculations for Matrix due to Laboratory 1 and Material 2

Z_1 = 7 234	Z_1^2 = 52 330 756	W_1^2 = 3 270 672.25
Z_2 = 834	Z_2^2 = 695 556	W_2^2 = 43 472.25
Z_3 = 18	Z_3^2 = 324	W_3^2 = 20.25
Z_4 = −10	Z_4^2 = 100	W_4^2 = 6.25
Z_5 = 6	Z_5^2 = 36	W_5^2 = 2.25
Z_6 = 26	Z_6^2 = 676	W_6^2 = 42.25
Z_7 = −30	Z_7^2 = 900	W_7^2 = 56.25
Z_8 = 18	Z_8^2 = 324	W_8^2 = 20.25
Z_9 = 4	Z_9^2 = 16	W_9^2 = 1.00
Z_{10} = −16	Z_{10}^2 = 256	W_{10}^2 = 16
Z_{11} = 24	Z_{11}^2 = 576	W_{11}^2 = 36
Z_{12} = 124	Z_{12}^2 = 15 376	W_{12}^2 = 961
Z_{13} = 16	Z_{13}^2 = 256	W_{13}^2 = 16
Z_{14} = 116	Z_{14}^2 = 13 456	W_{14}^2 = 841
Z_{15} = 4	Z_{15}^2 = 16	W_{15}^2 = 1
Z_{16} = −48	Z_{16}^2 = 2 304	W_{16}^2 = 144

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TABLE A1.8 Results of Calculations for Matrix due to Laboratory 1 and Material 3

Z_1 = 58 618	Z_1^2 = 3 436 069 924	W_1^2 = 214 754 370.3
Z_2 = 6 898	Z_2^2 = 47 582 404	W_2^2 = 2 973 900.25
Z_3 = 312	Z_3^2 = 97 344	W_3^2 = 6 084
Z_4 = 624	Z_4^2 = 389 376	W_4^2 = 24 336
Z_5 = 456	Z_5^2 = 207 936	W_5^2 = 12 996
Z_6 = 764	Z_6^2 = 583 696	W_6^2 = 36 481
Z_7 = –214	Z_7^2 = 45 796	W_7^2 = 2 862.25
Z_8 = –218	Z_8^2 = 47 524	W_8^2 = 2 970.25
Z_9 = –318	Z_9^2 = 101 124	W_9^2 = 6 320.25
Z_{10} = –206	Z_{10}^2 = 42 436	W_{10}^2 = 2 652.25
Z_{11} = 216	Z_{11}^2 = 46 656	W_{11}^2 = 2 916
Z_{12} = 248	Z_{12}^2 = 61 504	W_{12}^2 = 3 844
Z_{13} = –288	Z_{13}^2 = 82 944	W_{13}^2 = 5 184
Z_{14} = 540	Z_{14}^2 = 291 600	W_{14}^2 = 18 225
Z_{15} = –150	Z_{15}^2 = 22 500	W_{15}^2 = 1 406.25
Z_{16} = –2	Z_{16}^2 = 4	W_{16}^2 = 0.25

TABLE A1.9 Results of Calculations for Matrix due to Laboratory 1 and Material 4

Z_1 = 14 692	Z_1^2 = 215 854 864	W_1^2 = 13 490 929
Z_2 = 1 892	Z_2^2 = 3 579 664	W_2^2 = 223 729
Z_3 = 208	Z_3^2 = 43 264	W_3^2 = 2 704
Z_4 = 122	Z_4^2 = 14 884	W_4^2 = 930.25
Z_5 = 232	Z_5^2 = 53 824	W_5^2 = 3 364
Z_6 = 94	Z_6^2 = 8 836	W_6^2 = 552.25
Z_7 = –78	Z_7^2 = 6 084	W_7^2 = 380.25
Z_8 = –162	Z_8^2 = 26 244	W_8^2 = 1 640.25
Z_9 = 26	Z_9^2 = 676	W_9^2 = 42.25
Z_{10} = 18	Z_{10}^2 = 324	W_{10}^2 = 20.25
Z_{11} = 2	Z_{11}^2 = 4	W_{11}^2 = .25
Z_{12} = 116	Z_{12}^2 = 13 456	W_{12}^2 = 841
Z_{13} = 18	Z_{13}^2 = 324	W_{13}^2 = 20.25
Z_{14} = 120	Z_{14}^2 = 14 400	W_{14}^2 = 900
Z_{15} = –64	Z_{15}^2 = 4 096	W_{15}^2 = 256
Z_{16} = –36	Z_{16}^2 = 1 296	W_{16}^2 = 81

TABLE A1.10 Results of Calculations for Matrix due to Laboratory 2 and Material 1

Z_1 = 32 692	Z_1^2 = 1 068 766 864	W_1^2 = 66 797 929
Z_2 = 3 708	Z_2^2 = 13 749 264	W_2^2 = 859 329
Z_3 = 190	Z_3^2 = 36 100	W_3^2 = 2 256.25
Z_4 = 516	Z_4^2 = 266 256	W_4^2 = 16 641
Z_5 = 130	Z_5^2 = 16 900	W_5^2 = 1 056.25
Z_6 = 544	Z_6^2 = 295 936	W_6^2 = 18 496
Z_7 = –358	Z_7^2 = 128 164	W_7^2 = 8 010.25
Z_8 = –382	Z_8^2 = 145 924	W_8^2 = 9 120.25
Z_9 = –32	Z_9^2 = 1 024	W_9^2 = 64
Z_{10} = –8	Z_{10}^2 = 64	W_{10}^2 = 4
Z_{11} = 30	Z_{11}^2 = 900	W_{11}^2 = 56.25
Z_{12} = –16	Z_{12}^2 = 256	W_{12}^2 = 16
Z_{13} = 10	Z_{13}^2 = 100	W_{13}^2 = 6.25
Z_{14} = 76	Z_{14}^2 = 5 776	W_{14}^2 = 361
Z_{15} = 218	Z_{15}^2 = 47 524	W_{15}^2 = 2 970.25
Z_{16} = 282	Z_{16}^2 = 79 524	W_{16}^2 = 4 970.25

TABLE A1.11 Results of Calculations for Matrix due to Laboratory 2 and Material 2

Z_1 = 7 543	Z_1^2 = 56 896 849	W_1^2 = 3 556 053.063
Z_2 = 803	Z_2^2 = 644 809	W_2^2 = 40 300.5625
Z_3 = 53	Z_3^2 = 2 809	W_3^2 = 175.5625
Z_4 = 57	Z_4^2 = 3 249	W_4^2 = 203.0625
Z_5 = 73	Z_5^2 = 5 329	W_5^2 = 333.0625
Z_6 = 81	Z_6^2 = 6 561	W_6^2 = 410.0625
Z_7 = –97	Z_7^2 = 9 409	W_7^2 = 588.0625
Z_8 = –49	Z_8^2 = 2 401	W_8^2 = 150.0625
Z_9 = 15	Z_9^2 = 225	W_9^2 = 14.0625
Z_{10} = 15	Z_{10}^2 = 225	W_{10}^2 = 14.0625
Z_{11} = –11	Z_{11}^2 = 121	W_{11}^2 = 7.5625
Z_{12} = 57	Z_{12}^2 = 3 249	W_{12}^2 = 203.0625
Z_{13} = –51	Z_{13}^2 = 2 601	W_{13}^2 = 162.5625
Z_{14} = 61	Z_{14}^2 = 3 721	W_{14}^2 = 232.5625
Z_{15} = 71	Z_{15}^2 = 5 041	W_{15}^2 = 315.0625
Z_{16} = 19	Z_{16}^2 = 361	W_{16}^2 = 22.5625

TABLE A1.12 Results of Calculations for Matrix due to Laboratory 2 and Material 3

Z_1 = 58 527	Z_1^2 = 3 425 409 729	W_1^2 = 214 088 108.1
Z_2 = 7 123	Z_2^2 = 50 737 129	W_2^2 = 3 171 070.563
Z_3 = 755	Z_3^2 = 570 025	W_3^2 = 35 626.5625
Z_4 = 423	Z_4^2 = 178 929	W_4^2 = 11 183.0625
Z_5 = 247	Z_5^2 = 61 009	W_5^2 = 3 813.0625
Z_6 = 191	Z_6^2 = 36 481	W_6^2 = 2 280.0625
Z_7 = 443	Z_7^2 = 196 249	W_7^2 = 12 265.5625
Z_8 = 171	Z_8^2 = 29 241	W_8^2 = 1 827.5625
Z_9 = –145	Z_9^2 = 21 025	W_9^2 = 1 314.0625
Z_{10} = –433	Z_{10}^2 = 187 489	W_{10}^2 = 11 718.0625
Z_{11} = 171	Z_{11}^2 = 29 241	W_{11}^2 = 1 827.5625
Z_{12} = 55	Z_{12}^2 = 3 025	W_{12}^2 = 189.0625
Z_{13} = –77	Z_{13}^2 = 5 929	W_{13}^2 = 370.5625
Z_{14} = 1 107	Z_{14}^2 = 1 225 449	W_{14}^2 = 76 590.5625
Z_{15} = –413	Z_{15}^2 = 170 569	W_{15}^2 = 10 660.5625
Z_{16} = –385	Z_{16}^2 = 148 225	W_{16}^2 = 9 264.0625

TABLE A1.13 Results of Calculations for Matrix due to Laboratory 2 and Material 4

Z_1 = 15 095	Z_1^2 = 227 859 025	W_1^2 = 14 241 189.06
Z_2 = 1 969	Z_2^2 = 3 876 961	W_2^2 = 242 310.0625
Z_3 = 179	Z_3^2 = 32 041	W_3^2 = 2 002.5625
Z_4 = 149	Z_4^2 = 22 201	W_4^2 = 1 387.5625
Z_5 = 265	Z_5^2 = 70 225	W_5^2 = 4 389.0625
Z_6 = 135	Z_6^2 = 18 225	W_6^2 = 1 139.0625
Z_7 = 5	Z_7^2 = 25	W_7^2 = 1.5625
Z_8 = –101	Z_8^2 = 10 201	W_8^2 = 637.5625
Z_9 = 115	Z_9^2 = 13 225	W_9^2 = 826.5625
Z_{10} = –121	Z_{10}^2 = 14 641	W_{10}^2 = 915.0625
Z_{11} = –67	Z_{11}^2 = 4 489	W_{11}^2 = 280.5625
Z_{12} = 195	Z_{12}^2 = 38 025	W_{12}^2 = 2 376.5625
Z_{13} = –69	Z_{13}^2 = 4 761	W_{13}^2 = 297.5625
Z_{14} = 189	Z_{14}^2 = 35 721	W_{14}^2 = 2 232.5625
Z_{15} = –65	Z_{15}^2 = 4 225	W_{15}^2 = 264.0625
Z_{16} = –11	Z_{16}^2 = 121	W_{16}^2 = 7.5625

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TABLE A1.14 Results of Calculations for Matrix due to Laboratory 3 and Material 1

Z_1 = 33 341	Z_1^2 = 1 111 622 281	W_1^2 = 69 476 392.56
Z_2 = 3 691	Z_2^2 = 13 623 481	W_2^2 = 851 467.5625
Z_3 = 171	Z_3^2 = 29 241	W_3^2 = 1 827.5625
Z_4 = 519	Z_4^2 = 269 361	W_4^2 = 16 835.0625
Z_5 = 141	Z_5^2 = 19 881	W_5^2 = 1 242.5625
Z_6 = 509	Z_6^2 = 259 081	W_6^2 = 16 192.5625
Z_7 = –51	Z_7^2 = 2 601	W_7^2 = 162.5625
Z_8 = –1	Z_8^2 = 1	W_8^2 = 0.0625
Z_9 = –45	Z_9^2 = 2 025	W_9^2 = 126.5625
Z_{10} = 5	Z_{10}^2 = 25	W_{10}^2 = 1.5625
Z_{11} = 45	Z_{11}^2 = 2 025	W_{11}^2 = 126.5625
Z_{12} = –15	Z_{12}^2 = 225	W_{12}^2 = 14.0625
Z_{13} = –5	Z_{13}^2 = 25	W_{13}^2 = 1.5625
Z_{14} = 115	Z_{14}^2 = 13 225	W_{14}^2 = 826.5625
Z_{15} = –85	Z_{15}^2 = 7 225	W_{15}^2 = 451.5625
Z_{16} = –95	Z_{16}^2 = 9 025	W_{16}^2 = 564.0625

TABLE A1.15 Results of Calculations for Matrix due to Laboratory 3 and Material 2

Z_1 = 7 078	Z_1^2 = 50 098 084	W_1^2 = 3 131 130.25
Z_2 = 824	Z_2^2 = 678 976	W_2^2 = 42 436
Z_3 = 26	Z_3^2 = 676	W_3^2 = 42.25
Z_4 = 108	Z_4^2 = 11 664	W_4^2 = 729
Z_5 = 0	Z_5^2 = 0	W_5^2 = 0
Z_6 = 126	Z_6^2 = 15 876	W_6^2 = 992.25
Z_7 = –8	Z_7^2 = 64	W_7^2 = 4
Z_8 = –34	$Z_8^2$2 = 1 156	$W_8^2$2 = 72.25
Z_9 = 0	$Z_9^2$2 = 0	$W_9^2$2 = 0
Z_{10} = –6	Z_{10}^2 = 36	W_{10}^2 = 2.25
Z_{11} = 16	Z_{11}^2 = 256	W_{11}^2 = 16
Z_{12} = 6	Z_{12}^2 = 36	W_{12}^2 = 2.25
Z_{13} = 22	Z_{13}^2 = 484	W_{13}^2 = 30.25
Z_{14} = 16	Z_{14}^2 = 256	W_{14}^2 = 16
Z_{15} = –18	Z_{15}^2 = 324	W_{15}^2 = 20.25
Z_{16} = 4	Z_{16}^2 = 16	W_{16}^2 = 1

TABLE A1.16 Results of Calculations for Matrix due to Laboratory 3 and Material 3

Z_1 = 57 932	Z_1^2 = 3 356 116 624	W_1^2 = 209 757 289
Z_2 = 6 770	Z_2^2 = 45 832 900	W_2^2 = 2 864 556.25
Z_3 = 390	Z_3^2 = 152 100	W_3^2 = 9 506.25
Z_4 = 948	Z_4^2 = 898 704	W_4^2 = 56 169
Z_5 = 288	Z_5^2 = 82 944	W_5^2 = 5 184
Z_6 = 1 070	Z_6^2 = 1 144 900	W_6^2 = 71 556.25
Z_7 = –190	Z_7^2 = 36 100	W_7^2 = 2 256.25
Z_8 = –168	Z_8^2 = 28 224	W_8^2 = 1 764
Z_9 = –58	Z_9^2 = 3 364	W_9^2 = 210.25
Z_{10} = –40	Z_{10}^2 = 1 600	W_{10}^2 = 100
Z_{11} = 180	$Z_{11}^2$2 = 32 400	$W_{11}^2$2 = 2 025
Z_{12} = –22	Z_{12}^2 = 484	W_{12}^2 = 30.25
Z_{13} = –62	Z_{13}^2 = 3 844	W_{13}^2 = 240.25
Z_{14} = 280	$Z_{14}^2$2 = 78 400	$W_{14}^2$2 = 4 900
Z_{15} = –60	$Z_{15}^2$2 = 3 600	$W_{15}^2$2 = 225
Z_{16} = –58	Z_{16}^2 = 3 364	W_{16}^2 = 210.25

TABLE A1.17 Results of Calculations for Matrix due to Laboratory 3 and Material 4

Z_1 = 14 259	Z_1^2 = 203 319 081	W_1^2 = 12 707 442.56
Z_2 = 1 831	Z_2^2 = 3 352 561	W_2^2 = 209 535.0625
Z_3 = 45	Z_3^2 = 2 025	W_3^2 = 126.5625
Z_4 = 343	Z_4^2 = 117 649	W_4^2 = 7 353.0625
Z_5 = 105	Z_5^2 = 11 025	W_5^2 = 689.0625
Z_6 = 267	Z_6^2 = 71 289	W_6^2 = 4 455.5625
Z_7 = –23	Z_7^2 = 529	W_7^2 = 33.0625
Z_8 = –107	Z_8^2 = 11 449	W_8^2 = 715.5625
Z_9 = –35	$Z_9^2$2 = 1 225	$W_9^2$2 = 76.5625
Z_{10} = –35	Z_{10}^2 = 1 225	W_{10}^2 = 76.5625
Z_{11} = 99	Z_{11}^2 = 9 801	W_{11}^2 = 612.5625
Z_{12} = 17	Z_{12}^2 = 289	W_{12}^2 = 18.0625
Z_{13} = 51	Z_{13}^2 = 2 601	W_{13}^2 = 162.5625
Z_{14} = 33	Z_{14}^2 = 1 089	W_{14}^2 = 68.0625
Z_{15} = –17	Z_{15}^2 = 289	W_{15}^2 = 18.0625
Z_{16} = –33	Z_{16}^2 = 1 089	W_{16}^2 = 68.0625

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TABLE A1.18 Summary of F Values For All Laboratories, All Materials, And All Factors

Laboratory	Material	Table	Temperature of Tube, F_a	Age, F_b	Vacuum, F_c	Stir, F_d	Vertical, F_e	Meniscus, F_f	Bath, F_g
1	1	A1.6	343.56	NS	NS	NS	NS	NS	NS
	2	A1.7	151.02	NS	NS	NS	NS	NS	NS
	3	A1.8	608.20	NS	NS	NS	7.46	NS	NS
	4	A1.9	739.16	8.93	NS	11.11	NS	NS	NS
2	1	A1.10	717.47	NS	13.89	NS	15.44	6.69	7.61
	2	A1.11	294.64	NS	NS	NS	NS	NS	NS
	3	A1.12	200.66	NS	NS	NS	NS	NS	NS
	4	A1.13	266.11	NS	NS	NS	NS	NS	NS
3	1	A1.14	3 001.24	6.44	59.34	NS	57.08	NS	NS
	2	A1.15	3 375.59	NS	57.99	NS	78.93	NS	5.74
	3	A1.16	2 593.81	8.61	50.86	NS	64.79	NS	NS
	4	A1.17	1 432.46	NS	50.26	NS	30.46	NS	NS

A2. THEORY OF THE RUGGEDNESS ANALYSIS

A2.1 Any mathematical analysis depends on assumptions. It is particularly difficult to make valid assumptions when there is little experience on which to make the assumptions. Since a ruggedness or screening program is usually run on a new test method, there is very little history or experience to validate the necessary assumptions. An extensive study could yield the experience to validate the assumptions, but it would also increase the cost of the ruggedness program to the point that few such programs could be undertaken. This practice seeks to balance these risks to make the practice practical and useful.

A2.2 A ruggedness program attempts to identify the important factors or variables which cause variability of results obtained using the test method. It is important that all of the major factors be included in the study, since, if one is left out, the study will not help in identifying its significance. The example in Annex A1 evaluates seven factors. This is usually sufficient to cover the major sources of variability. Design for both fewer and more factors are given in statistical texts for use when needed **(5).**

A2.2.1 It is unusual for more than seven or for less than five factors to be required. When only five factors are considered significant, two other factors can nearly always be selected about which there may be some doubt. A seven factor analysis is usually suitable for most ruggedness evaluations.

A2.2.2 A full factorial experiment for seven factors at two levels would require 2^7 or 128 runs or determinations for each laboratory and each material. If this design had been followed in Annex A1, 128 runs times 3 laboratories times 4 materials times 2 replications equals 3072 determinations instead of the 192 determinations actually required in the example.

A2.2.3 A full factorial experiment identifies not only significant effects of the main factors but also those of the interactions. An interaction is a source of variability due to the combination of main factors that cannot be explained by the individual variability of those main factors. There are instances where the effect of an interaction is greater than the sum of the effects of the main factors that create the interaction. However, interactions are usually regarded as being smaller sources of variation; particularly three and four factor interactions. In this standard, the effect of all interactions are assumed to be negligible. This is done to permit testing of the significance of a large number of main effects while holding the size of the experiment down to manageable levels. The effect of interactions will not always be negligible and there are times when an estimate of a main effect will include an interaction.

A2.2.4 The assumption is also made that the random errors are normally distributed. Since a new method is being evaluated, there is no data available to show that the errors are normally distributed. However, the assumption appears reasonable based on experience with other ASTM test methods.

A2.2.5 While the risks inherent in adopting these assumptions are real, it is thought that despite the risks the ruggedness program will serve a useful purpose in improving the precision of most test methods.

A2.3 Two levels have been chosen for this study. Three or more levels could have been used. The higher number of levels would have given information about the shape of the curves that could be derived by plotting the viscosity versus each of the main factors at the levels chosen. Increasing the levels would also increase the number of runs or determinations. For example, seven factors at three levels would require 2187 runs compared with 128 at two levels. Since each of the factors vary by a small amount, the curves would be substantially straight and there would be little gained by measuring at a higher number of levels than two.

A2.4 A linear model or equation for the seven main factor ruggedness program would be:

$$Z = B_0 + B_1X_1 + B_2X_2 + B_3X_3 + B_4X_4 + B_5X_5 + B_6X_6 + B_7X_7 + e \quad \text{(A2.1)}$$

where:

X_1 = through X_7 are the main effects,
B_0 = through B_7 are the unknown parameters, and
e = is random error.

A2.4.1 A Youden Square, which is the basis for this ruggedness program, is in turn part of a Hadamard matrix an example of which is shown in Table A2.1. The Youden Square would be Table A2.1 with the top or Z_1 line removed. Table A2.1 represents the values of B that equate each of the Z's to the X_0, X_1, X_2, through X_7 in eight linear equations. The fact

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TABLE A2.1 Values for the coefficients B_o through B_7

	X_0	X_1	X_2	X_3	X_4	X_5	X_6	X_7
Z_1	1	1	1	1	1	1	1	1
Z_2	1	1	1	1	−1	−1	−1	−1
Z_3	1	1	−1	−1	1	1	−1	−1
Z_4	1	−1	1	−1	1	−1	1	−1
Z_5	1	1	−1	−1	−1	−1	1	1
Z_6	1	−1	1	−1	−1	1	−1	1
Z_7	1	−1	−1	1	1	−1	−1	1
Z_8	1	−1	−1	1	−1	1	1	−1

that Hadamard matrices are orthogonal makes each row of Table A2.1 an independent vector in the transformation matrix which is Table A2.1. This also means that when any line in the table is multiplied by any other line the sum is always zero. The B_0 through B_7 are represented by numbers + 1 or − 1 shown on each line of Table A2.1.

A2.4.2 It should be noted that Z_2 divided by 4 is the difference between average results when temperature is at a high level and the average results when temperature is at a low level. The design of the experiment based on the characteristic of Hadamard matrices, is such that when determinations of temperature are at a high level all other factors are twice at a high level and twice at a low level. When determinations of temperature are at a low level, all other factors are twice at a high level and twice at a low level. Measurement of temperature is freed of the effect of the level of the factors other than temperature leaving only the effect of the temperature and of random error, *e* of the other factors.

A2.4.3 A close examination of Table A2.1 shows that what is true for temperature is also true for each of the other factors. With the experimental design in Table A2.1, separate assessments of each of the effects of seven factors can be made with only eight tests.

A2.4.4 There is no separate estimate of the error variance by which the statistical significance of the factor effects can be tested.

A2.5 An estimate of error variance can be obtained by replicating the experiment. It is important in experiments of this kind to keep the amount of work and therefore the cost as low as possible while obtaining valid results. The amount of work would be halved if the work of each laboratory is regarded as a replication of the experiment. Experience in ASTM interlaboratory studies shows that there usually are significant differences between laboratories. Therefore, the recommendation is that the experiment be replicated in each laboratory according to the experimental design shown in Table A1.4 and used in Annex A1.1.

A2.6 The first eight rows in Table A1.4 are the same as in Table A2.1 except that they are repeated in the second replication. Z_9 shows the differences between replications. The coefficients in Z_{10} through Z_{16} are exactly the same as those in Z_2 through Z_8 but in the replication all signs are reversed in Z_{10} through Z_{16}. It is these differences from replicate to replicate that yield the necessary estimate of error variance. The assumption as already stated is made that there are no real interactions between factor differences and replications.

A2.7 The transformation matrix for the 16 determinations is shown in Table A1.4. A column containing values for $W_i^2 = Z_i^2/D_1$ appears in Table A1.6 and Table A1.7 where: Z_i equals the sum of the Z's in the ith row squared, and D_i equals the sum of squares of the coefficients in the ith row.

In all instances for an Hadamard matrix D_i equals the number of columns in the matrix since both 1 and $-1^2 = 1$. All rows in Table A1.4 sum to 16 so $D_i = 16$ for every row.

If σ^2 is the true, but unknown error variance, then on the assumption that the errors are normally distributed each W_i^2/σ^2 will have an independent χ^2–distribution with 1° of freedom. The sum $\Sigma_{i=10}^{16} W_i^2/7\sigma^2$ represents the pooled sums of squares for error divided by the error variance that will have a χ^2 distribution with 7° of freedom. For the ith row of Table A1.4, j = 2 to 8, the ratio will have an F-distribution with 1 and 7° of freedom.

$$F_j = W_j^2/\sigma^2 / \sum_{i=10}^{16} W_i^2/7\sigma^2 = W_j^2/\sum_{i=10}^{16} W_i^2/7 \qquad \text{(A2.2)}$$

A2.8 Annex A1 consists of a detailed example using the theory of Annex A2. It is recommended that the test of significance be carried out at the probability level of 0.05 of the F-distribution. The ratio that is significant at the 0.05 probability level can be obtained from tables of the F-distribution that are in most standard statistical text books.

REFERENCES

(1) Youden, W. J.," Statistical Techniques for Collaborative Tests," Association of Official Analytical Chemists, Washington, DC, 1967.

(2) Duncan, A. J., "Application of Multiple Orthogonal Comparisons," Private Communication, 1983.

(3) Morrison, D. F., *Multivariate Statistical Methods*, McGraw-Hill Book Company, New York, NY, 1967.

(4) Kempthorne, Oscar, *Design and Analysis of Experiments*, John Wiley and Sons, Inc., New York, NY, 1952.

(5) Cochran, W. G., and Cox, G. M., *Experimental Designs*, John Wiley and Sons, Inc., New York, NY, 1957.

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Designation: C 1073 – 97a (Reapproved 2003)

Standard Test Method for Hydraulic Activity of Ground Slag by Reaction with Alkali[1]

This standard is issued under the fixed designation C 1073; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope

1.1 This test method covers the rapid determination of hydraulic activity of ground-granulated iron blast-furnace slag. This test method measures the accelerated strength development of the slag by using sodium hydroxide solution as mixing water and curing at elevated temperature.

1.2 The values stated in SI units are to be regarded as the standard.

1.3 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.* A specific warning statement is given in Section 6.

1.4 The text of this standard references notes and footnotes which provide explanatory information. These notes and footnotes (excluding those in tables) shall not be considered as requirements of this standard.

2. Referenced Documents

2.1 *ASTM Standards:*

C 109/C 109M Test Method for Compressive Strength of Hydraulic Cement Mortars (Using 2-in. or [50-mm] Cube Specimens)[2]

C 125 Terminology Relating to Concrete and Concrete Aggregates[3]

C 219 Terminology Relating to Hydraulic Cement[2]

C 305 Practice for Mechanical Mixing of Hydraulic Cement Pastes and Mortars of Plastic Consistency[2]

C 670 Practice for Preparing Precision and Bias Statements for Test Methods for Construction Materials[3]

C 778 Specification for Standard Sand[2]

C 989 Specification for Ground Blast-Furnace Slag for Use in Concrete and Mortars[3]

3. Terminology

3.1 *Definitions:*

3.1.1 Definitions are given in Terminology C 125 and C 219.

3.2 *Description of Term Specific to This Standard:*

3.2.1 *slag, n*—granulated blast-furnace slag as defined in Terminology C 125 and ground to cement fineness.

4. Significance and Use

4.1 This test method can be used as a quality-control test for slag production from a single source after adequate correlation with tests stipulated in Specification C 989.

4.2 This test method may be used as an evaluation technique for slag, when an appropriate correlation with various finenesses of slags from a specific source ground in a specific laboratory mill has been previously developed.

4.3 The hydraulic activity as measured by this test method on ground-slag samples can provide guidance to a manufacturer as to fineness level required to maintain a certain level of hydraulic activity.

4.4 While this test method is intended primarily as a quality control test, some studies have shown that the test method is capable of evaluating the hydraulic activity of slags from different sources.

5. Apparatus

5.1 *Three-Gang Molds for 2-in. or 50-mm Cubes and Compression Test Machine*, as specified in Test Method C 109/C 109M (Note 1).

NOTE 1—Silicone grease is recommended for protection of mold surfaces from the caustic solution in this test.

5.2 *Mixer*, as specified in Method C 305.

5.3 *Curing Chamber*, capable of maintaining a temperature of air or water bath of 55 ± 2°C.

5.4 *Containers*, capable of holding one three-cube mold in an essentially vapor-tight condition. If polyethylene or other plastic bags are used, they shall have a closure of the zip type. If rigid containers are used, they shall have tight sealing covers (Note 2). The acceptability of containers shall be determined by measuring the water loss after curing in air or the gain after curing in water bath. Water loss shall be less than 15 mL in air curing or gain less than 5 mL in water-bath curing.

NOTE 2—Plastic boxes designed for household storage of celery with a bottom grid have given good service.

[1] This test method is under the jurisdiction of ASTM Committee C09 on Concrete and Concrete Aggregates and is the direct responsibility of Subcommittee C09.27 on Ground Slag .

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[2] *Annual Book of ASTM Standards*, Vol 04.01.

[3] *Annual Book of ASTM Standards*, Vol 04.02.

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6. Materials

6.1 *Graded Standard Sand*—The sand used for making test specimens shall be natural silica sand conforming to the requirements for graded standard sand in Specification C 778.

6.2 *Reagent Sodium Hydroxide Solution* (20 %):

6.2.1 Prepare fresh daily using boiled distilled water and reagent grade sodium hydroxide (NaOH).

6.2.2 Dissolve 200 g of sodium hydroxide in 1 L of distilled water and cool to room temperature. **Warning—**All work with this highly caustic solution should be completed with the use of gloves, apron, and face mask.

NOTE 3—One litre will provide enough solution for eight three-cube batches. More or less solution in these proportions should be made depending on the number of batches to be mixed during the day.

7. Procedure

7.1 *Batch*—The quantities of materials to be mixed at one time in the batch of mortar for making three or six specimens shall be as follows:

	Number of Specimens	
	3	6
Slag, g	250	500
Sand, g	687.5	1375
NaOH solution, mL	112.5	225

7.2 *Preparation of Specimens*—Prepare specimens in accordance with Test Method C 109/C 109M, except that the mixing water shall be replaced by the volume of NaOH solution equal to the volume of water which would give a water/slag ratio of 0.45 by mass.

7.3 *Curing*—Immediately upon completion of molding place each three-cube mold in a container. Add approximately 50 mL of water into the container at the mold base in order to assure 100 % relative humidity during the curing cycle. In the case where plastic bags are employed, special care should be exercised to avoid tearing the plastic during handling. Place the container and molds in the curing chamber maintained at 55 ± 2°C. If water curing is used, rigid containers shall be required and the water temperature shall be controlled to the prescribed temperature and a minimum 5 mL of water shall cover the containers. At the end of 23 ± ¼ h remove the molds from the curing chamber and examine each container for leaks. If more than 15 mL of water has escaped or more than 5 mL of water has entered, discard the specimens and retest. Remove the specimens from the mold and store in room air until tested.

7.4 *Determination of Compressive Strength*—Test the specimens for compressive strength at 24 ± ½ h in accordance with Test Method C 109/C 109M.

8. Calculation

8.1 Calculate the compressive strength of the specimens in accordance with Test Method C 109/C 109M.

9. Faulty Specimens and Retests

9.1 Faulty specimens and the need for retest shall be determined in accordance with Test Method C 109/C 109M.

10. Report

10.1 The average strength in MPa rounded to the nearest 0.1 MPa at 24 h shall be reported as the hydraulic activity of the sample. For example, Hydraulic Activity with NaOH: 7.3 MPa.

11. Precision and Bias

11.1 *Precision*—The following precision statements were developed using data generated from an interlaboratory test program. Nine laboratories participated in the program and tested three slags with varied hydraulic activity. Duplicate tests were performed on different days. Revisions to the precision statements shall be made as more comprehensive data become available.

11.1.1 The precision statements are applicable when a test result is the average of compressive strengths of three cubes molded from a single batch of mortar and tested at the same age.

11.1.2 The multilaboratory coefficient of variation has been found to be 8.1 % (Note 4). Therefore, results of properly conducted tests of single batches by two different laboratories should not differ by more than 22.9 % of their average (Note 4).

11.1.3 The single-laboratory coefficient of variation has been found to be 4.6 % (Note 4). Therefore, results of two properly conducted tests of single batches of mortar made with the same materials either on the same day or within the same week should not differ from each other by more than 13.0 % of their average (Note 4).

NOTE 4—These numbers represent respectively the (Is) and (d2s) limits as described in Practice C 670.

11.2 *Bias*—The procedure in this test method has no bias since the hydraulic activity is defined only in terms of the test method.

12. Keywords

12.1 ground slag; hydraulic activity; slag

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Designation: C 1074 – 04

Standard Practice for Estimating Concrete Strength by the Maturity Method[1]

This standard is issued under the fixed designation C 1074; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope*

1.1 This practice provides a procedure for estimating concrete strength by means of the maturity method. The maturity index is expressed either in terms of the temperature-time factor or in terms of the equivalent age at a specified temperature.

1.2 This practice requires establishing the strength-maturity relationship of the concrete mixture in the laboratory and recording the temperature history of the concrete for which strength is to be estimated.

1.3 The values stated in SI units are to be regarded as the standard.

1.4 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.* (**Warning**—Fresh hydraulic cementitious mixtures are caustic and may cause chemical burns to skin and tissue upon prolonged exposure.[2])

2. Referenced Documents

2.1 *ASTM Standards:* [3]

C 39/C 39M Test Method for Compressive Strength of Cylindrical Concrete Specimens

C 78 Test Method for Flexural Strength of Concrete (Using Simple Beam with Third-Point Loading)

C 109/C 109M Test Method for Compressive Strength of Hydraulic Cement Mortars (Using 2-in. or 50-mm Cube Specimens)

C 192/C 192M Practice for Making and Curing Concrete Test Specimens in the Laboratory

C 403/C 403M Test Method for Time of Setting of Concrete Mixtures by Penetration Resistance

C 511 Specification for Mixing Rooms, Moist Cabinets, Moist Rooms, and Water Storage Tanks Used in the Testing of Hydraulic Cements and Concretes

C 684 Test Method for Making, Accelerated Curing, and Testing of Concrete Compression Test Specimens

C 803/C 803M Test Method for Penetration Resistance of Hardened Concrete

C 873 Test Method for Compressive Strength of Concrete Cylinders Cast in Place in Cylindrical Molds

C 900 Test Method for Pullout Strength of Hardened Concrete

C 918 Test Method for Measuring Early-Age Compressive Strength and Projecting Later-Age Strength

3. Terminology

3.1 *Definitions of Terms Specific to This Standard:*

3.1.1 *datum temperature*—the temperature that is subtracted from the measured concrete temperature for calculating the temperature-time factor according to Eq 1.

3.1.2 *equivalent age*—the number of days or hours at a specified temperature required to produce a maturity equal to the maturity achieved by a curing period at temperatures different from the specified temperature.

3.1.3 *maturity*—the extent of the development of a property of a cementitious mixture.

3.1.3.1 *Discussion*—While the term is used usually to describe the extent of relative strength development, it can also be applied to the evolution of other properties that are dependent on the chemical reactions that occur in a cementitious mixture. At any age, maturity depends on the curing history.

3.1.4 *maturity function*—a mathematical expression that uses the measured temperature history of a cementitious mixture during the curing period to calculate an index that is indicative of the maturity at the end of that period. Refer to Appendix X1 for additional discussion of this term.

3.1.5 *maturity index*—an indicator of maturity that is calculated from the temperature history of the cementitious mixture by using a maturity function.

[1] This practice is under the jurisdiction of ASTM Committee C09 on Concrete and Concrete Aggregates and is the direct responsibility of Subcommittee C09.64 on Nondestructive and In-Place Testing.

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[2] Section on Safety Precautions, Manual of Aggregate and Concrete Testing, *Annual Book of ASTM Standards*, Vol 04.02.

[3] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

***A Summary of Changes section appears at the end of this standard.**

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3.1.5.1 *Discussion*—The computed index is indicative of maturity provided there has been a sufficient supply of water for hydration or pozzolanic reaction of the cementitious materials during the time used in the calculation. Two widely used maturity indexes are the *temperature-time factor* and the *equivalent age*.

3.1.6 *maturity method*—a technique for estimating concrete strength that is based on the assumption that samples of a given concrete mixture attain equal strengths if they attain equal values of the maturity index **(1, 2, 3)**.[4]

3.1.7 *strength-maturity relationship*—an empirical relationship between compressive strength and maturity index that is obtained by testing specimens whose temperature history up to the time of test has been recorded.

3.1.8 *temperature-time factor*—the maturity index computed according to Eq 1.

4. Summary of Practice

4.1 A strength-maturity relationship is developed by laboratory tests on the concrete mixture to be used.

4.2 The temperature history of the field concrete, for which strength is to be estimated, is recorded from the time of concrete placement to the time when the strength estimation is desired.

4.3 The recorded temperature history is used to calculate the maturity index of the field concrete.

4.4 Using the calculated maturity index and the strength-maturity relationship, the strength of the field concrete is estimated.

5. Significance and Use

5.1 This practice can be used to estimate the in-place strength of concrete to allow the start of critical construction activities such as: (*1*) removal of formwork and reshoring; (*2*) post-tensioning of tendons; (*3*) termination of cold weather protection; and (*4*) opening of the roadways to traffic.

5.2 This practice can be used to estimate strength of laboratory specimens cured under non-standard temperature conditions.

5.3 The major limitations of the maturity method are: (*1*) the concrete must be maintained in a condition that permits cement hydration; (*2*) the method does not take into account the effects of early-age concrete temperature on the long-term strength; and (*3*) the method needs to be supplemented by other indications of the potential strength of the concrete mixture.

5.4 The accuracy of the estimated strength depends, in part, on determining the appropriate maturity function for the particular concrete mixture.

6. Maturity Functions

6.1 There are two alternative functions for computing the maturity index from the measured temperature history of the concrete.

6.2 One maturity function is used to compute the *temperature-time factor* as follows:

$$M(t) = \Sigma(T_a - T_o)\,\Delta t \quad (1)$$

where:

$M(t)$ = the temperature-time factor at age t, degree-days or degree-hours,
Δt = a time interval, days or hours,
T_a = average concrete temperature during time interval, Δt, °C, and
T_o = datum temperature, °C.

6.3 The other maturity function is used to compute *equivalent age* at a specified temperature as follows **(4)**:

$$t_e = \Sigma e^{-Q\left(\frac{1}{T_a} - \frac{1}{T_s}\right)}\,\Delta t \quad (2)$$

where:

t_e = equivalent age at a specified temperature T_s, days or h,
Q = activation energy divided by the gas constant, K,
T_a = average temperature of concrete during time interval Δt, K,
T_s = specified temperature, K, and
Δt = time interval, days or h.

NOTE 1—Temperature in kelvin (K) equals approximately temperature °C + 273 °C.

6.4 Approximate values of the datum temperature, T_o, and the activation energy divided by the gas constant, Q, are given in Appendix X1. Where maximum accuracy of strength estimation is desired, the appropriate values of T_o or Q for a specific concrete mixture are determined according to the procedures given in Annex A1.

7. Apparatus

7.1 A device is required to monitor and record the concrete temperature as a function of time. Acceptable devices include thermocouples or thermistors connected to strip-chart recorders, or digital data-loggers, or embedded digital devices that measure temperature and record and store the data. The recording time interval shall be ½ h or less for the first 48 h and 1 h or less thereafter. The temperature recording device shall be accurate to within ±1 °C.

7.2 Alternative devices include commercial maturity instruments that automatically compute and display either temperature-time factor or equivalent age.

NOTE 2—Commercial maturity instruments use specific values of datum temperature or activation energy in evaluating the maturity index; thus the displayed maturity index may not be indicative of the true value for the concrete mixture being used. Refer to Appendix X1 for information on correcting the displayed values.

8. Procedure to Develop Strength-Maturity Relationship

8.1 Prepare at least 15 cylindrical specimens according to Practice C 192/C 192M . The mixture proportions and constituents of the concrete shall be similar to those of the concrete whose strength will be estimated using this practice. If two batches are needed to prepare the required number of cylinders, cast an equal number of cylinders from each batch, and test one cylinder from each batch at the test ages given in 8.4.

8.2 Embed temperature sensors to within ±15 mm of the centers of at least two specimens. Immediately connect the

[4] The boldface numbers in parentheses refer to the list of references at the end of this practice.

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sensors to maturity instruments or to temperature-recording devices such as data-loggers or strip-chart recorders.

NOTE 3—A method to assist in the proper positioning of the sensor is to insert a small diameter rigid rod into the center of the freshly made cylinder. The rod will push aside any interfering aggregate particles. The rod is removed and the sensor is inserted into the cylinder. The side of the cylinder mold should be tapped with a rubber mallet or the tamping rod to ensure that the concrete comes into contact with the sensor.

8.3 Moist cure the specimens in a water bath or in a moist room meeting the requirements of Specification C 511.

8.4 Unless specified otherwise, perform compression tests at ages of 1, 3, 7, 14, and 28 days in accordance with Test Method C 39/C 39M. Test two specimens at each age and compute the average strength. If the range of compressive strength of the two specimens exceeds 10 % of their average strength, test another cylinder and compute the average of the three tests. If a low test result is due to an obviously defective specimen, discard the low test result.

NOTE 4—For concrete mixtures with rapid strength development, or when strength estimates are to be made at low values of maturity index, tests should begin as soon as practicable. Subsequent tests should be scheduled to result in approximately equal increments of strength gain between test ages. At least five test ages should be used.

8.5 At each test age, record the average maturity index for the instrumented specimens.

8.5.1 If maturity instruments are used, record the average of the displayed values.

8.5.2 If temperature recorders are used, evaluate the maturity index according to Eq 1 or Eq 2. Unless specified otherwise, use a time interval (Δt) of ½ h or less for the first 48 h of the temperature record. Longer time intervals are permitted for the relatively constant portion of the subsequent temperature record.

NOTE 5—Judgement should be used in selecting the initial time intervals to record temperature in mixtures that result in rapid changes in early-age temperature due to rapid hydration. Appendix X2 gives an example of how to evaluate the temperature-time factor or equivalent age from the recorded temperature history of the concrete.

8.6 Plot the average compressive strength as a function of the average value of the maturity index. Draw a best-fit curve through the data. The resulting curve is the strength-maturity relationship to be used for estimating the strength of the concrete mixture cured under other temperature conditions. Fig. 1 is an example of a relationship between compressive strength and temperature-time factor, and Fig. 2 is an example of a relationship between compressive strength and equivalent age at 20 °C.

NOTE 6—The strength-maturity relationship can also be established by using regression analysis to determine a best-fit equation to the data. Possible equations that have been found to be suitable for this purpose may be found in Ref. **(3)**. A popular equation is to express strength as a linear function of the logarithm of the maturity index (see Fig. 3).

8.7 When specified, a flexural strength versus maturity index relationship is permitted. Prepare at least 15 beam specimens in accordance with Practice C 192/C 192M. If two batches are needed to prepare the required number of specimens, cast an equal number of beams from each batch, and test one beam from each batch at the test ages given in 8.4. Embed

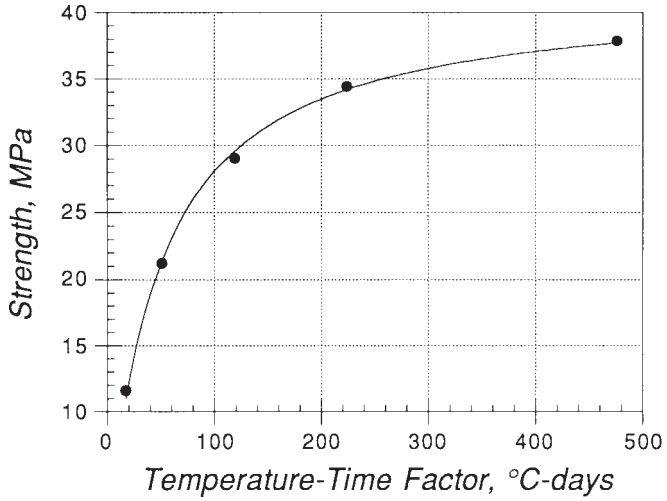

FIG. 1 Example of a Relationship Between Compressive Strength and Temperature-Time Factor

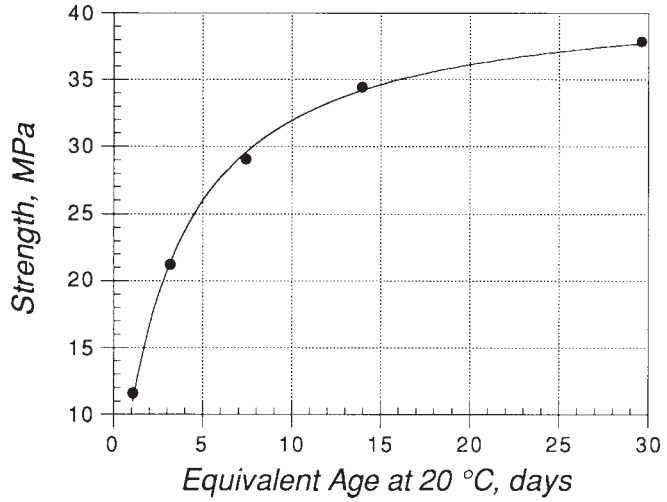

FIG. 2 Example of a Relationship Between Compressive Strength and Equivalent Age at 20 °C

temperature sensors in two specimens, one from each batch if two batches are made. Connect the sensors to maturity instruments or temperature recording devices, and moist cure the specimens in a water bath or in a moist room meeting the requirements of Specification C 511. Measure flexural strength in accordance with Test Method C 78 at time intervals of 1, 3, 7, 14 and 28 days, or as specified otherwise (See Note 4). Test two specimens at each age and compute the average strength. If the range of flexural strength of the two specimens exceeds 15 % of their average strength, test another beam and compute the average of the three tests. If a low test result is due to an obviously defective specimen, discard the low test result. Use the same procedures as in 8.5 and 8.6 to develop the flexural strength-maturity relationship.

9. Procedure to Estimate In-Place Strength

9.1 As soon as is practicable after concrete placement, embed temperature sensors into the fresh concrete. When using this practice to allow critical construction operations to begin,

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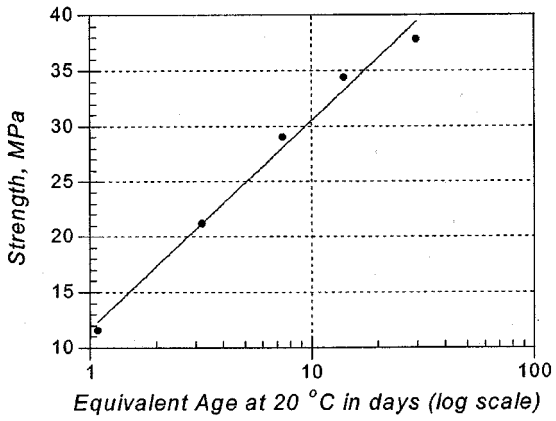

FIG. 3 Example of Compressive Strength as a Function of Logarithm of Equivalent Age

install sensors at locations in the structure that are critical in terms of exposure conditions and structural requirements.

NOTE 7—In building construction, exposed portions of slabs and slab-column connections are typically critical locations. The advice of the Engineer should be sought for critical locations in the particular structure under construction.

9.2 Connect the sensors to maturity instruments or temperature-recording devices and activate the recording devices as soon as is practicable. Use the same value of datum temperature or activation energy, whichever is applicable, as was used in computing the maturity index during development of the strength-maturity relationship (See Section 8).

9.3 When the strength at the location of a sensor is to be estimated, read the value of the maturity index from the maturity instrument or evaluate the maturity index from the temperature record.

9.4 Using the strength-maturity relationship developed in Section 8, read off the value of compressive (or flexural) strength corresponding to the measured maturity index.

9.5 Prior to performing critical operations, such as formwork removal or post-tensioning, supplement determination of the concrete maturity with other tests to ensure that the concrete in the structure has a potential strength that is similar to that of the concrete used to develop the strength-maturity relationship. Appropriate techniques include:

9.5.1 In-place tests that give indications of strength, such as Test Method C 803/C 803M, Test Method C 873, or Test Method C 900.

9.5.2 Early-age compressive strength tests in accordance with Test Method C 918 of standard-cured specimens molded from samples of the concrete as-delivered, or

9.5.3 Compressive strength tests on specimens molded from samples of the concrete as-delivered and subjected to accelerated curing in accordance with Test Method C 684.

9.5.4 Early-age tests of field-molded cylinders instrumented with maturity instruments. The measured strengths are compared with the strengths estimated from the established strength-maturity relationship. If the difference consistently exceeds 10 %, a new strength-maturity relationship is to be developed.

10. Precision and Bias

10.1 This practice is used to estimate the in-place strength of concrete based on the measured thermal history at a point in the structure and a previously established strength-maturity relationship. The accuracy of the estimated strength depends on several factors, such as the appropriateness of the maturity function for the specific mixture, the early-age temperature history, and the actual mixture proportions. For this reason, it is not possible to write statements about the precision and bias of the estimated strength.

11. Keywords

11.1 in-place strength; maturity method; nondestructive testing; temperature

ANNEX

(Mandatory Information)

A1. DETERMINATION OF DATUM TEMPERATURE OR ACTIVATION ENERGY

A1.1 Procedure

A1.1.1 The testing required to determine experimentally the datum temperature or the activation energy can be performed using mortar specimens, and the results are applicable to the concrete under investigation **(5, 6, 7)**. The basic approach is to establish the compressive strength versus age relationships for mortar specimens cured in water baths maintained at three different temperatures. Two baths are at the maximum and minimum concrete temperatures expected for the in-place concrete during the period when strengths are to be estimated. The third bath temperature is midway between the extremes. Depending on the data analysis procedure that is used, the final setting times of the mortar at the three temperatures may also have to be measured.

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A1.1.2 Proportion a mortar mixture having a fine aggregate-to-cement ratio (by mass) that is the same as the coarse aggregate-to-cement ratio of the concrete mixture under investigation **(6)**. The paste shall have the same water-cementitious materials ratio and the same amounts of admixtures that will be used in the concrete.

A1.1.3 If the strength data will be analyzed using the reciprocal plotting procedure in A1.1.7, final setting times must be measured. Prepare three mortar specimens using containers specified in Test Method C 403/C 403M. Carefully submerge each specimen into its corresponding temperature bath. Determine the time of final setting for each temperature in accordance with Test Method C 403/C 403M. The specimens are removed from the water baths and excess water is removed prior to making penetration measurements. If the data will be analyzed using the regression procedures in A1.1.8, it is not necessary to measure times of final setting.

A1.1.4 Prepare three sets of 50-mm mortar cubes, with 18 cubes per set. Mold the cubes in accordance with Test Method C 109/C 109M and carefully submerge each set into one of the temperature baths. For each set, remove the molds and return the specimens to their respective baths approximately 1 h before the first series of compression tests.

A1.1.5 For each set of cubes, determine the compressive strength of three cubes in accordance with Test Method C 109/C 109M at an age that is approximately twice the time of final setting. If final setting times were not measured, perform the first test when the compressive strength is approximately 4 MPa. Perform subsequent tests on three cubes from each set at ages that are approximately twice the age of the previous tests. For example, if the time of the first test was 12 h, successive compressive strength tests would be performed at 1, 2, 4, 8, 16, and 32 days.

A1.1.6 The strength versus age data obtained at the three curing temperatures are analyzed to determine the relationship between the rate constant for strength development (*k*-value) and the curing temperature. Different procedures can be used depending on the available computational tools. If the user has the capability to perform only linear regression analysis, use the procedure in A1.1.7 or A1.1.8.2. If the user has a computer program that can perform regression analyses with a general function, use the procedure in A1.1.8.1.

A1.1.7 To use this procedure, the final setting times at the three temperatures must be measured. Prepare a graph with the reciprocal of strength as the *y*-axis and the reciprocal of age as the *x*-axis. For each curing temperature, plot the reciprocal of the average cube strength along the *y*-axis and the reciprocal of the age beyond the time of final setting along the *x*-axis. An example of such a plot is shown in Fig. A1.1. Determine the slope and the intercept of the best-fitting straight line through the data for each curing temperature. For each straight-line, divide the value of the intercept by the value of the slope. These quotients are the *k*-values that are used to calculate the datum temperature or the activation energy.

A1.1.8 As an alternative to the procedure in A1.1.7, the *k*-values can be estimated by either of the following methods. In these cases, the final setting times do not have to be measured.

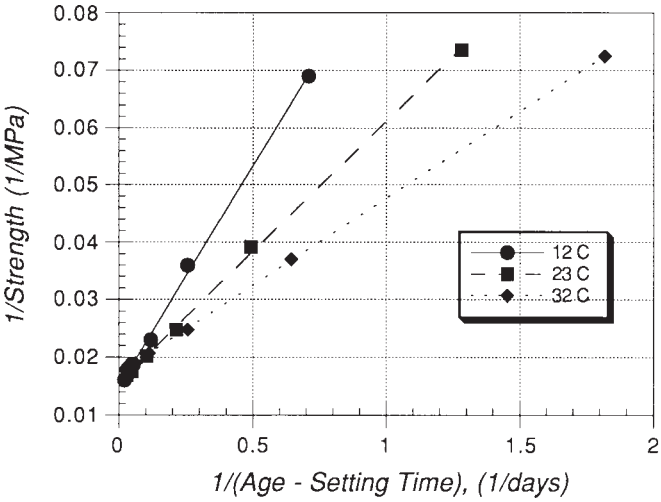

FIG. A1.1 Reciprocal of Strength Versus Reciprocal of Age Beyond Time of Final Setting

A1.1.8.1 If the user has access to a computer program that will permit the fitting of a general equation to a set of data, determine the *k*-values by fitting the following equation to the strength-age data for each curing temperature:

$$S = S_u \frac{k(t - t_o)}{1 + k(t - t_o)} \quad \text{(A1.1)}$$

where:

S = average cube compressive strength at age t,
t = test age,
S_u = limiting strength,
t_o = age when strength development is assumed to begin, and
k = the rate constant.

The computer program will calculate the best-fit values of S_u, t_o, and k.

A1.1.8.2 The *k*-values can also be estimated by the following method **(5, 8)**.

(1) Using the strength-age data for the last four test ages, plot the reciprocal of strength (*y*-axis) versus the reciprocal of age (*x*-axis). Determine the *y*-axis intercept. The inverse of the intercept is the limiting strength, S_u. Repeat this procedure for each curing temperature.

(2) For each curing temperature, use the strength-age data at the four earliest test ages and the value of S_u to compute the values of *A* for each strength, where *A* is given by the following equation:

$$A = \frac{S}{(S_u - S)} \quad \text{(A1.2)}$$

(3) For each curing temperature, plot the values of *A* versus age. Determine the slopes of the best-fit straight lines for each curing temperature. These slopes are the *k*-values.

A1.2 Determination of Datum Temperature

A1.2.1 Plot the *k*-values as a function of the water bath temperatures (Fig. A1.2). Determine the best-fitting straight line through the three points and determine the intercept of the line with the temperature axis. This intercept is the datum

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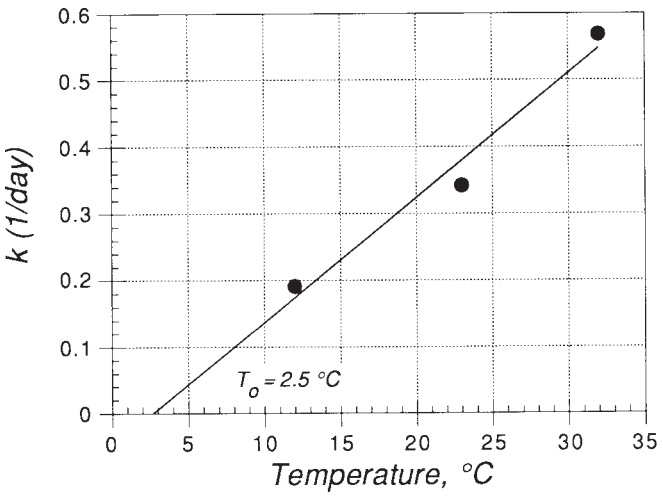

FIG. A1.2 Example of Plot of *k*-Values Versus Curing Temperature for Determining the Datum Temperature

temperature, T_o, that is to be used in computing the temperature-time factor according to Eq 1.

A1.3 Determination of Activation Energy

A1.3.1 Calculate the natural logarithms of the *k*-values, and determine the absolute temperatures (in kelvin) of the water baths (kelvin = Celsius + 273).

A1.3.2 Plot the natural logarithm of the *k*-values as a function of the reciprocal absolute temperature (Fig. A1.3). Determine the best-fitting straight line through the three points. The negative of the slope of the line is the value of the activation energy divided by the gas constant, *Q*, that is to be used in computing equivalent age according to Eq 2.

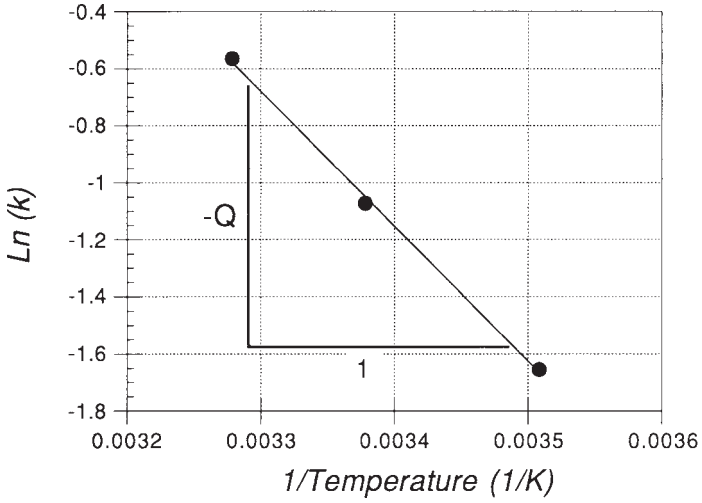

FIG. A1.3 Example of Plot of the Natural Logarithm of *K*-Values Versus the Inverse Absolute Temperature for Determining the Value of *Q* used in Calculating Equivalent Age

APPENDIXES

(Nonmandatory Information)

X1. MATURITY FUNCTIONS

X1.1 General

X1.1.1 A maturity function is a mathematical expression to account for the combined effects of time and temperature on the strength development of a cementitious mixture. The key feature of a maturity function is the representation of how temperature affects the rate of strength development. There are two widely-used approaches; one assumes that the rate of strength development is a linear function of temperature, and the other assumes that rate of strength development obeys the exponential Arrhenius equation **(3, 4, 5)**.

X1.2 Temperature-Time Factor

X1.2.1 The assumption that the rate of strength development is a linear function of temperature leads to the maturity function given in Eq 1, which is used to compute the temperature-time factor. To compute the temperature-time factor, it is necessary to know the appropriate value of the datum temperature for the specific materials and conditions. The datum temperature may depend on the type of cement, on the type and the dosage of admixtures or other additives that affect hydration rate, and on the temperature range that the

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concrete will experience while hardening **(5, 7)**. For Type I cement without admixtures and a curing temperature range from 0 to 40 °C, the recommended datum temperature is 0 °C **(5)**. For other conditions and when maximum accuracy of strength estimation is desired, the appropriate datum temperature can be determined experimentally according to the procedures in Annex A1.

X1.2.2 Some types of maturity instruments that compute temperature-time factor may not employ the appropriate datum temperature, and therefore may not indicate the true value of the factor. The value of the temperature-time factor displayed by the instrument can be corrected for the datum temperature as follows:

$$M_c = M_d - (T_o - T_d)\, t \qquad \text{(X1.1)}$$

where:

M_c = the corrected temperature-time factor, degree-days or degree-hours,
M_d = the temperature-time factor displayed by the instrument, degree-days or degree-h,
T_o = the appropriate datum temperature for the concrete, °C,
T_d = the datum temperature incorporated into the instrument, °C, and
t = the elapsed time from when the instrument was turned on to when a reading was taken, days or h.

X1.3 Equivalent Age

X1.3.1 The assumption that the rate of strength development obeys the Arrhenius equation leads to the maturity function given in Eq 2, which is used to compute equivalent age at a specified temperature. Note that in using Eq 2, the temperature must be in kelvin (kelvin = Celsius + 273). To compute equivalent age it is necessary to know the activation energy for the specific materials and conditions. It has been shown that the activation energy depends on the type of cement, the type and the dosage of admixtures that affect the rate of strength development, and the water-cementitious materials ratio **(7)**. In general, for Type I cement without admixtures or additions, values of activation energy in the range of 40 000 to 45 000 J/mol have been reported **(6)**. Thus an approximate value of Q, the activation energy divided by the gas constant for use in Eq 2, is 5000 K. (The value of the gas constant is 8.31 J/(K·mol)). For other conditions and when maximum accuracy of strength estimation is desired, the appropriate value for Q can be determined experimentally according to the procedures in Annex A1.

X1.3.2 The calculation of equivalent age also requires a specified temperature, T_s. Traditionally, a value of 20 °C has been used **(4)**, but any other convenient temperature, such as 23 °C, is permissible provided that it is reported along with the value of the equivalent age.

X1.3.3 Maturity instruments that compute equivalent age according to Eq 2, are based on specific values of activation energy. The displayed readings cannot be corrected for the appropriate activation energy value of the concrete being used. The user should recognize this limitation when the in-place concrete has an activation energy that is widely different from that incorporated into the instrument. Refer to **(3)** for information on the effect of the activation energy on the computed value of equivalent age.

X2. EXAMPLE MATURITY CALCULATIONS

X2.1 Temperature Record

X2.1.1 Fig. X2.1 shows a hypothetical temperature history for concrete that will be used to illustrate the calculations of temperature-time factor and equivalent age. The temperature values at half-hour intervals are tabulated in column 2 of Table X2.1.

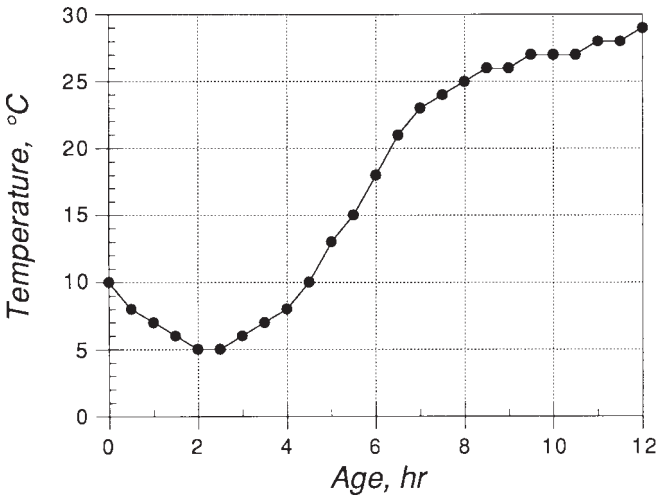

FIG. X2.1 Hypothetical Temperature History used to Illustrate Computations of Temperature-Time Factor and Equivalent Age

X2.2 Calculation of Temperature-time Factor

X2.2.1 The value of the datum temperature, T_o, is required to compute the temperature-time factor according to Eq 1. For this example, a value of 2.5 °C is assumed as indicated in Fig. A1.2.

X2.2.2 The average temperature during each half-hour interval is computed and the results are given in column 4 of Table X2.1. The datum temperature is subtracted from the average temperature, and the difference is multiplied by the age interval, which in this example is 0.5 h. The product gives the incremental value of the temperature-time factor for that age interval. The incremental values are shown in column 5 of Table X2.1.

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TABLE X2.1 Example Maturity Calculations

(1) Age, h	(2) Temperature, °C	(3) Age Increment, h	(4) Average Temperature, °C	(5) Temp-Time Factor, Increment °C-h	(6) Temp-Time Factor, Cumulative °C-h	(7) Age Factor	(8) Eq. Age at 20 °C, Increment h	(9) Eq. Age at 20 °C, Cumulative h
0	10	...	...	...	0	...	...	0.0
0.5	8	0.5	9	3.3	3	0.53	0.27	0.3
1.0	7	0.5	7.5	2.5	6	0.49	0.24	0.5
1.5	6	0.5	6.5	2.0	8	0.46	0.23	0.7
2.0	5	0.5	5.5	1.5	9	0.43	0.22	1.0
2.5	5	0.5	5	1.3	11	0.42	0.21	1.2
3.0	6	0.5	5.5	1.5	12	0.43	0.22	1.4
3.5	7	0.5	6.5	2.0	14	0.46	0.23	1.6
4.0	8	0.5	7.5	2.5	17	0.49	0.24	1.9
4.5	10	0.5	9	3.3	20	0.53	0.27	2.1
5.0	13	0.5	11.5	4.5	24	0.62	0.31	2.4
5.5	15	0.5	14	5.8	30	0.72	0.36	2.8
6.0	18	0.5	16.5	7.0	37	0.82	0.41	3.2
6.5	21	0.5	19.5	8.5	46	0.97	0.49	3.7
7.0	23	0.5	22	9.8	55	1.11	0.56	4.3
7.5	24	0.5	23.5	10.5	66	1.21	0.60	4.9
8.0	25	0.5	24.5	11.0	77	1.27	0.64	5.5
8.5	26	0.5	25.5	11.5	88	1.34	0.67	6.2
9.0	26	0.5	26	11.8	100	1.38	0.69	6.9
9.5	27	0.5	26.5	12.0	112	1.42	0.71	7.6
10.0	27	0.5	27	12.3	124	1.45	0.73	8.3
10.5	27	0.5	27	12.3	137	1.45	0.73	9.0
11.0	28	0.5	27.5	12.5	149	1.49	0.75	9.8
11.5	28	0.5	28	12.8	162	1.53	0.77	10.5
12.0	29	0.5	28.5	13.0	175	1.57	0.79	11.3

X2.2.3 The summation of the incremental temperature-time factors gives the cumulative temperature-time factor at each age. For example, at an age of 12 h the temperature-time factor is 175 °C-h.

X2.3 Calculation of Equivalent Age

X2.3.1 The value of Q and the value of the specified temperature, T_s, are required to compute the equivalent age according to Eq 2. For this example, the value of Q is assumed to be 4700 K, and the specified temperature is assumed to be 20 °C (293 K).

X2.3.2 Using the average temperature, in kelvin, during each age interval, the values of the exponential function in Eq 2 are calculated. These values are given in column 7 of Table X2.1 under the heading Age Factor. The product of each of the age factors and the age interval (0.5 h) gives the incremental equivalent ages at 20 °C; the incremental equivalent ages are shown in column 8 of Table X2.1.

X2.3.3 The summation of the incremental equivalent ages gives the cumulative equivalent age at 20 °C (column 9 of Table X2.1). For example, at an age of 12 h the equivalent age at 20 °C is 11.3 h. Note that because the concrete temperature is less than 20 °C for the first six hours, the equivalent age at 6 h is only 3.2 h.

REFERENCES

(**1**) Saul, A. G. A., "Principles Underlying the Steam Curing of Concrete at Atmospheric Pressure," *Magazine of Concrete Research*, Vol 2, No. 6, March 1951, pp. 127–140.

(**2**) Malhotra, V. M., "Maturity Concept and the Estimation of Concrete Strength," *Information Circular IC 277*, Dept. of Energy Mines Resources (Canada), Mines Branch, Nov. 1971, 43 pp.

(**3**) Carino, N. J., "The Maturity Method," Chapter 5 in *Handbook on Nondestructive Testing of Concrete, 2nd Edition*, Malhotra, V. M. and Carino, N. J., Eds., CRC Press Inc., Boca Raton, FL, and ASTM International, West Conshohocken, PA, 2004.

(**4**) Freiesleben Hansen, P., and Pedersen, J., "Maturity Computer for Controlled Curing and Hardening of Concrete," *Nordisk Betong*, 1, 1977, pp. 19–34.

(**5**) Carino, N. J., "The Maturity Method: Theory and Application," *ASTM Journal of Cement, Concrete, and Aggregates*, Vol 6, No. 2, Winter 1984, pp. 61–73.

(**6**) Tank, R. C., and Carino, N. J., "Rate Constant Functions for Strength Development of Concrete," *ACI Materials Journal*, Vol 88, No. 1, Jan.–Feb. 1991, pp. 74–83.

(**7**) Carino, N. J., and Tank, R. C., "Maturity Functions for Concrete Made with Various Cements and Admixtures," *ACI Materials Journal*, Vol 89, No. 2, March–April 1992, pp. 188–196.

(**8**) Knudsen, T., "On Particle Size Distribution in Cement Hydration," *Proceedings, 7th International Congress on the Chemistry of Cement* (Paris, 1980), Editions Septima, Vol II, I-170–175.

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SUMMARY OF CHANGES

Committee C09 has identified the location of selected changes to this practice since the last issue, C 1074 – 98, that may impact the use of this practice. (Approved June 2004)

(*1*) Added a warning about chemical burns in 1.4
(*2*) Added new Note 1.
(*3*) Updated 7.1 to include other embedded devices for recording temperature data.
(*4*) Revised 8.1 to provide guidance on the use two batches to prepare test cylinders.
(*5*) Revised 8.4 and added new Note 4 to provide guidance on test ages for concrete mixtures with rapid strength development.
(*6*) Revised Note 5 to provide guidance on time intervals to record temperature in mixtures with rapid hydration.
(*7*) Revised Note 6 to refer to semi-log strength-maturity relationship and provided new Fig. 3.
(*8*) Added new section 8.7 to permit development of flexural strength versus maturity relationship.
(*9*) Revised 9.2 to clarify that same values of datum temperature or activation energy must be used in the field as during development of the strength-maturity relationship.
(*10*) Added 9.5.4 on the use of instrumented field cylinders to verify the strength-maturity relationship.

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Designation: C 1077 – 09b

Standard Practice for Laboratories Testing Concrete and Concrete Aggregates for Use in Construction and Criteria for Laboratory Evaluation[1]

This standard is issued under the fixed designation C 1077; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

This standard has been approved for use by agencies of the Department of Defense.

1. Scope*

1.1 This practice identifies and defines the duties, responsibilities, and minimum technical requirements of testing laboratory personnel and the minimum technical requirements for laboratory equipment utilized in testing concrete and concrete aggregates for use in construction.

1.2 This practice provides criteria for the evaluation of the capability of a testing laboratory to perform designated ASTM test methods on concrete and concrete aggregates. It can be used by an evaluation authority in the inspection or accreditation of a laboratory or by other parties to determine if the laboratory is qualified to conduct the specified tests.

NOTE 1—Specification E 329 provides criteria for the evaluation of laboratories that perform the inspection of concrete during placement.

1.3 If the laboratory requires external technical services to conduct tests, the external agency shall be subject to separate evaluation.

1.4 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

2. Referenced Documents

2.1 *ASTM Standards:*[2]

C 31/C 31M Practice for Making and Curing Concrete Test Specimens in the Field

C 39/C 39M Test Method for Compressive Strength of Cylindrical Concrete Specimens

C 40 Test Method for Organic Impurities in Fine Aggregates for Concrete

C 117 Test Method for Materials Finer than 75-μm (No. 200) Sieve in Mineral Aggregates by Washing

C 125 Terminology Relating to Concrete and Concrete Aggregates

C 127 Test Method for Density, Relative Density (Specific Gravity), and Absorption of Coarse Aggregate

C 128 Test Method for Density, Relative Density (Specific Gravity), and Absorption of Fine Aggregate

C 136 Test Method for Sieve Analysis of Fine and Coarse Aggregates

C 138/C 138M Test Method for Density (Unit Weight), Yield, and Air Content (Gravimetric) of Concrete

C 143/C 143M Test Method for Slump of Hydraulic-Cement Concrete

C 172 Practice for Sampling Freshly Mixed Concrete

C 173/C 173M Test Method for Air Content of Freshly Mixed Concrete by the Volumetric Method

C 231 Test Method for Air Content of Freshly Mixed Concrete by the Pressure Method

C 617 Practice for Capping Cylindrical Concrete Specimens

C 802 Practice for Conducting an Interlaboratory Test Program to Determine the Precision of Test Methods for Construction Materials

C 1064/C 1064M Test Method for Temperature of Freshly Mixed Hydraulic-Cement Concrete

C 1231/C 1231M Practice for Use of Unbonded Caps in Determination of Compressive Strength of Hardened Concrete Cylinders

D 75 Practice for Sampling Aggregates

D 2419 Test Method for Sand Equivalent Value of Soils and Fine Aggregate

E 4 Practices for Force Verification of Testing Machines

E 11 Specification for Woven Wire Test Sieve Cloth and Test Sieves

E 329 Specification for Agencies Engaged in Construction Inspection and/or Testing

[1] This practice is under the jurisdiction of ASTM Committee C09 on Concrete and Concrete Aggregates and is the direct responsibility of Subcommittee C09.98 on Evaluation of Laboratories.

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[2] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

***A Summary of Changes section appears at the end of this standard.**

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E 1301 Guide for Proficiency Testing by Interlaboratory Comparisons

2.2 *ACI Standards:*

ACI 214-77 Recommended Practice for Evaluation of Strength Test Results of Concrete[3]

3. Terminology

3.1 *Definitions*:

3.1.1 For definitions of terms used in this practice, refer to Terminology C 125.

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *evaluation authority*, *n*—an independent entity, apart from the testing laboratory being evaluated, that has the capability to provide an unbiased evaluation of the professional and technical activities of concrete and concrete aggregates testing laboratories.

3.2.1.1 *Discussion*—Two acceptable methods of evaluation are inspection and accreditation, and these evaluations are offered by many evaluation authorities. An inspection is an evaluation of equipment and procedures based on the Test Methods and Procedures section, along with a review of the quality system. An inspection report is the final step in the process for an inspection agency. The testing laboratory being evaluated performs corrective actions for any deficiencies noted, and these corrections are to be placed with the other inspection documentation as part of the permanent record of the inspection. An accreditation agency uses the results of the inspection report or the results of their own onsite assessment as one phase of the accreditation process. As a separate phase, the accreditation agency also reviews the testing laboratory's corrective actions for the deficiencies noted and issues a certificate of accreditation once all of the deficiencies have been corrected. There is no universally accepted evaluation authority in the construction materials testing field; therefore, testing laboratories should give careful consideration when selecting an evaluation authority to gain the most benefit from the evaluation. In most cases, a testing laboratory will select an evaluation authority as a result of requirements in a project specification, or contract, or in response to local codes, or other industry requirements. In those circumstances, the requirements will stipulate the acceptable evaluation authorities. If there are no specific requirements and the evaluation is in anticipation of future work or to compete with other local testing laboratories, then the laboratory should contact the organization(s) most likely to use their services for a list of acceptable evaluation authorities. A list of evaluation authorities is provided in the Qualification of Personnel and Laboratory Evaluation section of the Manual of Aggregate and Concrete Testing.[4] The list is merely a collection of organizations willing to provide this service and is not an endorsement of any particular organization. Other organizations may also be available to provide this service.

3.2.2 *external technical services*, *n*—those services required by a testing laboratory that are provided by another organization.

3.2.3 *field technician*, *n*—an employee of the laboratory who is assigned to perform sampling and testing functions outside the laboratory.

3.2.4 *laboratory technician*, *n*—an employee of the laboratory who is assigned to perform the actual testing operations primarily conducted in the laboratory.

3.2.5 *quality systems*, *n*—those internal procedures and practices that a laboratory utilizes to ensure continued compliance with applicable testing standards for concrete and concrete aggregates.

3.2.6 *testing laboratory*, *n*—an organization that measures, examines, performs tests, or otherwise determines the characteristics or performance of materials or products. This may include organizations that offer commercial testing services, an in-house quality control function, an academic institution, or any other organization providing the required testing services.

4. Significance and Use

4.1 The testing and inspection of concrete and concrete aggregates are important elements in obtaining quality construction. A testing laboratory providing these services must be selected with care.

4.2 A testing laboratory shall be deemed qualified to perform and report the results of its tests if the laboratory meets the requirements of this practice. The testing laboratory services shall be provided under the technical direction of a registered professional engineer.

4.3 This practice establishes essential characteristics pertaining to the organization, personnel, facilities, and quality systems of the laboratory. This practice may be supplemented by more specific criteria and requirements for particular projects.

5. Organization

5.1 The following information shall be readily available for review:

5.1.1 Description of the organization, including:

5.1.1.1 Complete legal name and address of the main office and each laboratory location,

5.1.1.2 Names and positions of the principal officers and the responsible, registered professional engineer in charge, and

5.1.1.3 Description of the organization management structure.

5.1.2 Listing of the relevant technical services offered, and

5.1.3 All external technical services normally utilized.

5.2 The laboratory shall designate an individual with access to management who has the responsibility of seeing that procedures required in this document are being carried out.

6. Personnel Qualifications

6.1 Information shall be made available to substantiate personnel qualifications as follows:

6.1.1 All relevant testing services are provided under the full-time technical direction of a registered professional engineer with at least 5 years experience in construction materials testing.

[3] Available from American Concrete Institute (ACI), P.O. Box 9094, Farmington Hills, MI 48333-9094, http://www.aci-int.org.

[4] Manual of Aggregate and Concrete Testing, *Annual Book of ASTM Standards* , Vol 04.02.

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6.1.2 Supervising laboratory technicians shall possess a minimum of 3 years relevant experience and current technician certification. The technician certification program must include a written examination and performance examination of relevant tests. Relevant tests that must be covered by the certification program are: Practice C 31/C 31M, Test Methods C 39/C 39M, C 40, C 117, C 127, C 128, C 136, C 138/C 138M, C 143/C 143M, Practice C 172, Test Methods C 173/C 173M, C 231, and Test Method C 1064/C 1064M. In cases where the supervising laboratory technician is supervising technicians who only test concrete, the applicable relevant tests are the concrete tests listed in the group. Where the supervising laboratory technician is supervising technicians who only test aggregates, the applicable relevant tests are the aggregate tests listed in the group.

6.1.3 Supervising field technicians shall possess a minimum of 3 years relevant experience and current technician certification. The technician certification program must include a written examination and performance examination of relevant tests. Relevant tests that must be covered by the certification program are: Practice C 31/C 31M, Test Methods C 138/C 138M, C 143/C 143M, Practice C 172, Test Methods C 173/C 173M, C 231, and C 1064/C 1064M.

6.1.4 Concrete laboratory technicians shall possess current technician certification. The technician program must include a written examination and performance examination of relevant tests. Relevant tests that must be covered by the certification program are: Test Method C 39/C 39M and Practice C 617 or C 1231/C 1231M.

6.1.5 Aggregate laboratory technicians shall possess current technician certification. The technician certification program must include a written examination and performance examination of relevant tests. Relevant tests that must be covered by the certification program are: Test Methods C 40, C 117, C 127, C 128, and C 136.

6.1.6 Concrete field technicians shall possess current technician certification. The technician certification program must include a written examination and performance examination of relevant tests. Relevant tests that must be covered by the certification program are: Practice C 31/C 31M, Test Methods C 138/C 138M, C 143/C 143M, Practice C 172, Test Methods C 173/C 173M, C 231, and C 1064/C 1064M.

6.1.7 The technician certification program shall meet the following criteria:

6.1.7.1 The written examination shall be of sufficient length and detail to cover the entire test method,

6.1.7.2 The performance examination shall adequately cover procedures of the test method, and

6.1.7.3 The written and performance examinations shall include all relevant test methods that are listed in the section above for the type of technician being certified.

NOTE 2—A list of technician certification programs is provided in the Qualification of Personnel and Laboratory Evaluation section of the Manual of Aggregate and Concrete Testing.[4] The list is merely a collection of certification programs and is not an endorsement of any particular program. Other programs may also be available.

7. Test Methods and Procedures

7.1 The testing laboratory shall be capable of performing the required ASTM test methods, guides, or practices in 7.2 and may request additional evaluation for the optional methods in 7.3 to the extent that those services are provided by the laboratory.

7.2 *Required Test Methods and Practices*:

7.2.1 *For Laboratories Testing Concrete*:

7.2.1.1 *Sampling*, Practice C 172,

7.2.1.2 *Slump*, Test Method C 143/C 143M,

7.2.1.3 *Unit Weight, Yield, and Air Content*, Test Method C 138/C 138M,

7.2.1.4 *Air Content*, Test Method C 173/C 173M (volumetric method), or Test Method C 231 (pressure method), or both.

7.2.1.5 *Temperature*, Test Method C 1064/C 1064M,

7.2.1.6 *Making and Curing Test Specimens*, Practice C 31/C 31M,

7.2.1.7 *Compressive Strength*, Test Method C 39/C 39M,

7.2.2 *For Laboratories Testing Concrete Aggregates*:

7.2.2.1 *Sieve Analysis*, Test Method C 136,

7.2.2.2 *Material Finer Than 75-μm (No. 200) Sieve*, Test Method C 117,

7.2.2.3 *Specific Gravity and Absorption*, Test Method C 127 (Coarse Aggregate) and Test Method C 128 (Fine Aggregate), and

7.2.2.4 *Organic Impurities in Fine Aggregate*, Test Method C 40.

7.3 *Optional Test Methods or Practices*:

7.3.1 Some laboratories conduct other tests on concrete and concrete aggregates in addition to those listed in The *Required Test Methods and Practices* Section. These optional test methods and practices could include any of the test methods or practices developed by Committee C09 and contained in volume 04.02, as well as other related standards such as Practice D 75 and Test Method D 2419. The laboratory shall have evidence of proper facilities, equipment, and trained personnel to comply with the applicable test method or practice, if it is included in the scope of services as defined by the laboratory. The laboratory and the evaluation authority will mutually agree upon which optional test methods or practices will be included in the laboratory's evaluation. The evaluation authority shall then select which of the optional test methods or practices offered by the laboratory need to be demonstrated by the personnel.

7.4 The laboratory shall use the latest version of each referenced method within one year of its publication unless an earlier version of the standard is required by the client.

7.5 Laboratory personnel shall have convenient access to applicable standards.

8. Facilities, Equipment, and Supplemental Procedures

8.1 *General*—The laboratory shall have facilities and equipment conforming to the requirements of the applicable test method. This section contains equipment requirements and procedures that clarify certain provisions of the test methods.

8.2 *Procedures Related to Required Test Methods*—In addition to standard test method requirements, the conditions listed in 8.3 and 8.4 must be met.

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8.3 *For Laboratories Testing Concrete*:

8.3.1 *Compressive Strength Testing Machines*, shall conform to the applicable requirements of Test Method C 39/C 39M and have a capacity, loading range, and the appropriate heads for specimens to be tested. Testing machines shall be verified at least annually in accordance with Practices E 4 and a report giving details of the verification shall be readily available.

8.4 *For Laboratories Testing Concrete Aggregates*:

8.4.1 *Sieve Accuracy*—Verification of sieve accuracy shall be performed at least annually on each sieve used in the test for sieve analysis (Test Methods C 117 and C 136). Any one of the following three methods of verification is acceptable. Each method of sieve verification shall include an inspection of the sieve cloth for punctures or obvious defects.

8.4.1.1 Verification of each sieve used according to the procedures prescribed in the Annex of Specification E 11.

8.4.1.2 A comparison of the results of a split sample sieved on different sieve sets. Results shall be verified for single operator precision to be within the acceptable range of two results stated in the test method.

8.4.1.3 Participation in the sieve analysis test in an aggregate proficiency sample program, as described in the Quality Systems section. Results shall be verified for multilaboratory precision to be within the acceptable range of two results stated in the test method.

8.4.2 *Mechanical Sieve Shaker*—When mechanical sieving devices are used, the period of mechanical agitation shall be checked at least annually for adequacy of sieving as described in Test Method C 136. Mechanical agitation periods must be established for each different type of aggregate tested.

NOTE 3—Different types of aggregate refer to shape and composition, not supplier. For example, agitation periods for elongated materials may need to be extended, while softer materials that break down easily may require a shorter period to minimize alteration of the particle size distribution.

8.4.3 *Relative Density (Specific Gravity) and Absorption Tests*—When performing the procedures of Test Methods C 127 and C 128, duplicate tests shall be made at least once every 6 months. Results shall be verified for single operator precision within the tolerance stated in the respective test method. Participation in a proficiency sample program with relative density (specific gravity) and absorption testing is an acceptable alternative.

8.4.4 Balances or scales for all concrete and aggregate tests shall be calibrated annually.

8.5 *Procedures Related to Optional Test Methods*:

8.5.1 If the applicable test method requires equipment calibration and does not specify a frequency, then the laboratory shall establish a frequency in its quality assurance program and conform thereto.

8.5.2 In the event that the laboratory borrows or rents equipment to perform an optional test method, the laboratory must be able to document that it obtained the appropriate equipment and that the equipment was calibrated, standardized, or verified.

8.6 All equipment listed in this section shall be calibrated or verified before being placed in service. Equipment not in operating condition or out of tolerance shall be marked as such and taken out of service until corrected.

9. Laboratory Records and Reports

9.1 The laboratory shall maintain a system of records that permits verification of any issued report.

9.2 The records of the laboratory shall contain the following information:

9.2.1 Standard operating procedures for the following:

9.2.1.1 Identification of the test sample,

9.2.1.2 Transfer of the sample from the field to the laboratory, and

9.2.1.3 Recording of test results.

9.2.2 Calibrations or verifications of equipment required by the test method for all of the tests offered in the scope of the laboratory's services. The records shall include:

9.2.2.1 The identification of the specific piece of equipment,

9.2.2.2 The identification of the equipment used to perform the calibration or verification,

9.2.2.3 The name of the individual who performed the calibration or verification,

9.2.2.4 The date the calibration or verification was performed,

9.2.2.5 The quantity measured by the equipment (such as length, force, or mass), and

9.2.2.6 The associated accuracy of the measurement or a comparison of the measured quantity with the associated allowable tolerances, as necessary to verify that the equipment complies with the requirements in the relevant standards. Where additional calibration or verification requirements have been listed in the *Facilities, Equipment, and Supplemental Procedures* Section, this information shall also be included in the records.

9.2.3 Records on laboratory personnel that document work experience, education, on-the-job training, and methods used to ensure continued competence in performing the required test methods,

9.2.4 Audits and inspections by outside agencies and all reports or certifications, with applicable dates, of any evaluation or accreditations issued by any evaluating authorities,

9.2.5 The laboratory shall retain results of participation in proficiency sample programs, including data sheets, summary reports and, if low proficiency sample ratings are received, a record of the laboratory's investigation into the reason for the low ratings and corrective action taken.

9.2.6 Current standard test methods and other pertinent reference material in a library,

9.2.7 Identification of the person performing the field tests, and

9.2.8 Documents that establish the traceability to an acceptable reference standard or a national standard for load cells, proving rings, thermometers, test weights, and test equipment used for verification or calibration of laboratory equipment.

9.3 Laboratory test reports shall accurately and clearly present the specified test results and all pertinent data.

9.4 Test reports shall include the following information:

9.4.1 Name and address of the laboratory,

9.4.2 Identification of the report and the date issued,

9.4.3 Name of the client,

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9.4.4 Project identification,

9.4.5 Sample identification,

9.4.6 Identification of the standard test method used, a notation of all known deviations from the test method, and all requirements of the test method that were not performed by the laboratory (Note 5),

9.4.7 Test results and other pertinent data required by the standard,

9.4.8 Name of the registered professional engineer or his designee, and

9.4.9 Identification of results obtained from tests performed by other laboratories.

9.5 Corrections or additions to reports shall clearly reference the report being amended.

9.6 All records required by this standard shall be stored safely for at least 3 years, unless otherwise required by law or governing specifications. Those records that are confidential in nature, including test reports and other records generated as required by contract with the client, shall be stored safely in confidence to the client, unless otherwise required by law, governing specification, or client requirements.

NOTE 4—There are circumstances when a longer retention period may be advantageous to the laboratory. Records concerning the calibration, verification, and standardization of equipment are an example. Records of this type are often held throughout the useful life of the equipment.

NOTE 5—Deviation from standard test methods may adversely affect results.

10. Quality Systems

10.1 The laboratory shall maintain a quality manual of written procedures for ensuring the quality of the services offered (Note 8). In addition to the following information, each page in the manual shall contain a preparation or revision date to ensure the latest procedure is being followed.

10.1.1 Internal quality assurance program, including:

10.1.1.1 Personnel evaluation including the method of evaluation, the frequency of the review, the criteria used, and the title or name of the individual responsible for administering the evaluations; and technician training including a description of the levels of training, the testing used to determine when a level has been reached and the title or name of the individual responsible for administering the training,

10.1.1.2 Equipment calibration and maintenance,

10.1.1.3 A current library including all relevant test methods, and

10.1.1.4 Inventory of all test equipment requiring both an initial and a subsequent periodic calibration or verification that is used by the laboratory to perform the test methods covered by this standard and within the laboratory's scope of services. The inventory shall include the equipment description, identification number, and next date of calibration or verification.

NOTE 6—The inventory should include equipment such as scales, compression machines, and slump cones. Equipment such as tamping rods and expendable supplies such as single-use cylinder molds need not be included on the inventory.

10.1.1.5 Participation in proficiency sample programs (PSP). The laboratory shall participate in concrete or aggregate proficiency sample programs or both if the laboratory performs testing in both areas. The PSP used must meet the following criteria: (1) include a minimum of 10 participants, (2) issue a report that includes the laboratory's results, the average of all results, the standard deviation of the results, and rating(s) based on the number of standard deviations that the laboratory's results vary from the grand average for the test method(s) covered, (3a) include at least one of the following methods if the laboratory tests concrete: C 39/C 39M, C 138/C 138M, C 143/C 143M, C 173/C 173M, or C 231; and, (3b) include at least one of the following methods if the laboratory tests concrete aggregates: C 136, C 127, or C 128, (4) be independent of the participating laboratories, (5) distribute samples at least once annually, and (6) maintain a record of all sample test results from participants for at least 3 years.

NOTE 7—For additional guidance in selecting a proficiency sample program the laboratory may wish to consult Guide E 1301.

10.1.2 The laboratory shall establish procedures for responding to low proficiency sample program ratings. Ratings are considered to be low if the laboratory's result is beyond two standard deviations from the grand average on the final report.

10.1.3 The laboratory shall establish procedures for handling technical complaints from clients that includes the title or name of the individual responsible for handling the complaint, the review system in the laboratory and the type of reply to be issued.

10.1.4 The laboratory shall establish procedures for ensuring the quality of external technical services, such as: calibration services used by the laboratory, equipment and materials procured by the laboratory from vendors, and subcontractors (that is, a laboratory contracted to perform a standard test method or part of a test method). The laboratory should be able to demonstrate that the subcontractor is competent and is in compliance with the requirements of the test methods. The laboratory should maintain records of the subcontractor and vendor evaluations. The selection and evaluation criteria for the subcontractor should include a review of external audits, inspections, certifications, and laboratory accreditations held by the laboratory.

NOTE 8—Other recommended quality programs for a laboratory include: (*1*) Conducting within-laboratory statistical computations on concrete tests. Randomly selecting 10 tests per month and determining the within-test standard deviation (see ACI 214-77 and Practice C 802 for statistical methods); (*2*) Participation in an interlaboratory proficiency program on concrete tests. A quarterly exchange of samples between laboratories in accordance with Practice C 802 will provide excellent quality assurance data.

11. Laboratory Evaluation

11.1 The testing laboratory shall have its facilities, equipment, personnel, and procedures evaluated at intervals of approximately 24 months by an evaluation authority to confirm its ability to perform the required tests. The personnel and equipment used by the laboratory during the evaluation shall be representative of the personnel and equipment available during the period between evaluations. Temporary acquisition of personnel or equipment to enhance the results of the evaluation shall not be permitted.

11.2 Deficiencies noted in the final report provided to the laboratory by the evaluation authority shall be corrected within 30 days of receipt of the report.

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11.3 The laboratory shall (*1*) report deficiency corrections to the accrediting body who will issue a certificate of accreditation when their requirements are satisfied, or (*2*) if an inspection service is used, supplement copies of the final report with a statement of corrective actions taken signed by the laboratory's professional engineer.

12. Keywords

12.1 aggregates; concrete; criteria; evaluation; laboratory; quality assurance (QA); testing

SUMMARY OF CHANGES

Committee C09 has identified the location of selected changes to this practice since the last issue, C 1077 – 09a, that may impact the use of this practice. (Approved August 1, 2009)

(*1*) Removed the certification agency names in 6.1.2-6.1.6. Revised 6.1.7. Added new Note 2.

(*2*) Replaced "performance evaluation" with "performance examination" in Section 6.

Committee C09 has identified the location of selected changes to this practice since the last issue, C 1077 – 09, that may impact the use of this practice. (Approved July 1, 2009)

(*1*) Revised 9.2.1 and 9.2.2. Deleted old 9.2.3 and 9.2.4 and renumbered subsequent paragraphs.

(*2*) Revised 9.6 to clarify requirements for the retention of records. Added new Note 4 and renumbered subsequent notes.

Committee C09 has identified the location of selected changes to this practice since the last issue, C 1077 – 08a, that may impact the use of this practice. (Approved June 1, 2009)

(*1*) Revised the title of Section 6 from "Human Resources" to "Personnel Qualifications."

(*2*) Revised Section 3 and deleted 3.1.7.

Committee C09 has identified the location of selected changes to this practice since the last issue, C 1077 – 08, that may impact the use of this practice. (Approved December 1, 2008)

(*1*) Revised 4.1.

(*2*) Revised 11.1.

Committee C09 has identified the location of selected changes to this practice since the last issue, C 1077 – 07a, that may impact the use of this practice. (Approved November 1, 2008)

(*1*) Revised 3.1.1.1.

(*2*) Revised 10.1.1.5.

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Designation: C 1084 – 02

Standard Test Method for Portland-Cement Content of Hardened Hydraulic-Cement Concrete[1]

This standard is issued under the fixed designation C 1084; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope

1.1 This test method covers the determination of portland-cement content of a sample of hardened hydraulic-cement concrete.

1.2 The values stated in SI units are to be regarded as the standard. The values given in parentheses are provided for information purposes only.

1.3 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.* Disposal of some or all of the chemicals used in this method may require adherence to EPA or other regulatory guidelines.

2. Referenced Documents

2.1 *ASTM Standards:*

C 42 Test Method for Obtaining and Testing Drilled Cores and Sawed Beams of Concrete[2]

C 114 Test Methods for Chemical Analysis of Hydraulic Cement[3]

C 670 Practice for Preparing Precision and Bias Statements for Test Methods for Construction Materials[3]

C 702 Practice for Reducing Samples of Aggrgate to Testing Size[2]

C 823 Practice for Examination and Sampling of Hardened Concrete in Constructions[2]

C 856 Practice for Petrographic Examinations for Hardened Concrete[2]

D 1193 Specification for Reagent Water[4]

E 11 Specification for Wire-Cloth and Sieves for Testing Purposes[2]

E 832 Specification for Laboratory Filter Papers[5]

3. Significance and Use

3.1 This test method consists of two independent procedures: an oxide-analysis procedure that consists of two subprocedures and an extraction procedure. Each procedure requires a substantial degree of chemical skill and relatively elaborate chemical instrumentation. Except for the influence of known interferences, determined cement contents are normally equal to, or slightly greater than, actual values except for the Maleic Acid procedure where results can also be significantly low when the paste is carbonated (Note 1).

NOTE 1—With certain limitations, the procedure is also applicable for estimating the combined content of portland cement and pozzolan or slag in concretes made with blended hydraulic cement and blends of portland cement with pozzolans or slags. The results of this test method when applied to concretes made with blended cements or pozzolans depend on the composition of the pozzolan, the age of the concrete, the extent of reaction of the pozzolan and the fact that this test method may determine only the portland-cement component of a blended cement. The test method should be applied to determination of the blended cement content or the pozzolanic content only by use of calibration concrete samples or other information. Earlier versions of this test method can provide useful information as detailed by Hime[6] and Minnick.[7]

4. Interferences

4.1 Many constituents of concrete may interfere with the analysis of the concrete for portland-cement content. The following limited lists of materials have been provided as a guide. The rocks, minerals or mineral admixtures listed will interfere with the cement content determination to the extent of their solubility during the dissolution procedure used. The solubility of rocks, minerals or mineral admixtures may depend on the fineness of the test sample, the water-cement ratio of the concrete, the extent of hydration, and the age of the concrete (extended exposure to the high pH of the concrete may affect the solubility of some minerals).

[1] This method is under the jurisdiction of ASTM Committee C09 on Concrete and Concrete Aggregates and is the direct responsibility of Subcommittee C09.69 on Miscellaneous Tests.

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[2] *Annual Book of ASTM Standards*, Vol 04.02.

[3] *Annual Book of ASTM Standards*, Vol 04.01.

[4] *Annual Book of ASTM Standards*, Vol 11.01.

[5] *Annual Book of ASTM Standards*, Vol 15.09.

[6] Hime, W. G., "Cement Content," *Significance of Tests and Properties of Concrete and Concrete-Making Materials, ASTM STP 169B*, ASTM, 1978, pp. 462–470, and "Analyses for Cement and Other Materials in Hardened Concrete," Chapter 29, Significant of Tests and Properties of Concrete and Concrete-Making Materials, ASTM STP 169C, 1994, pp. 315–319.

[7] Minnick, L. J., "Cement-Content, Hardened Concrete," *Significance of Tests and Properties of Concrete and Concrete-Making Materials*, ASTM STP 169A, ASTM, 1966, p. 326–329.

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4.2 *Substances Affecting Calcium Oxide Sub-procedure*:

4.2.1 The following are soluble in even the cold dilute hydrochloric acid of this procedure and will contribute a high bias to the cement content calculated from the soluble calcium oxide: limestone, marble, dolomitic limestone, calcareous sandstone, calcareous chert, and caliche encrusted and calcite or dolomite coated rocks.

4.2.2 The following may be soluble depending on the age and pH of the concrete; whether the mineral present is glassy or crystalline, or weathered or strained; and the fineness of the mineral present, and, if soluble, will bias the cement content calculated from the soluble calcium oxide high depending on the calcium content of the minerals: weathered or altered plagioclase feldspar, caliche-encrusted rocks, altered volcanic rocks (with calcareous inclusions), and many other calcium containing rocks.

4.2.3 Every percent of soluble calcium oxide that is contributed by soluble aggregate or mineral admixtures will bias the cement content high by approximately 1.6 %.

4.2.4 Silica fume may lower the acid solubility of the sample and hence bias the result low.

4.3 *Substances affecting the Soluble Silica Sub-procedure*:

4.3.1 The following may be soluble depending on the age and pH of the concrete; whether the aggregate is glassy or crystalline, or weathered or strained; and the fineness of the mineral: chert, opal, chalcedony, glassy volcanic rock, strained quartz (highly strained), quartzite, cataclastic rocks (mylonite, phyllonite), gneiss, schist, metagraywacke, and many other soluble silicon containing rocks or minerals.

4.3.2 Every percent of soluble SiO_2 contributed by aggregates or mineral admixtures will bias the reported cement content high by approximately 4.7 %.

4.3.3 Silica fume may lower the acid solubility of the sample and hence bias the result low. If the digestion time or temperature are sufficient to digest all of the portland cement, the silica fume will also be solubilized and bias the calculated cement content high.

4.4 *Substances affecting the Maleic Acid Procedure*:

4.4.1 The same substances that are soluble in the soluble calcium or the soluble silica subprocedures may be soluble in the maleic acid procedure. (See 4.2.1, 4.2.2 and 4.3.1.)

4.4.2 Every 1 % of the sample that is aggregate or mineral admixture dissolved by the maleic acid will bias the cement content high by 1 %.

4.4.3 Carbonated cement paste may not be soluble in the maleic acid-methanol dissolution and thus may bias the cement content results low.

4.4.4 The unhydrated iron and aluminum phases of the portland cement may not be soluble in the maleic acid and, if not soluble, will bias the cement content low. This may be significant at early ages and less significant at later ages.

5. Apparatus

5.1 Choose the apparatus from applicable items given in Test Methods C 114 and from the following:

5.1.1 Chipmunk (jaw ore crusher).

5.1.2 Disk Pulverizer.

5.1.3 Rotary Mill (rotating puck).

5.1.4 Sieve, 300 um (No. 50), 1.18-mm (No. 16) and 4.75-mm (No. 4).

5.1.5 Ice Bath or electric cooling apparatus.

5.1.6 Steam Bath.

5.1.7 Funnel, Buchner-type porcelain funnel.

5.1.8 Filter Paper, Type II, Class F and Class G as described in Specification E 832.

5.1.9 Beakers, 1000 and 250 mL.

5.1.10 Magnetic stirrer, variable speed, with a TFE-fluorocarbon-coated magnetic stirring rod, or an overhead stirrer with a propeller.

5.1.11 Volumetric flask, 1000 mL and 500 mL.

5.1.12 Filtering flask, 2000 mL.

5.1.13 Vacuum pump.

5.1.14 Watch glass, 125 mm.

6. Reagents and Materials

6.1 *Soluble Silica Sub-procedure*:

6.1.1 *Hydrochloric Acid*, reagent grade, density 1.19 Mg/m^3.

6.1.2 *Hydrochloric Acid (1:3)*—Mix 300 mL of hydrochloric acid into 900 mL of water.

6.1.3 *Hydrochloric Acid (1:9)*—Mix 100 mL of hydrochloric acid into 900 mL of water.

6.1.4 *Sodium Hydroxide (10 g/L)*—Dissolve 5 g of reagent grade sodium hydroxide in 200 mL of water and dilute to 500 mL.

6.1.5 *Hydrofluoric Acid*, 48 %, reagent grade.

6.1.6 *Sulfuric Acid*, density 1.84 Mg/m^3, reagent grade.

6.2 *Calcium Oxide Sub-procedure*—Use reagents as required in Test Methods C 114.

6.3 *Maleic Acid Procedure*:

6.3.1 *Maleic acid*, technical grade.

6.3.2 *Methanol*, technical grade, anhydrous.

6.3.3 *Maleic acid solution*—prepare a fresh solution of 15 % maleic acid in methanol by dissolving and diluting 180 + 1 g of maleic acid with methanol to a final solution volume of 1200 millilitres. Prepare this solution fresh daily. Care must be taken to use methanol only in well ventilated areas, preferably under a hood, to avoid skin contact and breathing vapors. Disposal of the maleic acid/methanol solution shall be according to applicable regulations.

6.3.4 *Fuller's earth*—a clay-like material consisting of a porous colloidal aluminum silicate. Its high adsorptivity has been found very beneficial for decolorizing and purifying materials.

6.4 *Water*—All references to water shall be understood to mean reagent water Types I through IV of Specification D 1193.

7. Sampling

7.1 Choose the concrete sample in accordance with the purposes of the investigation (Note 2).

NOTE 2—A standard procedure for sampling hardened concrete is given in Practice C 823 and a standard procedure for obtaining cores is given in Test Method C 42.

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7.2 Both the sample for cement content and for density shall have a minimum length and diameter of four times the nominal maximum size of the aggregate (Note 3).

NOTE 3—A single concrete core taken through the entire depth of the concrete is ordinarily an appropriate sample. This sample may be sawed or split lengthwise to provide samples for cement content, density, and petrographic examination, provided that the length and thickn ess of the split samples for cement content and density meet the minimum size specified in 7.2. If the split sample would not meet the minimum size requirement, perform the density measurement first, and then crush the entire dry sample for cement content determination. The recommended mass of concrete for cement content determination is 4.5 kg (10 lb). This mass should be obtained from more than one core when the concrete depth is small and one core will not supply a mass of 4.5 kg (10 lb). If the concrete sample did not have a mass of 4.5 kg (10 lb) it should be so stated in the final report for the cement content result.

7.3 For cement content determination, crush the sample to pass a 4.75-mm (No. 4) sieve, mix thoroughly, and obtain a representative subsample for analysis by coning and quartering or by riffle splitting as described in Practice C 702. The subsample should have a mass of 0.45 kg (1 lb).

8. Cement Content Procedure

8.1 *Oxide Analysis Procedure*:

8.1.1 Crush or grind the subsample prepared as described in 7.3 using a chipmunk (jaw ore crusher), a disk pulverizer, or a rotary mill (rotating-puck) device, so that all of the material passes a 300-μm (No. 50) sieve. To minimize production of very fine material, use several passes of the sample through the equipment, removing the portion passing the sieve before regrinding the remainder of the sample. Thoroughly mix by coning ten times from one paper to another.

8.1.2 Dry the crushed or ground material in an oven at 105 to 115°C (220 to 240°F) for 3 h and retain the sample in a sealed container.

8.1.3 *Sub-procedure to be used*:

8.1.3.1 The soluble silica sub-procedure shall be performed in all cases except where a petrographic examination has indicated there are siliceous aggregates or mineral admixtures that will be soluble in cold hydrochloric acid.

8.1.3.2 The calcium oxide sub-procedure shall also be employed unless the aggregate contains a significant amount of calcareous components.

8.1.3.3 All analyses shall be done in triplicate and the average of the three values used in calculating cement content.

8.1.4 *Soluble Silica Sub-procedure*:

8.1.4.1 Introduce 100 mL of dilute hydrochloric acid (1:3) into each of three 250-mL beakers. Cool until within the range of 3 to 5°C (38 to 41°F), using an ice bath or electric cooling apparatus.

8.1.4.2 Weigh a 2 g sample to 0.001 g and slowly, over a 1-min period, add it to the cold hydrochloric acid. Maintain the 3 to 5°C (38 to 41°F) temperature for a 5-min period, and stir the mixture either continuously or at least several times during this period (Note 4).

NOTE 4—Observation of the solution during the introduction of the sample may provide useful information. Considerable effervescence indicates a substantial amount of calcite or carbonated paste. Delayed effervescence suggests a dolomitic aggregate. Lack of effervescence suggests the applicability of the calcium oxide sub-procedure.

8.1.4.3 Decant through a Buchner-type porcelain funnel fitted snugly with two disks of a quantitative filter paper for fine precipitates, Type II, Class G filter paper. Once the filtration has begun, take care so that the mat and accumulated residue do not dry completely until the filtration process is complete. Regulate the suction so as to maintain a rapid rate of dripping during the greater part of the filtration. Retain as much of the residue in the beaker as possible. Wash twice by decantation with hot water. Save the filtrate. Transfer the filter paper from the funnel to the beaker containing the balance of the residue, being careful that no residue is lost. Add 75 mL of hot sodium hydroxide solution (10 g/L) to the residue while stirring, macerate the filter paper, and digest, covered, on a steam bath for 15 min. During the digestion, occasionally stir the mixture. Filter all solids, and wash twice with hot water until the filtrate is neutral to litmus. Combine the filtrates.

8.1.4.4 The filtrate now contains the silica in the form of silicic acid, either in true solution or in suspension in the hydrochloric acid medium. To ensure analysis of only the soluble silicon, refilter any filtrate that is cloudy. (Allowing the filtrate to stand overnight will usually permit suspended silica to settle.) The soluble silica may be analyzed by either of the following procedures 8.1.4.4.1 or 8.1.4.4.2.

8.1.4.4.1 *Analysis of soluble silica by conversion to silicon tetrafluoride with hydrofluoric acid*—In the case where the aggregate of the original sample contains substantial amounts of material that yields calcium oxide (CaO) on acid treatment, add 10 mL of hydrochloric acid (density 1.19 Mg/m^3) to the solution from 8.1.4.4. Transfer to a suitable beaker, with several rinsings of the filter flask. Evaporate to dryness with great care to minimize spattering, bake at not over 120°C (248°F) for 1 h, moisten with hydrochloric acid (density 1.19 Mg/m^3), evaporate and bake again, and take up for filtration in 75 mL of hydrochloric acid (1:3). Heat to boiling, filter through an ashless filter paper, and wash the residue with 50 mL of hot hydrochloric acid (1:9) and then with hot water until the washings are free of chlorides. Determine the silica present in the sample by treatment with hydrofluoric acid and sulfuric acid in accordance with the procedure given in Test Methods C 114.

8.1.4.4.2 *Instrumental analysis of soluble silica*—Transfer the filtrate from 8.1.4.4 to a 500-mL volumetric flask with several rinsings of the filtration flask and bring the volume in the volumetric flask to 500 mL with water. Analyze the soluble silica by any instrumental method found acceptable for cement analysis in accordance with the performance requirement for rapid methods of Test Methods C 114, provided it can be applied to the filtrate. Suitable instrumental techniques may include atomic absorption or inductively coupled plasma spectroscopy.

8.1.4.5 *Calculation*—Calculate the cement percentage, C_s, by dividing the percent silica (SiO_2) in the concrete by the percent silica (SiO_2) in the cement, and multiplying by 100. If the cement silica value is unknown, assume 21.0 %.

8.1.5 *Calcium Oxide Sub-procedure*—Calcium oxide may be determined by either of the following procedures. Omit the determination if it is known that the aggregate contains substantial amounts of calcareous components.

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8.1.5.1 *Oxalate precipitation of calcium*— Using the filtrate from the removal of silica (8.1.4.4), separate the ammonium hydroxide group and then determine the calcium oxide, both in accordance with Test Methods C 114, or proceed as described in 8.1.5.2.

8.1.5.2 *Instrumental analysis of calcium oxide*—Any calcium method found acceptable for cement analysis in accordance with the performance requirements for rapid methods of Test Methods C 114 may be used, provided that the method may be applied to the filtrate of . Further, the method must be acceptable for cement analysis in the same silica-present or silica-absent condition as is the case for the state of analysis of the concrete.

8.1.5.3 *Calculation*—Calculate the cement percentage, C_c, by dividing the percentage calcium oxide in the concrete by the percentage calcium oxide in the cement, and multiplying by 100. If the cement calcium oxide value is unknown, assume 63.5 %.

8.2 *Maleic Acid Extraction Procedure*:

8.2.1 Crush or grind and dry the sample as described in 8.1.1 and 8.1.2 except that the material shall pass a 1.18-mm (No. 16) sieve meeting Specification E 11.

8.2.2 *Combined water*—Measure 10 g of the dried crushed sample to the nearest 0.001 g into a tared pre-heated crucible, and dry at 520 ± 5°C for 3 h or to constant mass (Note 5). Cool in a desiccator and determine the mass.

NOTE 5—The temperature of 540°C should not be exceeded to avoid the decomposition of calcitic or dolomitic carbonates in certain aggregates.

8.2.2.1 Calculate the percentage of combined water as follows:

$$L_c\,\% = \frac{(C - D) \times 100}{C} \quad (1)$$

where:

L_c = percent combined water, dry basis,
C = mass of dried sample, g, and
D = mass after heating at 520°C, g.

8.2.3 *Extraction*—Determine the mass of a 20-g sample of the ground dried concrete and a 2.5-g sample of Fuller's earth, dried at 105 to 115°C (220 to 240°F), to 0.001 g, and transfer both to a 1000-mL beaker or flask. Add 800-mL of maleic acid solution, and stir with a magnetic stirrer (or overhead stirrer equipped with a propeller) for 60 min. Allow the mixture to settle for 60 min. Filter the solution by carefully decanting through a Whatman 41 filter paper or equivalent of known mass fitted into a 100-mm Buchner funnel, using suction, and collect the filtrate in a 2000-mL vacuum filtering flask. Allow the residue to remain in the beaker.

8.2.3.1 Add 400-mL of maleic acid solution to the residue in the beaker, and stir for 10 min. Allow the mixture to settle for 30 min, and filter the entire contents of the beaker through the original filter paper. Rinse the beaker thoroughly with methanol to insure complete transfer. Wash the residue contained on the filter paper 4 to 5 times with approximately 50 mL portions of methanol to remove any residual maleic acid. Also wash any iron fillings that may be attached to the magnetic stir bar into the Buchner funnel. The filtrate should be clear.

8.2.3.2 Transfer the filter paper and residue onto a 125-mm watch glass, and place in an oven at 105°C (220°F). Dry to a constant mass, and determine the mass of the residue and filter paper to the nearest 0.001 g.

8.2.4 *Calculation*—Calculate the percentage of insoluble residue as follows:

$$R,\,\% = \frac{(F - G) \times 100}{E} \quad (2)$$

where:

R = percent insoluble residue,
E = mass of sample used, g,
F = combined mass of residue, filter paper, and Fuller's earth, g, and
G = combined mass of filter paper and Fuller's Earth, g.

8.2.5 *Calculation*—Calculate the percent cement content, C_m by subtracting R and L_c from 100.

9. Unit Weight and Loss of Free Water

9.1 Determine the density of a separate sample of the concrete, of a minimum dimension four times the maximum size of the aggregate and a sample mass of at least 0.45 kg (1 lb), as follows:

9.1.1 *Saturated surface dry density*— For saturated surface dry density, which will usually correlate well with the density of the concrete as placed. Immerse the concrete in water and soak it for a minimum of 24 h or to constant weight. (Constant weight may take 48 h for ½ of a 100-mm (4-in.) diameter core.) Determine the mass of the sample while immersed in the water to the nearest 0.1 g (0.001 lb). Remove from the water, surface dry, and determine the mass to the nearest 0.1 g (0.001 lb). Calculate the density, D_{SSD}, in kilograms per cubic metre (or alternately in pounds per cubic foot), as:

$$D_{SSD} = \frac{W_1 \times \rho}{W_1 - W_2} \quad (3)$$

where:

D_{SSD} = saturated surface dry unit weight, kg/m^3(or alternately lb/ft ^{3}),
W_1 = saturated surface dry (SSD) mass in air after the 48 h soak, kg,
W_2 = SSD mass suspended and immersed in water, kg, and
ρ = density of water, 997 kg/m ^{3}(62.3 lb/ft^3).

9.1.2 *Dry unit weight and free water*— Dry the sample from 9.1.1 for a minimum of 24 h or to constant weight at 105 to 115°C (220 to 240°F). Cool. Determine the mass to the nearest 0.1 g (0.001 lb). Calculate the density, D_{SSD}, in kilograms per cubic metre (pounds per cubic foot), and the free water, L_f, as:

$$D_{dry} = \frac{D_{SSD} \times W_3}{W_1} \quad (4)$$

$$L_f = \frac{(W_1 - W_3) \times \rho}{(W_1 - W_2)}$$

where:

D_{SSD} = saturated surface dry unit weight, kg/m^3(or alternately lb/ft ^{3}),
W_1 = saturated surface dry (SSD) mass in air after the 48 h soak, kg,

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W_3 = dry mass, kg, and
L_f = free water, kg/m^3(or alternately lb/ft^3).

10. Additional Calculations

10.1 *Cement Content*—Calculate the cement content of the concrete from the data for each procedure used, as follows:

$$\text{Cement content, kg/m}^3 = \frac{C \times D_1}{100} \quad (5)$$

$$\text{Cement content, lb/yd}^3 = \frac{C \times D_2 \times 27}{100} \quad (6)$$

where:
C = determined cement percentage, percent by mass, either as C_s, C_c, or C_m,
D_1 = D_{dry}, kg/m^3,
D_2 = D_{dry}, lb/ft^3.

11. Report

11.1 Report the cement percentage, and if required, the cement content, to the nearest kg/m^3(lb/yd^3), as follows:

11.1.1 If two or more procedures or subprocedures have been performed, report the lowest result and report the procedure used.

12. Precision and Bias

12.1 *Precision*—The precision of the cement content test procedures is dependent upon the composition of the concrete.[8]

12.1.1 The use of the soluble silica procedure may lead to erroneously high results for concretes that contain siliceous aggregates, pozzolans, or other cementitious components.

12.1.2 The use of the calcium oxide procedure will lead to erroneously high results if calcareous aggregates or other cementitious materials are present, and may do so with many pozzolanic materials.

12.1.3 The use of the maleic acid procedure may lead to erroneously low or high results, depending upon the solubility of the aggregates in the maleic acid solution, the amount of unhydrated aluminate and ferrite phases in the cement which are insoluble, and the carbonation of the paste.

12.1.4 For these reasons, precision data obtained on one concrete may not be useful in estimating that obtainable for another concrete.

12.1.5 The following sections on the soluble silica and calcium oxide procedures are based on results of cooperative analyses of a suite of three samples (Note 6), one having an aggregate providing a calcium interference, one an aggregate providing a silica interference, and one providing both interferences.

NOTE 6—These precision statements are based on tests of samples that were ground to pass a 600-mm (No. 30) sieve by a single laboratory. For this reason, interlaboratory tests did not include any variation in results that will occur because of sampling and sample preparation.

12.1.6 The section on maleic acid extraction is based on results of cooperative analyses from eleven laboratories on a suite of four concrete samples (Note 7), one with a limestone coarse aggregate, one with dolomite, and two with siliceous aggregates. One specimen contained fly ash. Total cementitious material contents ranged from 250 to 355 kg/m^3(400 to 600 lb/yd^3).

NOTE 7—This precision statement is based on tests of samples that were ground to pass a 1.18 mm (No. 16) sieve by a single laboratory. For this reason, interlaboratory tests did not include any variation in results that will occur because of sampling and sample preparation.

12.1.7 *Soluble Silica Procedure*—The single laboratory standard deviation has been found to be 15.6 kg/m^3(26.3 lb/yd^3) (Note 8). Therefore, results of two properly conducted tests in the same laboratory on the same material should not differ by more than 44.1 kg/m^3(74.3 lb/yd^3) (Note 8).

12.1.7.1 The miltilaboratory standard deviation has been found to be 25.1 kg/m^3(42.3 lb/yd^3) (Note 8). Therefore, results of two properly conducted tests from two different laboratories on samples of the same material should not differ by more than 71.4 kg/m ^{3}(120.3 lb/yd^3) (Note 8).

12.1.8 *Calcium Oxide Procedure*—Where applicable, the single laboratory standard deviation has been found to be 2.8 kg/m ^{3}(4.7 lb/yd^3) (Note 8). Therefore, results of two properly conducted tests in the same laboratory on the same material should not differ by more than 7.8 kg/m^3(13.2 lb/yd^3) (Note 8).

12.1.8.1 The multilaboratory standard deviation has been found to be 10.0 kg/m^3(16.9 lb/yd^3) (Note 8). Therefore, results of two properly conducted tests from two different laboratories on samples of the same material should not differ by more than 28.4 kg/m ^{3}(47.9 lb/yd^3) (Note 8).

NOTE 8—These numbers represent, respectively, the 1s and d2s limits as described in Practice C 670.

12.1.9 *Maleic Acid Procedure*—The single laboratory standard deviation has been found to be 14 kg/m^3(24 lb/yd^3) (Note 8). Therefore, results of two properly conducted tests in the same laboratory on the same material should not differ by more than 40 kg/m^3(67 lb/yd^3) (Note 8).

12.1.9.1 The multilaboratory standard deviation has been found to be 22 kg/m^3(37 lb/yd^3) (Note 8). Therefore, results of two properly conducted tess from two different laboratories on samples of the same material should not differ by more than 62 kg/m ^{3}(104 lb/yd^3) (Note 8).

12.2 *Bias*—The bias of the test procedures is dependent upon the composition of the concrete for reasons described in 12.1.1-12.1.3. For these reasons, bias data obtained on one concrete may be useless in estimating that obtainable for another concrete. Refer to 12.1.5 for a description of the test program on which the following is based.

12.2.1 *Soluble Silica Subprocedure*—For the soluble silica procedure, determined values may be expected to be from about 20 kg/m^3(50 lb/yd^3) below the true value to 10 kg/m^3(25 lb/yd^3) above for no silica interference, to 45 kg/m^3(100 lb/yd^3) or more above for severe silica interferences (for example, for samples containing slag or volcanic aggregate, or a fly ash addition).

12.2.2 *Calcium Oxide Subprocedure*—Where the calcium procedure is applicable, determined values should be within 10 kg/m^3(25 lb/yd^3) of the true value.

12.2.3 The use of either of the oxide determination procedures may lead to error to the extent that the oxide content used

[8] Supporting data have been filed at ASTM International Headquarters and may be obtained by requesting Research Report RR:C09-1003 and RR:C09-1012.

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for calculations differs from the true value for the cement. Errors greater than 4 % relative are unusual for this parameter.

12.2.4 Bias may be reduced by analysis of separate samples of calcareous aggregates representing those used in the concrete, employing the same procedures and applying corrections based on mix design data or estimates of aggregate proportion as based on petrographic studies. Where corrected values are 45 kg/m^3(100 lb/yd^3) or more below uncorrected values, the method is probably inapplicable.

12.2.5 *Maleic Acid Procedure*—The bias of the maleic acid procedure is dependent upon the composition of the concrete for reasons stated in 12.1.3. Based on the mean values from the interlaboratory test program described under Precision, the values determined should be within – 10 to + 4 kg/m^3(–17 to + 6 lb/yd^3) of the actual values.

12.2.5.1 Approximately 40 % of the fly ash in the interlaboratory test program was consumed in the extraction and contributed to the determined cement content of the concrete. Other sources have found that variable amounts of fly ash can be consumed in some cases. This demonstrates the need for caution and compensation for induced bias when testing concretes containing fly ash, slag, silica fume, or natural pozzolans. Various sources of these materials will have highly variable effects on the results from this test.

12.2.5.2 Concrete samples that have deeply carbonated should be tested with caution as the maleic acid test results can be significantly affected, producing erroneously low cement content values.

12.2.6 Particular aggregate sources have been found to significantly affect the bias of this test method. Therefore, the separate testing of aggregate materials may be useful to indicate the solubility of the materials and possible significant contribution from the aggregate to the cement content results.

12.2.7 Petrographic studies such as those performed according to Practice C 856 can be useful in indicating potential interferences to each of the cement content procedures.

13. Keywords

13.1 cement content; concrete; hardened

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Designation: C 1090 – 01 (Reapproved 2005)ε1

Standard Test Method for Measuring Changes in Height of Cylindrical Specimens of Hydraulic-Cement Grout[1]

This standard is issued under the fixed designation C 1090; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

ε[1] NOTE—Footnotes 4 and 5 were removed editorially June 2005.

1. Scope

1.1 This test method covers measurement of the changes in height of hydraulic-cement grout by the use of 75 by 150-mm (3 by 6-in.) cylinders, when the cylinders are protected so that the tendency to change in height does not include evaporation so as to cause drying, uptake of moisture, carbonation, or exposure to temperatures outside the range 23 ± 2.0 °C (73 ± 3 °F) or, optionally, to another specified temperature controlled within ± 2.0 °C (± 3 °F).

1.2 If desired, this test method can be adapted to studies of changes in height involving either schedules or environmental treatment different from the standard procedures prescribed by this test method.

1.3 The values stated in SI units are to be regarded as the standard.

1.4 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

2. Referenced Documents

2.1 *ASTM Standards:* [2]

C 172 Practice for Sampling Freshly Mixed Concrete

C 305 Practice for Mechanical Mixing of Hydraulic Cement Pastes and Mortars of Plastic Consistency

C 511 Specification for Mixing Rooms, Moist Cabinets, Moist Rooms, and Water Storage Tanks Used in the Testing of Hydraulic Cements and Concretes

C 670 Practice for Preparing Precision and Bias Statements for Test Methods for Construction Materials

C 827 Test Method for Change in Height at Early Ages of Cylindrical Specimens from Cementitious Mixtures

C 939 Test Method for Flow of Grout for Preplaced-Aggregate Concrete (Flow Cone Method)

3. Terminology

3.1 *Definition of Term Specific to This Standard:*

3.1.1 *change in height*—either an increase or decrease in the vertical dimension of a test specimen, provided the change has been caused by factors other than externally applied forces, changes in ambient temperature not conforming to the specified range, drying caused by evaporation, carbonation, or uptake of moisture.

4. Significance and Use

4.1 This test method is intended to provide a means of assessing the ability of a hydraulic-cement grout to retain a stable volume during the stipulated testing period of 28 days, provided that the tendency to change height does not include the effects of drying caused by evaporation, uptake of moisture, carbonation, or exposure to temperatures outside the range 23.0 ± 2.0 °C (73 ± 3 °F) (Note 1). An exception is made when the options described in the section on test conditions are exercised.

NOTE 1—This test method does not measure the change in height before hardening (see Test Method C 827).

5. Apparatus

5.1 *Cylinder Molds* steel cylindrical molds with minimum wall thickness of 6 mm (¼ in.) fitted with clamp assemblies for closing, 75 mm (3 in.) ± 1 % in inside diameter by 150 mm (6 in.) ± 2 % in height (Note 2)), fitted with a removable 6-mm (¼-in.) steel base plate that can be clamped in place with the cylinder molds, top edge machined to a narrow rim as shown in Fig. 1.

[1] This test method is under the jurisdiction of ASTM Committee C09 on Concrete and Concrete Aggregates and is the direct responsibility of Subcommittee C09.68 on Volume Change of Concrete.

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[2] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

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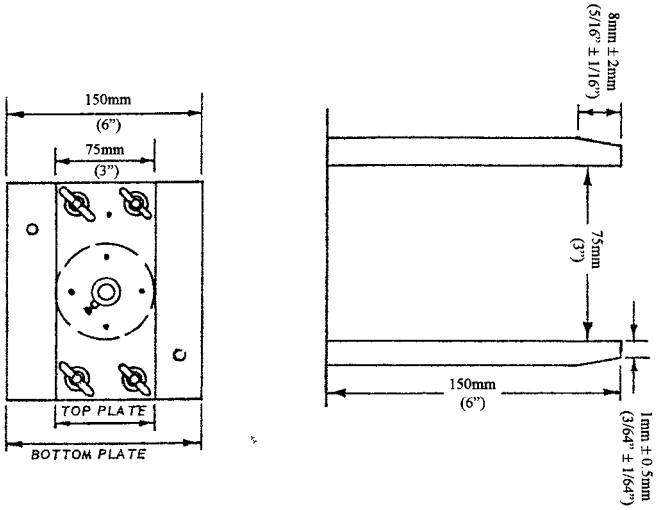


FIG. 1 Cylinder Mold with Machined (Tapered) Top Edge

NOTE 2—Satisfactory molds can be made from lengths of steel tubing or pipe that is slit on one side parallel to the longitudinal axis and fitted with a means of closing the vertical slit as well as a means of attaching a base plate.

5.2 *Glass Plate* approximately 100 mm (4 in.) square by 6 mm (¼ in.) thick, coated as thinly as possible on one surface with a silicone-base spray or other inert material such as mineral oil, and permitted to dry before use.

5.3 *Hold-Down Weight* having a mass of 1.5 kg (3 lb.) ± 1 %.

5.4 designed to support and hold one cylinder in a level, firm position (Fig. 2), with steel rods, and a top made of noncorroding metal, not more than 1 mm (3⁄64 in.) larger than the diameter of the measuring shaft of the micrometer depth gage, and numbered 1 to 4 (Note 3).

NOTE 3—The four holes should be 30 ± 2 mm (1¼ ± 1⁄16 in.) from the center of the hold-down device.

5.5 *Micrometer Depth Gage* having a range from 25 to 50 mm. (1.000 to 2.000 in) graduated in units not larger than 0.02 mm (0.001 in.) (Note 4).

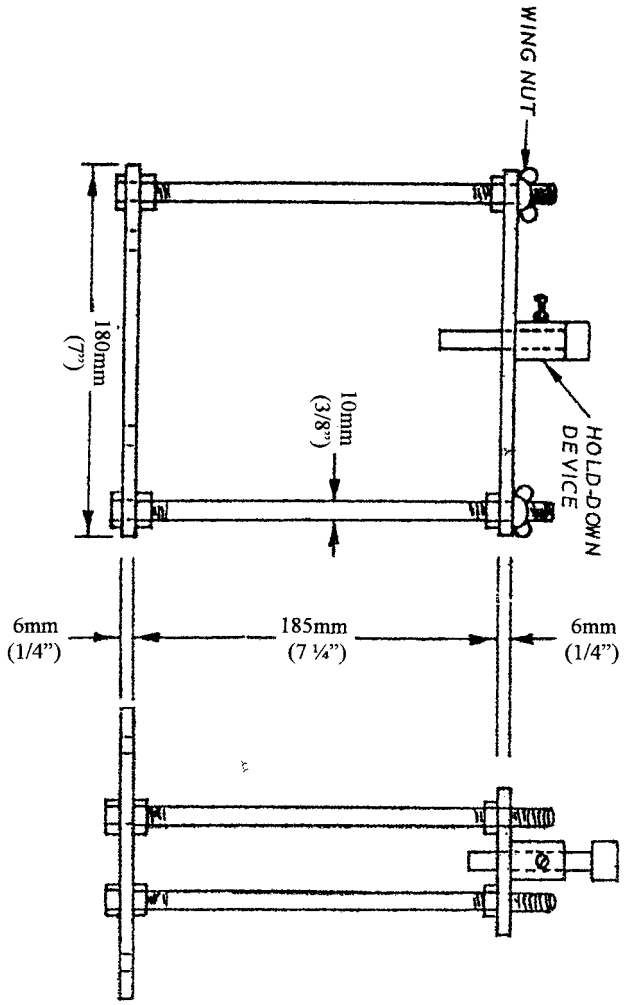
NOTE 4—The diameter of the shaft of the depth micrometer should be 3.0 ± 0.4 mm (⅛ ± 1⁄64 in.).

5.6 *Outside Micrometer Caliper*, used to measure the thickness of the plate, with a capacity of at least 12 mm (½ in.) and graduated in units not larger than 0.02 mm (0.001 in.) having throat depth of at least 50 mm (2.0 in.).

5.7 *Tamping Rod*, a straight steel rod with at least the tamping end rounded to a hemispherical tip of the same diameter as the rod, 10 mm (⅜ in.) in diameter and at last 250 mm (10 in.) long.

5.8 *Mechanical Mixer*, as described in Practice C 305 (Note 5).

NOTE 5—This mixer has clearances between paddle and bowl that are suitable only for mortars made with fine aggregates that are finer than the 850-µm (No. 20) sieve. Mortars made with aggregates containing particles coarser than the 850-µm sieve may require special clearance or a different type of paddle to permit the mixer to operate freely and avoid damage to the paddle and bowl.



NOTE 1—All parts of this bridge shall be made of a noncorroding metal.
NOTE 2—The diameter of the measuring shaft of the depth micrometer shall be 3.0 ± 0.4 mm (⅛ ± 1⁄64 in. The four holes should be 25 ± 1 mm (1 ± 1⁄16 in. from the center of the cylinder as shown in Fig. 1.

FIG. 2 Dimensions of Micrometer Bridge

6. Preparation of Sample

6.1 Take a sample of the freshly mixed grout to be tested either in accordance with Practice C 172 or prepared in sufficient quantity to permit molding at least one test specimen for height-change measurements and such additional tests as may be required or specified.

6.2 If the grout to be tested is blended from individual components, mix in accordance with Practice C 305 (Note 6). If the grout is made using a packaged product, proceed as follows, unless otherwise recommended by the manufacturer.

6.2.1 Use 3000 to 3500 g of dry material as required and the proportionate amount of water required for the test. Record amounts used.

6.2.2 Place mixing water in mixing bowl.

6.2.3 Add dry material during the first 30-s period while mixing at slow speed, 140 ± 5 r/min.

6.2.4 Continue mixing for 3 min, stopping the mixer for not over 15 s after 1 min to scrape down into the batch any grout that may have collected on the side of the bowl.

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NOTE 6—If the grout contains fine aggregate, the mixing procedure for mortar is applicable; if it does not, that for paste is applicable.

6.3 Cast the sample and lock the glass plate, micrometer bridge, top plate, plunger, and weight into position within 4 min after completion of mixing. Complete the initial measurements within 3 min after completion of these operations.

6.4 If it is required or desired to cast the specimen after a longer holding period, continue mixing of either the whole or remaining portion, as appropriate, at slow speed for the specified time and the sample cast, apparatus locked, and take initial measurements within 3 min after completion of these operations.

7. Preparation of Apparatus

7.1 Coat the exterior seams of the cylinder mold and the exterior joint between the mold and the base plate with melted paraffin wax. Coat the interior of the cylinder mold and base plate lightly with mineral oil (Note 7). Attach the mold to the micrometer bridge.

NOTE 7—The exterior of the mold and the base plate may be coated with paraffin wax to facilitate cleanup after completion of the test.

8. Conditioning

8.1 Keep the air temperature at 23 ± 2 °C (73 ± 3 °F), and a relative humidity of not less than 50 %. Store the test specimen at a temperature of 23 ± 2 °C for the duration of the test, unless otherwise specified. When it is desired to test the height change of material that is permitted to be used in the field at temperatures either below or above 23 ± 2 °C, use such other temperatures controlled to ±2 °C (3 °F) throughout instead of 23 ± 2 °C. Record the temperature of the mixing water, other materials, and of the mixture immediately after mixing is completed. Store the height-change apparatus in air at the desired test storage temperature within ±2 °C before casting the specimen.

8.2 Protect the test specimen from loss of moisture, absorption of moisture, or reaction with carbon dioxide for the duration of the test. Store the specimen in the moist room or in laboratory air described as follows: Under either condition, the specimen shall remain protected at all times during the test for 28 days except during removal of the glass plate and the taking of measurements.

8.2.1 *Moist Room Storage*—Immediately after taking the initial measurements, cover the plunger and bridge apparatus with a plastic bag previously fitted and cut to a length that extends downward to the midpoint of the specimen mold to prevent water from dripping on the bridge, glass plate, or specimen. Then carefully place the specimen in a moist room or moist cabinet meeting the requirements of Specification C 511.

8.2.2 *Laboratory Air Storage*—Prior to casting the test specimen, place the entire apparatus in a prefitted plastic bag just large enough to be gathered and tied above the plunger and bridge. Roll down or collapse the bag so as not to interfere with the casting operation. Immediately after taking the initial measurement, place a damp, but not dripping, towel around the outside of the lower portion of the four posts supporting the bridge, inside the plastic bag. The towel shall extend upward, but not to more than half the height of the cylinder. Gather and tie the plastic bag just above the plunger and bridge.

8.2.3 *Subsequent Storage*—If after 28-days storage, as previously described, it is desired to observe height change while allowing some drying or carbonation, or both, to occur, remove the specimen from the moist room, or from being protected by the plastic bag and damp towels, exposed to air at 50 ± 4 % relative humidity and at the same temperature at which the test was previously maintained.

9. Procedure

9.1 Place the apparatus on a smooth, horizontal surface, which is free of vibration or disturbance. Remove the top of the bridge after it has been pre-leveled parallel to the top of the mold rim by using the four lower nuts.

9.2 Determine consistency in accordance with Test Method C 827. Consider mixtures having a flow of less than 100 % as "stiff plastic;" those having flows between 100 and 125 % are considered "plastic." A "flowable" mixture shall have a flow between 125 and 145 % when tested in accordance with Test Method C 827, but not less than 30 s when tested in accordance with Test Method C 939. A "fluid" mixture shall have a flow of 10 to 30 s when tested in accordance with Test Method C 939.

9.3 When testing a material that does not flow easily into the mold, fill by using three equal layers, rod each layer 15 times with the tamping rod. When testing materials that flow easily into the mold, fill the mold and tap the side of the mold lightly three times with the tamping rod. Use sufficient material so that after consolidation the mold is slightly overfilled.

9.4 Carefully place the coated surface of the glass plate on top of the test specimen as follows: Hold the plate, coated side down, with the index finger placed in the center and the thumb and other fingers on two opposite edges. Bring the plate, held at an angle of approximately 45°, to the beveled edge of the cylinder mold at a point 12 mm (½ in.) from the lower edge of the plate. Using this contact point as a fixed hinge, lower the plate in a single motion until the excess material is extruded and full contact with the rim is established. Neither slide nor use the glass plate in a screeding motion, as this will either smear the material on the glass or cover voids, thus making their detection at this time difficult. After placing the glass plate, maintain contact between the plate and the rim until the plunger and weight have been placed.

9.4.1 Quickly examine the grout surface through the glass plate for voids. If there is an area larger than 3.2 mm (⅛ in.) in diameter which lacks contact with the plate, discard the entire test specimen (Note 8).

NOTE 8—In order to keep rejected test specimens to a minimum, operators conducting this operation for the first time have found it helpful to practice several times placing the plate on a cylinder filled with an easily available plain mortar before starting the test.

9.5 Immediately after placing the glass plate, place the preleveled top plate of the micrometer bridge in position, tighten wing nuts, and lower the plunger of the hold-down device until it makes contact with the top surface of the glass plate. To ensure firm contact between the plunger and the plate, place a 1.5-kg (3-lb) mass on the top of the plunger prior to the tightening of the setscrew of the plunger. Following the

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tightening of the setscrew, remove the mass and immediately insert the depth micrometer shaft through the four holes located on the top plate of the bridge until the finger rests are in full contact with it. Turn the shaft down and determine four initial measurements from this surface to the top surface of the glass plate covering the cylinder mold. Make measurements to the nearest 0.02 mm (0.001 in.). Calculate the average; do not round the numerical value. While the shaft is still touching the glass plate, use a glass marker to make a circle around the contact areas as the points at which later plate-thickness measurements will be taken.

9.6 Release the plunger and remove the glass plate from the top of the test specimen 24 ± ½ h after starting the mixing.

9.7 Immediately after removal, measure the thickness of the glass plate at the points of contact between the glass plate and the micrometer depth gage and record to the nearest 0.02 mm (0.001 in.).

9.8 At ages of 24 ± ½ h, 3 days ± 1 h, 14 days ± 6 h, and 28 days ± 12 h, measured from the time of contact of the dry materials and the mixing water, take four measurements directly to the top of the test specimen at the gage points. If the rod end of the depth micrometer either contacts the specimen surface within a bubble that has formed after placing the glass plate or breaks through the surface of a hidden bubble or other placing defect, discard the reading at that point. If less than three valid gage points remain, discard the test specimen. Measurements may be continued for additional specified periods of time. Calculate the average; do not round the numerical value.

9.9 On completion of measurements, carefully strip the test specimen and make careful visual examination of the cylindrical surface. Discard measurements made on a specimen that is cracked or otherwise manifestly faulty.

10. Calculation

10.1 To determine V_1, correct the initial measurements by adding the thickness of the glass plate measured at each corresponding contact point. Calculate the height change in percent for each age to the nearest 0.01 %, using non-rounded values for V_1 and V_2 as follows:

$$V = \frac{V_1 - V_2}{H} \times 100 \quad (1)$$

where:

V = height change, %,
V_1 = average of at least three adjusted micrometer depth gage readings at beginning of test, mm (in.),
H = height, 152-mm (6-in.), and
V_2 = average of at least three-micrometer depth gage readings at test age, mm (in.).

11. Report

11.1 Report the calculated height change (either positive or negative) at each test age. Also report the temperature and relative humidity at which the tests were performed, mixture proportions (if not prepackaged), as-mixed temperature, and consistency. Also report any deviations from the provisions given herein.

12. Precision and Bias

12.1 *Precision*—Based on an analysis of results of cooperative tests of three materials tested at two consistencies, stored at two storage conditions, it was concluded that separate precision statements are needed for flowable and fluid mixtures.

12.1.1 *Flowable Mixtures*—The single-operator standard deviation has been found to be 0.07 % (Note 9). This does not vary with test age (up to 28 days) or with expansion (over the range from 0.02 to 0.43 %). Therefore, results from two properly conducted tests by the same operator on the same material should not differ by more than 0.196 % (Note 9).

12.1.1.1 The multilaboratory standard deviation has been found to be 0.08 % (Note 9). This does not vary with test age (up to 28 days) or with expansion (over the range from 0.02 to 0.43 %). Therefore, results of two properly conducted tests on the same material in two laboratories should not differ by more than 0.216 % (Note 9).

12.1.2 *Fluid Mixtures*—The single-operator standard deviation has been found to be 0.11 % (Note 9). This does not vary with test age (up to 28 days) or with expansion (over the range from 0.11 to 0.33 %). Therefore, results of two properly conducted tests by the same operator on the same material should not differ by more than 0.3255 % (Note 9).

12.1.2.1 The multilaboratory standard deviation has been found to be 0.11 % (Note 9). This does not vary with test age (up to 28 days) or with expansion (up to 0.43 %). Therefore, results of two properly conducted tests on the same material in two laboratories should not differ by more than 0.30 % (Note 9).

NOTE 9—These numbers represent, respectively, the (1s) and (d2s) limits as described in Practice C 670.

12.2 *Bias*—No statement on bias is being made because there is no accepted reference material suitable for determining the bias in this test method.

13. Keywords

13.1 grout; height change; hydraulic cement; nonshrink grout

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Designation: C 1097 – 07

Standard Specification for Hydrated Lime for Use in Asphalt Cement or Bituminous Pavements[1]

This standard is issued under the fixed designation C 1097; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope*

1.1 This specification covers high calcium, dolomitic and magnesian-hydrated lime for use in asphalt cement or bituminous pavement.

NOTE 1—Hydrated lime, either calcitic, dolomitic, or magnesian, improves bonding of bitumen and aggregates which reduces susceptibility to moisture damage, reduces age hardening by chemically stabilizing polar compounds found in asphalts, and increases initial stiffness of asphalt mixtures.

NOTE 2—No attempt is made to present requirements for any by-product lime.

1.2 *This standard does not purport to address the safety concerns associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

2. Referenced Documents

2.1 *ASTM Standards:* [2]

C 25 Test Methods for Chemical Analysis of Limestone, Quicklime, and Hydrated Lime

C 50 Practice for Sampling, Sample Preparation, Packaging, and Marking of Lime and Limestone Products

C 51 Terminology Relating to Lime and Limestone (as used by the Industry)

C 110 Test Methods for Physical Testing of Quicklime, Hydrated Lime, and Limestone

D 8 Terminology Relating to Materials for Roads and Pavements

D 242 Specification for Mineral Filler For Bituminous Paving Mixtures

D 546 Test Method for Sieve Analysis of Mineral Filler for Bituminous Paving Mixtures

3. Terminology

3.1 For definitions of terms used in this specification, refer to Terminology C 51 or Terminology D 8.

4. Chemical Requirements

4.1 Hydrated lime for use in bituminous paving mixtures shall conform to the following chemical composition:

Calcium and Magnesium Oxides (on an LOI-free basis, minimum %)	90.0
Carbon Dioxide (taken at point of manufacture, maximum %)	5.0
Unhydrated Calcium and Magnesium Oxides (maximum%)	5.0
Free Moisture of Dry Hydrates (taken at point of manufacture, maximum %)	2.0

4.2 The chemical analysis of the hydrated lime shall be determined in accordance with Test Methods C 25.

5. Physical Requirements

5.1 Hydrated lime, either dry or slurry form, shall not have more than 3.0 % retained on a No. 30 (600 µm) sieve and not more than 30 % retained on a No. 200 (75 µm) sieve.

NOTE 3—Specification D 242 also contains physical specifications for hydrated lime. Specification D 242 includes four size gradations, expressed as percent passing the sieve. For the two size gradations included in both Specification D 242 and Specification C 1097, the specifications are the same.

5.2 The particle size of hydrated lime shall be determined in accordance with Test Methods C 110.

NOTE 4—Some hydrated limes may require a full 30-min wash time.

NOTE 5—The Test Methods C 110 method for particle size analysis is required instead of the Test Method D 546 method because the because the Test Methods C 110 method uses a standardized spray nozzle and pressure gauge.

6. Sampling, Inspection, Packaging and Marking

6.1 The sampling, inspection, rejection, retesting, packaging, and marking shall be done in accordance with Practice C 50.

7. Keywords

7.1 additive; asphalt; bituminous; hydrated; lime; mineral filler; mixtures; modifier; pavement

[1] This specification is under the jurisdiction of ASTM Committee C07 on Lime and is the direct responsibility of Subcommittee C07.02 on Specifications and Guidelines.

Current edition approved June 15, 2007. Published July 2007. Originally approved in 1990. Last previous edition approved in 2006 as C 1097 – 06a.

[2] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

***A Summary of Changes section appears at the end of this standard.**

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SUMMARY OF CHANGES

Committee C07 has identified the location of selected changes to this specification since the last issue, C 1097 – 06a, that may impact the use of this specification. (Approved June 15, 2007)

(*1*) Revised 5.1.
(*2*) Revised Note 5.
(*3*) Added Terminology section and renumbered subsequent sections. Moved old 3.1 into new 3.1 and renumbered subsequent paragraphs.

Committee C07 has identified the location of selected changes to this specification since the last issue, C 1097 – 06, that may impact the use of this specification. (Approved November 15, 2006)

(*1*) Revised the text throughout.

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Designation: C 1105 – 08a

Standard Test Method for Length Change of Concrete Due to Alkali-Carbonate Rock Reaction[1]

This standard is issued under the fixed designation C 1105; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope*

1.1 This test method covers the determination, by measurement of length change of concrete prisms, the susceptibility of cement-aggregate combinations to expansive alkali-carbonate reaction involving hydroxide ions associated with alkalies (sodium and potassium) and certain calcitic dolomites and dolomitic limestones.

1.2 The values stated in SI units are to be regarded as the standard. No other units of measurement are included in this standard. When combined standards are cited, the selection of measurement system is at the user's discretion subject to the requirements of the referenced standard.

1.3 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

2. Referenced Documents

2.1 *ASTM Standards:*[2]

C 33 Specification for Concrete Aggregates
C 125 Terminology Relating to Concrete and Concrete Aggregates
C 150 Specification for Portland Cement
C 157/C 157M Test Method for Length Change of Hardened Hydraulic-Cement Mortar and Concrete
C 233 Test Method for Air-Entraining Admixtures for Concrete
C 294 Descriptive Nomenclature for Constituents of Concrete Aggregates
C 295 Guide for Petrographic Examination of Aggregates for Concrete
C 490 Practice for Use of Apparatus for the Determination of Length Change of Hardened Cement Paste, Mortar, and Concrete
C 511 Specification for Mixing Rooms, Moist Cabinets, Moist Rooms, and Water Storage Tanks Used in the Testing of Hydraulic Cements and Concretes
C 586 Test Method for Potential Alkali Reactivity of Carbonate Rocks as Concrete Aggregates (Rock-Cylinder Method)
C 595 Specification for Blended Hydraulic Cements
C 670 Practice for Preparing Precision and Bias Statements for Test Methods for Construction Materials
C 702 Practice for Reducing Samples of Aggregate to Testing Size
D 75 Practice for Sampling Aggregates

3. Terminology

3.1 Terminology used in this standard is defined in Terminology C 125 or Descriptive Nomenclature C 294.

4. Significance and Use

4.1 Two types of alkali reactivity of aggregates have been described in the literature: the alkali-silica reaction involving certain siliceous rocks, minerals, and artificial glasses (**1**),[3] and the alkali-carbonate reaction involving dolomite in certain calcitic dolomites and dolomitic limestones (**2**). This test method is not recommended as a means to detect combinations susceptible to expansion due to alkali-silica reaction since it was not evaluated for this use in the work reported by Buck (**2**). This test method is not applicable to aggregates that do not contain or consist of carbonate rock (see Descriptive Nomenclature C 294).

4.2 This test method is intended for evaluating the behavior of specific combinations of concrete-making materials to be used in the work. However, provisions are made for the use of substitute materials when required. This test method assesses the potential for expansion of concrete caused by alkali-carbonate rock reaction from tests performed under prescribed

[1] This test method is under the jurisdiction of ASTM Committee C09 on Concrete and Concrete Aggregates and is the direct responsibility of Subcommittee C09.26 on Chemical Reactions.

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[2] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

[3] The boldface numbers in parentheses refer to the list of references at the end of this test method.

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laboratory curing conditions that will probably differ from field conditions. Thus, actual field performance will not be duplicated due to differences in wetting and drying, temperature, other factors, or combinations of these (see Appendix X1).

4.3 Use of this test method is of particular value when samples of aggregate from a source have been determined to contain constituents that are regarded as capable of participation in a potentially deleterious alkali-carbonate rock reaction either by petrographic examination, Guide C 295, by the rock cylinder test, Test Method C 586, by service record; or by a combination of these.

4.4 Results of tests conducted as described herein should form a part of the basis for a decision as to whether precautions be taken against excessive expansion due to alkali-carbonate rock reaction. This decision should be made before a particular cement-aggregate combination is used in concrete construction (see Note 1).

NOTE 1—Other elements that may be included in the decision-making process for categorizing an aggregate or a cement-aggregate combination with respect to whether precautions are needed, and examples of precautions that may be taken, are described in Appendix X1.

4.5 While the basic intent of this test method is to develop information on a particular cement-aggregate combination, it will usually be very useful to conduct control tests in parallel using the aggregate of interest with other cements or the cement of interest with other aggregates.

5. Apparatus

5.1 The molds, the associated items for molding test specimens, and the length comparator for measuring length change shall conform to the applicable requirements of Test Method C 157/C 157M and Practice C 490, and the molds shall have nominal 75-mm square cross sections.

6. Materials

6.1 *Maximum Size of Coarse Aggregate*—Coarse-aggregate fractions larger than the 19.0-mm sieve shall not be tested as such. When petrographic examination using Guide C 295 reveals that the material making up the size fractions larger than the 19.0-mm sieve is of such a composition and lithology that no differences should be expected compared with the smaller size material to be tested, or when tests, made in accordance with Test Method C 586, of material in such sizes reveal no significant differences from the sizes to be tested, then no further attention need be paid to the larger sizes. If results of petrographic examination or tests made in accordance with Test Method C 586 suggest that the larger size material should be studied for its effects in concrete, one or the other of two alternative procedures described herein may be used.

6.1.1 *Proportional Testing*—Material larger than the 19.0-mm sieve shall be crushed to pass the 19.0-mm sieve and material larger than the 4.75-mm sieve shall be proportioned to include the same proportion by mass of the crushed material originally retained on the 19.0-mm sieve and that originally passing this sieve, as may be expected to be used in the field concrete.

6.1.2 *Separated Size Testing*—Material larger than the 19.0-mm sieve shall be crushed to pass this sieve and shall be used in concrete as a second aggregate.

6.1.2.1 In the case of construction where several size ranges coarser than the 19.0-mm sieve are contemplated, each of these may, if desired, be separately crushed to pass this sieve and may be tested separately.

6.2 *Job Cement*—When it is desired to evaluate a particular cement-aggregate combination for use in particular work, the cement or cements used shall meet the requirements for the work and shall be from the source or sources and in the amounts expected to be used in the work. If several cements may be used in the work, it is desirable that tests be made using each cement separately.

6.3 *Reference Cements*—When it is desired to evaluate aggregates for general use or to compare aggregates for investigational purposes, the cement used shall be of the highest alkali content representative of the general use intended, or available to the laboratory making the tests. The cement or cements selected should comply with Specification C 150 or Specification C 595. Additional information of value may be obtained by conducting parallel tests with cements of different alkali content, of different sodium oxide to potassium oxide ratio, or blended with pozzolan or ground blast-furnace slag, or both.

6.4 *Substitute Fine Aggregate*—If the test aggregate is to be used only as coarse aggregate and the fine aggregate that it will be used with is not available, a fine aggregate that is not expected to participate in an expansive reaction with alkalies (see Note 2) shall be used.

NOTE 2—Advice on judging the expansive reactivity of aggregate is given in Appendix XI of Specification C 33.

7. Sampling

7.1 Obtain the sample in accordance with Practice D 75 and reduce it to test portion size in accordance with Practice C 702.

8. Test Specimens

8.1 Prepare six specimens, of the type required for concrete Test Method C 157/C 157M, from one batch of concrete. The concrete mixture shall be the mixture in which the aggregates are proposed for use. In the event that no specific concrete mixture is being considered, that described in Test Method C 233 shall be used.

8.2 If control or comparison mixtures are made, specimens shall be made from those mixtures as described in 8.1.

9. Conditioning

9.1 Cure, store, and remove molds in accordance with Test Method C 157/C 157M. Thereafter, keep the specimens in moist storage in accordance with Specification C 511 but do not immerse in water.

10. Procedure

10.1 Follow the procedure of Test Method C 157/C 157M, except that the specimens shall be stored in a moist room or moist cabinet meeting the requirements of Specification C 511 and length measurements shall be made at ages 7, 28, and 56 days, and 3, 6, 9, and 12 months.

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11. Calculation

11.1 Calculate the change in length of each of the prisms at each of the ages at which determinations are made and express as a percentage change based on the length at the time of removal from the mold at an age of 23½ ± ½ h. Calculate the average length change in percentage for the group of prisms.

11.2 Data from at least three bars must be available at any age to constitute a valid test at that age.

12. Report

12.1 Report the following information:

12.1.1 Pertinent details about materials and mixtures used,

12.1.2 The length change in percentage for each specimen and for the group of prisms at each test age, and

12.1.3 Description of the circumstances under which results on any one of the specimens are not included in the average.

13. Precision and Bias [4]

13.1 *Precision*:

13.1.1 *Single-Operator Precision*—The precision statement is based on calculations made using data reported by Buck (**2**). The particular within-laboratory variability for which precision is reported was obtained by a single operator, using the same materials and equipment over a short period of time. The single-operator standard deviation (1s[A]) does not vary appreciably with age over the range of 90 through 365 days. Standard deviation varies with the magnitude of the expansion described as follows:

	Average % Expansion	
	<0.040 %	≥0.040 %
Single-operator standard deviation (1s) among individual bars	0.003 %	0.005 %
Maximum difference (d2s[A]) between extreme values within a set of bars in a properly conducted test should not exceed:		
number of bars in set		
6	0.013 %	0.021 %
5	0.012 %	0.020 %
4	0.012 %	0.019 %
3	0.011 %	0.017 %
Calculated expected 1S associated with a mean of 3 bars	0.002 %	0.003 %
Maximum permissible difference between two such means in properly conducted tests should not exceed	0.005 %	0.008 %

[A] As described in Practice C 670.

13.1.2 *Multilaboratory Precision*—In studies involving 12 and 20 laboratories (**8**,9), testing three specimens rather than the six specified in this test method, and testing nominal 19 mm maximum size coarse aggregates known to be susceptible to alkalicarbonate rock reaction, in concrete mixtures with a cement content of 310 kg/m^3 , the multilaboratory precision was found to be as follows:

13.1.2.1 For concrete with an average expansion less than 0.014 % the multilaboratory standard deviation of a single test result (mean of measurements on three prisms) for average expansion less than 0.014 % has been found to be 0.0032 %. Therefore, results of two properly conducted tests in different laboratories using the same aggregate should not differ by more than 0.009 %.[5]

13.1.2.2 For concrete with an average expansion greater than 0.014 % the multilaboratory coefficient of variation of a single test result (mean of measurements on three prisms) for average expansion greater than 0.014 % has been found to be 23 %. Therefore, results of two properly conducted tests in different laboratories using the same aggregate should not differ from each other by more than 65 % of their average.[5]

13.2 *Bias*—A statement on bias has not been developed since no reference materials are available.

[4] Supporting data have been filed at ASTM International Headquarters and may be obtained by requesting Research Report RR: C09-1002.

[5] These numbers represent, respectively, the (1s %) and (d2s %) limits as described in Practice C 670.

APPENDIX

(Nonmandatory Information)

X1. GENERAL INFORMATION

X1.1 The question of whether or not criterion based on the results obtained using this test method should be used for acceptance of materials for use as concrete aggregate will be dealt with, if deemed appropriate, in Specification C 33.

X1.2 Work has been reported from which it may be inferred that a cement-aggregate combination might reasonably be classified as potentially deleteriously reactive if the average expansion of six concrete specimens is equal to or greater than: 0.015 % at 3 months; 0.025 % at 6 months; or 0.030 % at 1 year (**1**,**2**). Data for later ages are preferred but the 3-month or 6-month average may be used if necessary.

X1.3 If this test method has been performed on a cement-aggregate combination involving an aggregate that has not been examined petrographically using Practice C 295, or that has not been measured by the rock prism expansion in Test Method C 586, it is recommended that one or both of those

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procedures be performed.

X1.4 When it has been concluded from the results of tests performed using this test method and supplementary information from petrographic examination, rock-prism testing, service records, or combinations of these, that a given cement-aggregate combination is potentially deleteriously expansive, additional studies may be appropriate to develop information on the potential expansion of other combinations containing the same cement with other aggregates, the same aggregate with other cements, or the same cement-aggregate combination with a pozzolan or slag.

X1.5 If a cement-aggregate combination tested using this test method is judged by the results to be "non-reactive," no restrictions on the use of the aggregate with the cement used in the test are necessary in order to protect against probable alkali-carbonate rock reaction. If the combination is judged to be "reactive," measures to control the effects of the reaction (**3**,**4**) include:

X1.5.1 The use of the smallest nominal maximum size coarse aggregate that is practical.

X1.5.2 A maximum of 20 % reactive rock in the coarse aggregate, 20 % reactive rock in the fine aggregate, or a total of 15 % reactive rock if the coarse and fine aggregate both contain reactive rock.

X1.5.3 Use of a cement having no greater an alkali content than a cement tested using test method for which the results are judged to be "non-reactive."

X1.5.4 Additional useful information about this chemical reaction is included in (**5-7**).

REFERENCES

(**1**) Newlon, H. H., and Sherwood, W. C.," A Study of Remedial Methods for Reducing Alkali-Carbonate Reaction,'' *Progress Report No. 4—Potentially Reactive Carbonate Rocks*, Virginia Council of Highways Investigation and Research, May 1963.

(**2**) Buck, A. D., "Control of Reactive Carbonate Rocks in Concrete,'' *Technical Report C-75-3*, U.S. Army Engineer Waterways Experiment Station, CE, September 1975.

(**3**) Newlon, H. H., Sherwood, W. C., and Ozol, M. A.," A Strategy for Use and Control of Potentially Reactive Carbonate Rocks'' (Including an Annotated Bibliography of Virginia Research), *Progress Report No. 8—Potentially Reactive Carbonate Rocks*—Virginia Council of Highways Investigation and Research, June 1972.

(**4**) Mather, Bryant, "Developments in Specifications and Control,'' *Cement-Aggregate Reaction, Transportation Research Record 525*, National Research Council, 1974, pp. 38–42.

(**5**) Hadley, D. W., "Alkali Reactivity of Dolomitic Carbonate Rocks,'' Highway Research Record 45, Highway Research Board, 1964, pp. 1–19.

(**6**) Walker, H. N., "Chemical Reactions of Carbonate Aggregates in Cement Paste," *Significance of Tests and Properties of Concrete and Concrete-Making Materials, ASTM STP169B*, ASTM, 1978, pp. 722–743.

(**7**) Rogers, C. A., "Evaluation of the Potential for Expansion and Cracking of Concrete Caused by the Alkali-Carbonate Reaction,'' *Cement, Concrete, and Aggregates*, Vol. 8, No. 1, Summer 1986, pp. 13–23.

(**8**) Rogers, C. A.," Interlaboratory Study of the Concrete Prism Expansion Test for the Alkali-Carbonate Reaction," Proceedings of the 7th International Conference on Concrete Alkali-Aggregate Reactions, Ottawa, Published by Noyes Publications, Park Ridge, N.J., 1987, pp. 270–274.

(**9**) Rogers, C. A.," Interlaboratory Study of the Concrete Prism Expansion Test for the Alkali-Carbonate Reaction," *Canadian Developments in Testing Concrete Aggregates for Alkali-Aggregate Reactivity*, Ontario Ministry of Tranportation, Engineering Materials Report EM-92, March 1990, pp. 136–149.

SUMMARY OF CHANGES

Committee C09 has identified the location of selected changes to this test method since the last issue, C 1105 – 08, that may impact the use of this test method. (Approved December 1, 2008)

(*1*) Revised 1.2.

Committee C09 has identified the location of selected changes to this test method since the last issue, C 1105 – 05, that may impact the use of this test method. (Approved February 1, 2008)

(*1*) Revised 1.2, 5.1, and 8.1.

(*2*) Removed all informational inch-pound units throughout to conform to ASTM Form and Style.

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Designation: C 1107/C 1107M – 08

Standard Specification for Packaged Dry, Hydraulic-Cement Grout (Nonshrink)[1]

This standard is issued under the fixed designation C 1107/C 1107M; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

This standard has been approved for use by agencies of the Department of Defense.

1. Scope*

1.1 This specification covers packaged dry, hydraulic cement grout (nonshrink) intended for use under applied load (such as to support a structure, a machine, and the like) where a change in height below initial placement height is to be avoided.

1.2 Grouts covered are composed of hydraulic cement, fine aggregate, and other ingredients. They require only the addition of mixing water for use.

1.3 The values stated in either SI units or inch-pound units are to be regarded separately as standard. The values stated in each system may not be exact equivalents; therefore, each system shall be used independently of the other. Combining values from the two systems may result in non-conformance with the standard.

1.4 The following safety hazards caveat pertains only to the test method portion of this specification: *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

2. Referenced Documents

2.1 *ASTM Standards:*[2]

C 109/C 109M Test Method for Compressive Strength of Hydraulic Cement Mortars (Using 2-in. or [50-mm] Cube Specimens)

C 125 Terminology Relating to Concrete and Concrete Aggregates

C 138/C 138M Test Method for Density (Unit Weight), Yield, and Air Content (Gravimetric) of Concrete

C 157/C 157M Test Method for Length Change of Hardened Hydraulic-Cement Mortar and Concrete

C 185 Test Method for Air Content of Hydraulic Cement Mortar

C 305 Practice for Mechanical Mixing of Hydraulic Cement Pastes and Mortars of Plastic Consistency

C 702 Practice for Reducing Samples of Aggregate to Testing Size

C 827 Test Method for Change in Height at Early Ages of Cylindrical Specimens of Cementitious Mixtures

C 939 Test Method for Flow of Grout for Preplaced-Aggregate Concrete (Flow Cone Method)

C 1090 Test Method for Measuring Changes in Height of Cylindrical Specimens of Hydraulic-Cement Grout

C 1437 Test Method for Flow of Hydraulic Cement Mortar

3. Terminology

3.1 *Definitions*—For definitions of terms used in this specification, refer to Terminology C 125.

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *consistency, flowable*, *n*—a grout consistency having a flow of 125 to 145 by the flow test in accordance with the applicable provisions of Test Method C 1437; the flow after 5 drops of the flow table in 3 s.

3.2.2 *consistency, fluid*, *n*—a grout consistency having a time of efflux of 10 to 30 s when tested by the flow cone procedure of Test Method C 939.

3.2.3 *consistency, plastic*, *n*—a grout consistency having a flow of 100 to 125 by the flow test in accordance with the applicable provisions of Test Method C 1437; the flow after 5 drops of the flow table in 3 s.

4. Ordering Information

4.1 When the purchaser specifies that properties of the packaged, dry grout meet the requirements of this specification, also specify which, if any, of the optional requirements apply.

4.2 When the grout is to be used in contact with stressed tendons or other corrosion-sensitive, load-bearing structural members, the purchaser shall supply this information to the manufacturer and obtain assurances that the material meets

[1] This specification is under the jurisdiction of ASTM Committee C09 on Concrete and Concrete Aggregates and is the direct responsibility of Subcommittee C09.43 on Packaged Dry Combined Materials.

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[2] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

***A Summary of Changes section appears at the end of this standard.**

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relevant chloride, nitrite, nitrate, sulfide, and sulfate requirements, and any other material limitations imposed by the applicable codes and standards (See Note 1).

4.3 When the grout is to be used in abnormal or aggressive environments, the purchaser shall supply this information to the manufacturer and obtain assurance that the grout has a successful history of performance in the same or similar exposures.

NOTE 1—Since all conditions of use cannot be anticipated, this specification requires nonshrink grout to exhibit no shrinkage when tested in a laboratory-controlled, moist-cured environment, and requires only the reporting of the observed height change, usually shrinkage, when test specimens are subjected to some degree of drying. It is suggested that users consult with manufacturers on specific applications to determine the applicability of specific test results.

5. Materials

5.1 The materials used as ingredients in packaged, dry, grout include hydraulic cement, fine aggregate, and other ingredients.

6. Performance Requirements

6.1 Specimens shall be made from freshly mixed grout and from grout that has been retained in the mixer for the maximum usable working time allowed by the manufacturer. Specimens from both conditions shall meet the requirements prescribed in Table 1.

6.2 Specimens shall be prepared using materials and equipment at temperatures representing the maximum and minimum usable temperatures specified by the manufacturer for his product. Specimens from both conditions shall meet the requirements prescribed in Table 1, except that the compressive-strength requirements do not have to be met at minimum usable temperature.

6.3 Specimens for testing shall be prepared by combining the use of grout retained in the mixer as in 6.1 with the minimum and maximum as mixed and curing temperatures used in 6.2. Specimens from these combinations of conditions shall meet the requirements of Table 1, except that the compressive-strength requirements do not have to be met at minimum usable temperature.

6.4 All test specimens for performance evaluation shall be prepared using the highest water to solids ratio, maximum flow, or most fluid consistency stated on the package.

TABLE 1 Performance Requirements

Compressive Strength, min	MPa	[psi]
1 day[A]	7.0	[1000]
3 day	17.0	[2500]
7 day	24.0	[3500]
28 day	34.0	[5000]
Early Age Height Change Max % @ Final Set		+ 4.0
Height Change of Moist Cured Hardened Grout at 1, 3, 14 and 28 Days		
Maximum, %		+ 0.3
Minimum, %		0.0

[A] When required, the purchaser must so specify in the purchase contract.

7. Sampling

7.1 Use whole packages of grout selected at random from the lot of grout to be examined.

7.2 Where lesser quantities of grout will serve the purpose, select 3000 g [7 lb] of dry grout from a whole package in accordance with the mechanical-splitter method in Practice C 702. For high-density grouts, adjust the mass to provide an equivalent volume.

8. Batching

8.1 Grout mixtures shall be produced in the following conditions:

8.1.1 Batch grout mixtures at temperature conditions corresponding to the maximum recommended temperature limit and at a temperature corresponding to the minimum temperature stated by the manufacturer.

8.1.2 For standard temperature testing, maintain the grout mixture and the testing equipment at a temperature of 23 ± 2 °C [73.5 ± 3.5 °F].

8.2 Bring all materials and equipment to be used in preparing test specimens to the specified test temperature, ± 3 °C [± 5 °F] prior to use.

8.2.1 When the controlled-environment test room is too small to accommodate large equipment, immediately prior to use, bring the mixer to the desired testing temperature by filling it with water at the appropriate temperature and agitating it by turning the mixer on. When this water has stabilized at the desired temperature, discard it and start preparing the batch immediately.

8.3 The manufacturer is not prohibited from including, in the package instructions, procedures for adjusting the mixing water temperature to achieve limitations imposed on the grout use temperatures. Use of this technique shall not abrogate the extended mixing time requirement of this specification.

9. Proportioning

9.1 The minimum and maximum amount of water recommended by the manufacturer on the package shall be used to determine conformance with the requirements of this specification. If the manufacturer provides maximum flow (thinnest consistency) information on the package, conduct consistency tests to an accuracy of ±5 % to determine the amount of water to be added for testing. In either case, express the weight of water so determined as a ratio of water to dry grout material by weight. If both are given, make tests at whichever involves the larger amount of water by ratio of dry grout mixture.

10. Mixing

10.1 Either the mixer described in Practice C 305 or the mortar mixer described in 10.1.2 shall be used for performance qualifications. In the event of a dispute, the mixer described in 10.1.2 shall be used for the referee test.

NOTE 2—The referee test is a test made to settle disagreement as to the conformance to the specified requirements.

10.1.1 *Bench Scale Epicyclic Mixer*—The mortar-mixing apparatus shall be as specified in Practice C 305. However, the

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mixer shall be provided with a bowl positioner to enable clearance of the largest sized aggregate in the mixture being tested.

10.1.2 *Mortar Mixer*—A 110 to 125-L [4 to 4½-ft^3] capacity horizontal shaft stationary drum mortar mixer (See Note 3) is required. The mortar mixer shall have a metal shell with horizontal mixing blades. The mixing blades shall be angled so that adjacent paddle arms reverse the flow of the grout in the mixing drum during rotation of the horizontal shaft. The mixing blades shall have adjustable wiper blades that wipe the inner surfaces of the mixing chamber. The wiper blades shall be rubber or other flexible, wear-resistant material that does not deleteriously react with the grout mixture. The wiper blades shall be adjusted to continuously wipe the curved inner surface of the mixing chamber below the grout level and the ends of the chamber. The horizontal shaft shall rotate the mixing paddles at 28 to 35 r/min. The mixer shall be clean, pre-wetted, and drained and essentially free of hardened mortar and other foreign material that can be removed with a trowel or by reasonably striking with a hammer.

NOTE 3—An electric motor-driven mixer is preferable in the laboratory to avoid noise and exhaust fumes. For greater safety, the mixer should be equipped with a lever-operated clutch. While these comments are selected safety precautions, it is the user's responsibility to see that any equipment in use is not hazardous in a physical or mechanical way to operators and attendant personnel, and that safe work practices are required at all times.

10.2 *Mixing Procedure for Bench Scale Mixing*:

10.2.1 Use a 3000-g [7-lb] sample to determine the consistency classification and to determine the water content of grout tested at maximum flow or most fluid consistency.

10.2.2 Weigh all grout on a balance or on a platform scale to the nearest 0.1 %.

10.2.3 Measure the water by mass or volume to the nearest 0.1 %. If the manufacturer recommends maximum water content, calculate the percent water from the packaging information and use that amount of water to prepare the grout mixture. If the manufacturer recommends maximum flow or most fluid consistency, use the suggested water content as a starting point and adjust water as necessary to achieve the maximum flow or most fluid consistency stated on the package. If the required consistency has not been met, make additional adjustments to estimate the water content to use for the next batch. Discard current batch and repeat with newly established water content.

10.2.4 Place water in the bowl. Start the mixer at speed 1. Add the dry grout material to the water over approximately 30 sec. After 1 min, stop the mixer for 15 sec and scrape into the batch any grout that may have collected on the side of the bowl. Switch to speed 2 and mix for a total of 5 min as measured from first contact of dry material with water. Use other mixing procedures if recommended by the manufacturer.

NOTE 4—It is advisable to cover the bowl with a lid while mixing. A metal disc in which a slit has been cut to accommodate the mixer shaft has been found suitable. If excessive splash-over occurs, a larger mixer should be used.

10.2.5 Prepare required specimens from additional batches of grout as needed. Use the water content established above for all successive batches. When testing grout at the end of its working time, a separate batch of grout shall be mixed continually until the time of test unless otherwise recommended by the manufacturer.

10.3 *Procedure for Using The Mortar Mixer*:

10.3.1 Prepare all specimens from a single batch of grout using the horizontal shaft stationary drum mortar mixer. Perform tests to verify compliance with performance requirements.

10.3.2 With materials and equipment brought to the testing temperature, use enough whole bags of material to produce at least 56 L [2 ft^3] of mixed grout. Use this batch for both freshly-mixed and delayed-mixed testing at one specified temperature. Place the total required amount of mixing water in the mixer (See Note 5).

10.3.2.1 When testing a grout to a maximum water to solids ratio, use the weighed contents of the packages to determine the amount of water to be used.

10.3.2.2 When testing a grout to a maximum recommended flow or most fluid consistency, adjust the water content at the time of mixing to achieve the recommended consistency. With the mixer running, add the grout material to the water in a steady flow, sliding it into the mixer along the side away from the discharge. After mixing for 1 min, stop the mixer for not more than 30 s and scrape down the sides and blades. Mix for an additional 5 min after all the dry material has been added, unless otherwise recommended by the manufacturer. If the required consistency has not been met, make additional adjustments to estimate the water content to use for the next batch. Discard current batch and repeat with newly established water content.

NOTE 5—Extensive lumping generally occurs during the procedure for adding grout to water. If it occurs repeatedly, try adding about 80 % of the water, then add all of the dry grout material. Add the remaining water after about 1 min of mixing. If lumping persists, contact the grout manufacturer for recommendations.

10.3.3 After completely mixing, discharge a portion of the material through a 9.5-mm [⅜-in.] mesh screen into a clean, pre-wetted container. If lumps or balls of partially mixed material remain on the screen, reject the entire batch and start over.

10.3.4 Leave the portion of grout to be tested later in the mixer with the mixer running, unless otherwise recommended by the manufacturer, for the period recommended by the manufacturer as the maximum usable working time.

10.3.5 If the manufacturer requires other equipment or a different mixing procedure, or both, when using a particular grout, they shall be used if adequately detailed in the manufacturer's instructions.

11. Test Methods

11.1 *Consistency*:

11.1.1 Determine the consistency of the grout mixture in accordance with Test Method C 827, Preparation of Mixtures, with the exception of temperature. To adjust for consistency, repeat the procedure starting with dry material. Do not add water or dry material to an existing mixture.

11.1.2 Determine the consistency with the required water content, at the temperature extremes allowed by the manufacturer, both with freshly mixed grout and grout mixed to the

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maximum allowed usable working time. The consistency at the end of the maximum allowed usable working time at each of the allowed temperature extremes shall remain within the specified flow ranges.

11.1.3 Do not adjust the water at extreme conditions unless recommended by the manufacturer. When water adjustment is recommended, perform tests required by this specification to verify that the water-adjusted grout meets the requirements of this specification.

11.2 *Yield*—Determine the yield of the grout using the 400-mL cylindrical measure described in Test Method C 185.

11.2.1 *Calculation*—Calculate the density of the grout in accordance with Test Method C 138 and calculate the yield of freshly mixed grout per package of specified mass as follows:

$$Y = (1 + A)\frac{W_t}{W} \quad (1)$$

where:

Y = Yield of grout, L [ft^3] (expressed to nearest 0.5 L [0.01 ft^3]),

W = Unit weight of grout, kg/m^3 [lb/ft^3],

A = Fraction of water added to grout,

$$\frac{\text{Mass of Water}}{\text{Mass of Dry Grout}}$$

W_t = Net weight marked on package, kg [lb].

11.3 *Early Age Height Change*—Determine the early-age height change of grout in accordance with the applicable portions of Test Method C 827.

11.4 *Height Change of Hardened Grout*:

11.4.1 Determine height change of hardened grout at 1, 3, 14, and 28 days in accordance with Test Method C 1090 and report.

11.4.2 At 28 days age, leave specimens in the apparatus and expose to 50 % relative humidity air, in accordance with Test Method C 157, until 56 days age. Determine the net change in specimen height after 28 days of moist curing followed by 28 days of storage in 50 % relative humidity air at 23 ± 2 °C [73 ± 5 °F].

11.5 *Compressive Strength*—Determine compressive strength in accordance with the applicable portions of Test Method C 109/C 109M except as modified in this section.

11.5.1 For fluid or flowable grouts, fill each mold in the set halfway. Puddle each with a gloved finger five times to consolidate. Fill the mold and puddle again. When filling the mold, use sufficient material so that after the final consolidation the mold is slightly overfilled. Bring the excess grout to the center and finish the surface by cutting off the excess with the straight edge of a trowel held vertically and drawn across the top of the mold with a sawing motion. Plastic grouts shall be consolidated as described in Test Method C 109/C 109M.

11.5.2 Clamp a cover plate over the cube molds using two C-clamps, taking care that the grout does not prevent seating of the plate. The cover plate shall be rigid, nonreactive and not less than 6 mm [¼ in.] thick. The cover plate shall overlap the cube mold by not less than 6 mm [¼ in.]. Immediately place test specimens in moist room.

11.5.3 For 1 day compressive strength specimen, strip molds at 24 ± ½ h after molding. Strip remaining molds at 72 ± 1 h after molding and place specimens in moist cabinet or moist room protected from dripping water. Three cubes shall be tested at each age—1, 3, 7, and 28 days.

12. Report

12.1 Report the following information:

12.1.1 Source and identification of grout tested,

12.1.2 Details of any variations and options practiced by the tester that are recommended or allowed by the manufacturer or others. Also, designate by whom exceptions are allowed or recommended,

12.1.3 Number and size of each grout specimen and the date molded,

12.1.4 Consistency at the time the specimens were molded and the water to dry solids ratio,

12.1.5 Mixing temperature and curing temperature,

12.1.6 Identify the usable working time, and temperature range within which the grout specimens were prepared, placed, cured, and tested,

12.1.7 Height change from placement to time of final setting, %,

12.1.8 Height change of hardened, moist-cured grout at specimen age of 1, 3, 14, and 28 days, %,

12.1.9 Height change of hardened grout at 56 days of age when exposed to air drying for 28 days after 28 days of moist-curing, %,

12.1.10 Compressive strength of cubes at 1, 3, 7, and 28 days, and

12.1.11 Yield, determined in 11.2.

13. Inspection and Rejection

13.1 Inspection of the dry grout material shall be agreed upon between the purchaser and the manufacturer as part of the purchase contract.

13.2 Any material that fails to conform to any of the requirements in this specification shall be designated as nonconforming material. In the event of a failure to conform to any part of the requirements of this specification when using the mixer described according to Practice C 305, the mortar mixing procedure as described in 10.1.2 shall be used to resolve compliance with the specification. The purchaser has the right to reject any nonconforming material. Rejection shall be reported to the producer or supplier in writing.

14. Certification

14.1 The manufacturer shall, at the time of purchase, provide the purchaser, on request, a certification under terms of the purchase contract, that the product meets the requirements of this standard.

15. Product Marking

15.1 All packages shall show at least the following information in clearly legible form:

15.1.1 Brand name, usable working time for high and low temperatures within which the grout will meet the requirements of this specification, net weight,

15.1.2 Date of manufacture and the recommended use expiration date, and

15.1.3 Lot identification number.

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15.2 The following additional information shall be either marked on package or attached to it:

15.2.1 Surface preparation, mixing, placing, and curing instructions,

15.2.2 Maximum amount of mixing water to be used, or maximum recommended consistency,

15.2.3 Yield at maximum mixing water content, or maximum consistency. The yield claimed shall not be greater than that measured in 11.2,

15.2.4 Recommended maximum usable working time, "pot-life," and approximate consistency at end of that time. Usable working time shall not exceed the time after initial mixing that grout retains properties required in this specification, and

15.2.5 High and low temperatures during preparation and placement within which the grout will meet the requirements of this specification.

16. Keywords

16.1 dry hydraulic cement grout; grout; nonshrink hydraulic cement grout; packaged dry grout; shrinkage compensated grout

SUMMARY OF CHANGES

Committee C09 has identified the location of selected changes to this specification since the last issue, C 1107 – 07a, that may impact the use of this specification. (Approved October 1, 2008)

(*1*) Made major revisions to Sections 6, 10, and 13 to permit the use of either a mortar mixer or a bench scale mixer to prepare samples for qualification testing.

Committee C09 has identified the location of selected changes to this specification since the last issue, C 1107 – 07, that may impact the use of this specification. (Approved July 15, 2007)

(*1*) Revised 8.1.2.

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Designation: C 1116/C 1116M – 09

Standard Specification for Fiber-Reinforced Concrete[1]

This standard is issued under the fixed designation C 1116/C 1116M; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

This standard has been approved for use by agencies of the Department of Defense.

1. Scope*

1.1 This specification covers all forms of fiber-reinforced concrete that are delivered to a purchaser with the ingredients uniformly mixed, and that can be sampled and tested at the point of delivery. It does not cover the placement, consolidation, curing, or protection of the fiber-reinforced concrete after delivery to the purchaser.

1.2 Certain sections of this specification are also applicable to fiber-reinforced concrete intended for shotcreting by the dry-mix process when sampling and testing of concrete is possible only at the point of placement. In this case, the sections dealing with batching plant, mixing equipment, mixing and delivery, and measurement of workability and air content, are not applicable.

1.3 This specification does not cover thin-section glass fiber-reinforced concrete manufactured by the spray-up process that is under the jurisdiction of ASTM Subcommittee C27.40.

1.4 The values stated in either SI units or inch-pound units are to be regarded separately as standard. The values stated in each system may not be exact equivalents; therefore, each system shall be used independently of the other. Combining values from the two systems may result in non-conformance with the standard.

1.5 The following precautionary statement pertains only to the test method portion, Sections 15 and 18, of this specification: *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

2. Referenced Documents

2.1 *ASTM Standards:*[2]

A 820/A 820M Specification for Steel Fibers for Fiber-Reinforced Concrete
C 31/C 31M Practice for Making and Curing Concrete Test Specimens in the Field
C 39/C 39M Test Method for Compressive Strength of Cylindrical Concrete Specimens
C 42/C 42M Test Method for Obtaining and Testing Drilled Cores and Sawed Beams of Concrete
C 94/C 94M Specification for Ready-Mixed Concrete
C 125 Terminology Relating to Concrete and Concrete Aggregates
C 138/C 138M Test Method for Density (Unit Weight), Yield, and Air Content (Gravimetric) of Concrete
C 150 Specification for Portland Cement
C 172 Practice for Sampling Freshly Mixed Concrete
C 173/C 173M Test Method for Air Content of Freshly Mixed Concrete by the Volumetric Method
C 192/C 192M Practice for Making and Curing Concrete Test Specimens in the Laboratory
C 231 Test Method for Air Content of Freshly Mixed Concrete by the Pressure Method
C 387 Specification for Packaged, Dry, Combined Materials for Mortar and Concrete
C 567 Test Method for Determining Density of Structural Lightweight Concrete
C 666/C 666M Test Method for Resistance of Concrete to Rapid Freezing and Thawing
C 684 Test Method for Making, Accelerated Curing, and Testing Concrete Compression Test Specimens
C 685/C 685M Specification for Concrete Made by Volumetric Batching and Continuous Mixing
C 1077 Practice for Laboratories Testing Concrete and Concrete Aggregates for Use in Construction and Criteria for Laboratory Evaluation
C 1140 Practice for Preparing and Testing Specimens from Shotcrete Test Panels
C 1385/C 1385M Practice for Sampling Materials for Shotcrete
C 1399 Test Method for Obtaining Average Residual-Strength of Fiber-Reinforced Concrete
C 1436 Specification for Materials for Shotcrete
C 1480 Specification for Packaged, Pre-Blended, Dry,

[1] This specification is under the jurisdiction of ASTM Committee C09 on Concrete and Concrete Aggregates and is the direct responsibility of Subcommittee C09.42 on Fiber-Reinforced Concrete.

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[2] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

***A Summary of Changes section appears at the end of this standard.**

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Combined Materials for Use in Wet or Dry Shotcrete Application
C 1550 Test Method for Flexural Toughness of Fiber Reinforced Concrete (Using Centrally Loaded Round Panel)
C 1602/C 1602M Specification for Mixing Water Used in the Production of Hydraulic Cement Concrete
C 1604/C 1604M Test Method for Obtaining and Testing Drilled Cores of Shotcrete
C 1609/C 1609M Test Method for Flexural Performance of Fiber-Reinforced Concrete (Using Beam With Third-Point Loading)
C 1666/C 1666M Specification for Alkali Resistant (AR) Glass Fiber for GFRC and Fiber-Reinforced Concrete and Cement
D 6942 Test Method for Stability of Cellulose Fibers in Alkaline Environments
D 7357 Specification for Cellulose Fibers for Fiber-Reinforced Concrete

2.2 *ACI Standards and Reports:*
211.1 Standard Practice for Selecting Proportions for Normal, Heavyweight, and Mass Concrete[3]
211.2 Standard Practice for Selecting Proportions for Structural Lightweight Concrete[3]
506.2 Specification for Materials, Proportioning and Application of Shotcrete[3]

3. Terminology

3.1 *Definitions*

3.1.1 For definitions of terms used in this specification, refer to Terminology C 125.

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *manufacturer*, *n*—the producer who furnishes the fiber-reinforced concrete.

3.2.2 *purchaser*, *n*—the owner, or representative thereof, who buys the fiber-reinforced concrete.

4. Classification

4.1 This specification classifies fiber-reinforced concrete by the material type of the fiber incorporated.

NOTE 1—The performance of fiber-reinforced concrete depends upon the susceptibility of the fibers to physical damage during mixing or shotcreting and to chemical damage on exposure to the cement paste solution, which is highly alkaline and may also contain carbon dioxide, chlorides, sulfates or oxygen. Improper methods of fiber addition to a concrete mix can lead to balling of some types of fiber; consult manufacturer for advice as to correct method before use. The magnitude of improvements in the mechanical properties of the concrete or shotcrete imparted by fibers can also reflect the material characteristics, geometry, and design of the fiber type.

4.1.1 *Type I Steel Fiber-Reinforced Concrete*—Contains stainless steel, alloy steel, or carbon steel fibers conforming to Specification A 820/A 820M.

4.1.2 *Type II Glass Fiber-Reinforced Concrete*—Contains alkali-resistant (AR) glass fibers conforming to Specification C 1666/C 1666M.

4.1.3 *Type III Synthetic Fiber-Reinforced Concrete*—Contains synthetic fibers for which documentary evidence can be produced confirming their resistance to deterioration when in contact with the moisture and alkalis present in cement paste and the substances present in admixtures throughout the anticipated useful life of the structure (see Note 2 and 4.2).

NOTE 2—Fibers such as polyolefins (polypropylene and polyethylene), nylon, and carbon have been shown to be durable in concrete.

4.1.4 *Type IV Natural Fiber-Reinforced Concrete*—Contains natural fibers for which documentary evidence can be produced confirming their resistance to deterioration when in contact with the moisture and alkalis present in cement paste and the substances present in admixtures throughout the anticipated useful life of the structure. When Type IV fiber-reinforced concrete contains cellulose fibers they shall conform to Specification D 7357.

NOTE 3—The classification, natural fibers, refers to a population of fibers that are manufactured from natural fibrous resources and are used for the first time in concrete. Depending on the initial raw material and the manufacturing process employed to produce the fiber, the final physical and chemical fiber properties in this general classification can vary greatly. Some natural fibers are susceptible to deterioration from exposure to alkalis; Test Method D 6942 may be used to determine the susceptibility of these fibers to deterioration as a result of exposure to alkalis in concrete. Conversely, many other natural fiber types are highly resistant to alkalis and can remain in concrete with no degradation for the complete product life cycle.

4.2 When the purchaser chooses to permit the use of fibers other than those complying with the classifications in 4.1, the manufacturer or supplier shall show evidence satisfactory to the purchaser that the type of fiber proposed for use shows resistance to deterioration when in contact with the moisture and alkalis present in cement paste and the substances present in admixtures throughout the anticipated useful life of the structure.

5. Basis of Purchase

5.1 The basis of purchase for fiber-reinforced concrete shall be in accordance with the *Basis of Purchase* Sections of Specification C 94/C 94M or Specification C 685/C 685M.

6. Ordering Information

6.1 In the absence of designated applicable general specifications, the purchaser shall specify the following:

6.1.1 Type of fiber-reinforced concrete required. See Section 4.

6.1.2 Type of cement at the purchaser's option, otherwise the cement shall be Type 1 meeting the requirements of Specification C 150;

6.1.3 Designated size, or sizes, of coarse aggregates;

6.1.4 Slump required at the point of delivery, or when appropriate the point of placement, subject to the tolerances hereinafter specified;

6.1.5 Air content when air-entrainment is required, based on the air content of samples taken at the point of discharge, or when appropriate the point of placement, subject to the tolerances hereinafter specified;

NOTE 4—In selecting the specified air content, the purchaser should

[3] Available from American Concrete Institute (ACI), P.O. Box 9094, Farmington Hills, MI 48333-9094, http://www.aci-int.org.

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consider the exposure conditions to which the concrete will be subjected. Air contents less than shown in Table 1 may not produce adequate durability. Air contents higher than the levels shown may reduce strength without contributing further to freeze-thaw resistance.

6.1.6 When structural lightweight concrete is specified, the purchaser shall specify the density as freshly mixed density, equilibrium density, or oven-dry density.

NOTE 5—The freshly mixed density of lightweight concrete, that is the only density determinable at the time of delivery, is always higher than the equilibrium density or oven-dry density. Definitions of, and methods for determining or calculating freshly mixed, equilibrium, and oven-dry densities of lightweight concrete are covered in Test Methods C 138/C 138M and C 567.

6.1.7 If desired, any of the optional requirements of Table 2 of Specification C 1602/C 1602M.

6.1.8 One of the following Options A, B, or C, shall be used as the basis for determining the proportions of the fiber-reinforced concrete of the quality required.

6.2 *Option A*:

6.2.1 When the purchaser assumes responsibility for mixture proportioning, the following parameters shall also be specified by the purchaser:

6.2.1.1 The cement content in kilograms per cubic metre [pounds per cubic yard],

6.2.1.2 If supplementary cementitious materials are required, the type, and amounts to be used in kilograms per cubic metre [pounds per cubic yard], or in percentages by mass of cement,

6.2.1.3 The maximum allowable amount of mixing water in litres per cubic metre [gallons per cubic yard], including surface moisture on the aggregates, but excluding water absorbed by the aggregate,

6.2.1.4 If air-entraining admixtures are required, the type, name, and dosage range to be used to achieve the specified air content, (see 6.1.4),

6.2.1.5 If chemical admixtures are required, the type, name, and dosage range to be used, and:

6.2.1.6 The type of fibers to be used and the amount in kilograms per cubic metre [pounds per cubic yard], (see Classification Section 4).

NOTE 6—The dosage of air-entraining, water-reducing (including high-range), accelerating, and retarding admixtures needed to satisfy the material performance requirements varies. Therefore, dosage ranges should be specified to ensure that the material performance requirements can be met.

NOTE 7—The purchaser, in selecting requirements for which he assumes responsibility should give consideration to requirements for workability, placeability, durability, surface texture, and density. The purchaser is referred to ACI Practices 211.1 and 211.2 for selecting proportions that will result in concrete suitable for various types of structures and conditions of exposure, and to ACI Report 544.3R[4] for selecting concrete and fiber parameters suitable for fiber-reinforced concrete. For guidance on selecting proportions for fiber-reinforced shotcrete, the purchaser is referred to ACI Reports 506.1R[5] and 506.R[6] and ACI Specification 506.2.

6.2.2 At the request of the purchaser, the manufacturer shall, prior to the actual delivery of concrete, furnish a statement to the purchaser giving the sources, relative densities, sieve analyses, and saturated surface-dry masses of fine and coarse aggregates, and the amount of mixing water per cubic metre [per cubic yard] that will be used in the manufacture of each class of concrete ordered by the purchaser.

6.3 *Option B*:

6.3.1 When the purchaser requires the manufacturer to assume full responsibility for mixture proportioning (see Note 7), the purchaser shall also specify the following:

6.3.1.1 Requirements for flexural performance determined in accordance with one of the following: Test Method C 1399, C 1550 or C 1609/C 1609M, using samples obtained at the point of discharge, or when appropriate at the point of placement. At the option of the purchaser, compressive strength (Test Method C 39/C 39M) shall be specified when the flexural requirements are considered inadequate for ensuring the quality of the matrix of the fiber-reinforced concrete. Unless accelerated curing and testing in accordance with the warm water or boiling water procedures of Test Method C 684 is specified, tests shall be performed after standard moist curing in accordance with Practices C 31/C 31M at 28 days, or such other ages as are specified by the purchaser.

NOTE 8—While flexural strength at first peak is affected by the type and amount of fibers, it is more dependent on the characteristics of the mortar or concrete matrix, so it is recommended that the purchaser, when specifying flexural strength at first peak, consider factors known to influence the strength of normal concrete such as, water-cement ratio, aggregate maximum size, and the presence of chemical or supplementary cementitious materials.

6.3.2 At the request of the purchaser, the manufacturer shall, prior to the actual delivery of concrete, furnish a statement to the purchaser giving the sources, relative densities, sieve analyses, and saturated surface-dry masses of fine and coarse aggregates, the dry masses of cement and supplementary cementitious materials, the type, dimensions, and weight of fibers, the quantities, types and names of chemical and air-entraining admixtures (if any), and the amount of mixing water per cubic metre [per cubic yard] that will be used in the manufacture of each class of concrete ordered by the purchaser. The manufacturer shall also furnish evidence satisfactory to the purchaser that the materials to be used and the proportions selected will produce fiber-reinforced concrete of the quality specified.

6.4 *Option C*:

6.4.1 When the purchaser requires the manufacturer to assume responsibility for mixture proportioning with the minimum allowable cement content specified (see Note 7), the purchaser shall also specify the following:

6.4.1.1 Requirements for flexural performance determined in accordance with one of the following: Test Method C 1399, C 1550, or C 1609/C 1609M, using samples obtained at the point of discharge, or when appropriate the point of placement. At the option of the purchaser, compressive strength (Test

[4] ACI 544.3R-08, "Guide for Specifying, Proportioning and Production of Fiber-Reinforced Concrete," American Concrete Institute (ACI), PO Box 9094 Farmington Hills, MI 48333-9094.

[5] ACI 506.1R-08, "Guide to Fiber-Reinforced Shotcrete," American Concrete Institute (ACI), PO Box 9094 Farmington Hills, MI 48333-9094.

[6] ACI 506R-05, "Guide to Shotcrete," American Concrete Institute (ACI), P.O. Box 9094, Farmington Hills, MI 48333-9094.

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Method C 39/C 39M) shall be specified when the flexural requirements are considered inadequate for ensuring the quality of the matrix of the fiber-reinforced concrete. Unless accelerated curing and testing in accordance with the warm water or boiling water procedures of Test Method C 684 is specified, tests shall be performed after standard moist curing in accordance with Practices C 31/C 31M at 28 days, or such other ages as are specified by the purchaser (see Note 8).

6.4.1.2 Minimum cement content in kilograms per cubic metre [pounds per cubic yard].

6.4.1.3 If admixtures are required, the type, name, and dosage to be used. The cement content shall not be reduced when admixtures are used.

NOTE 9—Option C can be distinctive and useful only if the designated minimum cement content is at about the same level that would ordinarily be required for the mechanical properties, aggregate size, and workability specified. It must be an amount that will be sufficient to ensure durability under expected service conditions, as well as satisfactory surface texture and density. For additional information refer to ACI Practices 211.1 and 211.2.

6.4.2 At the request of the purchaser, the manufacturer shall, prior to the actual delivery of the concrete, furnish a statement to the purchaser giving the sources, relative densities, sieve analyses and saturated surface-dry masses of fine and coarse aggregates, the dry masses of cement and supplementary cementitious materials, the type, dimensions, and weight of fibers, the quantities, types and names of chemical and air-entraining admixtures (if any), and the amount of mixing water per cubic metre [per cubic yard] that will be used in the manufacture of each class of concrete ordered by the purchaser. The manufacturer shall also furnish evidence satisfactory to the purchaser that the materials to be used and the proportions selected will produce fiber-reinforced concrete of the quality specified.

6.5 The proportions arrived at by Options A, B, or C for each class of fiber-reinforced concrete approved for use in a project shall be assigned a designation to facilitate identification of each mixture delivered to the project. A certified copy of the proportions of all mixtures as established in Options A, B, or C shall be kept on file by the manufacturer.

6.6 The purchaser shall ensure that the manufacturer is provided copies of all reports of tests performed on concrete samples taken to determine compliance with specification requirements. Reports shall be provided on a timely basis.

7. Materials and Manufacture

7.1 In the absence of designated applicable specifications covering requirements for quality of materials, the following specifications shall govern:

7.1.1 Except for fibers, materials for the manufacture of fiber-reinforced concrete shall conform to Specification C 94/C 94M and materials for the manufacturer of fiber-reinforced concrete intended for shotcreting shall conform to Specification C 1436.

7.1.2 *Fibers*—Fibers shall be capable of producing fiber-reinforced concrete meeting the requirements of this specification. Steel fibers shall conform to Specification A 820/A 820M, alkali-resistant (AR) glass fibers shall conform to Specification C 1666/C 1666M, and cellulose fibers shall conform to Specification D 7357.

8. Measuring Materials

8.1 Except as otherwise specifically permitted by the purchaser, cement, supplementary cementitious materials, fine and coarse aggregates, mixing water, and admixtures shall be measured in accordance with the applicable requirements of Specification C 94/C 94M or Specification C 685/C 685M.

8.2 Fibers shall be batched by mass or volume with an accuracy of –3 % and +5 % of the amount required per batch.

8.3 Fibers shall be measured by mass when fiber-reinforced concrete is produced in accordance with Specification C 94/C 94M, and by volume when the fiber-reinforced concrete is produced in accordance with Specification C 685/C 685M. When the fibers are to be measured by mass, bags, boxes, or like containers are acceptable provided that such like containers are sealed by the fiber manufacturer and have the mass contained therein clearly marked. No fraction of a container delivered unsealed, or left over from previous work, shall be used unless weighed.

8.4 Prepackaged, dry, combined materials, including fibers, shall comply with the packaging and marking requirements of Specification C 387 or C 1480 and shall be accepted for use provided that after addition of water, the resulting fiber-reinforced concrete meets the performance requirements of this specification.

9. Batching Plant

9.1 Batching plant used for the preparation of batch-mixed fiber-reinforced concrete shall comply with the applicable requirements of Specification C 94/C 94M.

NOTE 10—A vibrating screen or other device for separating fibers may be required to avoid clumping of some types of fibers prior to mixing with concrete.

9.2 Batching plant used for the preparation of continuously-mixed fiber-reinforced concrete shall comply with the applicable requirements of Specification C 685/C 685M.

10. Mixing Equipment

10.1 Mixers or agitators for batch-mixed fiber-reinforced concrete shall comply with the applicable requirements of Specification C 94/C 94M.

10.2 Mixers for continuously mixed fiber-reinforced concrete shall comply with the applicable provisions of Specification C 685/C 685M.

11. Mixing and Delivery

11.1 Batch-mixed fiber-reinforced concrete, whether prepared on site or at a location remote from the site, shall be mixed and delivered to the point designated by the purchaser in accordance with the applicable requirements of Specification C 94/C 94M including the requirements for uniformity in the Annex.

11.2 Continuously mixed fiber-reinforced concrete, whether prepared on site or at a location remote from the site, shall be mixed and delivered to the point designated by the purchaser in

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TABLE 1 Recommended Total Air Content for Air-Entrained Concrete[A,B]

Exposure Condition[C]	Total Air Content, %						
	Nominal Maximum Sizes of Aggregate, mm [in.]						
	9.5 [⅜]	12.5 [½]	19.0 [¾]	25.0 [1]	37.5 [1½]	50.0 [2]	75.0 [3]
Mild	4.5	4.0	3.5	3.0	2.5	2.0	1.5
Moderate	6.0	5.5	5.0	4.5	4.5	4.0	3.5
Severe	7.5	7.0	6.0	6.0	5.5	5.0	4.5

[A] For air-entrained concrete, when specified.
[B] Unless exposure conditions dictate otherwise, air contents recommended above may be reduced by up to 1 % for concretes with specified compressive strength, f'_c, of 34.5 MPa [5000 psi] or above.
[C] For description of exposure conditions, refer to ACI 211.1, Table number 5.3.3 with attention to accompanying footnotes.

accordance with the applicable requirements of Specification C 685/C 685M including the requirements for uniformity in the Annex.

11.3 Fiber-reinforced concrete shall be free of fiber balls when delivered.

12. Batch Ticket Information

12.1 The manufacturer of the fiber-reinforced concrete shall furnish to the purchaser a delivery ticket or statement of particulars on which is printed, stamped, or written, information in one of the following two alternative formats:

12.1.1 *Batch-Mixing Format*—The details identified in the applicable requirements of Specification C 94/C 94M, and details of the type, brand, and amount of fibers used.

12.1.2 *Continuous Mixing Format*—The details identified in the applicable requirements of Specification C 685/C 685M, and details of the type, brand, and amount of fibers used.

13. Inspection of Materials, Production, and Delivery

13.1 The manufacturer shall afford the inspector all reasonable access, without charge, for making necessary checks of the production facilities and for securing necessary samples to determine if the materials used in the fiber-reinforced concrete comply with the requirements of this specification. Inspection, sampling, and testing shall not interfere unnecessarily with the manufacturing and delivery operations.

14. Sampling

14.1 The contractor shall afford the inspector all reasonable access, without charge, for the procurement of samples of freshly mixed fiber-reinforced concrete at the time of placement to determine compliance with the requirements of this specification.

14.2 Samples of batch-mixed fiber-reinforced concrete shall be obtained in accordance with Practice C 172 or C 1385/C 1385M as appropriate, except that wet-sieving shall not be permitted. Sampling for uniformity tests shall be in accordance with Specification C 94/C 94M.

14.3 Samples of continuously mixed fiber-reinforced concrete shall be obtained in accordance with the applicable requirements of Specification C 685/C 685M, except that wet-sieving shall not be permitted. Sampling for uniformity tests shall be in accordance with Specification C 685/C 685M.

15. Slump and Air Content Tests

15.1 Make tests for slump and air content at the time of placement at the option of the inspector as often as necessary for control checks and acceptance purposes, and always when specimens for tests on hardened concrete are made. When water is added in accordance with the requirements of this specification (see Tolerances in Slump Section 16), repeat all tests, and use the results of the second set of tests to establish whether or not the requirements of this specification are met.

15.2 If the measured slump or air content fall outside the limits permitted by this specification, make a check test immediately on another portion of the same sample. If the results again fall outside the permitted limits, the material represented by the sample fails to meet the requirements of this specification.

16. Tolerances in Slump

16.1 Unless other tolerances are included in the project specifications, the following shall apply to all forms of fiber-reinforced concrete except dry-mix shotcrete.

16.1.1 When the project specifications for slump are written as a "maximum" or "not to exceed" requirement:

	Specified Slump	
	If 75 mm [3 in.] or less	If more than 75 mm [3 in.]
Plus Tolerance	0	0
Minus Tolerance	40 mm [1½ in.]	65 mm [2½ in.]

These tolerances apply only if one addition of water is permitted on the job provided such addition does not increase the water-cement ratio above the maximum permitted by the project specifications.

NOTE 11—The slump of a fiber-reinforced concrete is less than the slump of an otherwise identical concrete without fibers. The magnitude of the difference depends strongly on the amount and type of fibers, so it is recommended that trial mixtures representing the amount and type of fibers to be used in the work be prepared and tested to ensure that the specified slump requirements are met.

16.1.2 When the project specifications for slump are not written as a "maximum" or "not to exceed" requirement:

Tolerances for Nominal Slumps

For Specified Slump of	Tolerance
50 mm [2 in.] and less	±15 mm [½ in.]
50 to 100 mm [2 to 4 in.]	±25 mm [1 in.]
more than 100 mm [4 in.]	±40 mm [1½ in.]

16.2 Fiber-reinforced concrete shall be available within the permissible range of slump for a period of 30 min starting either on arrival at the job site or after the permitted slump adjustment, whichever is later. The first and last ¼ m^3 [¼ yd^3] discharged are exempt from this requirement. If the user is unprepared for discharge of the material at the job site, the manufacturer shall not be responsible for failure to meet slump

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requirements after 30 min have elapsed beyond either the actual arrival time at the job site or the requested delivery time, whichever is later.

17. Tolerance in Air Content

17.1 When air-entrainment is specified, the total air content measured using Test Method C 173/C 173M or Test Method C 231 shall be within a tolerance of ±1.5 of the specified value in percent.

18. Acceptance Testing of Hardened Fiber-Reinforced Concrete

18.1 Obtain material for the preparation of test specimens in accordance with the sampling section of this specification.

18.2 When post-crack flexural performance is used as the basis for acceptance of fiber-reinforced concrete, make, condition, and test sets of test specimens in accordance with Test Method C 1399, C 1550 or C 1609/C 1609M as specified.

18.3 When flexural strength is used as the basis for acceptance, make and test sets of at least three test specimens in accordance with the requirements for sampling and conditioning given in Test Method C 1609/C 1609M. Test specimens representing thin sections, as defined in Test Method C 1609/C 1609M, or specimens representing fiber-reinforced shotcrete of any thickness, shall be tested as cast or placed without being turned on their sides before placement on the support system. Acceptance shall not be based on flexural strength alone when post-crack performance is important.

NOTE 12—Test Method C 1609/C 1609M provides for the determination of first peak flexural strength when required by the purchaser. For many type-amount fiber combinations, the first peak flexural strength is not significantly greater than the peak strength in flexure.

18.4 When compressive strength is used as part of the basis for acceptance of fiber-reinforced concrete, make sets of at least two test specimens in accordance with the applicable requirements of Practices C 31/C 31M and C 192/C 192M, or Test Methods C 42/C 42M or C 1604/C 1604M and condition and test in accordance with Test Methods C 39/C 39M, C 42/C 42M, or C 1604/C 1604M. Acceptance shall not be based on compressive strength alone.

18.5 The testing laboratory performing acceptance tests shall comply with the requirements of Practice C 1077.

19. Frequency of Tests

19.1 The frequency of tests on hardened fiber-reinforced concrete shall be in accordance with the following requirements:

19.1.1 *Batch-Mixing*—Tests shall be made with a frequency of not less than one test for each 115 m^3 [150 yd^3]. Each test shall be made from a separate batch. On each day fiber-reinforced concrete is mixed, at least one test shall be made for each class of material.

19.1.2 *Continuous Mixing*—Tests shall be made for each 19 m^3 [25 yd^3] or fraction thereof, or whenever significant changes have been made in the proportioning controls. On each day fiber-reinforced concrete is mixed, at least one test shall be made for each class of material.

19.1.3 *Shotcrete*—Tests shall be made for each 38 m^3 [50 yd^3] placed using specimens sawed or cored from the structure or from corresponding test panels prepared in accordance with Practice C 1140. On each day fiber-reinforced shotcrete is prepared, at least one test shall be made for each class of material.

19.2 The representative of the purchaser shall ascertain and record the delivery-ticket number or equivalent information and the exact location in the work at which the material represented by each test is deposited.

20. Calculation of Test Results

20.1 A test result shall be based on the mean of the property values for a set of hardened concrete test specimens constituting a test unit as defined herein or in the applicable test method.

20.2 Any individual test specimen in a set constituting a test unit, as defined herein or in the applicable test method, shall be deemed defective and discarded if it shows definite evidence of improper sampling, molding, handling, curing, or testing, and the mean of the property values for the remaining test specimens shall be considered the test result. If more than one specimen in the set is deemed defective on this basis, the test result shall be rejected.

21. Performance Requirements

21.1 Unless specifically excluded by the purchaser when ordering material in accordance with Option B or C, fiber-reinforced concrete prepared in accordance with this specification shall meet the following requirements:

21.2 For post-crack flexural performance determined in accordance with Test Method C 1399, C 1550 or C 1609/C 1609M, the test results shall equal or exceed the specified values at the applicable test age.

NOTE 13—A post-crack performance requirement should not be specified when fibers are used only to control plastic shrinkage cracking.

21.3 When first-peak and peak flexural strength, in accordance with Test Method C 1609/C 1609M, or compressive strength, in accordance with Test Method C 39/C 39M, are performance requirements, the test results shall equal or exceed the specified values at the applicable test age.

21.4 When the fiber-reinforced concrete is to be exposed to cycles of freezing and thawing, and the purchaser requires evidence of satisfactory durability, such evidence shall be provided by the manufacturer. A proven record of satisfactory freeze-thaw durability for concrete with or without fibers, made using the same air content, aggregates, and mixture proportions as the fiber-reinforced concrete specified for the work, shall be considered acceptable evidence when the concrete has been in place for at least two winters. In the absence of such a record, satisfactory durability shall be demonstrated for the fiber-reinforced concrete proposed for the work by the attainment of an average durability factor of at least 80 % for a set of three specimens tested according to Procedure A of Test Method C 666/C 666M.

22. Failure to Meet Requirements

22.1 When fiber-reinforced concrete fails to meet the requirements of this specification, the manufacturer and the purchaser shall confer to determine whether agreement can be reached as to what adjustment, if any shall be made. If

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agreement on a mutually satisfactory adjustment cannot be reached by the manufacturer and the purchaser, a decision shall be made by a panel of three qualified engineers, one of whom shall be designated by the purchaser, one by the manufacturer, and the third chosen by these two members of the panel. The question of responsibility for the cost of such arbitration shall be determined by the panel. Its decision shall be binding, except as modified by a court decision.

23. Keywords

23.1 accuracy; average residual-strength; certification; fibers; fiber-reinforced concrete; flexural parameters; materials for; scales; testing; toughness

SUMMARY OF CHANGES

Committee C09 has identified the location of selected changes to this specification since the last issue, C 1116/C 1116M – 08a, that may impact the use of this specification. (Approved June 1, 2009)

(*1*) Deleted references to Test Method C 995, which was withdrawn in 2008, in 6.1.4, 15.2, 16.1, Note 11, 16.2, and Referenced Documents. Deleted 6.1.4.1. Deleted old Note 4 and renumbered subsequent notes.
(*2*) Replaced "workability" with "slump" in Sections 15 and 16.
(*3*) Revised the order of the units in Sections 6, 16, 19, and Table 1 to comply with C09's units policy.
(*4*) Updated references in Footnotes 4 and 5.

Committee C09 has identified the location of selected changes to this specification since the last issue, C 1116/C 1116M – 08, that may impact the use of this specification. (Approved December 15, 2008)

(*1*) Revised 4.1.3, 4.1.4, and 4.2 to better define what is expected in terms of resistance to deterioration.
(*2*) Revised Note 1.
(*3*) Added new 8.2 to provide batching tolerances for fibers and renumbered subsequent paragraphs.

Committee C09 has identified the location of selected changes to this specification since the last issue, C 1116/C 1116M – 06, that may impact the use of this specification. (Approved January 1, 2008)

(*1*) Added new 9.2 to add reference to continuous batching to avoid confusion as to batching and mixing.
(*2*) Revised the Terminology Section to comply with ASTM Form and Style and revised the definitions of *manufacturer* and *purchaser*.
(*3*) Extensively revised Section 4.
(*4*) Revised 5.1 and 8.3 to accommodate production of fiber-reinforced concrete in accordance with Specification C 685/C 685M.

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Designation: C 1137 – 05

Standard Test Method for Degradation of Fine Aggregate Due to Attrition[1]

This standard is issued under the fixed designation C 1137; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope*

1.1 This test method provides a procedure for indicating the relative degree to which a fine aggregate is likely to degrade due to the mixing and agitation of hydraulic cement concrete.

1.2 The values given in SI units are to be regarded as the standard. The values given in inch-pound units are for information only.

1.3 The text of this test method references notes and footnotes which provide explanatory material. These notes and footnotes (excluding those in tables and figures) shall not be considered as requirements of this test method.

1.4 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

2. Referenced Documents

2.1 *ASTM Standards:* [2]

C 33 Specification for Concrete Aggregates

C 117 Test Method for Materials Finer Than 75-µm (No. 200) Sieve in Mineral Aggregates by Washing

C 125 Terminology Relating to Concrete and Concrete Aggregates

C 136 Test Method for Sieve Analysis of Fine and Coarse Aggregates

C 295 Guide for Petrographic Examination of Aggregates for Concrete

C 670 Practice for Preparing Precision and Bias Statements for Test Methods for Construction Materials

C 702 Practice for Reducing Samples of Aggregate to Testing Size

D 75 Practice for Sampling Aggregates

E 11 Specification for Wire Cloth and Sieves for Testing Purposes

3. Summary of Test Method

3.1 A specimen of fine aggregate, of specified grading, is subjected to vigorous agitation under water from the action of a high-speed impeller. Degradation is measured by the decrease in fineness modulus (as defined in Terminology C 125) and the increase in amount of material finer than the 75-µm (No. 200) sieve.

4. Significance and Use

4.1 The tendency of some fine aggregates, including those that comply with the requirements of Specification C 33, to degrade from the grinding action in a concrete mixer may affect mixing water demand, entrained air, and slump. When it is suspected that degradation during mixing is a problem, this test method may be useful for evaluating the extent of the problem.

4.2 This test method is of use for preliminary screening to indicate the need for further evaluation through petrographic examination (Guide C 295) or testing the quality of mortar, or concrete, or both made from the fine aggregate in question.

4.3 This test method is of use for comparing the results obtained with unknown materials against those with materials of known performance in concrete.

5. Apparatus

5.1 *Sieves*, conforming to Specification E 11: 75-µm (No. 200), 150-µm (No. 100), 300-µm (No. 50), 600-µm (No. 30), 1.18-mm (No. 16), 2.36-mm (No. 8), 4.75-mm (No. 4), and 9.5-mm (⅜-in.).

5.2 *Balance*—A balance or scale readable and accurate to 0.1 g or 0.1 % of the test specimen mass, whichever is greater, at any point within the range of use.

5.3 *Oven*—An oven of appropriate size capable of maintaining a uniform temperature of 110 ± 5 °C (230 ± 9 °F).

[1] This test method is under the jurisdiction of ASTM Committee C09 on Concrete and Concrete Aggregates and is the direct responsibility of Subcommittee C09.20 on Normal Weight Aggregates.

Current edition approved July 15, 2005. Published August 2005. Originally approved in 1990. Last previous edition approved in 1997 as C 1137 – 97.

[2] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

***A Summary of Changes section appears at the end of this standard.**

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5.4 *Attrition Device*—A stainless steel octagonal tank, 140 mm (5½ in.) high and 110 mm (4½ in.) minimum inside width, with a motor-driven 19-mm (¾-in.) vertical shaft so mounted that it can be lowered into the desired position within the octagonal tank. Mounted on the shaft there shall be three horizontal sets of six pitched stainless steel blades[3]. A lid shall be provided with a hole for the shaft. See Figs. 1 and 2.

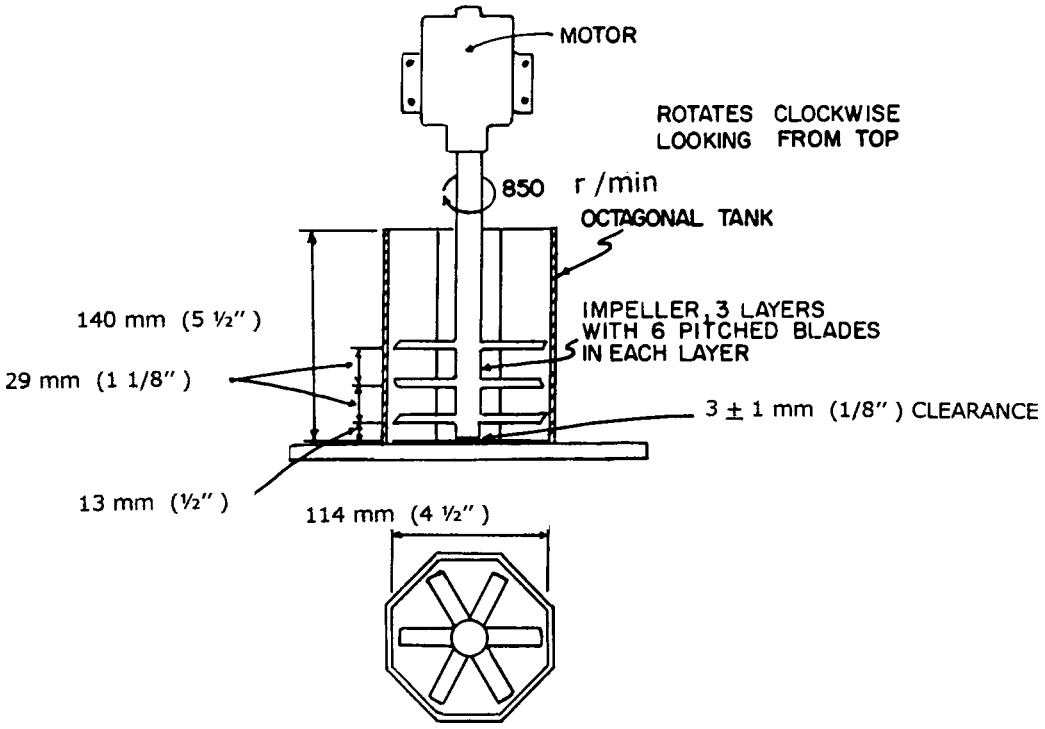

FIG. 1 Attrition Machine

5.5 *Rotating Device*—An electric motor-driven device or drill press suitable for driving the impeller clockwise as shown in Fig. 1. It shall be capable of driving the impeller at 850 ± 50 r/min with the specimen and water in the tank.

6. Sample Preparation

6.1 Sample the aggregate in accordance with Practice D 75 and reduce to test specimen size in accordance with Practice C 702.

6.2 Prepare a test specimen of 500 ± 5 g to a grading listed in Table 1. If these gradings are not practicable, it is permitted to use a grading not listed in Table 1 and compute the fineness modulus of this grading.

6.3 In preparing a test specimen, first remove material passing the 75-µm sieve by washing (in accordance with Test Method C 117), then oven dry and sieve (in accordance with Test Method C 136) into separate size fractions. Weigh and combine the fine aggregate size fractions to the selected grading.

6.4 If the test is to be performed on one of the standard gradings from Table 1, use the grading nearest that of the as-received sample. Where different fine aggregates are to be compared, use the same initial grading for each.

7. Procedure

7.1 Determine the mass of the test specimen of oven-dry fine aggregate to the nearest 0.1 g and record.

7.2 Determine the mass of the cleaned, dry impeller. Insert the container and impeller in the drill press and adjust the vertical stop on the feed to position the bottom of the impeller shaft 3 ± 1 mm (⅛ ± 1/32 in.) above the bottom of the container. Make this adjustment prior to each test before introducing the specimen. Using a funnel, place the test specimen in the container. Brush any remaining material from the funnel into the container and add 175 g ± 5 g of water. Place the lid firmly on the container to avoid loss of the fine aggregate and the water. It is permitted, as an alternative method, to add the test specimen to the container and then insert the impeller by turning the shaft by hand until the impeller penetrates through the fine aggregate.

7.3 Run the attrition device for 6 ± 1/10 min at 850 ± 50 r/min.

[3] The sole source of supply of the apparatus known to the committee at this time is Dorr-Oliver Eimco, 2850 South Decker Lake Drive, Salt Lake City, Utah, 84119, phone 801–526–2000, www.glv.com. An attrition tank with 100 mm attriting element (impeller) that can be used in a 850-r/min drill press or in a WEMCO laboratory flotation machine, parts No. 23828 (impeller), 23844 (tank), and 44519 (cover). If you are aware of alternative suppliers, please provide this information to ASTM International Headquarters. Your comments will receive careful consideration at a meeting of the responsible technical committee,[1] which you may attend.

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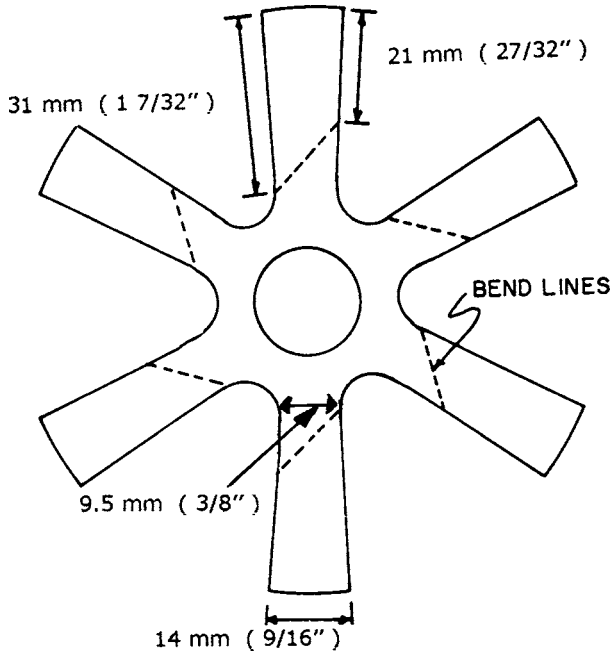

TOP VIEW—TOP IMPELLER BLADE ENDS BENT LEFT (COUNTERCLOCKWISE)

Impeller—102 mm (4 in.) diameter × 1.5 mm (No. 16 gage) thick; Three Layers Shaft—19 mm (¾ in.) diameter extending 9.5 mm (⅜ in.) below bottom layer and the ends of the blades bent to 45° pitch. Blades on the top and bottom layer bent to the left (counterclockwise) and the middle layer bent to the right (clockwise).

FIG. 2 Impeller Details

TABLE 1 Alternative Test Gradings

Sieve Size	% Passing				
	No. 1	1A[A]	No. 2	No. 2A[B]	No. 3
4.75-mm (No. 4)	100	100	100	100	100
2.36-mm (No. 8)	80	100	88	100	100
1.18-mm (No. 16)	50	60	74	80	85
600-µm (No. 30)	25	30	49	50	60
300-µm (No. 50)	10	10	20	20	30
150-µm (No. 100)	2	0	5	0	10
75-µm (No. 200)	0	0	0	0	0
Fineness Modulus	3.33	3.00	2.64	2.50	2.15

[A] Similar to No. 1 but with the fine and coarser fractions removed.
[B] Similar to No. 2 but with the fine and coarser fractions removed.

7.4 Remove the container, lid, and impeller from the drill press and place in a pan. Using a minimum amount of water, wash the test specimen from the container, impeller, and lid into the pan. Avoid loss of any portion of the test specimen.

7.5 Test the whole test specimen in accordance with Test Method C 117 and test the washed material remaining in accordance with Test Method C 136.

7.6 Determine the mass of the clean, dry impeller after the test and record its mass to detect any long-term change in the impeller.

NOTE 1—Repeated testing will cause abrasive wear to the blades of the impeller. In a study of testing 100 specimens of siliceous fine aggregate, it was found that these specimens caused sufficient wear to the impeller to result in a 14 to 25 % reduction in the ability of the apparatus to cause degradation of the aggregate[4]. Degradation was measured by the increase in amount of material passing the 75-µm (No. 200) sieve. For this reason, it is good practice to monitor change in equipment efficiency by periodically testing replicate specimens of an aggregate of known behavior in the test. Such an aggregate can be established at the time the equipment is first used and a sufficient supply retained for monitoring purposes.

8. Report

8.1 Report the following data:

8.1.1 Grading as-received,

8.1.2 Grading as-tested (from Table 1 or as otherwise specified),

8.1.3 Grading after attrition,

8.1.4 Percent finer than the 75-µm (No. 200) sieve after attrition,

8.1.5 Fineness modulus before and after attrition, and

8.1.6 The mass of the clean, dry impeller before and after the test.

9. Precision and Bias

9.1 *Within Laboratory Precision*—In a study using one test apparatus, involving six different operators, testing six specimens of three materials of different attrition loss passing the 75-µm (No. 200) sieve, the following data on repeatability were obtained:

Mean % Loss Passing 75-µm (No. 200) Sieve, by Mass	Sample Standard Deviation, % by Mass[A]	Acceptable Range of Two Results, % by Mass[A]
5.5	0.31	0.88
9.9	0.26	0.74
29.1	0.47	1.33

[A] These numbers represent, respectively, the (1s%) and (d2s%) limits as described in Practice C 670.

9.2 *Multilaboratory Precision*—Data on multi-laboratory variation are not available.

9.3 *Bias*—The procedure in this test method has no bias because the values obtained for attrition loss can be defined only in terms of the test method.

10. Keywords

10.1 agitation; attrition; concrete; degradation; fine aggregates; mixing

[4] Rogers, C. A., Bailey, M. L., Price, B., "Micro-Deval test for evaluating the quality of fine aggregate for concrete and asphalt," Transportation Research Board, Washington, D. C., Record 1301, pp. 68-76, 1991.

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APPENDIX

(Nonmandatory Information)

X1. Interpretation of Results

X1.1 No specifications have been developed for results obtained with this test method. Davis et al.[5] developed the attrition test to evaluate fine aggregate degradation that might occur during mixing. Meininger[6] found that the amount of material that passed the 75-μm (No. 200) sieve might be a better indicator of fine aggregate behavior than change in fineness modulus. He found that sands that gave attrition losses [measured by material finer than 75-μm (No. 200)] greater than about 20 % were most likely to be susceptible to breakdown during concrete mixing. He also noted that such sands might still be used satisfactorily in some cases. He also found that lesser problems might be experienced with sands giving losses above about 12 %.

It has been found[4] that there is a moderate correlation between attrition loss of natural sands [material passing 75-μm (No. 200)] and the magnesium sulfate soundness loss of the sands. Crusher screenings and manufactured stone sands give considerably greater attrition losses than that obtained with natural sands of the same sulfate loss. This is due to breakage of the sharp and relatively brittle edges found in such angular products. It should be noted that for a given material, attrition loss of coarse graded sand [as measured by material passing 75-μm (No. 200)] is considerably greater than that of fine graded sand [4,6].

[5] Davis, R. E., Mielenz, R. C., and Polivka, M., Importance of Petrographic Analysis and Special Tests not Usually Required in Judging Quality of Concrete Sand, Journal of Materials, ASTM, Vol. 2, No. 3, pp. 461-486, 1967.

[6] Meininger, R. C., Aggregate Degradation During Mixing, National Ready Mixed Concrete Association, Technical Information Letter No. 341, Feb., 1978.

SUMMARY OF CHANGES

Committee C09 has identified the location of selected changes to this test method since the last issue, C 1137 – 97, that may impact the use of this specification. (Approved July 15, 2005)

(*1*) Revised Section 1.
(*2*) Updated Referenced Documents.
(*3*) Revised Sections 4-10.
(*4*) Added a within laboratory precision statement.
(*5*) Added an appendix to provide guidance on the interpretation of test results.

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Designation: C 1138M – 05

Standard Test Method for Abrasion Resistance of Concrete (Underwater Method)[1]

This standard is issued under the fixed designation C 1138M; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope

1.1 This test method covers a procedure for determining the relative resistance of concrete (including concrete overlays and impregnated concrete) to abrasion under water (see Note 1). This procedure simulates the abrasive action of waterborne particles (silt, sand, gravel, and other solids).

NOTE 1—Other procedures are available for measuring abrasion resistance of concrete surfaces not under water. These include Test Methods C 418, C 779, and C 944.

1.2 The values stated in acceptable metric units are to be regarded as the standard.

1.3 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.* (**Warning**—Fresh hydraulic cementitious mixtures are caustic and may cause chemical burns to skin and tissue upon prolonged exposure.)[2]

2. Referenced Documents

2.1 *ASTM Standards:* [3]

C 42/C 42M Test Method for Obtaining and Testing Drilled Cores and Sawed Beams of Concrete

C 418 Test Method for Abrasion Resistance of Concrete by Sandblasting

C 642 Test Method for Density, Absorption, and Voids in Hardened Concrete

C 670 Practice for Preparing Precision and Bias Statements for Test Methods for Construction Materials

C 779/C 779M Test Method for Abrasion Resistance of Horizontal Concrete Surfaces

C 944 Test Method for Abrasion Resistance of Concrete or Mortar Surfaces by the Rotating-Cutter Method

E 18 Test Methods for Rockwell Hardness and Rockwell Superficial Hardness of Metallic Materials

3. Significance and Use

3.1 This test method is intended to qualitatively simulate the behavior of swirling water containing suspended and transported solid objects that produce abrasion of concrete and cause potholes and related effects.

3.2 This test method should provide a relative evaluation of the resistance of concrete to such action.

3.3 The results are expected to be useful in selection of materials, mixtures, and construction practices for use where such action is to be expected.

3.4 The test method is not intended to provide a quantitative measurement of the length of service that may be expected from a specific concrete.

4. Apparatus

4.1 *Rotating Device*—A drill press or similar device with a chuck capable of holding and rotating the agitation paddle under test conditions at a speed of 1200 ± 100 rpm shall be used.

4.2 *Test Container*—A steel pipe, 305 ± 6-mm (12 ± ¼-in.) inside diameter by 450 ± 25-mm (18 ± 1-in.) high, fitted with a watertight steel base shall be used (see Fig. 1).

4.3 *Agitation Paddle*—The agitation paddle shall be as shown in Fig. 2.

4.4 *Abrasive Charges*—Seventy grade 1000 chrome steel grinding balls with nominal sizes as specified in Table 1 shall be used. The steel of which the balls are made shall have a Rockwell C-scale hardness of 65 ± 5 as determined by Test Methods E 18. The balls shall have a smooth texture and no apparent mold seam (see Note 2).

NOTE 2—An abrasive charge meeting the requirements of Table 1 will have a mass of approximately 1530 to 1900 g (3.8 to 4.2 lb). When the mass of the charge approaches the lower limit, replace the undersize or underweight balls not complying with Table 1.

4.5 *Scales*—A platform scale having a capacity of at least 45 kg (100 lb) or more and accurate to within at least 5.0 g (0.01 lb) at any point within the range used in this test shall be

[1] This test method is under the jurisdiction of ASTM Committee C09 on Concrete and Concrete Aggregates and is the direct responsibility of Subcommittee C09.62 on Abrasion Testing.

Current edition approved Dec. 15, 2005. Published January 2006. Originally approved in 1989. Last previous edition approved in 1997 as C 1138 – 97.

[2] Section on Safety Precautions, *Manual of Aggregate and Concrete Testing*, *Annual Book of ASTM Standards*, Vol. 04.02.

[3] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

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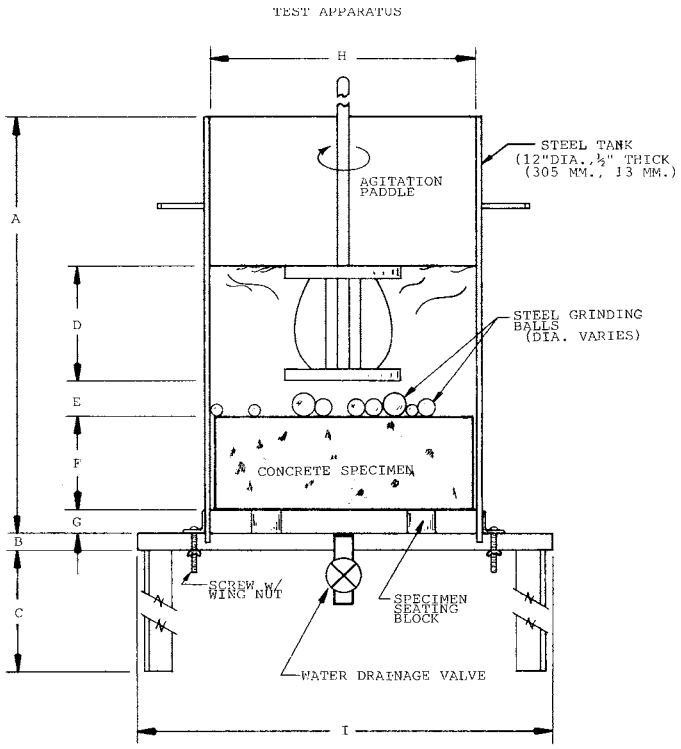

	in.	mm
A	18.0	457
B	0.75	19
C	Optional - to suit	
D	5.0	127
E	1.5	38
F	4.0	102
G	1.0	25.4
H	12.0	305
I	18.0	457

FIG. 1 Test Apparatus

used. The scale shall be equipped with a suitable apparatus for suspending the sample in its container in water from the center of the weighing platform.

4.6 *Weighing Basket*—A wire basket or other suitable support shall be provided for weighing the specimen in water. The weighing basket shall be constructed to prevent entrapping air when it and the specimen are submerged.

4.7 *Water Tank*—A suitable watertight tank into which the basket and the specimen can be suspended below the scale shall be furnished.

4.8 *Seating Block*—A minimum of three steel blocks 25 by 25 by 25 mm (1 by 1 by 1 in.) shall be used to support the specimen.

5. Test Specimens

5.1 The test specimen shall be cylindrical in shape, having a diameter approximately 6-mm (¼-in.) less than that of the inside diameter of the test container and a height of 100 ± 13 mm (4 ± ½ in.). It may be molded from freshly mixed concrete or cored from hardened concrete (see Note 3). Cores shall be taken in accordance with Methods C 42.

NOTE 3—Specimens should be tested at an age appropriate for the material being evaluated. Most testing done to date has been done at 28 days. Concretes containing pozzolans should be tested at an age that allows development of appropriate strength. Toppings and impregnated concretes should be tested at an age appropriate for the material and in compliance with the manufacturer's recommendations. The appropriate testing age may also depend upon when the concrete will be put into service.

5.2 If the specimen has a membrane curing compound on the surface, remove it completely by steel wire brushing prior to the soaking period.

5.3 Soak the specimen in lime-saturated water or in the water to which the concrete shall be subjected in service for a minimum of 48 h prior to testing.

5.4 Determine the average diameter of the top surface of the specimen to be tested to the nearest 2 mm (1/16 in.) by averaging two diameters measured at right angles to each other. This average diameter shall be used in calculating the top surface area.

5.5 Surface dry the specimen. Determine and record the mass in air to the nearest 25.0 g (0.05 lb). Determine and record the apparent mass of the specimen immersed in water to the nearest 25.0 g (0.05 lb). The procedure of Test Method C 642 shall be followed using water at 23 ± 1.7 °C (73.4 ± 3 °F) having a density of 997 ± 2 kg/m^3. Remove all entrapped air by shaking the specimen while it is immersed in the water for weighing.

6. Procedure

6.1 Place the specimen in the test container with the surface to be tested facing up and the seating blocks in place.

6.2 Position the specimen so that its surface is normal to the drill shaft and the center of the specimen coincides with the drill shaft.

6.3 Mount the agitation paddle in the drill press. The bottom of the agitation paddle shall be 38 ± 5 mm (1½ ± ¼ in.) above the surface of the specimen.

6.4 Determine and record the mass of the abrasive charge to the nearest 10 g (0.02 lb). Place it on the surface of the specimen and add water of the same type as used in the saturation period to 165 ± 5 mm (6½ ± ¼ in.) above the surface of the specimen.

6.5 Start the paddle rotating and check that the paddle is rotating at the required speed with the paddle immersed.

6.6 Remove the specimen from the test container at the end of every 12 h of operation. Flush off the abraded material and surface dry. Determine and record the mass of the specimen in air and in water.

6.7 The standard test shall consist of six 12-h periods for a total of 72 h (see Note 4).

NOTE 4—Testing totalling 24 h generally produces significant abrasion in most concrete surfaces, but it is recommended to extend the period of simulation if more severe abrasion is desired. Additional testing time may be required for concrete that is highly resistant to abrasion.

7. Calculation

7.1 Calculate the abrasion loss as follows:

7.1.1 Calculate the volume of the specimen at any time as follows:

$$V_t = \frac{W_{air} - W_{water}}{G_w} \quad (1)$$

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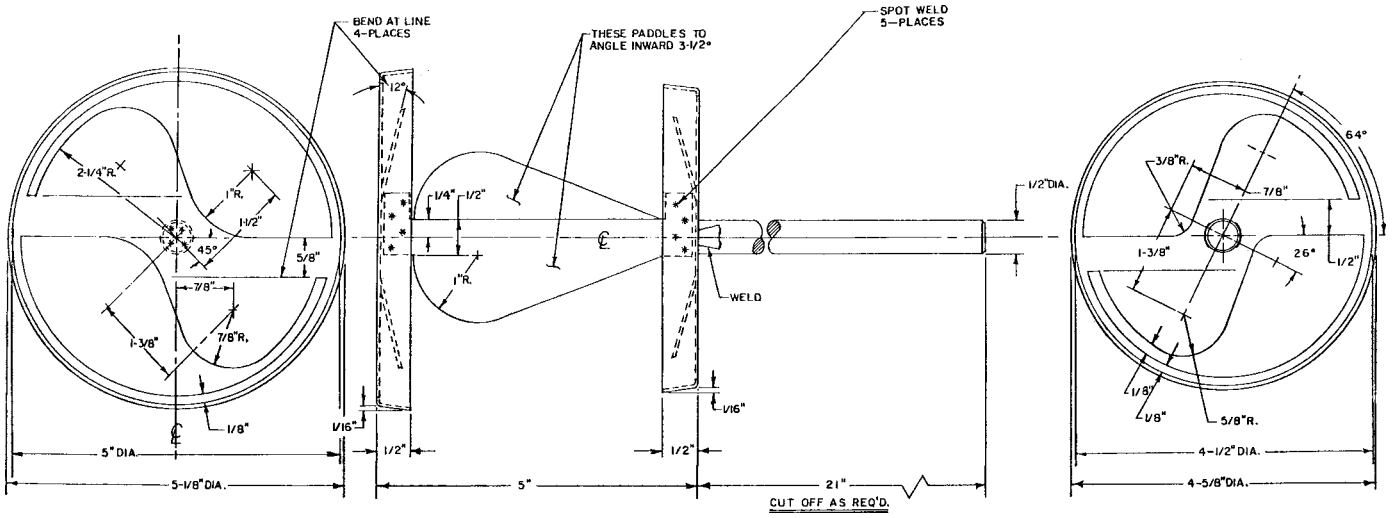

NOTE 1—1—16 Ga (0.059 in.)—304 Stainless Steel
NOTE 2—Rotation of agitation paddle clockwise when viewed from shaft end.
NOTE 3—Shaft length to be adjusted to fit assembly in Fig. 11.

in.	mm
21	533
5⅛	130
5	127
4⅝	117
4½	114
3⁹⁄₁₆	97
2¼	57
1½	38
1⅜	35
1	25
⅞	22
⅝	16
½	13
⅜	10
¼	6
⅛	3
¹⁄₁₆	2

TOLERANCE UNLESS	Material 16 GA.(.059) STEEL	FINISH		TITLE
OTHERWISE SPECIFIED	REVISIONS	BY	DATE	AGITATION PADDLE

FIG. 2 Agitation Paddle

TABLE 1 Abrasive Charges

Number of Balls	Nominal Size	Minimum Diameter
10	1.00 in.	25.3 mm (0.95 in.)
35	0.75 in.	19.0 mm (0.70 in.)
25	0.50 in.	12.6 mm (0.45 in.)

where:
V_t = volume of the specimen at the desired time, m^3,
W_{air} = mass of the specimen in air at the desired time, kg,
W_{water} = apparent mass of the specimen in water at the desired time, kg, and
G_w = unit weight of water kg/m^3.

7.1.2 Calculate the volume of concrete lost at the end of any time increment of testing as follows:

$$VL_t = V_i - V_t \quad (2)$$

where:
VL_t = volume of material lost by abrasion at the end of the test increment in question, m^3,
V_i = volume of specimen before testing, m^3, and
V_t = volume of the specimen at the end of the test increment in question m^3.

7.2 Should it be desired to calculate the average depth of wear at the end of any time increment of testing based on volume of abraded material, it may be done as follows:

$$ADA_t = VL_t/A \quad (3)$$

where:
ADA_t = average depth of abrasion at the end of the test increment in question, m, and
A = area of top of specimen m^2.

8. Report

8.1 The report shall include the following:

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8.1.1 A plot of time versus abrasion loss of at least three individual test specimens and the average of all specimens of a type that were tested.

8.1.2 The average diameter of each specimen. The volume of each specimen at the end of each test period.

8.1.3 Relevant data as desired on the concrete represented by the specimens.

8.1.4 Mass of the grinding balls at the beginning and end of the testing.

9. Precision and Bias

9.1 *Precision*—The single laboratory coefficient of variation among test specimens made from a single batch of concrete was found to be 14.0 %. Therefore, in a properly conducted test, the range among test results from the three specimens required by the test method should be no greater than 46.2 % of their mean. (See Note 5.)[4]

NOTE 5—This number represents the 1 S limit, as defined by Practice C 670. This limit was calculated according to paragraph 3.3.2 of Practice C 670 – 91a. The variation due to making specimens from different concrete batches was found to be too small to detect.

9.2 *Bias*—No estimate of bias is being made because there is no recognized standard material for this test method.

[4] Supporting data have been filed at ASTM International Headquarters and may be obtained by requesting Research Report RR: C09-1009.

APPENDIX

(Nonmandatory Information)

X1. PRECISION OF THE TEST METHOD

X1.1 This test method was originally developed and used by the Corps of Engineers.[5] When developed and during its initial use, abrasion loss as determined by the test method was expressed as a percentage of the original mass of the specimen. For tests so conducted the single-operator standard deviation (1S) was found to be 0.42 % and hence, the results of two properly conducted tests by the same operator on specimens from the same batch of concrete should not differ by more than 1.18 % (D2S). These limits were calculated as described in Practice C 670.

X1.2 The test method was revised to reflect loss in terms of volume rather than in terms of mass to eliminate differences in results resulting from the allowable variations in specimen size.

[5] Liu, Tony C., "Abrasion Resistance of Concrete," *ACI Journal*, *Proceedings* Vol 78, No. 5, Sept.-Oct. 1981, pp 341-350.

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Designation: C 1138M – 05

Standard Test Method for Abrasion Resistance of Concrete (Underwater Method)[1]

This standard is issued under the fixed designation C 1138M; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope

1.1 This test method covers a procedure for determining the relative resistance of concrete (including concrete overlays and impregnated concrete) to abrasion under water (see Note 1). This procedure simulates the abrasive action of waterborne particles (silt, sand, gravel, and other solids).

NOTE 1—Other procedures are available for measuring abrasion resistance of concrete surfaces not under water. These include Test Methods C 418, C 779, and C 944.

1.2 The values stated in acceptable metric units are to be regarded as the standard.

1.3 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.* (**Warning**—Fresh hydraulic cementitious mixtures are caustic and may cause chemical burns to skin and tissue upon prolonged exposure.)[2]

2. Referenced Documents

2.1 *ASTM Standards:* [3]

C 42/C 42M Test Method for Obtaining and Testing Drilled Cores and Sawed Beams of Concrete

C 418 Test Method for Abrasion Resistance of Concrete by Sandblasting

C 642 Test Method for Density, Absorption, and Voids in Hardened Concrete

C 670 Practice for Preparing Precision and Bias Statements for Test Methods for Construction Materials

C 779/C 779M Test Method for Abrasion Resistance of Horizontal Concrete Surfaces

C 944 Test Method for Abrasion Resistance of Concrete or Mortar Surfaces by the Rotating-Cutter Method

E 18 Test Methods for Rockwell Hardness and Rockwell Superficial Hardness of Metallic Materials

3. Significance and Use

3.1 This test method is intended to qualitatively simulate the behavior of swirling water containing suspended and transported solid objects that produce abrasion of concrete and cause potholes and related effects.

3.2 This test method should provide a relative evaluation of the resistance of concrete to such action.

3.3 The results are expected to be useful in selection of materials, mixtures, and construction practices for use where such action is to be expected.

3.4 The test method is not intended to provide a quantitative measurement of the length of service that may be expected from a specific concrete.

4. Apparatus

4.1 *Rotating Device*—A drill press or similar device with a chuck capable of holding and rotating the agitation paddle under test conditions at a speed of 1200 ± 100 rpm shall be used.

4.2 *Test Container*—A steel pipe, 305 ± 6-mm (12 ± ¼-in.) inside diameter by 450 ± 25-mm (18 ± 1-in.) high, fitted with a watertight steel base shall be used (see Fig. 1).

4.3 *Agitation Paddle*—The agitation paddle shall be as shown in Fig. 2.

4.4 *Abrasive Charges*—Seventy grade 1000 chrome steel grinding balls with nominal sizes as specified in Table 1 shall be used. The steel of which the balls are made shall have a Rockwell C-scale hardness of 65 ± 5 as determined by Test Methods E 18. The balls shall have a smooth texture and no apparent mold seam (see Note 2).

NOTE 2—An abrasive charge meeting the requirements of Table 1 will have a mass of approximately 1530 to 1900 g (3.8 to 4.2 lb). When the mass of the charge approaches the lower limit, replace the undersize or underweight balls not complying with Table 1.

4.5 *Scales*—A platform scale having a capacity of at least 45 kg (100 lb) or more and accurate to within at least 5.0 g (0.01 lb) at any point within the range used in this test shall be

[1] This test method is under the jurisdiction of ASTM Committee C09 on Concrete and Concrete Aggregates and is the direct responsibility of Subcommittee C09.62 on Abrasion Testing.

Current edition approved Dec. 15, 2005. Published January 2006. Originally approved in 1989. Last previous edition approved in 1997 as C 1138 – 97.

[2] Section on Safety Precautions, *Manual of Aggregate and Concrete Testing*, *Annual Book of ASTM Standards*, Vol. 04.02.

[3] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

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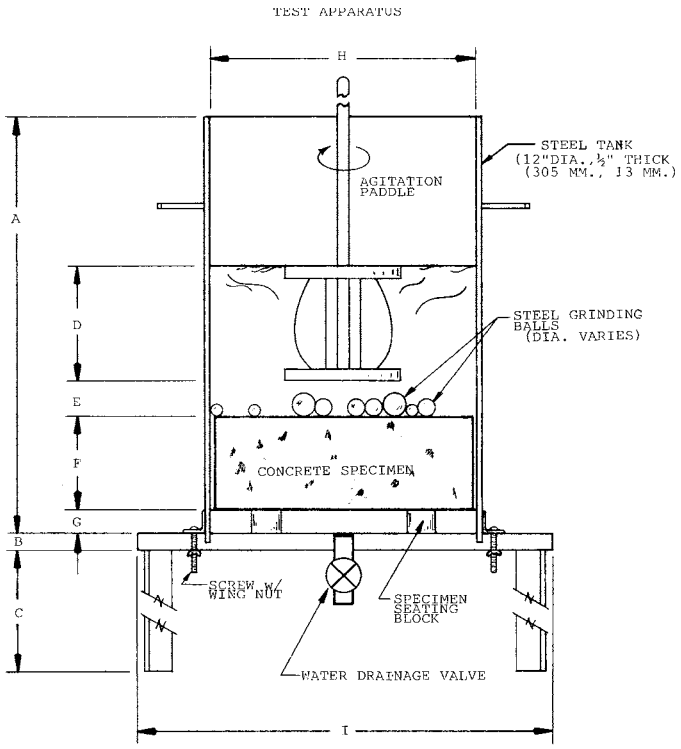

	in.	mm
A	18.0	457
B	0.75	19
C	Optional - to suit	
D	5.0	127
E	1.5	38
F	4.0	102
G	1.0	25.4
H	12.0	305
I	18.0	457

FIG. 1 Test Apparatus

used. The scale shall be equipped with a suitable apparatus for suspending the sample in its container in water from the center of the weighing platform.

4.6 *Weighing Basket*—A wire basket or other suitable support shall be provided for weighing the specimen in water. The weighing basket shall be constructed to prevent entrapping air when it and the specimen are submerged.

4.7 *Water Tank*—A suitable watertight tank into which the basket and the specimen can be suspended below the scale shall be furnished.

4.8 *Seating Block*—A minimum of three steel blocks 25 by 25 by 25 mm (1 by 1 by 1 in.) shall be used to support the specimen.

5. Test Specimens

5.1 The test specimen shall be cylindrical in shape, having a diameter approximately 6-mm (¼-in.) less than that of the inside diameter of the test container and a height of 100 ± 13 mm (4 ± ½ in.). It may be molded from freshly mixed concrete or cored from hardened concrete (see Note 3). Cores shall be taken in accordance with Methods C 42.

NOTE 3—Specimens should be tested at an age appropriate for the material being evaluated. Most testing done to date has been done at 28 days. Concretes containing pozzolans should be tested at an age that allows development of appropriate strength. Toppings and impregnated concretes should be tested at an age appropriate for the material and in compliance with the manufacturer's recommendations. The appropriate testing age may also depend upon when the concrete will be put into service.

5.2 If the specimen has a membrane curing compound on the surface, remove it completely by steel wire brushing prior to the soaking period.

5.3 Soak the specimen in lime-saturated water or in the water to which the concrete shall be subjected in service for a minimum of 48 h prior to testing.

5.4 Determine the average diameter of the top surface of the specimen to be tested to the nearest 2 mm (1/16 in.) by averaging two diameters measured at right angles to each other. This average diameter shall be used in calculating the top surface area.

5.5 Surface dry the specimen. Determine and record the mass in air to the nearest 25.0 g (0.05 lb). Determine and record the apparent mass of the specimen immersed in water to the nearest 25.0 g (0.05 lb). The procedure of Test Method C 642 shall be followed using water at 23 ± 1.7 °C (73.4 ± 3 °F) having a density of 997 ± 2 kg/m^3. Remove all entrapped air by shaking the specimen while it is immersed in the water for weighing.

6. Procedure

6.1 Place the specimen in the test container with the surface to be tested facing up and the seating blocks in place.

6.2 Position the specimen so that its surface is normal to the drill shaft and the center of the specimen coincides with the drill shaft.

6.3 Mount the agitation paddle in the drill press. The bottom of the agitation paddle shall be 38 ± 5 mm (1½ ± ¼ in.) above the surface of the specimen.

6.4 Determine and record the mass of the abrasive charge to the nearest 10 g (0.02 lb). Place it on the surface of the specimen and add water of the same type as used in the saturation period to 165 ± 5 mm (6½ ± ¼ in.) above the surface of the specimen.

6.5 Start the paddle rotating and check that the paddle is rotating at the required speed with the paddle immersed.

6.6 Remove the specimen from the test container at the end of every 12 h of operation. Flush off the abraded material and surface dry. Determine and record the mass of the specimen in air and in water.

6.7 The standard test shall consist of six 12-h periods for a total of 72 h (see Note 4).

NOTE 4—Testing totalling 24 h generally produces significant abrasion in most concrete surfaces, but it is recommended to extend the period of simulation if more severe abrasion is desired. Additional testing time may be required for concrete that is highly resistant to abrasion.

7. Calculation

7.1 Calculate the abrasion loss as follows:

7.1.1 Calculate the volume of the specimen at any time as follows:

$$V_t = \frac{W_{air} - W_{water}}{G_w} \quad (1)$$

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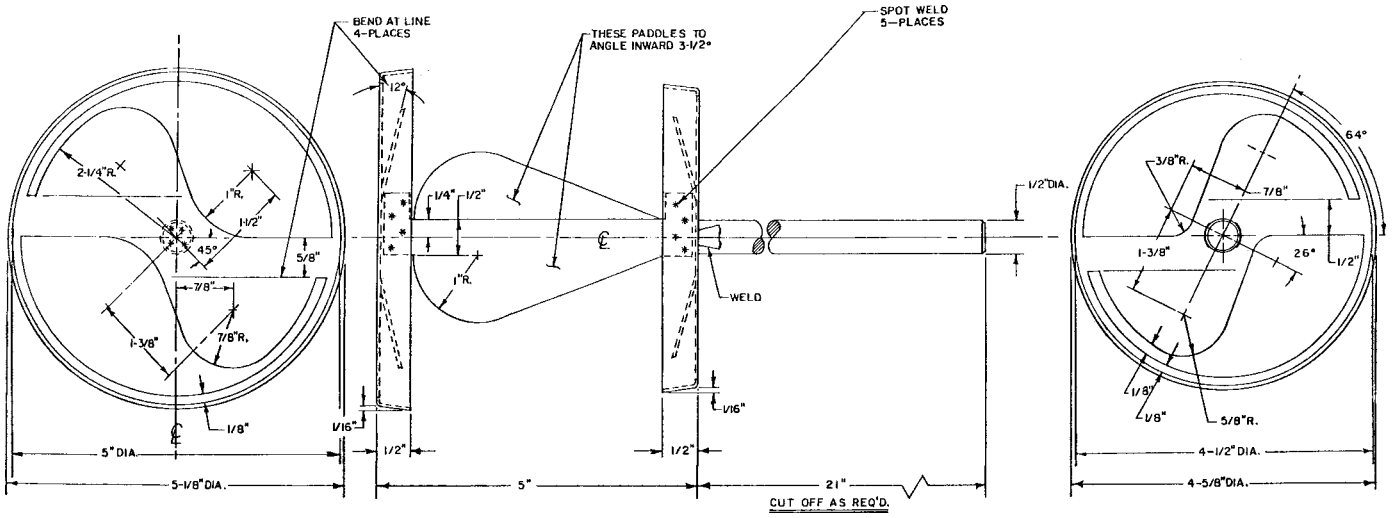

NOTE 1—1—16 Ga (0.059 in.)—304 Stainless Steel
NOTE 2—Rotation of agitation paddle clockwise when viewed from shaft end.
NOTE 3—Shaft length to be adjusted to fit assembly in Fig. 11.

in.	mm
21	533
5⅛	130
5	127
4⅝	117
4½	114
3⁹⁄₁₆	97
2¼	57
1½	38
1⅜	35
1	25
⅞	22
⅝	16
½	13
⅜	10
¼	6
⅛	3
¹⁄₁₆	2

TOLERANCE UNLESS	Material 16 GA.(.059) STEEL	FINISH		TITLE
OTHERWISE SPECIFIED	REVISIONS	BY	DATE	AGITATION PADDLE

FIG. 2 Agitation Paddle

TABLE 1 Abrasive Charges

Number of Balls	Nominal Size	Minimum Diameter
10	1.00 in.	25.3 mm (0.95 in.)
35	0.75 in.	19.0 mm (0.70 in.)
25	0.50 in.	12.6 mm (0.45 in.)

where:
V_t = volume of the specimen at the desired time, m^3,
W_{air} = mass of the specimen in air at the desired time, kg,
W_{water} = apparent mass of the specimen in water at the desired time, kg, and
G_w = unit weight of water kg/m^3.

7.1.2 Calculate the volume of concrete lost at the end of any time increment of testing as follows:

$$VL_t = V_i - V_t \quad (2)$$

where:
VL_t = volume of material lost by abrasion at the end of the test increment in question, m^3,
V_i = volume of specimen before testing, m^3, and
V_t = volume of the specimen at the end of the test increment in question m^3.

7.2 Should it be desired to calculate the average depth of wear at the end of any time increment of testing based on volume of abraded material, it may be done as follows:

$$ADA_t = VL_t/A \quad (3)$$

where:
ADA_t = average depth of abrasion at the end of the test increment in question, m, and
A = area of top of specimen m^2.

8. Report

8.1 The report shall include the following:

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8.1.1 A plot of time versus abrasion loss of at least three individual test specimens and the average of all specimens of a type that were tested.

8.1.2 The average diameter of each specimen. The volume of each specimen at the end of each test period.

8.1.3 Relevant data as desired on the concrete represented by the specimens.

8.1.4 Mass of the grinding balls at the beginning and end of the testing.

9. Precision and Bias

9.1 *Precision*—The single laboratory coefficient of variation among test specimens made from a single batch of concrete was found to be 14.0 %. Therefore, in a properly conducted test, the range among test results from the three specimens required by the test method should be no greater than 46.2 % of their mean. (See Note 5.)[4]

NOTE 5—This number represents the 1 S limit, as defined by Practice C 670. This limit was calculated according to paragraph 3.3.2 of Practice C 670 – 91a. The variation due to making specimens from different concrete batches was found to be too small to detect.

9.2 *Bias*—No estimate of bias is being made because there is no recognized standard material for this test method.

[4] Supporting data have been filed at ASTM International Headquarters and may be obtained by requesting Research Report RR: C09-1009.

APPENDIX

(Nonmandatory Information)

X1. PRECISION OF THE TEST METHOD

X1.1 This test method was originally developed and used by the Corps of Engineers.[5] When developed and during its initial use, abrasion loss as determined by the test method was expressed as a percentage of the original mass of the specimen. For tests so conducted the single-operator standard deviation (1S) was found to be 0.42 % and hence, the results of two properly conducted tests by the same operator on specimens from the same batch of concrete should not differ by more than 1.18 % (D2S). These limits were calculated as described in Practice C 670.

X1.2 The test method was revised to reflect loss in terms of volume rather than in terms of mass to eliminate differences in results resulting from the allowable variations in specimen size.

[5] Liu, Tony C., "Abrasion Resistance of Concrete," *ACI Journal*, *Proceedings* Vol 78, No. 5, Sept.-Oct. 1981, pp 341-350.

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Designation: C 1140 – 03a

Standard Practice for Preparing and Testing Specimens from Shotcrete Test Panels[1]

This standard is issued under the fixed designation C 1140; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope

1.1 This practice covers procedures for preparing test panels of dry-mix or wet-mix shotcrete and for testing specimens sawed or cored from the panels.

1.2 The values stated in inch-pound units are to be regarded as the standard.

1.3 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

2. Referenced Documents

2.1 *ASTM Standards:*

C 42/C 42M Test Method for Obtaining and Testing Drilled Cores and Sawed Beams of Concrete[2]

C 78 Test Method for Flexural Strength of Concrete (Using Simple Beam with Third-Point Loading)[2]

C 138/C 138M Test Method for Density (Unit Weight), Yield, and Air Content (Gravimetric) of Concrete[2]

C 143/C 143M Test Method for Slump of Hydraulic Cement Concrete[2]

C 171 Specification for Sheet Materials For Curing Concrete[2]

C 231 Test Method for Air Content of Freshly Mixed Concrete by the Pressure Method[2]

C 457 Test Method for Microscopical Determination of Parameters of the Air-Void System in Hardened Concrete[2]

C 511 Specification for Moist Cabinets, Moist Rooms, and Water Storage Tanks Used in the Testing of Hydraulic Cements and Concretes[2]

C 513 Test Method for Obtaining and Testing Specimens of Hardened Lightweight Insulating Concrete for Compressive Strength[2]

C 642 Test Method for Density, Absorption, and Voids in Hardened Concrete[2]

C 995 Test Method for Time of Flow of Fiber-Reinforced Concrete Through Inverted Slump Cone[2]

C 1018 Test Method for Flexural Toughness and First-Crack Strength of Fiber-Reinforced Concrete (Using Beam with Third-Point Loading)[2]

C 1399 Test Method for Obtaining Average Residual-Strength of Fiber-Reinforced Concrete[2]

3. Summary of Practice

3.1 Test panels of shotcrete are fabricated using the personnel, materials, equipment, and shooting positions under investigation. Specimens are core drilled or sawed from these panels for evaluation.

4. Significance and Use

4.1 Specimens obtained in accordance with the procedure section of this practice may be used for preconstruction studies of shotcrete mixtures, to qualify nozzlemen and equipment, or for quality control, or compressive or flexural strength testing, during the progress of a project.

5. Test Panels

5.1 *Forms for Panels*:

5.1.1 The form for receiving the shotcrete shall be either wood or steel construction and sufficiently rigid to prevent dislodging of the shotcrete through vibration or deformation. The form shall have a minimum width and length of 24 in. (610 mm) and a minimum depth of 3½ in. (89 mm) with either square or sloped sides. Larger panels may be desirable for qualifying nozzlemen, equipment, or mixture design.

5.1.1.1 *Wood Forms*—Wood forms shall have a back made from plywood at least ¾ in. (19 mm) thick. Side pieces shall be made of lumber with a minimum thickness of 1½ in. (38 mm).

5.1.1.2 *Steel Forms*—Steel forms shall be made using material having a minimum thickness of 3⁄16 in. (5 mm).

6. Materials

6.1 *Dry-Mix Process*—The test mixture shall be of the same materials and proportions being used or proposed for use in the structure.

6.2 *Wet-Mix Process*—The test mixture shall be of the specified slump and have the specified air content and unit weight, or, when fibers are used, the specified time of flow, air

[1] This practice is under the jurisdiction of ASTM Committee C09 on Concrete and Concrete Aggregates and is the direct responsibility of Subcommittee C09.46 on Shotcrete.

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[2] *Annual Book of ASTM Standards*, Vol 04.02.

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content, and unit weight as the mixture being used or proposed for use in the structure. Determine the air content by Test Method C 231, the unit weight by Test Method C 138/C 138M, slump by Test Method C 143/C 143M and time of flow by Test Method C 995 prior to shooting the panels.

7. Procedure

7.1 *Number of Panels*—A separate panel shall be shot for each mixture representing each admixture type or dosage, fiber type or fiber volume and each shooting position anticipated in the structure (that is, slab, slopes, vertical, and overhead).

7.2 The admixture, if one is used, shall be added in the same manner and dosage as proposed for use or used in the structure.

7.3 Reinforcing bars shall be included in test specimens used for bar encapsulation studies and qualification of personnel, equipment, and application techniques. Reinforcing bars should be excluded from samples prepared for compressive, flexural, and tensile tests. If fibers are added to the shotcrete, they should be included in the respective test samples.

7.4 *Shotcreting*:

7.4.1 *Equipment*—Shotcrete shall be applied using the equipment, water pressure, and air pressure to be used on the structure.

7.4.2 *Personnel*—The operating personnel (nozzlemen and gun operator) shall be those to be used on the structure.

7.4.3 *Application of Shotcrete*—Apply the shotcrete to the panel forms in the manner as proposed for use or as is being done in the structure. Dampen wood forms just prior to shotcreting.

8. Curing

8.1 To prevent evaporation of water from the panels, the panels shall be covered and tightly wrapped (as soon after fabrication as is safe to prevent damage) with a sheet of material meeting requirements of Specification C 171 or stored in a moist room meeting the requirements of Specification C 511. Field cured specimens shall be moved to the laboratory just prior to testing.

8.2 Latex admixed shotcrete panels shall be moist-cured for 24 h and then air-dried for the balance of the curing cycle.

9. Obtaining and Testing Specimens

9.1 Specimens shall be obtained from panels by drilling cores or sawing beams in accordance with Test Method C 42/C 42M, or by sawing cubes in accordance with Test Method C 513. Samples to be cored or sawed shall be removed from the central portion of the specimen. Samples shall not be taken from the shotcrete in the space equal to the depth plus 1 in. (25.4 mm) from the outside edges. For 3½ in. (89 mm) deep, 24 × 24 in. (610 × 610 mm) forms, this corresponds to 4½ in. (114 mm) from the inside of the bottom corner formed by the base of the form, resulting in a sample area of 15 × 15 in. (381 × 381 mm). Cores and beams shall be free from corrugations and striations caused by uneven sawing or coring. It is recommended that all flat surfaces be sawed to ensure parallel and smooth surfaces. Cores shall be drilled and tested for compressive strength perpendicular to the surface of the panel. Cubes and beams may be tested either perpendicular or parallel to the surface of the panel. The direction of testing can influence the results and shall be specified. Proper handling of freshly applied specimens requires they be protected from damage due to extremes of temperature and vibrating movements, shaking, or shock during the hydration process. Beams shall be tested in accordance with Test Method C 78 except that beams of fiber-reinforced concrete shall be tested in accordance with Test Method C 1018 or Test Method C 1399.

9.1.1 *Age*—Specimens shall be obtained from panels and tested at designated ages. Unless moisture conditioning is specified, the specimens shall be obtained from panels no more than 2 h before being tested.

9.1.2 *Conditioning*—When moisture conditioning is specified, it shall be in accordance with the provisions of Test Method C 42/C 42M unless otherwise specified by the purchaser.

9.2 The density, absorption, and voids shall be determined in accordance with the provisions of Test Method C 642. Data obtained in flexural tests shall be treated in accordance with Test Methods C 78, C 1018 or C 1399.

NOTE 1—If the purchaser requests it, the air content of the hardened shotcrete may be determined by Test Method C 457.

10. Calculation

10.1 The length to diameter correction factor found in Test Method C 42/C 42M shall be applied to compressive strengths. For sawed cubes, compressive strengths shall be multiplied by a correction factor of 0.85 to obtain equivalent strength of drilled cores.

11. Report

11.1 The report shall include the following data pertinent to the variables or combinations of variables studied in the tests:

11.1.1 Type and proportions of cement and admixture, fine and coarse aggregate including maximum size and grading, free water content, in the case of wet-mix shotcrete, and temperature.

11.1.2 Type and proportion of any fibers used.

11.1.3 Position of panel as shot.

11.1.4 Type of shotcrete, that is, wet or dry.

11.1.5 Name of nozzleman and gun operator.

11.1.6 Specimen size and moisture conditioning.

11.1.7 Direction of testing relative to panel surface.

11.1.8 Unit weight, air content, absorption and voids, slump, and time of flow, if applicable.

11.1.9 Strength and other mechanical properties evaluated and test methods used, and correction factors applied.

12. Precision and Bias

12.1 The precision and bias of tests conducted on specimens prepared according to this practice will be that of the referenced test methods.

13. Keywords

13.1 beams; cores; cubes; shotcrete; test panels

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Designation: C 1141 – 06

Standard Specification for Admixtures for Shotcrete[1]

This standard is issued under the fixed designation C 1141; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope*

1.1 This specification covers materials proposed for use as admixtures to be added to a portland-cement shotcrete mixture for the purpose of altering the properties of the mixture.

1.2 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

1.3 The values stated in inch-pound units are to be regarded as the standard.

2. Referenced Documents

2.1 *ASTM Standards:* [2]

C 125 Terminology Relating to Concrete and Concrete Aggregates

C 136 Test Method for Sieve Analysis of Fine and Coarse Aggregates

C 138/C 138M Test Method for Density (Unit Weight), Yield, and Air Content (Gravimetric) of Concrete

C 173/C 173M Test Method for Air Content of Freshly Mixed Concrete by the Volumetric Method

C 183 Practice for Sampling and the Amount of Testing of Hydraulic Cement

C 231 Test Method for Air Content of Freshly Mixed Concrete by the Pressure Method

C 260 Specification for Air-Entraining Admixtures for Concrete

C 311 Test Methods for Sampling and Testing Fly Ash or Natural Pozzolans for Use in Portland-Cement Concrete

C 494/C 494M Specification for Chemical Admixtures for Concrete

C 618 Specification for Coal Fly Ash and Raw or Calcined Natural Pozzolan for Use in Concrete

C 979 Specification for Pigments for Integrally Colored Concrete

C 989 Specification for Ground Granulated Blast-Furnace Slag for Use in Concrete and Mortars

C 1240 Specification for Silica Fume Used in Cementitious Mixtures

C 1398 Test Method for The Laboratory Determination of the Time of Setting of Hydraulic-Cement Mortars Containing Additives for Shotcrete by the Use of Gillmore Needles

C 1438 Specification for Latex and Powder Polymer Modifiers for Hydraulic Cement Concrete and Mortar

D 98 Specification for Calcium Chloride

2.2 *ACI Documents:*

318 Building Code Requirements for Reinforced Concrete[3]

3. Terminology

3.1 The terms used in this standard are defined in Terminology C 125.

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *dry-mix shotcrete*—Shotcrete in which most of the mixing water is added at the nozzle.

3.2.2 *shotcrete*—Mortar or concrete pneumatically projected at high velocity onto a surface.

3.2.3 *wet-mix shotcrete*—Shotcrete in which most of the ingredients, including the water, are mixed prior to introduction into the delivery hose.

4. Classification

4.1 This specification recognizes grades of admixtures, used in shotcrete made by either of two processes, as follows:

4.1.1 *Type I*—Dry mix shotcrete.

4.1.1.1 *Grade 1*—Accelerating admixture, conventional.

4.1.1.2 *Grade 2*—Retarding admixture.

4.1.1.3 *Grade 3*—Pozzolanic admixture.

4.1.1.4 *Grade 4*—Metallic iron admixture.

4.1.1.5 *Grade 5*—Coloring admixture.

4.1.1.6 *Grade 6*—Organic polymer admixture.

4.1.1.7 *Grade 7*—Not applicable.

4.1.1.8 *Grade 8*—Not applicable.

4.1.1.9 *Grade 9*—Accelerating admixture, quick-setting.

4.1.2 *Type II*—Wet-mix shotcrete.

4.1.2.1 *Grade 1*—Accelerating admixture, conventional.

4.1.2.2 *Grade 2*—Retarding admixture.

[1] This specification is under the jurisdiction of ASTM Committee C09 on Concrete and Concrete Aggregates and is the direct responsibility of Subcommittee C09.46 on Shotcrete.

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[2] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

[3] Available from American Concrete Institute, P.O. Box 19150, Detroit, MI 48219.

***A Summary of Changes section appears at the end of this standard.**

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4.1.2.3 *Grade 3*—Pozzolanic admixture.
4.1.2.4 *Grade 4*—Metallic iron admixture.
4.1.2.5 *Grade 5*—Coloring admixture.
4.1.2.6 *Grade 6*—Organic polymer admixture.
4.1.2.7 *Grade 7*—Water reducing admixture.
4.1.2.8 *Grade 8*—Air-entraining admixture.
4.1.2.9 *Grade 9*—Accelerating admixture, quick-setting.

4.1.3 Each of the above grades is further classified by identifying it according to the following classes:
4.1.3.1 *Class A*—Liquid.
4.1.3.2 *Class B*—Non-liquid.

5. Ordering Information

5.1 The purchaser shall include the following information in the contract or purchase order, if applicable:
5.1.1 The specification designation and date of issue,
5.1.2 Type of shotcrete, grade and class of admixture,
5.1.3 Quantity of admixture required,
5.1.4 Special packaging and package marking requirements,
5.1.5 Special sampling for inspection requirements, and
5.1.6 Any supplementary requirements.

6. Requirements

6.1 Shotcrete admixtures shall conform to the requirements for the applicable type and grade as given in Table 1.

6.2 At the request of the purchaser, the manufacturer shall state in writing that the admixture supplied is essentially identical in concentration, composition, and performance to the admixture previously tested under this specification and found to comply with the applicable requirements thereof.

6.3 Requirements for establishing compositional or chemical equivalence of a lot or of a subsequent lot relative to a previous lot that was subjected to quality tests and found to comply with the applicable requirements may be determined by agreement between the purchaser and the manufacturer. At the request of the purchaser, the manufacturer shall recommend appropriate test procedures, such as infrared spectrophotometry, pH value, and solids content, for establishing the equivalence of material from different lots or different portions of the same lot.

6.4 At the request of the purchaser, the manufacturer shall state in writing the chloride content of the admixture.

NOTE 1—Ultraviolet absorption of solutions and infrared spectroscopy of dried residues have been found to be valuable for these purposes. The specific procedures to be employed and the criteria to establish equivalence should be stipulated with due regard to the composition and properties of the sample.

NOTE 2—Admixtures containing relatively large amounts of chloride ions may make embedded metals susceptible to corrosion when moisture and oxygen are present in hardened shotcrete.

7. Sampling

7.1 Access shall be provided to the purchaser for careful sampling, either at the point of manufacture, or at the site of the work, as may be specified by the purchaser.

7.2 Samples shall be either grab or composite samples, as specified or required by this specification. A grab sample is one secured in a single operation. A composite sample is one obtained by combining three or more grab samples.

TABLE 1 Shotcrete Admixture Requirements

Type I—Dry-Mix Shotcrete

Grade	Admixture	ASTM Standard	Other Limits
1	Accelerating, conventional	D 98, C 494 Type C or E	
2	Retarding	C 494 Type B or D	
3	Pozzolanic	C 618, C 989, C 1240	
4	Metallic iron	Not established	The metallic particles shall be ground iron free from rust, oil, foreign materials, and nonferrous metal particles. The grading of the metallic aggregates shall be as follows when tested according to C 136: U.S. Sieve No. — %Passing 4.75 mm (No. 4) — 100 2.36 mm (No. 8) — 90–100 1.18 mm (No. 16) — 70–85 600 µm (No. 30) — 20–35 300 µm (No. 50) — 0–10 150 µm (No. 100) — 0–5
5	Coloring	C 979	Even when using materials conforming to C 979, it may be difficult to obtain uniformity of coloring because of the placement procedures in dry-mix shotcreting.
6	Organic Polymer	C 1438	
9	Accelerating, quick-setting	C 1398	Initial time of setting 1 to 3 min and final time of setting not more than 12 min in two of every three tests and chloride llmits of ACI 318 shall not be exceeded.

Type II—Wet-Mix Shotcrete

Grade	Admixture	ASTM Standard	Other Limits
1	Accelerating, conventional	D 98, C 494 Types C or E	
2	Retarding	C 494, Type B, D or G	
3	Pozzolanic	C 618, C 989, C 1240	
4	Metallic iron	Not established	See Type I, Grade 4
5	Coloring	C 979	
6	Organic Polymer	C 1438	
7	Water reducing	C 494, Types A, D, E, F, or G	
8	Air-entraining	C 260	
9	Accelerating, quick-setting	C 1398	See Type I, Grade 9

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7.3 The sample size for each class of admixture shall be as follows:

7.3.1 *Class A Liquid Admixtures*:

7.3.1.1 Liquid admixtures shall be agitated thoroughly immediately prior to sampling. Individual grab samples shall represent not more than 2500 gal (9500 L) of admixture and shall have a volume of at least 1 qt (1 L). A minimum of four grab samples shall be taken from different locations well distributed throughout the quantity to be represented. Composite samples shall be prepared by thoroughly mixing the selected grab samples, and the resultant mixture sampled to provide at least 1 gal (4 L) for testing.

7.3.1.2 Admixtures in bulk storage tanks shall be sampled equally from the upper, intermediate, and lower levels by means of drain cocks in the sides of the tanks, or a weighted sampling bottle fitted with a stopper that can be removed after the bottle is lowered to the desired depth.

7.3.1.3 Samples shall be packaged in impermeable, airtight containers which are resistant to attack by the admixture.

7.3.2 *Class B Non-liquid Admixtures*:

7.3.2.1 Individual grab samples (except pozzolanic) shall not represent more than 2 tons (2 Mg) of admixture and shall weigh at least 2 lb (1 Kg). A minimum of four grab samples shall be taken from different locations well distributed throughout the quantity to be represented. Composite samples shall be prepared by thoroughly mixing the selected grab samples, and the resultant mixture sampled to provide at least 5 lb (2.1 Kg) for testing. Grading of composite samples shall be determined for each 2 tons (2 Mg) of Grade 4 metallic iron admixtures shipped.

7.3.2.2 Pozzolanic admixtures shall be sampled and tested in accordance with the requirements established in Test Methods C 311.

7.3.2.3 Samples of packaged admixtures shall be obtained by means of a tube sampler as described in Practice C 183.

7.3.2.4 When recommended by the manufacturer, the entire sample of an admixture shall be dissolved in water prior to testing.

7.3.2.5 Samples shall be packaged in moisture-proof, airtight containers.

8. Number of Tests and Retests

8.1 The number of tests and retests to be performed on specified materials shall be the number stipulated in the referenced ASTM standard.

9. Specimen Preparation

9.1 The specimens for tests shall be prepared as required by the particular test method referenced by the ASTM specification relating to the particular admixture.

NOTE 3—It is recommended that, whenever practicable, tests with the admixture be made using all of the ingredients of the shotcrete proposed for the specified work, because the effect produced by the admixture may vary with the properties of the other ingredients of the concrete.

10. Inspection

10.1 Inspection of the material shall be agreed upon between the purchaser and supplier as part of the purchase contract.

11. Rejection

11.1 The shotcrete admixture may be rejected if it fails to meet any of the applicable requirements of this specification. See Table 1.

11.2 An admixture stored at the point of manufacturer for more than six months prior to shipment or an admixture in local storage by a vendor for more than six months after completion of tests, may be retested before use and may be rejected if it fails to conform to any of the applicable requirements of this specification.

11.3 Packages or containers varying more than 2 % from the specified weight or volume shall be rejected. If the average weight or volume of 50 packages taken at random is less than that specified, the entire shipment shall be rejected.

11.4 When the admixture is to be used in non-air-entrained wet-mix shotcrete, it shall be rejected if the tested shotcrete containing the admixture has an air content greater than 5 %. When the admixture is to be used in air-entrained wet-mix shotcrete, it shall be rejected if the tested shotcrete containing the admixture has an air content greater than 12 % or less than 5 %. The air content shall be determined on a sample taken prior to shooting in accordance with either of Test Methods C 138, C 173 or C 231.

11.5 Rejection and reason(s) for rejection shall be reported to the producer or supplier promptly in writing.

12. Certification

12.1 When specified in the purchase order or contract, a certificate shall be furnished to the purchaser that the material has been tested in accordance with this specification and found to meet the requirements. When specified in the purchase order or contract, a report of test results on samples taken from material shipped shall be furnished. The test report requested in accordance with the purchase order shall be furnished within 60 days after shipment of the order.

13. Product Marking

13.1 When the admixture is delivered in packages or containers, the proprietary name of the admixture, the type, grade, and class under this specification, and the net weight or volume shall be plainly marked thereon. Similar information shall be provided in the shipping paper accompanying packaged or bulk materials.

14. Supplementary Requirements

14.1 Supplementary requirements may be specified by the purchaser and apply only when they appear separately on the purchase contract or order.

14.2 Quality assurance requirements shall be specified in the purchase contract or order with a reference to a pertinent document agreed upon by the supplier and purchaser.

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SUMMARY OF CHANGES

Committee C09 has identified the location of selected changes to this specification since the last issue, C 1141 – 01, that may impact the use of this specification. (Approved June 1, 2006)

(*1*) Replaced Test Method C 1102 with Test Method C 1398 in Table 1 and Referenced Documents.

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Designation: C 1152/C 1152M – 04ε1

Standard Test Method for Acid-Soluble Chloride in Mortar and Concrete[1]

This standard is issued under the fixed designation C 1152/C 1152M; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

ε[1] NOTE—A typo in the equation in paragraph 9.1 was corrected editorially February 2006.

1. Scope

1.1 This test method[2] provides procedures for the sampling and analysis of hydraulic-cement mortar or concrete for chloride that is acid soluble under the conditions of test. In most cases, acid-soluble chloride is equivalent to total chloride.

1.2 The text of this standard references notes and footnotes that provide explanatory information. These notes and footnotes shall not be considered as requirements of this standard.

1.3 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

1.4 The values stated in either SI units or inch-pound units are to be regarded separately as standard. Within the text, the inch-pound units are shown in brackets. The values stated in each system are not exact equivalents; therefore, each system shall be used independently of the other.

2. Referenced Documents

2.1 *ASTM Standards:* [3]

C 42/C 42M Test Method for Obtaining and Testing Drilled Cores and Sawed Beams of Concrete

C 114 Test Methods for Chemical Analysis of Hydraulic Cement

C 670 Practice for Preparing Precision and Bias Statements for Test Methods for Construction Materials

C 702 Practice for Reducing Samples of Aggregate to Testing Size

C 823 Practice for Examination and Sampling of Hardened Concrete in Constructions

C 1084 Test Method for Portland-Cement Content of Hardened Hydraulic-Cement Concrete

D 1193 Specification for Reagent Water

E 11 Specification for Wire Cloth and Sieves for Testing Purposes

3. Significance and Use

3.1 The amount of acid-soluble chloride in most hydraulic-cement systems is equal to the total amount of chloride in the system. However, some organic substances that may be introduced into mortar or concrete contain chloride that is initially acid-insoluble that can eventually ionize and thus become acid-soluble or water-soluble after a period of exposure in the very alkaline cement system.

3.2 Sulfides are known to interfere with the determination of chloride content. Blast-furnace slag aggregates and cements contain sulfide sulfur in concentrations that can cause such interference and produce erroneously high test results. Treatment with hydrogen peroxide, as discussed in Test Methods C 114, is used to eliminate such interference.

3.3 There are aggregates that contain chloride that is not available for corrosion. Such chloride will be detected by the use of this method.[4]

4. Apparatus

4.1 *Sampling Equipment*

4.1.1 The apparatus required for obtaining samples by coring or sawing is described in Test Method C 42/C 42M.

4.1.2 Use the following apparatus for sampling by drilling (pulverization):

4.1.2.1 *Rotary Impact Drill* and drill or pulverizing bits of sufficient diameter to provide a representative sample of sufficient size for testing.

4.1.2.2 *Spoon* or other suitable means to remove pulverized sample material from drill hole without contamination.

4.1.2.3 *Sample Containers* capable of maintaining samples in an uncontaminated state.

[1] This test method is under the jurisdiction of ASTM Committee C09 on Concrete and Concrete Aggregates and is the direct responsibility of Subcommittee C09.69 on Miscellaneous Tests.

Current edition approved June 1, 2004. Published July 2004. Originally approved in 1990. Last previous edition approved in 2003 as C 1152 – 03.

[2] This test method is based on a report by Clear, K. C., and Harrigan, E. T., "Sampling and Testing for Chloride Ion in Concrete," Report No. FHWA-RD77-85, Federal Highway Administration, Washington, DC, Aug. 1977 (Available as PB 275-428/AS National Technical Information Services).

[3] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

[4] For more information, see "The Determination of the Chloride Content of Concrete," by Brian B. Hope, John A. Page and John S. Poland, *Cement and Concrete Research*, Volume 15, Number 5, Pergamon Press, New York, September 1985, pp. 863-870.

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4.2 *Sample Processing Apparatus*—The apparatus required for processing samples shall be chosen for its suitability for the purposes of the investigation, and frequently includes a concrete saw and one or more pulverizers.

4.2.1 Samples more than 25 mm (1 in.) in maximum dimension shall be reduced in size by use of a jaw crusher or broken into smaller pieces by hammering carefully to avoid loss of smaller pieces.

4.2.2 Crush particles less than 25 mm (1 in.) in maximum dimension using a rotating puck grinding apparatus, or by using a disk pulverizer, or mortar and pestle operated to restrict to negligible levels the loss of fine particles.

4.2.3 *Sieve*, 850-µm [No. 20], which shall comply with Specification E 11.

4.3 *Chloride Determination*

4.3.1 *Balance*, shall be capable of reproducing results within 0.0002 g with an accuracy of ± 0.0002 g. Direct-reading balances shall have a sensitivity not exceeding 0.0001 g. Conventional two-pan balances shall have a maximum sensibility reciprocal of 0.0003 g. Any rapid weighing device that may be provided, such as a chain, damped motion, or heavy riders, shall not increase the basic inaccuracy by more than 0.0001 g at any reading and with any load within the rated capacity of the balance.

4.3.2 *Stirrer*, magnetic variable speed, with a TFE-fluorocarbon coated magnetic stirring bar.

4.3.3 *Chloride, Silver/Sulfide Ion Selective Electrode*, or a silver billet electrode coated with silver chloride (see Note 1) with an appropriate reference electrode.

4.3.4 *Potentiometer*, with millivolt scale readable to 1 mV or better. A digital readout is preferred but not required.

NOTE 1—See Note 67 of Test Methods C 114 for a discussion of suitable electrodes and coating methods.

4.4 *Glazed Paper*—Paper to which fine particles do not adhere, for use as described in 7.1.

5. Reagents

5.1 *Purity of Reagents*—Reagent grade chemicals shall be used in all tests. Unless otherwise indicated, it is intended that all reagents shall conform to the specifications of the Committee on Analytical Reagents of the American Chemical Society[5]. Other grades may be used, provided it is first ascertained that the reagent is of sufficiently high purity to permit its use without lessening the accuracy of the determination.

5.1.1 *Sodium Chloride* (NaCl).

5.1.2 *Silver Nitrate* ($AgNO_3$).

5.1.3 *Potassium Chloride* (KCl), (required for silver billet electrode only).

5.1.4 *Reagent Water* conforming to the requirements of Specification D 1193 for Type III reagent water.

5.1.5 *Sodium Chloride, Standard Solution* (0.05 N NaCl)—Dry sodium chloride at 105 to 110 °C to a constant mass. Weigh 2.9222 g of dried reagent. Dissolve in water and dilute to exactly 1 L in a volumetric flask and mix thoroughly. This solution is the standard and requires no further standardization.

5.1.6 *Silver Nitrate, Standard Solution* (0.05 N ($AgNO_3$))—Dissolve 8.4938 g of silver nitrate in water. Dilute to 1 L in a volumetric flask and mix thoroughly. Standardize against 5.00 mL of standard 0.05 N sodium chloride solution diluted to 150 mL with water following the titration test method given in 8.1 beginning with the second sentence. The exact normality shall be calculated from the average of three determinations as follows:

$$N = 0.25/V, \text{ where:}$$

N = normality of $AgNO_3$ solution,
0.25 = milliequivalents NaCl (5.0 × 0.05 N), and
V = volume of $AgNO_3$ solution, mL.

Commercially available standard solutions may be used provided the normality is checked according to the standardization procedure.

5.1.7 *Methyl Orange Indicator*—Prepare a solution containing 2 g of methyl orange per litre of 95 % ethyl alcohol.

5.1.8 *Nitric Acid* (1+1).

5.1.9 *Hydrogen Peroxide* (30 %).

6. Sampling

6.1 Select the sample per Practice C 823 or as required for the purpose of the investigation.

6.1.1 Because of the small nominal maximum size of the aggregate in a mortar, pieces of mortar having a mass of 10 g or more will be representative of a rather large volume of mortar.

6.1.2 Take concrete cores in accordance with Test Method C 42/C 42M unless otherwise specified.

NOTE 2—Concrete cores taken in accordance with Test Method C 42/C 42M may be cut longitudinally to provide a 12-mm [½-in.] thick section generally representative of the core, or cut laterally into 12-mm [½-in.] thick disks representative of the concrete core at various depths. Concrete farthest from a surface into which chloride has penetrated often provides chloride data close to that of the originally placed fresh concrete. The cooling water from core cutting may dissolve some of the chloride.

6.1.3 Powdered concrete obtained by use of a rotary impact drill is frequently used in determining chloride concentration with depth in bridge decks, pavements, etc. Such samples may be unrepresentative, especially when the nominal maximum coarse aggregate size is 25 mm [1 in.] or more. Thus, several such samples should be combined, or the data used with care. Procedures for this method of sampling are as follows:

6.1.3.1 Using the rotary impact drill, drill perpendicular to the concrete surface or parallel to the axis of a cored specimen to a specified depth or a depth sufficient to obtain a representative sample of the concrete mixture of at least 20 g of powdered material. To prevent sample contamination, avoid contact of sample with hands and other sources of perspiration. Clean all sampling tools prior to each sampling operation (See Note 3). No lubricants shall be used during drilling.

NOTE 3—Sampling tools may be cleaned with a brush, cloth, ethyl

[5] *Reagent Chemicals, American Chemical Society Specifications*, American Chemical Society, Washington, DC. For suggestions on the testing of reagents not listed by the American Chemical Society, see *Analar Standards for Laboratory Chemicals*, BDH Ltd., Poole, Dorset, U.K., and the *United States Pharmacopeia and National Formulary*, U.S. Pharmaceutical Convention, Inc. (USPC), Rockville, MD.

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alcohol rinse, water rinse, or other method that will not contaminate the sample.

6.1.3.2 Transfer powdered sample into sample container using a spoon or other suitable means.

7. Sample Preparation

7.1 Pulverize the sample so that all the material will pass a 850-µm [No. 20] sieve. Thoroughly blend the material by coning as described in Practice C 702 from one glazed paper to another at least 10 times.

8. Procedure

8.1 Determine the mass of approximately 10 g of sample to the nearest 0.01 g and transfer to a 250 mL beaker. Disperse the sample with 75 mL of water. Slowly add 25 mL of dilute (1+1) nitric acid and stir with a glass rod, breaking up any lumps of sample. If the smell of hydrogen sulfide is strongly present, add 3 mL of hydrogen peroxide (See Note 4). Add 3 drops of methyl orange indicator to the beaker and stir. Cover the beaker with a watch glass and allow to stand for 1 to 2 minutes. If the solution above the settled solids is not pink colored, add more nitric acid dropwise while stirring until a pink or reddish color persists, then add 10 additional drops of nitric acid and stir. Heat the covered beaker rapidly to boiling and remove from hot plate. Do not allow sample to boil more than a few seconds (See Note 5). Make a blank determination using 75 mL of water in place of sample.

NOTE 4—Slags and slag cements contain sulfide sulfur in concentrations that can interfere with chloride determination unless oxidized with hydrogen peroxide.

NOTE 5—To prevent loss of chloride by volatilization, it is important to keep the beaker covered during heating and digestion. Ten seconds of boiling is sufficient. Excessive amounts of acid can erode the silver chloride coating on the silver billet electrode prematurely. A slurry that is only slightly acidic is sufficient.

8.2 Filter the sample through a 9-cm coarse-textured filter paper in a 250 mL or 500 mL Buchner funnel and filtration flask using suction. Rinse the beaker and the filter paper twice with small portions of water. Transfer the filtrate from the flask to a 250 mL beaker and rinse the flask once with water. The original beaker may be used (See Note 6). Cool the filtrate to room temperature. The volume should not exceed 175 mL.

NOTE 6—It is not necessary to clean all the slurry residue from the sides of the beaker, nor is it necessary that the filter remove all the fine material. The titration may take place in a solution that contains a small amount of solid matter.

8.3 For instruments equipped with a dial readout it is necessary to establish an approximate ″equivalence point″ by immersing the electrodes in a beaker of water and adjusting the instrument to read about 20 mV lower than mid-scale. Record the approximate millivoltmeter reading. Remove the beaker and wipe the electrodes with absorbent paper.

8.4 Pipet 2.00 mL of standard 0.05 N NaCl solution into the cooled sample beaker (See Note 7). Place the beaker on a magnetic stirrer and add a TFE-fluorocarbon coated stir bar. Immerse the electrodes into the solution, taking care that the stir bar does not strike the electrodes. Begin stirring gently. Place the delivery tip of the 10 mL buret filled to the zero mark with standardized 0.05 N $AgNO_3$ in (preferably) or above the sample solution (See Note 8).

NOTE 7—It is advisable to maintain constant temperature during measurement, as the solubility of silver chloride varies markedly with temperature at low concentrations.

NOTE 8—If the tip of the buret is out of the solution, any adhering droplet should be rinsed into the beaker with a few millilitres of water following each titration increment.

8.5 Gradually titrate, record the amount of standard 0.05 N silver nitrate solution required to bring the millivoltmeter reading to -60.0 mV of the equivalence point determined in the water.

8.6 Continue the titration with 0.20 mL increments. Record the buret reading and the corresponding millivoltmeter reading. Allow sufficient time between each addition for the electrodes to reach equilibrium with the sample solution (See Note 9).

NOTE 9—Experience has shown that acceptable readings are obtained when the minimum scale reading does not change within a 5-s period.

8.7 As the equivalence point is approached, the equal additions of silver nitrate solution will cause larger and larger changes in the millivoltmeter readings. Past the equivalence point, the change per increment will decrease. Continue to titrate until three readings past the approximate equivalence point have been recorded.

8.8 Calculate the precise equivalence point of the titration (See Note 10) and subtract the results of the water blank (See Note 11)

NOTE 10—An example of recording solution, millivolt readings, and calculation of the titration equivalence point can be found in Appendix X1 of Test Methods C 114.

NOTE 11—For nonreferee analysis, the blank may be omitted.

9. Calculation

9.1 Calculate percent chloride by mass of mortar or concrete to the nearest 0.001 % as follows:

$$C1, \% = 3.545\ [(V_1\text{-}V_2)\ N]/W,$$ where:

V_1 = millilitres of 0.05 N $AgNO_3$ solution used for sample titration (equivalence point),
V_2 = millilitres of 0.05 N $AgNO_3$ solution used for blank titration (equivalence point),
N = exact normality of 0.05 N $AgNO_3$ solution,
W = mass of sample, g.

9.2 Other useful measures of chloride concentration can be obtained as follows:

9.2.1 For calculating kilograms of chloride per cubic metre [pounds of chloride per cubic yard] of concrete (see Note 12), multiply percent chloride by $D_1/100$ or $D_2/100$ to the nearest 0.1 kg/m^3[lb/yd^3], where:

D_1 = oven dry density as determined in the section on Concrete Density in Test Method C 1084, kg/m^3[lb/yd^3].
D_2 = saturated-surface-dry density as determined in the section on Concrete Density in Test Method C 1084, kg/m^3[lb/yd^3].

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Report which density was used in the calculation.

NOTE 12—In the case of drilled samples or where the actual density can not be determined: U = density of mortar or concrete, kg/m^3[lb/yd^3]. The air dry density of normal weight concrete for most purposes can be assumed to be 2263 kg/m^3[3815 lb/yd^3].

9.2.2 For calculating percent chloride by mass of cement, multiply percent chloride by 100/*P*, where:

P = percent cement by mass in the mortar or concrete, as known or determined in accordance with Test Method C 1084.

9.2.3 For calculating equivalent flake calcium chloride (calcium chloride dihydrate) concentrations, multiply percent chloride by 2.07.

10. Precision and Bias

10.1 *Precision*[6]

10.1.1 The single laboratory standard deviation has been found to be 0.0015 % chloride (*a*). Therefore, results of two properly conducted tests in the same laboratory on the same material should not differ by more than 0.0042 % (*b*).

10.1.2 The multilaboratory standard deviation has been found to be 0.0021 % (*a*). Therefore, results of two properly conducted tests from two different laboratories on samples of the same material should not differ by more than 0.0059 % (*b*).

NOTE 13—The numbers (*a*) and (*b*) represent, respectively, the (1S) and (D2S) limits as described in Practice C 670. This precision statement applies to tests of samples prepared and ground by a single laboratory. For this reason, test results will vary depending upon the method of obtaining the sample and the size of the sample before it is crushed and reduced to pass the 850-µm [No. 20] sieve, or pulverized. The effect may be small for large concrete cores or from mortars sectioned vertically to appreciable for large aggregate concretes sampled by rotary impact drilling with small diameter drills.

10.2 *Bias*—Since there is no accepted reference material suitable for determining the bias for the procedure in this test method, no statement on bias is being made.

[6] A copy of the research report used to develop the precision statement is available from ASTM Headquarters. Request RR:C9-1003.

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Designation: C 1157/C 1157M – 09

Standard Performance Specification for Hydraulic Cement[1]

This standard is issued under the fixed designation C 1157/C 1157M; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope*

1.1 This performance specification covers hydraulic cements for both general and special applications. There are no restrictions on the composition of the cement or its constituents (See Note 1).

NOTE 1—There are two related hydraulic cement standards, Specification C 150 for portland cement and Specifications C 595 for blended cements, both of which contain prescriptive and performance requirements

1.2 This performance specification classifies cements based on specific requirements for general use, high early strength, resistance to attack by sulfates, and heat of hydration. Optional requirements are provided for the property of low reactivity with alkali-silica-reactive aggregates.

1.3 The values stated in either SI units or inch-pound units are to be regarded separately as standard. The values stated in each system may not be exact equivalents; therefore, each system shall be used independently of the other. Combining values from the two systems may result in non-conformance with the standard. Values in SI units [or inch-pound units] shall be obtained by measurement in SI units [or inch-pound units] or by appropriate conversion, using the Rules for Conversion and Rounding given in IEEE/ASTM SI 10, of measurements made in other units [or SI units]. Values are stated in only SI units when inch-pound units are not used in practice.

1.4 The text of this standard refers to notes and footnotes that provide explanatory material. These notes and footnotes (excluding those in tables and figures) are not requirements of the standard.

1.5 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

2. Referenced Documents

2.1 *ASTM Standards:*[2]

C 109/C 109M Test Method for Compressive Strength of Hydraulic Cement Mortars (Using 2-in. or [50-mm] Cube Specimens)
C 114 Test Methods for Chemical Analysis of Hydraulic Cement
C 150 Specification for Portland Cement
C 151 Test Method for Autoclave Expansion of Hydraulic Cement
C 183 Practice for Sampling and the Amount of Testing of Hydraulic Cement
C 185 Test Method for Air Content of Hydraulic Cement Mortar
C 186 Test Method for Heat of Hydration of Hydraulic Cement
C 188 Test Method for Density of Hydraulic Cement
C 191 Test Methods for Time of Setting of Hydraulic Cement by Vicat Needle
C 204 Test Methods for Fineness of Hydraulic Cement by Air-Permeability Apparatus
C 219 Terminology Relating to Hydraulic Cement
C 227 Test Method for Potential Alkali Reactivity of Cement-Aggregate Combinations (Mortar-Bar Method)
C 359 Test Method for Early Stiffening of Hydraulic Cement (Mortar Method)
C 430 Test Method for Fineness of Hydraulic Cement by the 45-μm (No. 325) Sieve
C 441 Test Method for Effectiveness of Pozzolans or Ground Blast-Furnace Slag in Preventing Excessive Expansion of Concrete Due to the Alkali-Silica Reaction
C 451 Test Method for Early Stiffening of Hydraulic Cement (Paste Method)
C 595 Specification for Blended Hydraulic Cements
C 596 Test Method for Drying Shrinkage of Mortar Containing Hydraulic Cement

[1] This performance specification is under the jurisdiction of ASTM Committee C01 on Cement and is the direct responsibility of Subcommittee C01.10 on Hydraulic Cements for General Concrete Construction.

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[2] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

***A Summary of Changes section appears at the end of this standard.**

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C 1012 Test Method for Length Change of Hydraulic-Cement Mortars Exposed to a Sulfate Solution
C 1038 Test Method for Expansion of Hydraulic Cement Mortar Bars Stored in Water
IEEE/ASTM SI 10 Standard for Use of the International System of Units (SI): the Modern Metric System

3. Terminology

3.1 *Definitions:*

3.1.1 Terms used in this specification are defined in Terminology C 219.

4. Classification and Use

4.1 The types of hydraulic cement covered by this specification are given in 4.2.1-4.2.6 and are classified in accordance with specific properties defined in Table 1 (See Note 2).

NOTE 2—This specification is based on hydraulic cement attributes related to concrete performance, including strength development, sulfate resistance, heat of hydration, and resistance to alkali-silica reactivity. Concrete performance is dependent on many factors such as characteristics of other concrete materials, mix design, production, handling, and environmental conditions. For performance properties of concrete, including permeability, resistance to freeze-thaw cycles and deicer salt scaling, additional information may be obtained through the use of comparative testing of concretes.

4.2 Cements conforming to this specification shall be designated in accordance with the nomenclature with special characteristics indicated by type in accordance with the types in 4.2.1-4.2.6. When the type is not specified, the requirements of type GU shall apply.

4.2.1 *Type GU*— Hydraulic cement for general construction. Use when one or more of the special types are not required.

4.2.2 *Type HE*—High Early-Strength.

4.2.3 *Type MS*—Moderate Sulfate Resistance.

4.2.4 *Type HS*—High Sulfate Resistance.

4.2.5 *Type MH*—Moderate Heat of Hydration.

4.2.6 *Type LH*—Low Heat of Hydration.

4.3 *Additional Option*—The following additional purchase option applies for any of the principal types listed. When this option is invoked, its letter designation and title shall follow

TABLE 1 Standard Physical Requirements

Cement Type	Applicable Test Method	GU	HE	MS	HS	MH	LH
Fineness	C 204	[A]	[A]	[A]	[A]	[A]	[A]
Autoclave length change, max, %	C 151	0.80	0.80	0.80	0.80	0.80	0.80
Time of setting, vicat test[B]	C 191						
Initial, not less than, minutes		45	45	45	45	45	45
Initial, not more than, minutes		420	420	420	420	420	420
Air content of mortar volume, %	C 185	[C]	[C]	[C]	[C]	[C]	[C]
Compressive strength minimum, MPa [psi][D]	C 109/C 109M						
1 day		...	12 [1740]	...	...	...	...
3 days		13 [1890]	24 [3480]	11 [1600]	11 [1600]	5 [725]	...
7 days		20 [2900]	...	18 [2610]	18 [2610]	11 [1600]	11 [1600]
28 days		28 [4060]	...	...	25 [3620]	...	21 [3050]
Heat of hydration	C 186						
7 days, max, kJ/kg [kcal/kg]		...	...	...	...	290 [70]	250 [60]
28 days, max, kJ/kg [kcal/kg]		...	...	...	...	...	290 [70]
Mortar bar expansion	C 1038						
14 days, % max		0.020	0.020	0.020	0.020	0.020	0.020
Sulfate expansion (sulfate resistance)[E]	C 1012						
6 months, max, %		...	...	0.10	0.05	...	...
1 year, max, %		...	...	...	0.10	...	...
Optionial Physical Requirements							
Option R—Low reactivity with alkali-silica-reactive aggregates[F]	C 227						
Expansion at							
14 days, max, %		0.020	0.020	0.020	0.020	0.020	0.020
56 days, max, %		0.060	0.060	0.060	0.060	0.060	0.060
Early stiffening, final penetration, min,%	C 451	50	50	50	50	50	50
Compressive strength,[D] 28 days, min, MPa	C 109/C 109M	...	...	28.0	...	22.0	...
Drying Shrinkage, %	C 596	...[G]	...[G]	...[G]	...[G]	...[G]	...[G]

[A] Both amount retained when wet sieved on the 45-μm (No. 325) sieve and specific surface area by air permeability apparatus in m^2/kg shall be reported on all certificates of test results requested from the manufacturer.

[B] Time of setting refers to initial setting time in Test Method C 191.

[C] Air content shall be reported on all certificates of test results requested from the manufacturer. A given value in mortar does not necessarily assure that the desired air content will be obtained in concrete.

[D] Cements may be shipped prior to later-age test data being available. In such cases, the test value may be left blank. Alternatively, the manufacturer can generally provide estimates based on historical production data. The report shall indicate if such estimates are provided.

[E] In the testing of HS cement, testing at one year shall not be required when the cement meets the 6 month limit. An HS cement failing the 6 month limit shall not be rejected unless it also fails the one year limit.

[F] Compliance with this requirement shall not be requested unless the cement will be used with alkali-reactive aggregate.

[G] At the request of the purchaser, data on drying shrinkage shall be supplied.

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immediately after the respective letter designation and title of the principal type (for example, Type MS(R)).

4.3.1 *Option R*—Low Reactivity with alkali-silica-reactive aggregates. When tested for potential activity with reactive aggregates, the cement shall meet the requirements of Table 1 for Option R.

5. Ordering Information

5.1 Orders for cement meeting the requirements of this specification shall include:

5.1.1 The specification designation ASTM C 1157, and date,

5.1.2 The type of cement required. If no type is specified, Type GU shall be supplied.

5.1.3 A statement that an option is invoked, when such is desired, and

5.1.4 Manufacturer's certification, if required.

6. Chemical Composition

6.1 The chemical composition for the cement is not specified. However, the cement shall be analyzed for informational purposes.

7. Physical Properties

7.1 Cement of the type specified shall conform to all of the applicable standard physical requirements of Table 1.

7.2 When optional requirements are specified, the cement shall conform to the applicable optional limits of Table 1.

8. Sampling

8.1 When the purchaser requires that the cement be sampled and tested to verify compliance with this specification, sample in accordance with Practice C 183. Provide adequate facilities for sampling the finished cement. Sample the finished cement at the mill or at the site of transfer of ownership as may be specified by the purchaser.

8.2 Practice C 183 is not designed for manufacturing quality control and is not required for manufacturer's certification.

9. Test Methods

9.1 When testing a cement for compliance with this specification, or for general characterization, use the following methods, with modifications or exceptions as indicated.

9.2 *Chemical Analysis*—Chemically analyze the cement using Test Methods C 114 for major and minor oxides present in greatest quantity that together, including loss-on-ignition, constitute at least 98 % of the total mass of the cement.

9.3 *Fineness*:

9.3.1 Determine fineness by Test Method C 204.

9.3.2 Determine amount retained on the 45-μm (No. 325) sieve by Test Method C 430.

9.4 Determine autoclave expansion by Test Method C 151, except that for cements with 1-day compressive strengths anticipated to be below 3.4 MPa [500 psi], store the test specimen in a moist cabinet for a period of 48 h before demolding and measuring their length.

9.5 Determine the time of setting using Test Method C 191. Only the time of initial setting is required.

9.6 Test the mortar for air content using Test Method C 185 using the actual density of the cement, as determined by Test Method C 188, if it differs from 3.15 Mg/m^3 by more than 0.05 Mg/m^3.

9.7 Determine compressive strength using Test Method C 109/C 109M. Tests shall be conducted at each age specified in Table 1.

9.8 Determine heat of hydration using Test Method C 186.

9.9 Determine sulfate resistance using Test Method C 1012.

9.10 Determine reactivity of cement with alkali-silica-reactive aggregate (Option R) using Test Method C 227 using crushed borosilicate glass, as described in Test Method C 441, as aggregate.

9.11 Determine early stiffening using Test Method C 451 (See Note 3).

NOTE 3—Additional characterization information may be obtained with Test Method C 359.

9.12 Determine mortar bar expansion using Test Method C 1038 using a 14-day immersion period.

9.13 Determine drying shrinkage using Test Method C 596.

10. Testing Time Requirements

10.1 The purchaser shall make necessary arrangements for shipment of samples to the testing laboratory. Add the time required for transport to the laboratory to the minimum time intervals allowed from receipt of the samples by the testing laboratory.

10.2 The minimum time allowed from receipt of samples by the testing laboratory to the report of test results shall be determined by the required age of specimen at the time of testing plus seven days.

10.3 A written report of results of applicable tests shall be available within not more than three days of the interval indicated in 10.2.

10.4 These time limits do not apply to retesting or additional testing. Such testing shall not provide the basis for initial acceptance or rejection of the cement (See Note 4).

NOTE 4—Aging effects on small samples of cement stored for long periods of time can produce test results that are not representative of the fresh cement nor of cement stored in large quantity for equal periods of time.

11. Testing by the Manufacturer

11.1 Test samples of cement for compliance with this specification, and for chemical analysis and fineness. Location and frequency of sampling are at the discretion of the manufacturer and are permitted to be changed upon agreement between the purchaser and supplier. Sampling and testing shall be either part of, or in addition to, the manufacturer's normal quality control.

11.2 *Special Testing*:

11.2.1 The following requirements for testing apply only to tests for sulfate resistance and low reactivity with alkali-silica-reactive aggregates.

11.2.1.1 For sulfate resistance of Types MS and HS and for Option R of any cement, make tests at least once every 12 months.

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1. Retest if the amount of an ingredient making up 10 % by mass or more of the cement is changed by ± 5 % or more by mass (See Note 5).

NOTE 5—For example, if the cement met the applicable requirement with a slag or fly ash content of 25 % by mass, retesting is required if the slag or fly ash content is changed beyond the range of 20 to 30 %.

2. Retest if the amount of an ingredient making up less than 10 % by mass of the cement is changed by ± 50 % or more of the amount previously shown to satisfy the applicable requirements (See Note 6).

NOTE 6—For example, if the cement met the applicable requirement with a silica fume content of 5 % by mass, retesting is required if the silica fume content is changed beyond the range of 2.5 to 7.5 %.

3. Retest if the mass % of SiO_2 or CaO in the cement, or if the mass % of CaO or SiO_2 in an ingredient making up 10 % by mass or more of the cement, is changed by ± 3 % or more by mass (See Note 7).

NOTE 7—For example, if the SiO_2 content of the cement met the requirement at 20 % by mass of the cement, retesting is required if the SiO_2 content changes beyond the range of 17 to 23 %.

12. Inspection

12.1 Inspection of the material shall be as agreed upon between the purchaser and the seller as part of the purchase contract.

13. Rejection

13.1 At the option of the purchaser, material that fails to conform to the applicable requirements of this specification for the type specified shall be rejected. Report rejection to the manufacturer or supplier promptly and in writing, stating the specific reasons for rejection.

13.2 At the option of the purchaser, packages more than 2 % below the mass marked thereon shall be rejected, and if the average mass of packages in any shipment, as shown by determining the mass of 50 packages taken at random, is less than that marked on the packages, reject the entire shipment.

13.3 At the option of the purchaser, bulk cement remaining in storage for more than six months after testing, or packaged cement remaining in the possession of a vendor for more than three months, shall be sampled and retested and rejected if it fails to meet any of the applicable requirements of this specification.

14. Certification

14.1 Upon request of the purchaser in the contract or order, a manufacturer's report shall be furnished at the time of shipment stating the results of tests made on samples of the material taken during production or transfer and certifying that the cement conforms to applicable requirements of this specification.

14.2 At the request of the purchaser in the contract or order, the manufacturer shall state in writing the types and amounts of the ingredients used in manufacture of the hydraulic cement.

14.3 *Sulfate Resistance (Types MS and HS) and Low Reactivity with Aggregates (Option R)*—When specified, results from the tests demonstrating compliance with this specification shall be available for inspection and the manufacturer's report shall state that the applicable requirements of this specification for those properties have been met.

15. Package Marking

15.1 When the cement is delivered in packages, words stating the type of cement, the name and brand of manufacturer, the mass of cement contained therein, and a list of ingredients, using generic names in decreasing order of abundance (See Note 8), shall be plainly marked on each package. Provide similar information with the manufacturer's certification accompanying the shipment of packaged or bulk cement.

NOTE 8—The following list contains suggested generic names for some possible ingredients of hydraulic cements. The list is representative and is not inclusive.

Class of Ingredient	Examples of Generic Terms
Cement	Portland cement, portland cement clinker.
Calcium Ingredient	Calcium carbonate, limestone, lime, hydrated lime, cement kiln dust (CKD).
Pozzolan	Class F fly ash, Class C fly ash, uncalcined natural pozzolan, calcined natural pozzolan, silica fume.
Slag	Granulated iron blast-furnace slag.
Additions	Calcium sulfate, water reducer, accelerator, retarder, water-reducing retarder, air-entraining addition, processing addition.

16. Storage

16.1 The cement shall be stored in such a manner as to permit reasonable access for proper inspection and identification of each shipment and in a suitable weather-tight building, container, or package that will protect the cement from dampness and minimize warehouse set.

17. Uniformity of Source

17.1 Upon request of the purchaser in the contract or order, the manufacturer shall provide a report on the uniformity of strength of cement from the source.

18. Keywords

18.1 blended hydraulic cement; hydraulic cement; performance

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SUMMARY OF CHANGES

Committee C01 has identified the location of selected changes to this performance specification since the last issue, C 1157 – 08a, that may impact the use of this performance specification. (Approved July 1, 2009)

(*1*) Revised the standard as a dual units performance specification.

(*2*) Revised the minimum strength requirements in Table 1.

Committee C01 has identified the location of selected changes to this performance specification since the last issue, C 1157 – 08, that may impact the use of this performance specification. (Approved December 15, 2008)

(*1*) Revised Table 1.

Committee C01 has identified the location of selected changes to this performance specification since the last issue, C 1157 – 03, that may impact the use of this performance specification. (Approved September 1, 2008)

(*1*) The standard was heavily revised throughout to improve readability, flexibility for manufacturers, and quality assurance.

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Designation: C 1164 – 92 (Reapproved 2003)

Standard Practice for Evaluation of Limestone or Lime Uniformity From a Single Source[1]

This standard is issued under the fixed designation C 1164; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope

1.1 This practice is intended for use in instances where the purchaser desires information on the uniformity of limestone or lime produced at a single source. It is intended that this test method normally be used for the predominant material manufactured at a plant. Guidelines for sampling, testing and presentation of results (Table 1) are given.

1.2 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

2. Referenced Documents

2.1 *ASTM Standards:*

C 25 Test Methods for Chemical Analysis of Limestone, Quicklime, and Hydrated Lime[2]

C 50 Methods of Sampling, Inspection, Packing, and Marking of Lime and Limestone Products[2]

C 51 Terminology Relating to Lime and Limestone (As Used by the Industry)[2]

C 110 Test Methods for Physical Testing of Quicklime, Hydrated Lime, and Limestone[2]

C 141 Specification for Hydraulic Hydrated Lime for Structural Purposes[2]

3. Terminology

3.1 *Definitions:*

3.1.1 For definitions of terms relating to this practice refer to Terminology C 51.

4. Significance and Use

4.1 This practice is designed to present in a standardized format information on the variability of limestone or lime from a single source over a period of time. It can be applied to all materials covered in Test Methods C 25 and C 110, and Specification C 141.

TABLE 1 High Calcium Quicklime January 1989

NOTE 1—This data is presented only as a sample of the correct method for presentation. Other tests can be substituted and others omitted.

Day	Test			
	Acid Insoluble	% CaO	% MgO	Available CaO
1	0.66	95.85	2.27	94.90
2	0.84	95.03	2.87	94.08
3	1.24	95.85	1.57	94.90
4	1.22	96.67	1.49	95.71
5	1.22	96.26	1.32	95.31
8	0.68	95.85	2.06	94.69
9	0.96	95.54	2.27	94.89
10	1.26	96.15	1.74	95.20
11	1.04	96.04	2.00	95.11
13	1.26	96.26	1.51	95.31
15	1.34	95.23	2.09	94.28
16	1.28	95.44	2.34	94.69
19	0.68	96.15	1.46	95.20
20	1.42	95.85	1.27	94.90
22	1.06	95.85	1.86	94.90
23	0.58	96.15	2.09	95.31
24	0.84	95.03	2.61	94.08
26	1.28	95.64	1.39	94.69
27	1.48	95.54	1.58	94.39
29	0.98	94.82	2.71	93.67
30	1.24	94.41	3.42	93.67
Avg	1.07	95.70	2.00	94.76
Range	0.90	2.26	2.15	2.04
Std Dev	0.26	0.54	0.56	0.54

5. Sampling

5.1 The sampling shall be done in accordance with Methods C 50.

5.2 All sampling shall be performed by personnel qualified by specific training for this purpose.

5.3 Data points shall be an average of three or more separate determinations relative to a specified unit of time. For example: (*1*) *n* determinations for daily average, (*2*) daily determinations for weekly average.

5.4 The samples shall be identified by the date or dates that the represented material was obtained.

6. Procedure

6.1 The minimum amount of testing (see 5.3) and the type of test(s) to be performed should be agreed upon by the purchaser and producer.

NOTE 1—A single daily analysis does not necessarily characterize a

[1] This practice is under the jurisdiction of ASTM Committee C07 on Lime and is the direct responsibility of Subcommittee C07.11 on Statistics.

Current edition approved Feb. 15, 1992. Published April 1992. Originally approved in 1990. Last previous edition approved in 1991 as C 1164 – 91.

[2] *Annual Book of ASTM Standards*, Vol 04.01.

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product. A minimum of three analyses is more reasonable.

6.2 It is desirable that all tests used in a single evaluation be performed in the same laboratory, preferably by the same person, in order for the results to be comparable.

NOTE 2—In order to obtain comparable results when exchanging samples between laboratories, methods used in preparation, handling and storage of those samples must be uniform.

6.2.1 When separate evaluations of a single source are made by two or more laboratories, additional tests of a standard material or exchanged portions of the same sample may be necessary to determine differences in testing that are likely to be obtained in the different laboratories. Three or more batches may be necessary to obtain comparison between laboratories.

6.2.2 Where a within-laboratory testing standard deviation history has not been established, duplicate tests made from a single sample are required to determine the effect of testing variation on the uniformity of results made in a single laboratory.

7. Test Method

7.1 The chemical analysis of quicklime, hydrated lime, and limestone shall be determined in accordance with Test Methods C 25.

7.2 The physical analysis of quicklime, hydrated lime, and limestone shall be determined in accordance with Test Methods C 110.

7.3 The analysis of hydraulic hydrated lime shall be determined in accordance with Specification C 141.

8. Calculation

8.1 Average $\bar{X}$:

$$\bar{X} = \frac{(X_1 + X_2 + \ldots + X_n)}{n} \quad (1)$$

where:

$X_1, X_2, \ldots, X_n$ = the individual test results in accordance with Test Methods C 25 or C 110, or Specification C 141, and

n = the number of individual samples.

8.2 Total Standard Deviation:

$$s = \sqrt{\frac{(X_1 - \bar{X})^2 + (X_2 - \bar{X})^2 + \ldots + (X_n - \bar{X})^2}{(n - 1)}} \quad (2)$$

9. Report

9.1 Report the following information. Sufficient information shall be provided to identify the sample including:

9.1.1 Name of manufacturer and location,

9.1.2 Type of material or other identification,

9.1.3 All sampling and analytical practices used are to be noted (see Note 3), and

9.1.4 Period of time represented by the report.

9.2 The report shall not cover a period of time greater than one year.

NOTE 3—Laboratory designations are lost or are meaningless when averaging a number of determinations on individual samples. The purchaser needs to know the sampling and analytical practices used in generating a report to properly evaluate the information they receive concerning a specific product.

10. Keywords

10.1 hydrated lime; limestone; product uniformity; quicklime; sampling

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Designation: C 1170/C 1170M – 08

Standard Test Method for Determining Consistency and Density of Roller-Compacted Concrete Using a Vibrating Table[1]

This standard is issued under the fixed designation C 1170/C 1170M; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope*

1.1 This test method is used to determine the consistency of concrete using a vibrating table and a surcharge and to determine the density of the consolidated concrete specimen. This test method is applicable to freshly mixed concrete, prepared in both the laboratory and the field, having a nominal maximum size aggregate of 50 mm [2 in.] or less. If the nominal maximum size of aggregate is larger than 50 mm [2 in.], the test method is applicable only when performed on the fraction passing the 50-mm [2-in.] sieve with the larger aggregate being removed in accordance with Practice C 172.

1.2 This test method, intended for use in testing roller-compacted concrete, may be applicable to testing other types of concrete such as cement-treated aggregate and mixtures similar to soil-cement.

1.3 The values stated in either SI units or inch-pound units are to be regarded separately as standard. The values stated in each system may not be exact equivalents; therefore, each system shall be used independently of the other. Combining values from the two systems may result in non-conformance with the standard.

1.4 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*(**Warning**— Fresh hydraulic cementitious mixtures are caustic and may cause chemical burns to skin and tissue upon prolonged exposure.[2])

2. Referenced Documents

2.1 *ASTM Standards:*[3]

C 29/C 29M Test Method for Bulk Density ("Unit Weight") and Voids in Aggregate

C 125 Terminology Relating to Concrete and Concrete Aggregates

C 172 Practice for Sampling Freshly Mixed Concrete

D 1557 Test Methods for Laboratory Compaction Characteristics of Soil Using Modified Effort (56,000 ft-lbf/ft^3(2,700 kN-m/m^3))

E 11 Specification for Wire Cloth and Sieves for Testing Purposes

3. Terminology

3.1 *Definitions*:

3.1.1 For definitions of terms used in this test method, refer to Terminology C 125.

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *extremely dry consistency*, *n*—for the purpose of this standard, the consistency of concrete having no slump and a Vebe consistency greater than 20 s when measured with Procedure A or B.

3.2.2 *stiff consistency*, *n*—n—the consistency of concrete having a slump less than 25 mm [1 in] and a Vebe consistency ranging from 5 to 10 s when measured with Procedure A.[4]

3.2.3 *Vebe consistency*, *n*—the time required for a given mass of concrete to be consolidated by vibration in a cylindrically shaped mold under a surcharge mass.

3.2.4 *very stiff consistency*, *n*—for the purpose of this standard, the consistency of concrete having no slump and a Vebe consistency ranging from 10 to 20 s when measured with Procedure A.

4. Summary of Test Method

4.1 A vibrating table is used to measure the consistency of stiff to extremely dry concrete mixtures (See Note 1). Density of the compacted specimen is measured by determining the mass of the consolidated specimen and dividing by its volume.

NOTE 1—Further description of concrete of this consistency is given in ACI 207.5R[5] and ACI 211.3R.[4]

[1] This test method is under the jurisdiction of ASTM Committee C09 on Concrete and Concrete Aggregates and are the direct responsibility of Subcommittee C09.45 on Roller-Compacted Concrete.

Current edition approved Oct. 1, 2008. Published November 2008. Originally approved in 1991. Last previous edition approved in 2006 as C 1170 – 06.

[2] Section on Safety Precautions, Manual of Aggregate and Concrete Testing, *Annual Book of ASTM Standards*, Vol. 04.02

[3] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

[4] ACI 211.3R *"Guide for Selecting Proportions for No-Slump Concrete,"*, 2002. Available from American Concrete Institute (ACI), P.O. Box 9094, Farmington Hills, MI 48333, www.concrete.org.

[5] ACI 207.5R *"Report on Roller-Compacted Concrete,"*, 1999. Available from American Concrete Institute (ACI), P.O. Box 9094, Farmington Hills, MI 48333, www.concrete.org.

***A Summary of Changes section appears at the end of this standard.**

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4.2 Two procedures are provided:

4.2.1 *Procedure A* uses a 22.7-kg [50-lb] surcharge mass placed on top of the test specimen. Procedure A shall be used for testing concrete of very stiff to extremely dry consistency or when the Vebe consistency by Procedure B is 30 s or greater (See Note 2).

NOTE 2—Further description of the test procedure using a 22.7 kg [50 lb] surcharge can be found in the U. S. Bureau of Reclamation's Technical Memorandum No. 8.[6]

4.2.2 *Procedure B* uses a 12.5 kg [27.5 lb] surcharge mass placed on top of the test specimen. Procedure B shall be used for testing concrete of stiff to very stiff consistency or when the Vebe time by Procedure A is less than 20 s (See Note 3).

NOTE 3—Further description of the test procedure using a 12.5 kg [27.5 lb] surcharge can be found in the U. S. Army Corps of Engineer's test procedure CRD-C-53-01.[7]

4.2.3 Procedure A or B can be used for a Vebe consistency between 20 and 30 s.

5. Significance and Use

5.1 This test method is intended to be used for determining the consistency and density of stiff to extremely dry concrete mixtures common when using roller-compacted concrete construction.

5.1.1 Because of the stiff to extremely dry consistency of some roller-compacted concrete mixtures, the standard Vebe test method of rodding the specimen in a slump cone is substituted by Procedures A and B.[8]

5.2 Procedure A uses a 22.7-kg [50-lb] surcharge and is used for concrete consolidated by roller-compaction methods when the consistency of the concrete is very stiff to extremely dry.

5.3 Procedure B uses a 12.5-kg [27.5-lb] surcharge and is used for concrete consolidated by roller-compaction methods when the consistency of the concrete is stiff to very stiff consistency, but not extremely dry.

6. Apparatus

6.1 *Vibrating Table*—A vibrating table with a steel deck approximately 20-mm [¾-in.] thick with dimensions of approximately 380 mm [15 in.] in length, 250 mm [10 in.] in width, and 300 mm [12 in.] in height. The vibrating table shall be constructed in such a manner as to prevent flexing of the table during operation. The table deck shall be activated by an electromechanical vibrator. The table shall produce a sinusoidal vibratory motion with a frequency of at least 60 ± 2 Hz [3600 ± 100 vibrations per min] and a double amplitude of vibration of 0.43 ± 0.08 mm [0.0170 ± 0.0030 in.] when a 27 ± 2-kg [60.0 ± 2.5-lb] surcharge is bolted to the center of the table. The vibrator and table shall have a total mass of at least 90 kg [200 lb]. The table shall be level and clamped to a concrete floor or base slab that has sufficient mass to prevent displacement of the apparatus during performance of the test.

6.2 *Cylindrical Mold*—The cylindrical mold shall be made of steel or other hard metal resistant to corrosion by cement paste and shall have an inside diameter of 240 ± 2 mm [9 ½ ± 1/16 in.], a height of 200 ± 2 mm [7¾ ± 1/16 in.], and a wall thickness of 6 ± 2 mm [¼ ± 1/16 in.]. The mold shall be equipped with permanently affixed slotted metal brackets so it can be rigidly clamped to the vibrating table. The top rim of the mold shall be smooth, plane, and parallel to the bottom of the mold and shall be capable of providing an air and watertight seal when a glass or plastic plate is placed on the top rim.

6.3 *Swivel Arm and Guide Sleeve*—A metal guide sleeve with a clamp assembly or other suitable holding device mounted on a swivel arm (See Fig. 1). The swivel arm and guide sleeve must be capable of holding the metal shaft with the attached 22.7-kg [50-lb] or 12.5-kg [27.5-lb] cylindrical mass in a position perpendicular to the vibrating surface and allowing the shaft to slide freely when the clamp is released. The inside diameter of the guide sleeve shall be 3 ± 2 mm [⅛ ± 1/16 in.] larger than the diameter of the metal shaft of the surcharge. The swivel arm must be capable of maintaining the guide sleeve in a locked position directly over the center of the vibrating surface. The swivel arm shall be capable of being rotated away from the center of the table.

6.4 *Surcharge*—A cylindrical steel mass with a circular plastic plate attached to its base and a metal shaft at least 450 mm [18 in.] in length and 16 ± 2 mm [⅝ ± 1/16 in.] in diameter attached perpendicularly to the plate and embedded in the center of the mass. The shaft shall slide through the guide sleeve without binding. The plastic plate shall be approximately 13 mm [½ in.] in thickness and shall have a diameter of 230 ± 3 mm [9 ± ⅛ in.]. The surcharge assembly including the plastic plate and the metal shaft shall have a mass of either of the following:

Procedure A—22.7 ± 0.5 kg [50 ± 1 lb], or

Procedure B—12.5 ± 0.5 kg [27.5 lb ± 1 lb].

6.5 *Balance or Scale*—Balance or scale of sufficient capacity to determine the total mass of the concrete specimen and the mold. The balance or scale shall be readable to the nearest 5 g [0.01 lb].

6.6 *Strike-Off Plate*—A flat square metal plate at least 6 mm [¼ in.] thick, or a glass or clear plastic plate at least 13 mm [½ in.] thick, and at least 50 mm [2 in.] larger than the diameter of the cylindrical mold.

6.7 *Sieve*—A 50-mm [2-in.] sieve conforming to Specification E 11.

6.8 *Timing Device*—A stopwatch, capable of recording time intervals of at least 2 min to the nearest 1 s.

6.9 *Small Tools*—Square-ended shovel and hand scoops, wrench, tamping rod, and flashlight as required.

7. Sampling

7.1 Specimens of fresh concrete shall be obtained in accordance with Practice C 172.

7.2 Concrete samples shall have a nominal maximum size of aggregate of 50 mm [2 in.] or less. If the concrete has

[6] *"Guidelines for Designing and Constructing Roller-Compacted Concrete Dams,"* ACER Technical Memorandum No. 8, Bureau of Reclamation, Denver, CO, Appendix A, 1987.

[7] *"Test Method for Consistency of No-Slump Concrete Using the Modified Vebe Apparatus,"* CRD-C-53-01, U. S. Army Corps of Engineers, Vicksburg, MS, 2001.

[8] *ACI Manual of Concrete Practice, Part 1, Materials and General Properties of Concrete,* 2005. Available from American Concrete Institute (ACI), P.O. Box 9094, Farmington Hills, MI 48333, www.concrete.org.

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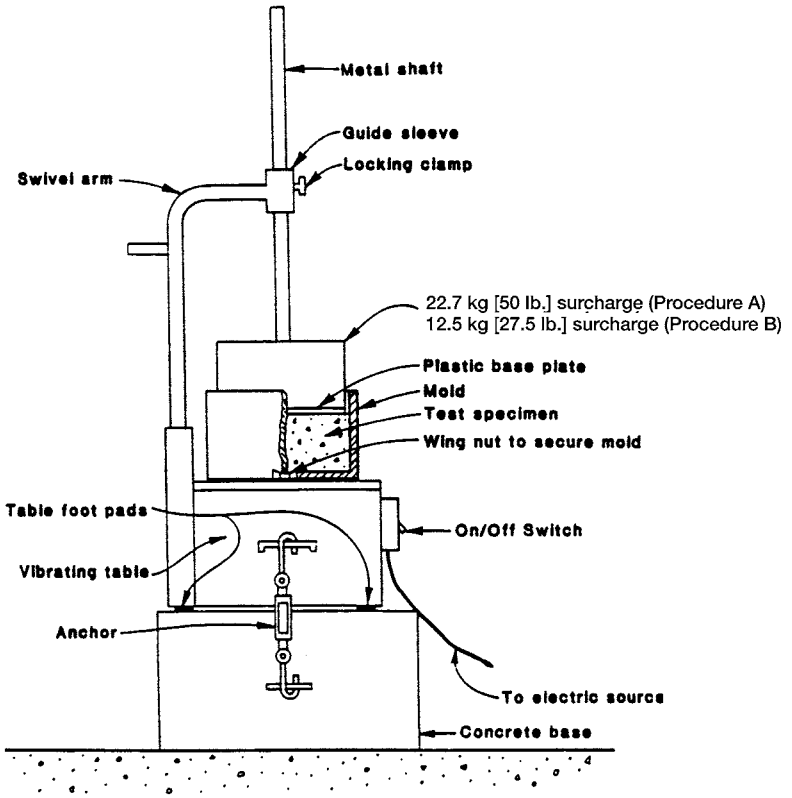

FIG. 1 Vibrating Table—Consistency Test

aggregate larger than 50 mm [2 in.], samples shall be obtained by wet sieving over a 50-mm [2-in.] sieve in accordance with Practice C 172.

7.3 Testing of concrete samples shall be completed within 45 min after the completion of mixing unless otherwise stipulated.

8. Preparation of Apparatus

8.1 *Vibrating Table*—Verify that the vibrating table meets the requirements of 6.1. Make adjustments if necessary.

8.1.1 Determine the frequency and double amplitude of the vibrating table under simulated test conditions prior to initial use and annually thereafter (See Note 4).

NOTE 4—A vibrating reed tachometer should be used to check the vibration frequency.[9]

8.2 *Cylindrical Mold*—Determine the volume of the cylindrical mold to the nearest 0.03 L [0.001 ft^3] in accordance with Test Method C 29/C 29M. Verify the volume of the mold monthly during times of regular use and annually when used infrequently. If used in density computations (that is, when a balance with tare is unavailable), determine the mass of the cylindrical mold to the nearest 5 g [0.01 lb]. For balances with tare capability, tare the balance with the mold.

8.3 In addition to the calibration schedule given in 8.1.1, calibrate the vibrating table after any event (including repairs) that might affect its operation, or whenever test results are questionable.

9. Technical Precautions

9.1 When obtaining samples, ensure that the samples are representative of the material being sampled.

9.2 Concrete with stiff to very dry consistency is highly susceptible to segregation during handling. To minimize segregation, use care in obtaining samples and during transporting, remixing, and testing of the concrete.

10. Procedure

10.1 *Vebe Consistency Time*:

10.1.1 Record the tare mass of the mold.

10.1.2 Using square-ended shovels and scoops, obtain a representative sample with a minimum mass of 25 kg [50 lb] in accordance with Practice C 172. Handle concrete in such a manner that coarse aggregate does not separate from the mortar.

10.1.3 Dampen the interior of the mold and fill with 13.5 ± 1 kg [29.5 ± 1.5 lb] of concrete. Using a square-edged scoop and tamping rod, place and distribute the concrete evenly to minimize segregation and rock pockets. Level the surface of the loose concrete.

10.1.4 Select either the 22.7 kg [50 lb] surcharge (Procedure A) or the 12.5 kg [27.5 lb] surcharge (Procedure B) (See Note 5).

[9] "Suggested Method for the Calibration of Vibrating Tables for Maximum Index Density Testing," *ASTM Geotechnical Journal,* Vol 2, No. 3, p. 152, September 1979.

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NOTE 5—The 12.5 kg [27.5 lb] surcharge is used for mixtures proportioned with a consistency of 20 s or less in accordance with Procedure A; or a paste volume in excess of the minimum volume of voids in the aggregate as determined using Test Method C 29/C 29M; or a total moisture content wet of the optimum, as determined using soil compaction test procedures in accordance with Test Methods D 1557. The 22.7 kg [50 lb] surcharge is used for mixtures proportioned with a consistency of more than 30 s in accordance with Procedure B; or with a paste volume approaching the minimum aggregate voids volume as determined using Test Method C 29/C 29M; or total moisture approaching the optimum moisture content as determined using soil compaction test procedures in accordance with Test Methods D 1557. Either procedure can be used if the consistency is between 20 and 30 s.

10.1.5 Secure the mold on the vibrating table by hand tightening the wing nuts. Slide the shaft of the surcharge mass through the guide sleeve, and rotate the surcharge to its locked position centered over the mold, ensuring that it will fit inside the mold when released. The surcharge may be lowered into the mold during this procedure to adjust the position of the mold but it shall not be placed on the specimen. Secure the wing nuts of the table with a wrench to prevent loosening during the test. Gently lower the surcharge onto the surface of the specimen.

10.1.6 If the surcharge cannot be centered in the mold without binding on the inside wall of the mold, place the surcharge directly onto the specimen in the mold without the use of the guide sleeve, and manually hold the surcharge shaft perpendicular to the top of the table. The surcharge shaft must be held manually throughout the remainder of the test. Do not apply additional hand pressure to the surcharge when manually holding the surcharge.

10.1.7 Start the vibrating table and timer. Using the flashlight, observe the concrete in the annular space between the edge of the surcharge and the inside wall of the mold. As the test progresses, mortar will fill in the annular space between the outer edge of the surcharge and the inside mold wall (See Note 6). Observe the mortar until it forms a complete ring around the total perimeter of the surcharge. When the mortar ring forms completely around the surcharge, stop the timer and vibrator; determine the elapsed time to the nearest second. Record this time as the Vebe consistency time, Procedure A or B, depending on which surcharge mass is used.

10.1.7.1 If a mortar ring forms around the total perimeter of the surcharge except at an isolated location where a rock or rock pocket impedes the complete mortar formation, the timer and vibrator shall be stopped and the elapsed time to the nearest second shall be recorded as the Vebe consistency time, Procedure A or B. Note the presence of the rock obstruction.

10.1.7.2 If the ring of mortar does not form after 90 s of vibration, stop the vibrating table and timer and record "> 90 s" as the Vebe consistency time.

NOTE 6—The time of the first appearance of mortar around the perimeter of the surcharge may be noted for information purposes only. However, this result should not be reported as a test value.

10.1.8 If the wing nuts loosen during the test, repeat the test with a fresh sample of concrete.

10.1.9 If the test result is out of the ranges specified in 4.2.1 or 4.2.2, change to the heavier or lighter surcharge mass, respectively, as needed. Once chosen, however, the same surcharge mass shall be used for the duration of the project.

10.1.10 Determine the density of the specimen in accordance with Section 10.2.

10.2 *Vebe Density of Freshly Consolidated Concrete*:

10.2.1 Following determination of the Vebe time, remove the surcharge. Add additional concrete on top of the previously compacted specimen. Overfill the mold by mounding the concrete above the top of the mold.

10.2.2 Place the surcharge on top of the loose concrete and consolidate by vibrating. If the surcharge consolidates concrete below the top level of the mold, turn off the vibrating table. Place additional concrete in the mold so that, when consolidated, the concrete will be less than 3 mm [⅛ in.] above the top of the mold. Continue vibrating; and with a sawing, screeding action, slide the surcharge across the top of the mold until the compacted concrete is level with the top of the mold. Do not allow the surcharge to remain in one position when the concrete is being finished because this can cause aggregates to be forced down and mortar to be forced out of the mold resulting in a non-representative test specimen.

10.2.3 After the surface has been screeded level with the top of the mold, stop the vibrating table. Remove the surcharge and vibrate the specimen for 5 ± 1 s to fill in minor surface tears. If the top surface of the specimen is disturbed by large amplitude oscillations, stop the vibrating table immediately

10.2.4 *Surface Strike-Off and Finishing*—After screeding the top surface even with the top of the mold, finish the surface with the strike-off plate. The strike-off is best accomplished by pressing the strike-off plate on the top surface of the cylinder mold to cover about two-thirds of the surface and withdrawing the plate with a sawing motion to finish only the area originally covered. Then place the plate on the top of the mold to cover the original two-thirds of the surface and advance it over the remaining third, with a vertical pressure and sawing motion to remove the concrete remaining above the top of the mold. Repeat section 10.2.2 and 10.2.3, if necessary, until the concrete is even with the top rim of the mold. If the finishing procedure causes surface tears that cannot be corrected with additional finishing, discontinue the surface strike-off and finishing and use the screeded surface for the density determination.

10.2.5 *Cleaning and Weighing*—After strike-off and finishing, loosen the wing nuts from the vibrating table and remove the cylinder mold. Clean all excess concrete from the exterior of the mold and determine the mass of the filled mold to the nearest 5 g [0.01 lb]. Determine the net mass of concrete by subtracting the mass of the empty mold. Alternatively, the net mass is permitted to be determined by taring the balance or scale with the empty mold.

10.2.6 Determine the density of the specimen in accordance with Section 11.

11. Calculation

11.1 Determine the density of the specimen as follows:

$$D = \frac{M_s}{V_s}$$

where:

D = density, kg/m^3 [lb/ft^3],

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M_s = mass of specimen, kg [lb] = mass of specimen plus cylindrical mold – mass of cylindrical mold
V_s = volume of cylindrical mold, m^3 [ft^3].

12. Report

12.1 Report the:
12.1.1 Procedure used (Procedure A or B),
12.1.2 Vebe consistency time in seconds,
12.1.3 Density in kg/m^3 [lb/ft^3],
12.1.4 Make and model of the vibrating table, and
12.1.5 Occurrence of an incomplete ring per 10.1.7.1, if applicable.

13. Precision and Bias

13.1 The precision of this test method for measuring consistency and density is being determined.

13.2 *Bias*—The procedure in this test method for determining consistency and density of roller-compacted concrete has no bias because consistency and density can only be defined in terms of this test method.

14. Keywords

14.1 concrete; consistency; density; fresh concrete properties; roller-compacted concrete

SUMMARY OF CHANGES

Committee C09 has identified the location of selected changes to this test method since the last issue, C 1170 – 06, that may impact the use of this test method. (Approved October 1, 2008)

(*1*) Revised the standard as a combined units standard with SI units listed first.
(*2*) Added three terms to the Terminology Section.
(*3*) Replaced the term "stiff plastic" with "stiff" in Sections 4 and 5.
(*4*) Revised 10.1.7, 10.1.8, and Section 12 for clarity.

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Designation: C 1176/C 1176M – 08

Standard Practice for Making Roller-Compacted Concrete in Cylinder Molds Using a Vibrating Table[1]

This standard is issued under the fixed designation C 1176/C 1176M; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope*

1.1 This practice covers procedures for making cylindrical test specimens from concrete when the standard procedures of rodding and internal vibration, as described in Practice C 31, are not practicable. This practice is applicable to freshly mixed concrete, prepared in the laboratory and the field, having a nominal maximum size aggregate of 50 mm [2 in.] or less. If the nominal maximum size aggregate is larger than 50 mm [2 in.], the practice is applicable only when performed on the fraction passing the 50-mm [2-in.] sieve with the larger aggregate being removed in accordance with Practice C 172. This practice, intended for use in testing roller-compacted concrete, may be applicable to testing other types of concrete such as cement-treated aggregate and mixtures similar to soil-cement.

1.2 Two methods are provided for making concrete cylinders using a vibrating table:

1.2.1 Method A is a procedure for making test specimens in steel reusable molds attached to a vibrating table.

1.2.2 Method B is a procedure for making test specimens in single-use plastic molds that have been inserted into a metal sleeve attached to a vibrating table.

1.3 The values stated in either SI units or inch-pound units are to be regarded separately as standard. The values stated in each system may not be exact equivalents; therefore, each system shall be used independently of the other. Combining values from the two systems may result in non-conformance with the standard.

1.4 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

2. Referenced Documents

2.1 *ASTM Standards:* [2]

C 31/C 31M Practice for Making and Curing Concrete Test Specimens in the Field

C 39/C 39M Test Method for Compressive Strength of Cylindrical Concrete Specimens

C 172 Practice for Sampling Freshly Mixed Concrete

C 192/C 192M Practice for Making and Curing Concrete Test Specimens in the Laboratory

C 470/C 470M Specification for Molds for Forming Concrete Test Cylinders Vertically

C 496/C 496M Test Method for Splitting Tensile Strength of Cylindrical Concrete Specimens

C 1170 Test Method for Determining Consistency and Density of Roller-Compacted Concrete Using a Vibrating Table

E 11 Specification for Wire Cloth and Sieves for Testing Purposes

3. Summary of Practice

3.1 This practice describes methods for making cylindrical concrete test specimens using a vibrating table. Test specimens are made in cylindrical molds that are attached to the vibrating table under a 9-kg [20-lb] surcharge to facilitate consolidation.

4. Significance and Use

4.1 This practice is intended to be used for stiff to extremely dry concrete mixtures commonly used in roller-compacted concrete construction. This practice is used instead of rodding or internal vibration, which cannot properly consolidate concrete of this consistency (Note 1).

NOTE 1—Further description of this concrete consistency is given in

[1] This practice is under the jurisdiction of ASTM Committee C09 on Concrete and Concrete Aggregates and is the direct responsibility of Subcommittee C09.45 on Roller-Compacted Concrete.

Current edition approved June 1, 2008. Published July 2008. Originally approved in 1991. Last previous edition approved in 2005 as C 1176 – 05.

[2] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

***A Summary of Changes section appears at the end of this standard.**

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ACI 207.5 Roller-Compacted Mass Concrete[3] and 211.3 Guide for Selecting Proportions for No-Slump Concrete[3]. The consistency of roller-compacted concrete may be determined in accordance with Test Method C 1170.

5. Apparatus

5.1 *Molds*:

5.1.1 *Type A Mold*—A cylindrical mold conforming to the requirements of Specification C 470 for 150-mm [6-in.] diameter by 300-mm [12-in.] high reusable molds. Molds shall be made of steel or other hard metal not readily attacked by the cement paste. Aluminum molds shall not be used. Molds shall be equipped with permanently affixed metal slotted brackets on the baseplate so the molds can be rigidly clamped to a vibrating table. The top rim of the mold shall be smooth, plane, and parallel to the bottom of the mold. The bottom of the mold shall provide a watertight seal.

5.1.2 *Type B Mold*—A single-use plastic, cylindrical mold 150 mm [6 in.] in diameter and 300 mm [12 in.] in height. The mold specifications shall conform to Specification C 470 for single-use plastic molds.

5.1.2.1 *Mold Sleeve*—A Type B cylindrical mold shall be inserted into a rigid cylindrical sleeve with a bottom baseplate that is clamped to the vibrating table. The mold sleeve shall be made of steel or other hard metal that does not react with concrete containing portland or other hydraulic cement. The sleeve shall be capable of firmly and vertically holding the plastic mold in place without deformation and shall be slotted vertically with adjustable clamps for tightening around the mold. The sleeve shall be hinged so that it can be opened to remove the mold (Fig. 1) and shall also have permanently affixed slotted metal brackets so the sleeve may be rigidly clamped to the vibrating table. The mold sleeve shall have a minimum wall thickness of 3 mm [⅛ in.], and a minimum baseplate thickness of 6 mm [¼ in.]. The inside diameter of the mold sleeve shall be 3 ± 1.5 mm [⅛ ± 1⁄16 in.] larger than the outside diameter of the Type B mold and have a height 6 to 13 mm [½ to ¼ in.] less than the height of the Type B mold.

5.2 *Vebe Vibrating Table*—A vibrating table with a 20-mm [¾-in.] thick steel deck with dimensions of approximately 380 mm [15 in.] in length, 260 mm [10 ¼ in.] in width, and 300 mm [12 in.] in height. The vibrating table shall be constructed in such a manner as to prevent flexing of the table during operation. The table deck shall be activated by an electromechanical vibrator. The total mass of the vibrator and table shall be approximately 95 kg [210 lb]. The table shall be level and clamped to a concrete floor or base slab that has sufficient mass to prevent displacement of the apparatus during specimen preparation (Note 2).

NOTE 2—The recommended vibrating table for these procedures is the Vebe vibrating table. Testing to date has been performed using this apparatus. An alternative vibrating table may be substituted for the Vebe apparatus provided it meets the specifications for the sinusoidal vibration given in 7.1.

[3] *ACI Manual of Concrete Practice, Part 1, Materials and General Properties of Concrete*, 2005, American Concrete Institute (ACI), P.O. Box 9094, Farmington Hills, MI 48333.

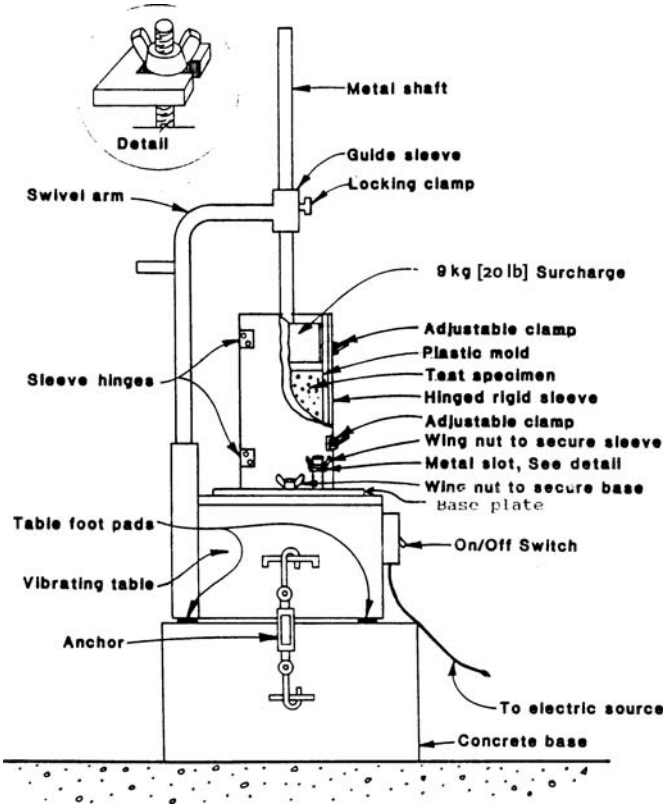

FIG. 1 Vibrating Table—Cylinder Preparation (Type B Mold)

5.3 *Swivel Arm and Guide Sleeve*—A metal guide sleeve with a clamp assembly or other suitable holding device mounted on a swivel arm. The swivel arm and guide sleeve must be capable of holding a metal shaft attached to a 9-kg [20-lb] cylindrical mass in a position perpendicular to the vibrating surface and allowing the shaft to slide freely when the clamp is released. The swivel arm must be capable of maintaining the guide sleeve in a locked position directly over the center of the specimens to be vibrated. The swivel arm shall also be capable of being rotated away from the center of the table (Note 3).

NOTE 3—The Vebe vibrating table comes equipped with the swivel arm and guide sleeve.

5.4 *Surcharge*—A cylindrical steel mass with a metal shaft at least 460 mm [18 in.] in length and 16 ± 2 mm [⅝ ± 1⁄16 in.] in diameter attached perpendicularly to and embedded in the center of the mass. The shaft shall slide through the guide sleeve without binding. The surcharge shall have a diameter of 145 ± 3 mm [5¾ ± ⅛ in.]. The surcharge assembly shall have a mass of 9.0 ± 0.25 kg [20 ± 0.5 lb] including the mass of the metal shaft (Fig. 1). If the surcharge is to be hand held, the length of the shaft may be reduced to about 300 mm [12 in.] and fabricated with a "T" or "D" handle for gripping the surcharge shaft to avoid slipping.

5.5 *Sieve*—A 50-mm [2-in.] sieve conforming to Specification E 11.

5.6 *Small Tools*—Trowels, square-ended shovel and hand scoops, steel trowel, wooden float, wrench, tamping rod, and flashlight as required.

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6. Sampling

6.1 Samples of fresh concrete shall be obtained in accordance with Practice C 172.

6.2 Concrete samples shall have a nominal maximum size aggregate of 50 mm [2 in.] or less. If the concrete has aggregate larger than 50 mm [2 in.], samples shall be obtained by wet sieving over a 50-mm [2-in.] sieve in accordance with Practice C 172.

6.3 Concrete test specimens shall be made within 45 min after the completion of mixing concrete unless otherwise stipulated.

7. Calibration and Standardization

7.1 The vibrating table shall produce a sinusoidal vibratory motion with a frequency of at least 60 ± 2 Hz [3600 ± 100 vibrations per min] and a double amplitude of vibration of 0.45 ± 0.1 mm [0.0170 ± 0.0030 in.] when a 27.0 ± 1.0-kg [60.0 ± 2.5-lb] surcharge is rigidly bolted to the center of the table.

7.1.1 Determine the frequency and double amplitude[4] of the vibrating table under simulated test conditions prior to initial use and annually thereafter. A vibrating reed tachometer should be used to check the frequency of vibration.

7.2 Recalibrate the vibrating table after any event (including repairs) that might affect its operation, or whenever test results are questionable.

8. Technical Precautions

8.1 When obtaining samples, ensure that the samples are representative of the material being sampled.

8.2 Concrete with stiff to extremely dry consistency is highly susceptible to segregation during handling. To minimize segregation, use care in obtaining samples and during transporting, remixing, and testing of the concrete.

8.3 After at least every three months of continued use, inspect and clean the underside of the vibrating table top of any hardened concrete or cement paste which may interfere with free movement of the table top.

9. Procedure

9.1 *Method A—Type A Molds*:

9.1.1 Coat Type A molds with a suitable lubricant or bond breaker prior to casting the test specimens to facilitate removal from the mold.

9.1.2 Place the mold on the vibrating table, and center the surcharge so that the edges of the plastic plate do not touch the walls of the mold. Lower the surcharge into the mold to check for proper clearance. Attach the mold to the vibrating table, and firmly tighten the wing nuts. Move the surcharge away from the mold.

9.1.3 Place enough concrete in the mold so that the mold will be filled to one-third of its volume after consolidation (approximately 4.5 kg [9.5 lb]). A tamping rod may be used to distribute the loose concrete as it is added. During filling, use square-ended shovels and scoops to obtain representative samples, and handle the concrete in such a manner that larger sized coarse aggregate particles do not separate from the mortar.

9.1.4 Move the surcharge over the center of the mold, release the guide sleeve clamp, and place the surcharge gently on the loose concrete. The surcharge shall be able to vertically slide free without binding on the guide sleeve.

9.1.5 If the surcharge cannot be centered in the mold without binding on the inside wall of the mold, place the surcharge directly onto the specimen in the mold without use of the guide sleeve, and hold the surcharge shaft perpendicular to the top of the table. Hold the surcharge shaft manually while vibrating the specimen. Do not apply any additional hand pressure to the surcharge when manually holding the surcharge.

9.1.6 Start the vibrator table, and allow the concrete to consolidate under the surcharge. Using a flashlight, observe the concrete in the annular space between the edge of the surcharge and the inside wall of the mold. As the concrete consolidates, mortar will fill in the annular space between the outer edge of the surcharge and the inside mold wall. Observe the mortar until it forms a ring around the total perimeter of the surcharge. When the mortar ring forms completely around the surcharge, stop the vibrator. If the wing nuts loosen while casting the specimen, retighten the wing nuts, then continue vibrating to ensure complete consolidation of the specimen.

9.1.7 If a rock pocket prevents the mortar ring from forming at one small location, even though it has formed in all other locations, the vibrator can be stopped and another layer of concrete added. If a significant portion of the mortar ring does not form, this indicates the concrete may have insufficient mortar due to either improper sampling, segregation, or improper mixture proportioning. In these instances, the concrete specimen should be visually inspected after stripping from the mold, and a decision then made whether to accept or reject the specimen.

9.1.8 Repeat the procedure in 9.1.3 through 9.1.7 for the second lift of concrete, filling the mold to approximately two-thirds of its volume. For the third lift, overfill the mold by mounding the concrete above the top of the mold. Again, place the surcharge on the loose concrete and consolidate. If the surcharge consolidates concrete below the top level of the mold, turn off the vibrating table. Place additional concrete in the mold so that, when consolidated, the concrete will be about 3 mm [⅛ in.] above the top of the mold. Continue vibrating, and slide the surcharge back and forth across the top of the mold until the compacted concrete is level with the top of the mold. This replaces strikeoff with a float since stiff concrete cannot be easily floated. Do not allow the surcharge to remain in one position when the concrete is being finished because this can cause aggregates to be forced down and mortar to be forced out of the mold resulting in a nonrepresentative test specimen. After the surface has been screeded with the surcharge, vibrate the specimen for 4 ± 1 s without the surcharge to fill in minor surface tears unless damage to the specimen by large-amplitude oscillations of the vibrator is anticipated.

[4] Kaufman, L.P., Strickland, E.A., and Benavidez, A.A. "Suggested Method for the Calibration of Vibrating Tables for Maximum Index Density Testing," *Geotechnical Testing Journal*, GTJODJ, Vol 2, No. 3, September 1979, pp. 152–157.

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9.1.8.1 When making test specimens using an alternative vibrating table, it may not be possible to vibrate the specimen without a surcharge. This is due to the disturbance of the compacted specimen when large-amplitude, low-frequency oscillations occur after the vibrator has been turned off. If this occurs, keep the surcharge in place until the vibrating table has completely stopped.

9.1.9 Remove the mold with the consolidated specimen from the vibrating table, and finish the top surface of the specimen with a steel trowel or wooden float. Avoid dislodging aggregate particles from the surface when using a wooden float.

9.2 *Method B—Type B Molds*:

Make concrete test specimens in Type B molds in accordance with 9.1. Prior to making test specimens, insert a Type B mold into the metal sleeve ensuring a close fit but not deforming the plastic mold. A sleeve assembly made from an existing steel cylindrical mold is shown in Fig. 1. Rigidly clamp the entire assembly to the vibrating table, and make the test specimen in accordance with procedures in 9.1.2 through 9.1.9.

10. Curing

10.1 Unless otherwise specified, all specimens shall be cured in accordance with the sections on curing in Practice C 192 or Practice C 31, whichever is applicable. Specimens tested for compressive strength and splitting tensile strength shall be in accordance with Test Method C 39/C 39M and Test Method C 496, respectively.

11. Keywords

11.1 concrete; cylinder preparation; roller-compacted concrete

SUMMARY OF CHANGES

Committee C09 has identified the location of selected changes to this practice since the last issue, C 1176 – 05, that may impact the use of this practice. (Approved June 1, 2008)

(*1*) Revised the standard to a dual designation with SI units listed first to comply with C09's policy on units. Only the units have been revised in the text.

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Designation: C 1177/C 1177M – 08

Standard Specification for Glass Mat Gypsum Substrate for Use as Sheathing[1]

This standard is issued under the fixed designation C 1177/C 1177M; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope*

1.1 This specification covers glass mat gypsum substrate, which is designed to be used as an exterior substrate for a weather barrier.

1.2 The values stated in either SI units or inch-pound units are to be regarded separately as standard. Within the text, the SI units are shown in brackets. The values stated in each system may not be exact equivalents; therefore, each system shall be used independently of the other. Combining values from the two systems may result in non-conformance with the standard.

1.3 The text of this standard references notes and footnotes that provide explanatory material. These notes and footnotes (excluding those in tables and figures) shall not be considered as requirements of the standard.

2. Referenced Documents

2.1 *ASTM Standards:* [2]

C 11 Terminology Relating to Gypsum and Related Building Materials and Systems

C 473 Test Methods for Physical Testing of Gypsum Panel Products

C 645 Specification for Nonstructural Steel Framing Members

C 1264 Specification for Sampling, Inspection, Rejection, Certification, Packaging, Marking, Shipping, Handling, and Storage of Gypsum Panel Products

E 119 Test Methods for Fire Tests of Building Construction and Materials

3. Terminology

3.1 Definitions shall be in accordance with Terminology C 11.

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *glass mat*, *n*—a mat of glass fibers with or without a binder.

3.2.2 *edge*, *n*—the bound edge as manufactured.

3.2.3 *weather barrier*, *n*—a material that prevents the passage of rain, sleet and snow.

4. Materials and Manufacture

4.1 *Glass Mat Gypsum Substrate* shall consist of a noncombustible water-resistant core, essentially gypsum, surfaced with glass mat partially, or completely embedded in the core.

4.2 *Glass Mat Gypsum Substrate, type X (special fire-resistant)* designates glass mat gypsum substrate complying with this specification that provide not less than 1-h fire resistance rating for substrate 5⁄8 in. [15.9 mm] thick or 3⁄4-h fire resistance rating for substrate 1⁄2 in. [12.7 mm] thick, applied parallel with and on each side of load bearing 2 by 4 wood studs spaced 16 in. [406 mm] on center with 6d coated nails, 1 7⁄8 in. [48 mm] long, 0.0915 in. [2.3 mm] diameter shank, 1⁄4 in. [6.4 mm] diameter heads, spaced 7 in. [178 mm] on center with glass mat gypsum substrate joints staggered 16 in. [406 mm] on each side of the partition and tested in accordance with Test Methods E 119.

NOTE 1—Consult manufacturers for independent test data on assembly details and fire resistance ratings for other types of construction. See fire test reports or listings from recognized fire testing laboratories for assembly particulars, materials, and ratings.

5. Physical Properties

5.1 Specimens shall be taken from the samples obtained in accordance with Specification C 1264.

5.2 Specimens shall be tested in accordance with Methods C 473.

5.2.1 *Flexural Strength*—The specimens shall be tested face up and face down. The average breaking load shall not be less than the following:

	Method B	
Thickness, in. [mm]	Load, lbf [N] Bearing edges perpendicular to the substrate edge	Load, lbf [N] Bearing edges parallel to the substrate edge
1⁄4 [6.4]	50 [222]	40 [178]
7⁄16 [11.1]	88 [394]	70 [314]
1⁄2 [12.7]	100 [445]	80 [356]
5⁄8 [15.9]	140 [623]	100 [445]

[1] This specification is under the jurisdiction of ASTM Committee C11 on Gypsum and Related Building Materials and Systems and is the direct responsibility of Subcommittee C11.01 on Specifications and Test Methods for Gypsum Products.

Current edition approved Sept. 15, 2008. Published October 2008. Originally approved in 1991. Last previous edition approved in 2006 as C 1177/C 1177M–06.

[2] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

***A Summary of Changes section appears at the end of this standard.**

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5.2.2 *Humidified Deflection*—Specimens shall have an average deflection of not more than the following:

Thickness, in. [mm]	Humidified deflection, eighths of an in. [mm]
¼ [6.4]	not required
7/16 [11.1]	3 [9]
½ [12.7]	2 [6]
⅝ [15.9]	1 [3]

5.2.3 *Core, End and Edge Hardness*—Specimens shall have an average hardness of not less than 15 lbf [67 N] when tested in accordance with Method B:

5.2.4 *Nail Pull Resistance*—Specimens shall have an average nail pull resistance of not less than the following when tested in accordance with Method B:

Thickness, in. [mm]	Nail pull resistance, lbf [N]
¼ [6.4]	40 [178]
7/16 [11.1]	70 [314]
½ [12.7]	80 [356]
⅝ [15.9]	90 [400]

5.2.5 *Water Resistance*—The three specimens selected shall have an average water absorption of not more than 10 weight % after a 2-h immersion.

6. Dimensions and Tolerances

6.1 Specimens shall be taken from the samples obtained in accordance with Specification C 1264.

6.2 *Thickness, width, length and end squareness* shall be determined in accordance with Test Methods C 473.

6.2.1 *Thickness*—The nominal thickness shall be ¼ , 7/16 , ½ , or ⅝ in. [6.4, 11.1, 12.7 or 15.9 mm], with tolerances in the nominal thickness of ± 1/32 in. [± 0.8 mm], and with local variations of ± 1/16 in. [± 1.6 mm] from the nominal thickness.

6.2.2 *Width*—The nominal width shall be up to 48 in. [1220 mm], with tolerance of ⅛ in. [3 mm] under the specified width.

6.2.3 *Length*—The tolerance in length shall be ± ¼ in. [± 6 mm]

6.2.4 *End Squareness*—Corners shall be square with a tolerance of ± ⅛ in. [± 3 mm] in the full width of the substrate.

6.3 *Edges and Ends*—The edges and ends shall be straight and either square, beveled, featured, tapered, or featured and tapered.

7. Finish and Appearance

7.1 Glass mat gypsum substrate shall be free of any cracks and imperfections that would render it unfit for its designed use.

8. Sampling, Inspection, Rejection, Certification, Packaging, Marking, Shipping, Handling, and Storage

8.1 Shall be in accordance with Specification C 1264.

9. Keywords

9.1 core; exterior substrate; fire-resistant classification; flexural strength; glass mat; glass mat gypsum substrate; gypsum; hardness; humidified deflection; nail pull resistance; noncombustible; sheathing; substrate; type X; water resistance; weather barrier

APPENDIX

(Nonmandatory Information)

This Appendix gives general information and also suggestions for inclusions to be made elsewhere by the specifier. They are not part of this specification.

The definitions of type X as given in 4.2 and the alternate definition given in this appendix, are intended only as a test to define glass mat gypsum substrate for use as sheathing as meeting the requirements of type X. These tests do not indicate a preferred application nor do they limit the use of the product in other fire related assemblies.

All gypsum panel products for which type X is defined, except gypsum lath and gypsum shaftliner board, use the same test for type X products, therefore the type X designation indicates a consistent level of fire resistance.

X1. ALTERNATE DEFINITION FOR TYPE X

X1.1 Glass mat gypsum substrate, type X (special fire-resistant) designates glass mat gypsum substrate providing a greater fire resistance than regular glass mat gypsum substrate of the same thickness. Type X (special fire-resistant) glass mat gypsum substrate, when tested in accordance with Test Methods E 119, shall provide the following minimum fire resistance ratings for the assemblies described:

X1.1.1 One hour for a ⅝ in. [15.9 mm] thickness applied to a partition in a single layer application on each side of 3⅝ in. [92 mm] deep non-loadbearing galvanized steel studs complying with Specification C 645 spaced 24 in. [610 mm] on center. The ⅝ in. [15.9 mm] thick glass mat gypsum substrate 48 in. [1220 mm] wide shall be attached using 1 in. [25 mm] long drywall screws spaced 8 in. [203 mm] on center along the edges and ends, and 12 in. [305 mm] along intermediate studs. All joints shall be oriented parallel to and located over studs and staggered on opposite sides of the assembly; and

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X1.1.2 Two hours for a ½ in. [12.7 mm] thickness applied to a partition in a double layer application on each side of 2½ in. [64 mm] deep non-loadbearing galvanized steel studs complying with Specification C 645 spaced 24 in. [610 mm] on center. The base layer 48 in. [1220 mm] wide shall be attached using 1 in. [25 mm] long drywall screws spaced 12 in. [305 mm] on center along substrate edges, ends and along intermediate studs. Joints shall be oriented parallel to and located over studs and staggered on opposite sides of the assembly. The face layer 48 in. [1220 mm] wide shall be attached using 1⅝ in. [41 mm] long drywall screws spaced 12 in. [305 mm] along substrate edges, ends and along intermediate studs. Joints shall be oriented parallel to and located over studs, offset 24 in. [610 mm] from the base layer joints, and staggered on opposite sides of the assembly.

SUMMARY OF CHANGES

Committee C11 has identified the location of selected changes to this specification since the last issue, C 1177/C 1177M – 06, that may impact the use of this specification. (Approved September 15, 2008)

(*1*) Revised 6.2.3.

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Designation: C 1178/C 1178M – 08

Standard Specification for Coated Glass Mat Water-Resistant Gypsum Backing Panel[1]

This standard is issued under the fixed designation C 1178/C 1178M; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope*

1.1 This specification covers coated glass mat water-resistant gypsum backing panel designed for use on ceilings and walls in bath and shower areas as a base for the application of ceramic or plastic tile.

1.2 The values stated in either SI units or inch-pound units are to be regarded separately as standard. The values stated in each system may not be exact equivalents; therefore, each system shall be used independently of the other. Combining values from the two systems may result in non-conformance with the standard. Within the text, the SI units are shown in brackets.

1.3 The text of this standard references notes and footnotes that provide explanatory material. These notes and footnotes (excluding those in tables and figures) shall not be considered as requirements of the standard.

2. Referenced Documents

2.1 *ASTM Standards:* [2]

C 11 Terminology Relating to Gypsum and Related Building Materials and Systems

C 473 Test Methods for Physical Testing of Gypsum Panel Products

C 645 Specification for Nonstructural Steel Framing Members

C 1264 Specification for Sampling, Inspection, Rejection, Certification, Packaging, Marking, Shipping, Handling, and Storage of Gypsum Panel Products

E 119 Test Methods for Fire Tests of Building Construction and Materials

3. Terminology

3.1 Definitions shall be in accordance with Terminology C 11.

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *glass mat*, *n*—a mat of glass fibers with or without a binder.

3.2.2 *edge*, *n*—the bound edge as manufactured.

3.2.3 *face*, *n*—the coated surface.

3.2.4 *nominal thickness*, *n*—the manufacturer-stated fractional value of thickness of the gypsum panel product expressed in decimal value to the nearest one-thousandth (0.001) of an inch.

4. Materials and Manufacture

4.1 *Coated glass mat water-resistant gypsum backing panel* shall consist of a noncombustible water-resistant core, essentially gypsum, surfaced with glass mat, partially or completely embedded in the core, and with a water-resistant coating on one surface.

4.2 Coated glass mat water-resistant gypsum panels, type X (special fire-resistant) designates glass mat gypsum panels complying with this specification that provide not less than 1-h fire resistance rating for boards ⅝ in. [15.9 mm] thick or ¾-h fire resistance rating for panels ½ in. [12.7 mm] thick, applied parallel with and on each side of load bearing 2 by 4 wood studs spaced 16 in. [406 mm] on center with 6d coated nails, 1 ⅞ in. [48-mm] long, 0.0915 in. [2.3 mm] diameter shank, ¼ in. [6.4 mm] diameter heads, spaced 7 in. [178 mm] on center with glass mat gypsum panel joints staggered 16 in. [406 mm] on each side of the partition and tested in accordance with Test Methods E 119.

NOTE 1—Consult manufacturers for independent test data on assembly details and fire resistance ratings for other types of construction. See fire test reports or listings from recognized fire testing laboratories for assembly particulars, materials, and ratings.

5. Physical Properties

5.1 Specimens shall be taken from the samples obtained in accordance with Specification C 1264.

5.2 Specimens shall be tested in accordance with Test Methods C 473.

5.2.1 *Flexural Strength*—The specimens shall be tested face up and face down. The average breaking load shall not be less than the following:

[1] This specification is under the jurisdiction of ASTM Committee C11 on Gypsum and Related Building Materials and Systems and is the direct responsibility of Subcommittee C11.01 on Specifications and Test Methods for Gypsum Products.

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	Method B Load, lbf [N]	
Thickness, in. [mm]	Bearing edges perpendicular to the board edge	Bearing edges parallel to the board edge
¼ [6.4]	50 [222]	40 [178]
½ [12.7]	100 [445]	80 [356]
⅝ [15.9]	140 [623]	100 [445]

5.2.2 *Humidified Deflection*—Specimens shall have an average deflection of not more than the following:

Thickness, in. [mm]	Humidified deflection, eighths of an in. [mm]
¼ [6.4]	not required
½ [12.7]	2 [6]
⅝ [15.9]	1 [3]

5.2.3 *Core, End and Edge Hardness*—Specimens shall have an average hardness of not less than 15 lbf [67 N] when tested in accordance with Method B.

5.2.4 *Nail Pull Resistance*—Specimens shall have an average nail pull resistance of not less than the following when tested in accordance with Method B:

Thickness, in. [mm]	Nail pull resistance, lbf [N]
¼ [6.4]	40 [178]
½ [12.7]	70 [311]
⅝ [15.9]	90 [400]

5.2.5 *Water Resistance*—The three specimens selected shall have an average water absorption of not more than 5 weight % after 2-h immersion.

5.2.6 *Surface Water Absorption*—Specimens shall have an average surface water absorption of the face side of the panel not more than 0.5 g after 2 h of elapsed time.

6. Dimensions and Tolerances

6.1 Specimens shall be taken from the samples obtained in accordance with Specification C 1264.

6.2 Thickness, width, and length shall be determined in accordance with Test Methods C 473.

6.2.1 *Thickness*—The thickness shall be ¼ in., ½ in. or ⅝ in. [6.4, 12.7 or 15.9 mm], with tolerances of ± 0.015 in. [± 0.40 mm] and with local variations of ± 0.030 in. [± 0.80 mm].

6.2.2 *Width*—The nominal width shall be up to 48 in. [1220 mm], with a tolerance of 3⁄32 in. [3 mm] under the specified width.

6.2.3 *Length*—The tolerance in length shall be ± ¼ in. [± 6 mm]

6.2.4 *End Squareness*—Corners shall be square with a tolerance of ± ¼ in. [±6 mm] in the full width of the panel.

6.3 *Edges and Ends*—The edges and ends shall be straight and either square or tapered.

7. Finish and Appearance

7.1 Coated glass mat water-resistant gypsum backing panel shall have surfaces true and free of imperfections that render the panel unfit for its designed use.

8. Sampling, Inspection, Rejection, Certification, Packaging, Marking, Shipping, Handling, and Storage

8.1 Shall be in accordance with Specification C 1264.

9. Keywords

9.1 bath; ceilings; ceramic or plastic tile; construction; core; end and edge hardness; fire-resistant; flexural strength; glass mat; gypsum; humidified deflection; immersion; nail pull resistance; shower; surface water absorption; type X; walls; water absorption; water resistance; water-resistant

APPENDIX

(Nonmandatory Information)

This Appendix gives general information and also suggestions for inclusions to be made elsewhere by the specifier. They are not part of this specification.

The definition of type X in 4.2 and the alternate definition given in this appendix are intended only as a test to define the coated glass mat water-resistant gypsum backing panels as meeting the requirements of type X. These tests do not indicate a preferred application nor do they limit the use of the product in other fire rated assemblies.

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All gypsum panel products for which type X is defined, except gypsum lath and gypsum shaftliner board, use the same test for type X products, therefore the type X definition indicates a consistent level of fire resistance.

X1. ALTERNATE DEFINITION FOR TYPE X

X1.1 Coated glass mat water-resistant gypsum panels, type X (special fire-resistant) designates glass mat gypsum panels providing a greater fire resistance than regular glass mat water-resistant gypsum panels of the same thickness. Type X (special fire-resistant) glass mat water-resistant gypsum panels, when tested in accordance with Test Methods E 119, shall provide the following minimum fire resistance ratings for the assemblies described:

X1.1.1 One hour for a ⅝ in. [15.9 mm] thickness applied to a partition in a single layer application on each side of 3 ⅝ in. [92 mm] deep non-load bearing galvanized steel studs complying with Specification C 645 spaced 24 in. [610 mm] on center. The ⅝ in. [15.9 mm] thick glass mat water-resistant gypsum panels 48 in. [1220 mm] wide shall be attached using 1 in. [25 mm] long drywall screws spaced 8 in. [203 mm] on center along the edges and ends, and 12 in. [305 mm] along intermediate studs. All joints shall be oriented parallel to and located over studs and staggered on opposite sides of the assembly; and

X1.1.2 Two hours for a ½ in. [12.7 mm] thickness applied to a partition in a double layer application on each side of 2 ½ in. [64 mm] deep non-load bearing galvanized steel studs complying with Specification C 645 spaced 24 in. [610 mm] on center. The base layer 48 in. [1220 mm] wide shall be attached using 1 in. [25 mm] long drywall screws spaced 12 in. [305 mm] on center along panel edges, ends and along intermediate studs. Joints shall be oriented parallel to and located over studs and staggered on opposite sides of the assembly. The face layer 48 in. [1220 mm] wide shall be attached using 1 ⅝ in. [41 mm] long drywall screws spaced 12 in. [305 mm] along panel edges, ends and along intermediate studs. Joints shall be oriented parallel to and located over studs, offset 24 in. [610 mm] from the base layer joints, and staggered on opposite sides of the assembly.

SUMMARY OF CHANGES

Committee C11 has identified the location of selected changes to this specification since the last issue, C 1178/C 1178M – 06, that may impact the use of this specification. (Approved August 1, 2008)

(*1*) Revised 6.2.3.

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Designation: C1202 – 10

Standard Test Method for Electrical Indication of Concrete's Ability to Resist Chloride Ion Penetration[1]

This standard is issued under the fixed designation C1202; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope*

1.1 This test method covers the determination of the electrical conductance of concrete to provide a rapid indication of its resistance to the penetration of chloride ions. This test method is applicable to types of concrete where correlations have been established between this test procedure and long-term chloride ponding procedures such as those described in AASHTO T 259. Examples of such correlations are discussed in Refs **1-5**.[2]

1.2 The values stated in inch-pound units are to be regarded as the standard, except where SI units are given first followed by inch-pound units in parentheses. The values given in parentheses are for information only.

1.3 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

2. Referenced Documents

2.1 *ASTM Standards:*[3]

C31/C31M Practice for Making and Curing Concrete Test Specimens in the Field

C42/C42M Test Method for Obtaining and Testing Drilled Cores and Sawed Beams of Concrete

C192/C192M Practice for Making and Curing Concrete Test Specimens in the Laboratory

C670 Practice for Preparing Precision and Bias Statements for Test Methods for Construction Materials

2.2 *AASHTO Standard:*

T 259 Method of Test for Resistance of Concrete to Chloride Ion Penetration[4]

3. Summary of Test Method

3.1 This test method consists of monitoring the amount of electrical current passed through 2-in. (51-mm) thick slices of 4-in. (102-mm) nominal diameter cores or cylinders during a 6-h period. A potential difference of 60 V dc is maintained across the ends of the specimen, one of which is immersed in a sodium chloride solution, the other in a sodium hydroxide solution. The total charge passed, in coulombs, has been found to be related to the resistance of the specimen to chloride ion penetration.

4. Significance and Use

4.1 This test method covers the laboratory evaluation of the electrical conductance of concrete samples to provide a rapid indication of their resistance to chloride ion penetration. In most cases the electrical conductance results have shown good correlation with chloride ponding tests, such as AASHTO T 259, on companion slabs cast from the same concrete mixtures (Refs **1-5**).

4.2 This test method is suitable for evaluation of materials and material proportions for design purposes and research and development.

4.3 Sample age has significant effects on the test results, depending on the type of concrete and the curing procedure. Most concretes, if properly cured, become progressively and significantly less permeable with time.

4.4 This test method was developed originally for evaluations of alternative materials, but in practice its use has evolved to applications such as quality control and acceptance testing.

[1] This test method is under the jurisdiction of ASTM Committee C09 on Concrete and Concrete Aggregates and is the direct responsibility of Subcommittee C09.66 on Concrete's Resistance to Fluid Penetration.

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[2] The boldface numbers in parentheses refer to the list of references at the end of this standard.

[3] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

[4] Methods of Sampling and Testing, 1986, American Association of State Highway and Transportation Officials, 444 N. Capitol St., NW, Washington, DC 20001.

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In such cases it is imperative that the curing procedures and the age at time of testing be clearly specified.

4.5 Table 1 provides a qualitative relationship between the results of this test and the chloride ion penetrability of concrete.

4.6 Numerical results of this test (total charge passed, in coulombs) can be used as a basis for determining the acceptability of a concrete mixture. Factors such as the ingredient materials used and method and duration of curing of test specimens affect results of this test. (See Note 1)

NOTE 1—When using this test for determining acceptability of concrete mixtures, statistically-based criteria and test age for prequalification, or for acceptance based on jobsite samples, should be stated in project specifications. Acceptance criteria for this test should consider the sources of variability affecting the results and ensure balanced risk between supplier and purchaser. The anticipated exposure conditions and time before a structure will be put into service should be considered. One approach to establishing criteria is discussed in Ref **6**.

4.7 Care should be taken in interpreting results of this test when it is used on surface-treated concretes, for example, concretes treated with penetrating sealers. The results from this test on some such concretes indicate low resistance to chloride ion penetration, while 90-day chloride ponding tests on companion slabs show a higher resistance.

4.8 The details of the test method apply to 4-in. (102-mm) nominal diameter specimens. This includes specimens with actual diameters ranging from 3.75 in. (95 mm) to 4.0 in. (102 mm). Other specimen diameters may be tested with appropriate changes in the applied voltage cell design (see 7.5 and Fig. 1).

4.8.1 For specimen diameters other than 3.75 in. (95 mm), the test result value for total charge passed must be adjusted following the procedure in 11.2. For specimens with diameters less than 3.75 in. (95 mm), particular care must be taken in coating and mounting the specimens to ensure that the conductive solutions are able to contact the entire end areas during the test.

5. Interferences

5.1 This test method can produce misleading results when calcium nitrite has been admixed into a concrete. The results from this test on some such concretes indicate higher coulomb values, that is, lower resistance to chloride ion penetration, than from tests on identical concrete mixtures (controls) without calcium nitrite. However, long-term chloride ponding tests indicate the concretes with calcium nitrite were at least as resistant to chloride ion penetration as the control mixtures.

NOTE 2—Other admixtures might affect results of this test similarly. Long term ponding tests are recommended if an admixture effect is suspected.

5.2 Since the test results are a function of the electrical resistance of the specimen, the presence of reinforcing steel or other embedded electrically conductive materials may have a significant effect. The test is not valid for specimens containing reinforcing steel positioned longitudinally, that is, providing a continuous electrical path between the two ends of the specimen.

TABLE 1 Chloride Ion Penetrability Based on Charge Passed (1)

Charge Passed (coulombs)	Chloride Ion Penetrability
>4,000	High
2,000–4,000	Moderate
1,000–2,000	Low
100–1,000	Very Low
<100	Negligible

6. Apparatus

6.1 *Vacuum Saturation Apparatus* (see Fig. 2 for example):

6.1.1 *Separatory Funnel*, or other sealable, bottom-draining container with a minimum capacity of 500 mL.

6.1.2 *Beaker (1000 mL or larger) or other container*—Capable of holding concrete specimen(s) and water and of fitting into vacuum desiccator (see 6.1.3).

6.1.3 *Vacuum Desiccator*—250-mm (9.8-in.) inside diameter or larger. Desiccator must allow two hose connections through a rubber stopper and sleeve or through a rubber stopper only. Each connection must be equipped with a stopcock.

6.1.4 *Vacuum Pump or Aspirator*—Capable of maintaining a pressure of less than 50 mm Hg (6650 Pa) in desiccator.

NOTE 3—Since vacuum will be drawn over water, a vacuum pump should be protected with a water trap, or pump oil should be changed after each operation.

6.1.5 *Vacuum Gage or Manometer*—Accurate to ± 5 mm Hg (± 665 Pa) over range 0–100 mm Hg (0–13300 Pa) pressure.

6.2 *Coating Apparatus and Materials*:

6.2.1 *Coating*—Rapid setting, electrically nonconductive, capable of sealing side surface of concrete cores.

6.2.2 *Balance or Scale, Paper Cups, Wooden Spatulas, and Disposable Brushes*—For mixing and applying coating.

6.3 *Specimen Sizing Equipment* (not required if samples are cast to final specimen size).

6.3.1 *Movable Bed Water-Cooled Diamond Saw or Silicon Carbide Saw*.

7. Reagents, Materials, and Test Cell

7.1 *Specimen-Cell Sealant*—Capable of sealing concrete to poly (methyl methacrylate), for example, Plexiglas, against water and dilute sodium hydroxide and sodium chloride solutions at temperatures up to 200 °F (90 °C); examples include RTV silicone rubbers, silicone rubber caulkings, other synthetic rubber sealants, silicone greases, and rubber gaskets.

7.2 *Sodium Chloride Solution*—3.0 % by mass (reagent grade) in distilled water.

7.3 *Sodium Hydroxide Solution*—0.3 N (reagent grade) in distilled water.

7.3.1 **Warning**—Before using NaOH, review: (*1*) the safety precautions for using NaOH; (*2*) first aid for burns; and (*3*) the emergency response to spills, as described in the manufacturer's Material Safety Data Sheet or other reliable safety literature. NaOH can cause very severe burns and injury to unprotected skin and eyes. Suitable personal protective equipment should always be used. These should include full-face shields, rubber aprons, and gloves impervious to NaOH. Gloves should be checked periodically for pin holes.

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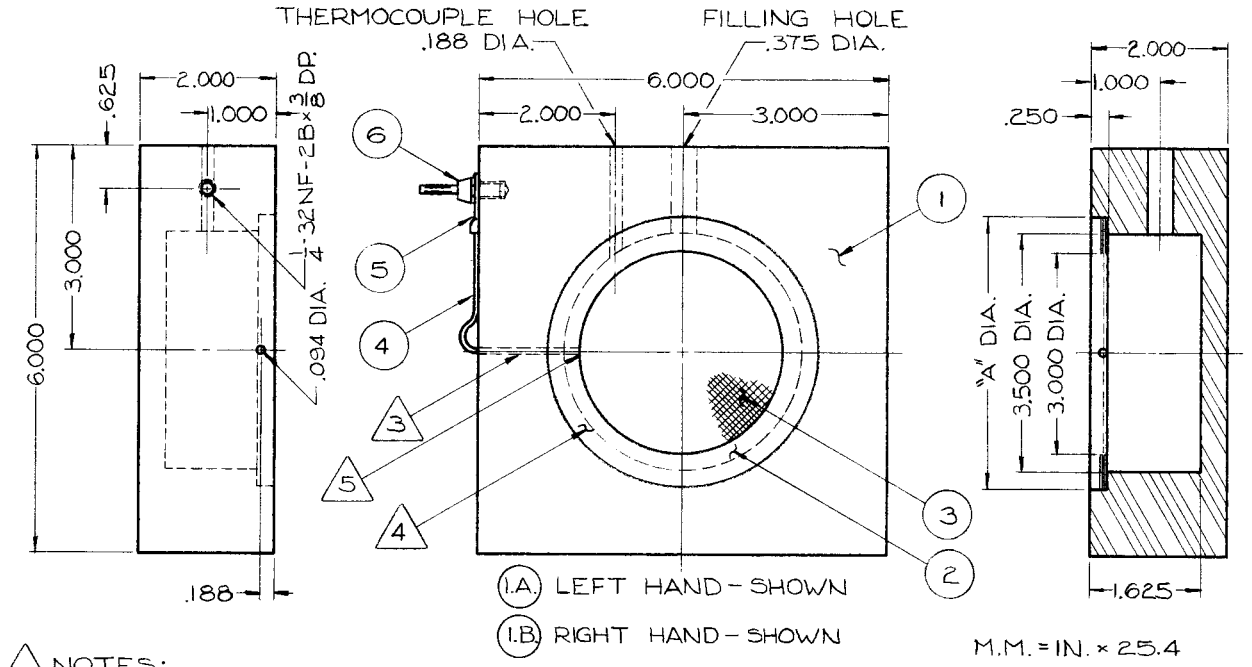

△ NOTES:

1.) DIAMETER "A" SHOULD BE $\frac{1}{8}$" LARGER THAN OUTSIDE DIA. OF SPECIMEN.
2.) NOT TO SCALE.
3.) SEAL WIRE IN HOLE WITH SILICONE RUBBER CAULK.
4.) SCREEN SOLDERED BETWEEN SHIMS.
5.) SOLDER WIRE TO BRASS SHIM.
6.) POLYMETHYLMETHACRYLATE, *e.g.*, PLEXIGLAS.

ITEM	QTY.	NOMENCLATURE	SPECIFICATION
6	2	BANANA PLUG	$\frac{1}{4}$ MALE, INSULATED
5	2	TERMINAL	12-10-$\frac{1}{4}$
4	2	WIRE, COPPER	#14, SOLID NYLCLAD
3	2	SCREEN, BRASS	#20 MESH, "A" DIA.
2	4	SHIM, BRASS	0.02 THK.
1.B. 1.A.	1 1	CELL BLOCK END	PMMA SHEET △6

FIG. 1 Applied Voltage Cell (construction drawing)

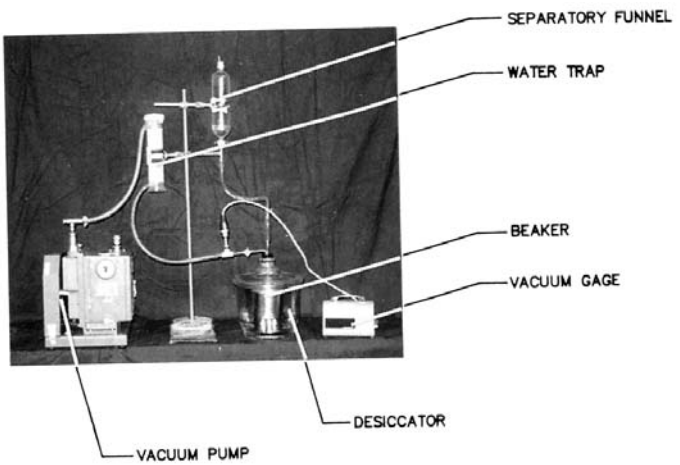

FIG. 2 Vacuum Saturation Apparatus

7.4 *Filter Papers*—No. 2, 90-mm (3.5-in.) diameter (not required if rubber gasket is used for sealant (see 7.1) or if sealant can be applied without overflowing from shim onto mesh).

7.5 *Applied Voltage Cell (see Fig. 1 and Fig. 3)*—Two

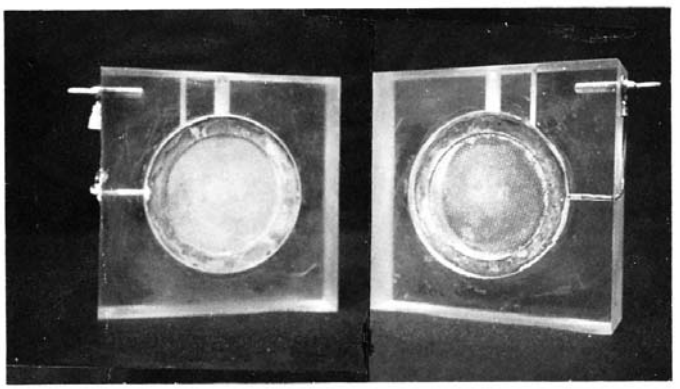

FIG. 3 Applied Voltage Cell-Face View

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symmetric poly (methyl methacrylate) chambers, each containing electrically conductive mesh and external connectors. One design in common use is shown in Fig. 1 and Fig. 3. However, other designs are acceptable, provided that overall dimensions (including dimensions of the fluid reservoir) are the same as shown in Fig. 1 and width of the screen and shims are as shown.

7.6 *Temperature Measuring Device (optional)*—30 to 250 °F (0 to 120 °C) range.

7.7 *Voltage Application and Data Readout Apparatus*—Capable of holding 60 ± 0.1 V dc across applied voltage cell over entire range of currents and of displaying voltage accurate to ± 0.1 V and current to ± 1 mA. Apparatus listed in 7.7.1-7.7.5 is a possible system meeting this requirement.

7.7.1 *Voltmeter*—Digital (DVM), 3 digit, minimum 0–99.9 V range, rated accuracy ± 0.1 %.

7.7.2 *Voltmeter*—Digital (DVM), 4½ digit, 0–200 mV range, rated accuracy ± 0.1 %.

7.7.3 *Shunt Resistor*—100 mV, 10A rating, tolerance ± 0.1 %. Alternatively, a 0.01 Ω resistor, tolerance ± 0.1 %, may be used, but care must be taken to establish very low resistance connections.

7.7.4 *Constant Voltage Power Supply*— 0–80 V dc, 0–2 A, capable of holding voltage constant at 60 ± 0.1 V over entire range of currents.

7.7.5 *Cable*—Two conductor, No. 14 (1.6 mm), insulated, 600 V.

8. Test Specimens

8.1 Sample preparation and selection depends on the purpose of the test. For evaluation of materials or their proportions, samples may be (*a*) cores from test slabs or from large diameter cylinders or (*b*) 4-in. (102-mm) diameter cast cylinders. For evaluation of structures, samples may be (*a*) cores from the structure or (*b*) 4-in. (102-mm) diameter cylinders cast and cured at the field site. Coring shall be done with a drilling rig equipped with a 4-in. (102-mm) diameter diamond-dressed core bit. Select and core samples following procedures in Test Method C42/C42M. Cylinders cast in the laboratory shall be prepared following procedures in Practice C192/C192M. When cylinders are cast in the field to evaluate a structure, care must be taken that the cylinders receive the same treatment as the structure, for example, similar degree of consolidation, curing, and temperature history during curing.

NOTE 4—The maximum allowable aggregate size has not been established for this test. Users have indicated that test repeatability is satisfactory on specimens from the same concrete batch for aggregates up to 25.0 mm (1 in.) nominal maximum size.

8.2 When results of this test method are used for evaluation of materials or mixture proportions based on cast specimens for purposes of quality control, mixture submittals, or acceptance of concrete, prepare 4-in (102-mm) diameter cylindrical specimens in accordance with Practice C192/C192M for concrete mixtures prepared in the laboratory or Practice C31/C31M from samples of fresh concrete obtained in the field. Unless otherwise specified, moist cure specimens in accordance with 8.2.1 for concrete mixtures containing only portland cement and in accordance with 8.2.2 for concrete mixtures containing supplementary cementitious materials. Use the same method and duration of curing test specimens when comparing two or more mixtures. The accelerated moist curing procedure in 8.2.3 is permitted as an alternative to the extended moist curing procedure for concrete mixtures containing supplementary cementitious materials (See Note 6).

8.2.1 *Moist Curing*—Cure test specimens for at least 28 days in accordance with Practice C192/C192M or in accordance with the standard curing procedure of Practice C31/C31M for specimens prepared in the field.

8.2.2 *Extended Moist Curing*—Cure test specimens for at least 56 days in accordance with Practice C192/C192M for specimens prepared in the laboratory or in accordance with the standard curing procedure of Practice C31/C31M for specimens prepared in the field.

8.2.3 *Accelerated Moist Curing*—Provide 7 days of moist curing in accordance with Practice C192/C192M for specimens prepared in the laboratory or in accordance with the standard curing procedure of Practice C31/C31M for specimens prepared in the field. After 7 days of moist curing, immerse the specimens for 21 days in lime-saturated water at 38.0 ± 2.0 °C (100 ± 3 °F).

NOTE 5—The 56-day moist curing period is to allow for some supplementary cementitious materials to develop potential properties because of their slower rate of hydration. Concrete containing supplementary cementitious materials may continue to show reductions in results of this test beyond 56 days, and in some cases, it may be appropriate to test at later ages, such as 3 months.

NOTE 6—The accelerated moist curing procedure has been found useful in providing an earlier indication of potential property development with slower hydrating supplementary cementitious materials (**7**). Because the two different curing methods may not provide the same results, the specifier of the test may require a correlation between results for extended moist cured and accelerated moist cured specimens and establish appropriate acceptance criteria when the accelerated moist curing procedure is used or permitted. Comparisons between results of moist cured specimens and field performance of concrete are documented in (**8**).

8.3 Transport the cores or field-cured cylinders to the laboratory in sealed (tied) plastic bags. If specimens must be shipped, they should be packed so as to be properly protected from freezing and from damage in transit or storage.

8.4 Using the water-cooled diamond saw or silicon carbide saw, cut a 2 ± ⅛ in. (51 ± 3 mm) slice from the top of the core or cylinder, with the cut parallel to the top of the core. This slice will be the test specimen. Use a belt sander to remove any burrs on the end of the specimen.

8.5 Special processing is necessary for core samples where the surface has been modified, for example, by texturing or by applying curing compounds, sealers, or other surface treatments, and where the intent of the test is not to include the effect of the modifications. In those cases, the modified portion of the core shall be removed and the adjacent 2 ± ⅛ in. (51 ± 3 mm) slice shall be used for the test.

9. Conditioning

9.1 Vigorously boil a litre or more of tapwater in a large sealable container. Remove container from heat, cap tightly, and allow water to cool to ambient temperature.

9.2 Allow specimen prepared in Section 8 to surface dry in air for at least 1 h. Prepare approximately ½ oz (10 g) of rapid

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setting coating and brush onto the side surface of specimen. Place the sample on a suitable support while coating to ensure complete coating of sides. Allow coating to cure according to the manufacturer's instructions.

9.3 The coating should be allowed to cure until it is no longer sticky to the touch. Fill any apparent holes in the coating and allow additional curing time, as necessary. Place specimen in beaker or other container (see 6.1.2), then place container in vacuum desiccator. Alternatively, place specimen directly in vacuum desiccator. Both end faces of specimen must be exposed. Seal desiccator and start vacuum pump or aspirator. Pressure should decrease to less than 50 mm Hg (6650 Pa) within a few minutes. Maintain vacuum for 3 h.

9.4 Fill separatory funnel or other container (see 6.1.1) with the de-aerated water prepared in 9.1. With vacuum pump still running, open water stopcock and drain sufficient water into beaker or container to cover specimen (do not allow air to enter desiccator through this stopcock).

9.5 Close water stopcock and allow vacuum pump to run for one additional hour.

9.6 Close vacuum line stopcock, then turn off pump. (Change pump oil if a water trap is not being used.) Turn vacuum line stopcock to allow air to re-enter desiccator.

9.7 Soak specimen under water (the water used in steps 9.4-9.6) in the beaker for 18 ± 2 h.

10. Procedure

10.1 Remove specimen from water, blot off excess water, and transfer specimen to a sealed can or other container which will maintain the specimen in 95 % or higher relative humidity.

10.2 Specimen mounting (all sealants other than rubber gaskets; use 10.2.2 or 10.2.3, as appropriate):

10.2.1 If using two-part specimen-cell sealant, prepare approximately 0.7 to 1.4 oz (20 to 40 g).

10.2.2 *Low Viscosity Specimen-Cell Sealant*—If filter paper is necessary, center filter paper over one screen of the applied voltage cell. Trowel sealant over brass shims adjacent to applied voltage cell body. Carefully remove filter paper. Press specimen onto screen; remove or smooth excess sealant which has flowed out of specimen-cell boundary.

10.2.3 *High Viscosity Specimen-Cell Sealant*—Set specimen onto screen. Apply sealant around specimen-cell boundary.

10.2.4 Cover exposed face of specimen with an impermeable material such as rubber or plastic sheeting. Place rubber stopper in cell filling hole to restrict moisture movement. Allow sealant to cure per manufacturer's instructions.

10.2.5 Repeat steps 10.2.2 (or 10.2.3) and 10.2.4 on second half of cell. (Specimen in applied voltage cell now appears as shown in Fig. 4.)

10.3 Specimen mounting (rubber gasket alternative): Place a 4-in. outside diameter by 3-in. inside diameter by ¼-in. (100 mm outside diameter by 75 mm inside diameter by 6 mm) circular vulcanized rubber gasket in each half of the test cell. Insert sample and clamp the two halves of the test cell together to seal.

10.4 Fill the side of the cell containing the top surface of the specimen with 3.0 % NaCl solution. (That side of the cell will be connected to the negative terminal of the power supply in

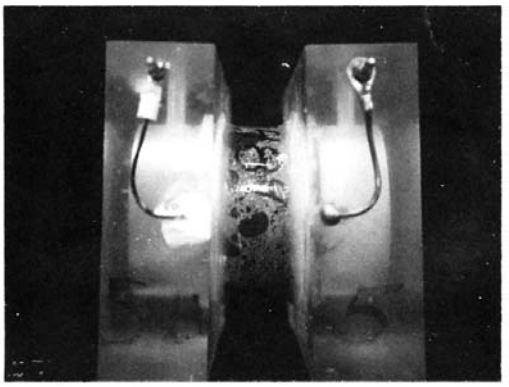

FIG. 4 Specimen Ready for Test

10.5.) Fill the other side of the cell (which will be connected to the positive terminal of the power supply) with 0.3 N NaOH solution.

10.5 Attach lead wires to cell banana posts. Make electrical connections to voltage application and data readout apparatus as appropriate; for example, for system listed in 7.7.1-7.7.5, connect as shown in Fig. 5. Turn power supply on, set to 60.0 ± 0.1 V, and record initial current reading. Temperatures of the specimen, applied voltage cell, and solutions shall be 68 to 77 °F (20 to 25 °C) at the time the test is initiated, that is, when the power supply is turned on.

10.6 During the test, the air temperature around the specimens shall be maintained in the range of 68 to 77 °F (20 to 25 °C).

10.7 Read and record current at least every 30 min. If a voltmeter is being used in combination with a shunt resistor for the current reading (see Fig. 5), use appropriate scale factors to convert voltage reading to amperes. Each half of the test cell must remain filled with the appropriate solution for the entire period of the test.

NOTE 7—During the test, the temperature of the solutions should not be allowed to exceed 190 °F (90 °C) in order to avoid damage to the cell and to avoid boiling off the solutions. Although it is not a requirement of the method, the temperature of the solutions can be monitored with thermocouples installed through the ⅛-in. (3-mm) venthole in the top of the cell. High temperatures occur only for highly penetrable concretes. If a test of a 2-in. (51-mm) thick specimen is terminated because of high temperatures, this should be noted in the report, along with the time of

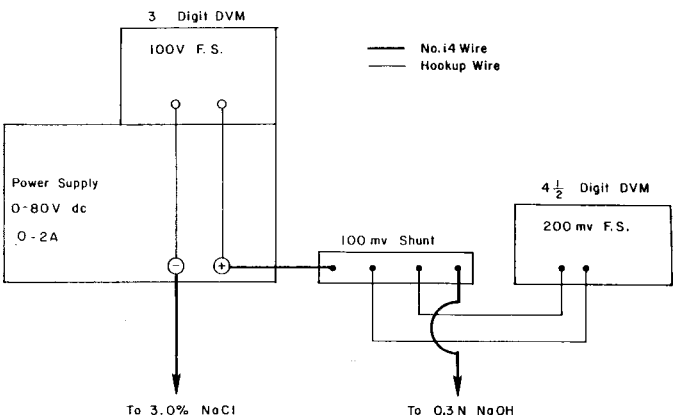

FIG. 5 Electrical Block Diagram (example)

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termination, and the concrete rated as having very high chloride ion penetrability (see 12.1.9).

10.8 Terminate test after 6 h, except as discussed in Note 7.

10.9 Remove specimen. Rinse cell thoroughly in tapwater; strip out and discard residual sealant.

11. Calculation and Interpretation of Results

11.1 Plot current (in amperes) versus time (in seconds). Draw a smooth curve through the data, and integrate the area underneath the curve in order to obtain the ampere-seconds, or coulombs, of charge passed during the 6-h test period. (See Note 8) Alternatively, use automatic data processing equipment to perform the integration during or after the test and to display the coulomb value. The total charge passed is a measure of the electrical conductance of the concrete during the period of the test.

NOTE 8—*Sample Calculation*—If the current is recorded at 30 min intervals, the following formula, based on the trapezoidal rule, can be used with an electronic calculator to perform the integration:

$$Q = 900\,(I_0 + 2I_{30} + 2I_{60} + \ldots + 2I_{300} + 2I_{330} + I_{360}) \quad (1)$$

where:

Q = charge passed (coulombs),
I_o = current (amperes) immediately after voltage is applied, and
I_t = current (amperes) at t min after voltage is applied.

11.2 If the specimen diameter is other than 3.75 in. (95 mm), the value for total charge passed established in 11.1 must be adjusted. The adjustment is made by multiplying the value established in 11.1 by the ratio of the cross-sectional areas of the standard and the actual specimens. That is:

$$Q_s = Q_x \times \left(\frac{3.75}{x}\right)^2 \quad (2)$$

where:

Q_s = charge passed (coulombs) through a 3.75-in. (95-mm) diameter specimen,
Q_x = charge passed (coulombs) through x in. diameter specimen, and
x = diameter (in.) of the nonstandard specimen.

11.3 Use Table 1 to evaluate the test results. These values were developed from data on slices of cores taken from laboratory slabs prepared from various types of concretes.

11.3.1 Factors which are known to affect chloride ion penetration include: water-cement ratio, the presence of polymeric admixtures, sample age, air-void system, aggregate type, degree of consolidation, and type of curing.

12. Report

12.1 Report the following, if known:

12.1.1 Source of core or cylinder, in terms of the particular location the core or cylinder represents,

12.1.2 Identification number of core or cylinder and specimen,

12.1.3 Location of specimen within core or cylinder,

12.1.4 Type of concrete, including binder type, water-cement ratio, and other relevant data supplied with samples,

12.1.5 Description of specimen, including presence and location of reinforcing steel, presence and thickness of overlay, and presence and thickness of surface treatment,

12.1.6 Curing history of specimen; indicate moist curing, extended moist curing, or accelerated moist curing as defined in this test method, as applicable,

12.1.7 Unusual specimen preparation, for example, removal of surface treatment,

12.1.8 Test results, reported as the total charge passed over the test period (adjusted per 11.2), and

12.1.9 The qualitative chloride ion penetrability equivalent to the calculated charge passed (from Table 1).

13. Precision and Bias [5]

13.1 *Precision*:

13.1.1 *Single-Operator Precision*—The single operator coefficient of variation of a single test result has been found to be 12.3 % (Note 9). Therefore the results of two properly conducted tests by the same operator on concrete samples from the same batch and of the same diameter should not differ by more than 42 % (Note 9).

13.1.2 *Multilaboratory Precision*—The multilaboratory coefficient of variation of a single test result has been found to be 18.0 % (Note 9). Therefore results of two properly conducted tests in different laboratories on the same material should not differ by more than 51 % (Note 9). The average of three test results in two different laboratories should not differ by more than 42 % (Note 10).

NOTE 9—These numbers represent, respectively, the (1s %) and (d2s %) limits as described in Practice C670. The precision statements are based on the variations in tests on three different concretes, each tested in triplicate in eleven laboratories. All specimens had the same actual diameters, but lengths varied within the range 2 ± ⅛ in. (51 ± 3 mm).

NOTE 10—Although the test method does not require the reporting of more than one test result, testing of replicate specimens is usually desirable. The precision statement for the averages of three results is given since laboratories frequently will run this number of specimens. When averages of three results are established in each laboratory, the multilaboratory coefficient of variation, s_{ML} is calculated as:

$$s_{ML} = \sqrt{\frac{s_{WL}^2}{3} + s_{BL}^2} \quad (3)$$

where:

s_{WL}^2 = within-laboratory variance and
s_{BL}^2 = between-laboratory variance.

The percentage cited represents the (d2s %) limit based on the value for the multilaboratory coefficient of variation.

13.2 *Bias*—The procedure of this test method for measuring the resistance of concrete to chloride ion penetration has no bias because the value of this resistance can be defined only in terms of a test method.

14. Keywords

14.1 chloride content; corrosion; deicing chemicals; resistance-chloride penetration

[5] Supporting data have been filed at ASTM International Headquarters and may be obtained by requesting Research Report RR:C09-1004.

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REFERENCES

(1) Whiting, D., "Rapid Determination of the Chloride Permeability of Concrete," *Final Report No. FHWA/RD-81/119*, Federal Highway Administration, August 1981, NTIS No. PB 82140724.

(2) Whiting, D., "Permeability of Selected Concretes," *Permeability of Concrete*, SP-108, American Concrete Institute, Detroit, Michigan, 1988, pp. 195–222.

(3) Whiting, D., and Dziedzic, W., "Resistance to Chloride Infiltration of Superplasticized Concrete as Compared with Currently Used Concrete Overlay Systems," *Final Report No. FHWA/OH-89/009*, Construction Technology Laboratories, May 1989.

(4) Berke, N. S., Pfeifer, D. W., and Weil, T. G., "Protection Against Chloride-Induced Corrosion," *Concrete International*, Vol. 10, No. 12, December 1988, pp. 45–55.

(5) Ozyildirim, C., and Halstead, W. J., "Use of Admixtures to Attain Low Permeability Concretes," *Final Report No. FHWA/VA-88-R11*, Virginia Transportation Research Council, February 1988, NTIS No. PB 88201264.

(6) Obla, K.H. and Lobo, C.L., "Acceptance Criteria for Durability Tests," *ACI Concrete International*, Vol. 29, No. 5, May 2007, pp. 43-48.

(7) Ozyildirim C., Effects of Temperature on the Development of Low Permeability in Concretes, VTRC R98-14, Virginia Transportation Research Council, Charlottesville, VA, 1998.

(8) Bouzoubaa, N., Bilodeau, A., Vasanthy, S., Fournier, B., and Golden, D., Development of Ternary Blends for High-Performance Concrete, *ACI Materials Journal*, Vol. 101, No. 1, pp. 19-29, 2004.

SUMMARY OF CHANGES

Committee C09 has identified the location of selected changes to this test method since the last issue, C1202 – 09, that may impact the use of this test method. (Approved February 1, 2010)

(*1*) Revised Sections 4, 8, and 12.

Committee C09 has identified the location of selected changes to this test method since the last issue, C1202 – 08, that may impact the use of this test method. (Approved May 1, 2009)

(*1*) Revised 4.4.

Committee C09 has identified the location of selected changes to this test method since the last issue, C1202 – 07, that may impact the use of this test method. (Approved December 15, 2008)

(*1*) Revised 4.4.

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Designation: C 1214 – 02 (Reapproved 2009)

Standard Test Method for Concrete Pipe Sewerlines by Negative Air Pressure (Vacuum) Test Method[1]

This standard is issued under the fixed designation C 1214; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope

1.1 This test method covers procedures for testing concrete pipe sewerlines, when using the negative air pressure (vacuum) test method to demonstrate the integrity of the installed material and the construction procedures. This test method covers testing of 4 to 36-in. diameter circular concrete pipe sewerlines utilizing gasketed joints.

NOTE 1—The user of this test method is advised that methods described herein may also be used as a preliminary test to enable the manufacturer or installer to demonstrate the condition of sewer pipe prior to delivery or backfill. Minimum test times presented in Table 1 are for pipelines. Holding times for testing an individual pipe may have to be increased to allow for the accumulation of leakage when the tested pipe are incorporated into a continuous pipeline.

NOTE 2—The user of this test method is advised that the negative air pressure (vacuum) test criteria presented in this test method are similar to those in general use. The test and criteria have been used widely and successfully in testing smaller diameter pipe. Larger pipe will be accepted more conveniently by visual inspection and individual joint testing.

NOTE 3—The user of this test method is advised that no correlation has been found between loss of vacuum and water leakage.

1.2 This test method is the inch-pound companion to Test Method C 1214M; therefore, no SI equivalents are presented in the test method.

1.3 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.* See Section 6 for specific safety precautions.

2. Referenced Documents

2.1 *ASTM Standards:*[2]

C 822 Terminology Relating to Concrete Pipe and Related Products

C 924 Practice for Testing Concrete Pipe Sewer Lines by Low-Pressure Air Test Method

C 969 Practice for Infiltration and Exfiltration Acceptance Testing of Installed Precast Concrete Pipe Sewer Lines

TABLE 1 Minimum Test Time

Nominal Pipe Size, in.	T (Time), min/100 ft	Nominal Pipe Size, in.	T (Time), min/100 ft
4	0.3	21	3.0
6	0.7	24	3.6
8	1.2	27	4.2
10	1.5	30	4.8
12	1.8	33	5.4
15	2.1	36	6.0
18	2.4		

3. Terminology

3.1 *Definitions*—For definitions of terms relating to concrete pipe, see Terminology C 822.

4. Summary of Test Method

4.1 The sewerline to be tested is plugged. Air is removed from the plugged line by a vacuum pump or vacuum reservoir. The amount of vacuum loss is used to determine the acceptability of the sewerline.

5. Significance and Use

5.1 This is not a routine test. The values recorded are applicable only to the sewer being tested and at the time of testing.

6. Safety Precautions

6.1 **Warning—**The user of this test method is advised that this test may be dangerous if a line is not prepared properly and proper procedures are not followed.

6.2 Access manholes or structures must be ventilated and air quality continuously monitored.

6.3 No one shall be allowed in or near the manholes during testing.

7. Preparation of the Sewerline

7.1 Where practical, clean the line prior to testing, wet the pipe surface, and eliminate debris.

[1] This test method is under the jurisdiction of ASTM Committee C13 on Concrete Pipe and is the direct responsibility of Subcommittee C13.09 on Methods of Test.

Current edition approved June 1, 2009. Published July 2009. Originally approved in 1992. Last previous edition approved in 2002 as C 1214 – 02.

[2] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

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NOTE 4—The user of this test method is advised that a wetted exterior pipe surface is desirable and will produce more consistent test results. Air may pass through the walls of dry pipe. This can be overcome by wetting the pipe. Usually, moisture absorbed from the backfill is sufficient to cope with this situation. If the problem persists, segmental testing of the line will establish if there is a significant leak.

7.2 Plug all pipe outlets including laterals. Review safety precautions in Section 6.

8. Procedure

8.1 Determine the test time for the sewerline to be tested by using Table 1. Table 1 has been established using the criteria specified in Table 2 and the formulas contained in the Appendixes. The test time is the time required for the vacuum to drop from 7 to 5 in. of mercury.

NOTE 5—To provide satisfactory test results, the vacuum pump shall be capable of evacuating the sewer test section in the required test time, or less, as determined by 8.1. The pump capacity required to accomplish the evacuation of the line is equal to the rate necessary to reduce the sewer to the desired pressure plus the allowable vacuum loss rate:

$$C = 0.17D^2L/T + Q \quad (1)$$

where:

C = vacuum pump capacity, ft^3/min,
T = required test time, or less, min,
D = pipe internal diameter, ft,
L = length of test section, ft, and
Q = allowable vacuum loss rate, ft^3/min.

TABLE 2 Allowable Air Loss

Nominal Pipe Size, in.	Q, ft^3/min	Nominal Pipe Size, in.	Q, ft^3/min
4	2.0	21	5.5
6	2.0	24	6.0
8	2.0	27	6.5
10	2.5	30	7.0
12	3.5	33	7.5
15	4.0	36	8.0
18	5.0		

8.2 Evacuate air until the internal air pressure of the sewerline is lowered by approximately 8 in. of mercury. Close the valve on the vacuum line and shut off the vacuum pump. Allow the air pressure to stabilize.

8.3 When the pressure has stabilized and is at or below the starting test vacuum of 7 in. of mercury, commence the test by allowing the gage pressure to drop to 7 in. of mercury, at which point the time recording is initiated. Record the drop in vacuum for the test period.

8.4 If the drop in vacuum is 2 in. of mercury or less during the test period, accept the line. If the drop in vacuum is more than 2 in. of mercury during the test period, inspect, evaluate, and retest the line to determine the cause of excessive vacuum loss.

8.5 Use or failure of this vacuum test shall not preclude acceptance by appropriate low-pressure air (see Practice C 924), water infiltration or exfiltration testing (see Practice C 969), or other means.

9. Vacuum Test Criteria

9.1 An appropriate allowable vacuum loss, Q, in cubic feet per minute has been established for each nominal pipe size. Based on field experience, the vacuum loss Qs that have been selected will enable detection of any significant leak. Table 2 lists the Q established for each pipe size.

9.2 When a main line with connected lateral is to be tested as a unit, the total volume of the main and laterals shall be considered and the allowable air loss rate shall be that listed for the main.

10. Precision and Bias

10.1 No justifiable statement is presently capable of being made either on precision or bias of this procedure since the test result merely states whether there is conformance to the criteria for success specified. Due to the sealing effects of ground water and internal flow on sewerline, the test conditions and results are not reproducible.

APPENDIXES

(Nonmandatory Information)

X1. EQUATIONS USED IN PRACTICE C 1214

X1.1 The required test time per 100 ft for a single diameter pipe using Table 2:

$$T_T = (0.00037)\,(D^2L/Q) \quad (X1.1)$$

X1.2 The required test time for a single diameter pipe using Table 1:

$$T_T = (L)\,(T/100) \quad (X1.2)$$

X1.3 For testing a sewer system involving different diameter pipe, the allowable vacuum loss rate shall be that for the main sewer. The volume of each size of lateral pipe is converted to an equivalent length of required test time as follows:

$$L_e = \Sigma\,(d^2 1/D^2) \quad (X1.3)$$

$$T_T = (L + L_e)\,(T/100) \quad (X1.4)$$

X1.4 The symbols used in the equations in this test method

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are defined as follows:

where:

T = minimum test time per 100 ft of pipe vacuum to drop from 7.0 to 5.0 in. of mercury, min,
T_T = minimum test time for total system, min,
D = designated inside diameter of test section or main sewer, in.,
d = designated inside diameter of lateral, in.,
L = length of test section or main sewer, ft,
L_e = total volume of all laterals connected to the main sewer expressed as an equivalent length of the main sewer, ft,
l = total length of each diameter lateral, ft, and
Q = allowable air loss rate, ft^3/min.

X2. APPLICATION OF PRACTICE C 1214

X2.1 The following examples have been prepared to demonstrate the techniques of applying this test method.

X2.2 *Example 1*—A sewer system consists of 600 ft of 18-in. diameter concrete pipe between manholes A and B; 35 ft of 12-in. diameter pipe between manholes B and C.

X2.2.1 *Find*—The appropriate test times to demonstrate the integrity of the installed lines.

X2.2.2 *Solution*:

X2.2.2.1 For the main sewer between manholes A and B, use Eq X1.2 and from Table 1;

$$T_T = (L)\,(T/100) \quad \text{(X2.1)}$$

$$T_T = (600)\,(2.4/100) \quad \text{(X2.2)}$$

$$T_T = 14 \text{ min} \quad \text{(X2.3)}$$

X2.2.2.2 Similarly, for the main sewer between manholes B and C:

$$T_T = (35)\,(1.8/100) \quad \text{(X2.4)}$$

$$T_T = 0.6 \text{ min} \quad \text{(X2.5)}$$

X2.3 *Example 2*—The 600 ft of 18-in. diameter concrete pipe between manholes A and B in Example 1 has connected 6-in. laterals with a total length of 900 ft.

X2.3.1 *Find*—The appropriate test time to demonstrate the integrity of the installed lines.

X2.3.2 *Solution*:

X2.3.2.1 Use Eq X1.3 to convert the total volume of 6-in. laterals to an equivalent length of main sewer:

$$L_e = \Sigma\,(d^2\,1/D^2) \quad \text{(X2.6)}$$

$$L_e = 6^2 \times 900/18^2 \quad \text{(X2.7)}$$

$$L_e = 100 \text{ ft} \quad \text{(X2.8)}$$

X2.3.2.2 For the connected system, use Eq X1.4 and from Table 1, T = 2.4 min./100 ft for 18-in. pipe:

$$T_T = (L + L_e)\,(T/100) \quad \text{(X2.9)}$$

$$T_T = (600 + 100)\,(2.4/100) \quad \text{(X2.10)}$$

$$T_T = 17 \text{ min} \quad \text{(X2.11)}$$

X2.4 If a line fails the vacuum test, the following course of action shall be considered:

X2.4.1 Segmentally test the line and compare the time-vacuum loss values in each segment.

X2.4.2 If the values in each segment are comparable, the vacuum loss problem shall be distributed throughout the line, and further analysis shall be made.

X2.4.3 If the values in each segment are significantly different, each segment shall be evaluated and further analysis be made to determine the location of any significant vacuum loss.

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Designation: C 1218/C 1218M – 99 (Reapproved 2008)

Standard Test Method for Water-Soluble Chloride in Mortar and Concrete[1]

This standard is issued under the fixed designation C 1218/C 1218M; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope

1.1 This test method provides procedures for the sampling and analysis of hydraulic-cement mortar or concrete for chloride that is water soluble under the conditions of test.

1.2 The text of this standard references notes and footnotes that provide explanatory information. These notes and footnotes shall not be considered as requirements of this standard.

1.3 The values stated in either SI units or inch-pound units are to be regarded separately as a standard. Within the text, the inch-pound units are shown in brackets. The values stated in each system are not exact equivalents; therefore, each system shall be used independently of the other.

1.4 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

2. Referenced Documents

2.1 *ASTM Standards:* [2]

C 42/C 42M Test Method for Obtaining and Testing Drilled Cores and Sawed Beams of Concrete

C 114 Test Methods for Chemical Analysis of Hydraulic Cement

C 670 Practice for Preparing Precision and Bias Statements for Test Methods for Construction Materials

C 823 Practice for Examination and Sampling of Hardened Concrete in Constructions

C 1084 Test Method for Portland-Cement Content of Hardened Hydraulic-Cement Concrete

D 1193 Specification for Reagent Water

E 11 Specification for Wire Cloth and Sieves for Testing Purposes

E 832 Specification for Laboratory Filter Papers

3. Significance and Use

3.1 Water-soluble chloride, when present in sufficient amount, is capable of leading to initiation or acceleration of the corrosion of metals, such as steel, embedded in or contacting a cement system such as mortar, grout, or concrete. Thus, its determination shall be required to evaluate the potential of a cement system for undergoing such reactions or to investigate cement systems where such reaction has already occurred. However, it must be recognized that water-soluble chloride determined at some particular time in the life of a cement system is capable of being substantially different than that at another time; for example, the service environment is capable of resulting in a higher water-soluble chloride content due to changes in solubility or a lower one due to leaching.

3.1.1 Test conditions are capable of affecting water-soluble chloride determinations. Take caution when comparing results from this test method with those from other test methods.

3.2 Sulfides are known to interfere with the determination of chloride content. Blast-furnace slag aggregates and cements contain sulfide sulfur in concentrations that are capable of such interference and produce erroneously high test results. Treatment with hydrogen peroxide, as discussed in Test Methods C 114, is used to eliminate such interference.

3.3 There are aggregates that contain chloride that is not available for corrosion. Such chloride will be detected by use of this test method.[3]

4. Apparatus

4.1 *Sampling Equipment*:

4.1.1 The apparatus required for obtaining samples by coring or sawing is described in Test Method C 42/C 42M.

4.1.2 Use the following apparatus for sampling by drilling (pulverization):

4.1.2.1 Rotary impact drill and drill or pulverizing bits.

4.1.2.2 Spoon or other suitable means to collect without contamination pulverized sample material produced by drilling.

[1] This test method is under the jurisdiction of ASTM Committee C09 on Concrete and Concrete Aggregates and is the direct responsibility of Subcommittee C09.69 on Miscellaneous Tests.

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[2] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

[3] For more information see "The Determination of the Chloride Content of Concrete," by Brian B. Hope, John A. Page and John S. Poland, *Cement and Concrete Research*, Volume 15, Number 5, Pergamon Press, New York, September 1985, pp. 863–870.

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4.1.2.3 Sample containers capable of maintaining samples in an uncontaminated state.

4.2 *Sample Processing Apparatus*—The apparatus required for processing samples shall be chosen for its suitability for the purposes of the investigation, and frequently includes a concrete saw and one or more pulverizers.

4.2.1 Samples more than 25 mm [1 in.] in maximum dimension shall be reduced in size by use of a jaw crusher or broken into smaller pieces by hammering carefully to avoid loss of smaller pieces.

4.2.2 Crush particles less than 25 mm [1 in.] in maximum dimension using a rotating-puck grinding apparatus, or by using a disc pulverizer, or mortar and pestle operated to restrict to negligible levels the loss of fine particles.

4.2.3 The 850-µm [No. 20] sieve shall comply with Specification E 11.

4.3 The apparatus required for the chloride determination step is given as the reference test method for chloride in Test Methods C 114.

4.4 Glazed paper to minimize adherence of fine particles for use as described in 7.1.

5. Reagents

5.1 The reagents required for the chloride determination are given in the reference test method for chloride of Test Methods C 114.

6. Sampling

6.1 Select the sample as required for the purpose of the investigation (Note 1).

NOTE 1—Because of the small nominal maximum size of the aggregate in a mortar, pieces of mortar having a mass of at least 10 g will be more representative of a much larger volume of mortar than would an equivalently sized sample of concrete. Practice C 823 may be used as a guide for sampling.

6.1.1 Take concrete cores in accordance with Test Method C 42/C 42M unless otherwise specified (Note 2):

NOTE 2—Concrete cores taken in accordance with Test Method C 42/C 42M may be cut longitudinally to provide a 12-mm [½-in.] thick section generally representative of the core, or cut laterally into 12-mm [½-in.] thick discs representative of the concrete core at various depths. Experience has shown that the cooling water from core cutting will not dissolve a significant amount of the chloride.

6.1.2 Powdered concrete obtained by use of a rotary impact drill is frequently useful in determining chloride concentration with depth in bridge decks and pavements. When the nominal maximum coarse aggregate size is 25 mm [1 in.] or more such samples are unrepresentative. The data must be used with care or several samples combined. Procedures for this method of sampling are as follows:

6.1.2.1 Using the rotary impact drill, drill perpendicular to the concrete surface or parallel to the axis of a cored specimen to a specified depth or a depth sufficient to obtain a representative sample of at least 20 g of powdered material. To prevent sample contamination, avoid contact of sample with hands and other sources of perspiration. Clean all sampling tools prior to each sampling operation (Note 3). Do not use lubricants during drilling.

NOTE 3—Sampling tools may be cleaned with a brush, cloth, ethyl alcohol rinse, water rinse, or other method that will not contaminate the sample.

6.1.2.2 Transfer powdered sample into the sample container using a spoon or other suitable means.

7. Sample Preparation

7.1 Pulverize the sample so that all the material will pass a 850-µm [No. 20] sieve. Thoroughly blend the material by transferring it from one glazed paper to another at least ten times.

8. Procedure

8.1 Select a sample having a mass of approximately 10 g. Weigh the sample to the nearest 0.01 g and place it into a 250-mL beaker. Add 50 ± 1 mL of reagent water meeting Specification D 1193, cover with a watch glass, bring to a boil and boil for 5 min. Allow to stand 24 h. Filter by gravity or suction through a fine-texture, Type II, Class G filter paper of Specification E 832. Transfer the filtrate to a 250-mL beaker. Add 3 ± 0.1 mL of (1:1) nitric acid and add 3 ± 0.1 mL of hydrogen peroxide (30 % solution) to the filtrate. Cover the beaker with a watch glass and allow to stand for 1 to 2 min. Heat the covered beaker rapidly to boiling. Do not allow to boil for more than a few seconds. Remove from hot plate (Note 4). Proceed in accordance with the reference test method for chloride of Test Methods C 114, starting with the procedure that follows removal of the sample from the hot plate in Test Methods C 114.

NOTE 4—It is important to keep the beaker covered during heating and digestion to prevent the loss of chloride by volatilization.

9. Calculation

9.1 Calculate percent chloride by mass of mortar or concrete, by the reference test method for chloride given in Test Methods C 114.

9.2 Other useful measures of chloride concentration can be obtained as follows:

9.2.1 For calculating kilograms of chloride per cubic meter [pounds of chloride per cubic yard] of concrete, multiply percent chloride by $D_1/100$ or $D_2/100$,

where:

D_1 = oven-dry density as determined in the section on Concrete Density in Test Method C 1084, kg/m^3[lb/yd^3].

D_2 = saturated-surface-dry density as determined in the section on Concrete Density in Test Method C 1084, kg/m^3[lb/yd^3].

The report must state which density is used in the calculation.

9.2.2 For calculating percent chloride by mass of cement, multiply percent chloride by $100/P$,

where:

P = percent cement by mass in the mortar or concrete, as known or determined in accordance with Test Method C 1084.

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10. Precision and Bias

10.1 *Precision*[4]—This precision statement is based on samples passing a 600-µm [No. 30] sieve instead of an 850-µm [No. 20] sieve and on a 1 min boil instead of a 5 min boil.

NOTE 5—It is the opinion of the committee that this difference in procedure should not significantly influence the precision beyond what is presented here.

10.1.1 The single-laboratory standard deviation has been found to be 0.0013 % chloride by mass of mortar or concrete.[5] Therefore, results of two properly conducted tests in the same laboratory on the same material are not expected to differ by more than 0.0037 %.

10.1.2 The multilaboratory standard deviation has been found to be 0.0037 % chloride by mass of mortar or concrete.[5] Therefore, results of two properly conducted tests from two different laboratories on samples of the same material are not expected to differ by more than 0.0106 %.[5] (Note 6).

NOTE 6—This precision statement applies to tests of samples prepared and ground by a single laboratory. Test results of concrete construction will vary depending upon the method of obtaining the sample and the size of the sample before it is crushed and reduced to pass the 850-µm [No. 20] sieve or pulverized.

10.2 *Bias*—The procedure in this test method has no bias because the value of water-soluble chloride is defined by the procedure.

11. Keywords

11.1 chloride; chloride content; concrete; mortar; water-soluble chloride

[4] Supporting data have been filed at ASTM International Headquarters and may be obtained by requesting Research Report RR: C09-1003.

[5] These numbers represent, respectively, the (1s) and (d2s) limits as described in Practice C 670.

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Designation: C 1222 – 09

Standard Practice for Evaluation of Laboratories Testing Hydraulic Cement[1]

This standard is issued under the fixed designation C 1222; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope*

1.1 This practice covers the technical training and experience of laboratory testing personnel and identifies the minimum technical requirements for laboratory equipment used in testing of hydraulic cement as prescribed by ASTM.

1.2 This practice provides minimum criteria for evaluating the capability of a laboratory to perform chemical or physical tests listed in the various specifications on hydraulic cement (see Note 1).

NOTE 1—Relevant hydraulic cement specifications are Specifications C 91, C 150, C 595, C 845, and Performance Specification C 1157.

1.3 The values stated in SI units are to be regarded as standard. No other units of measurement are included in this standard.

1.4 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

2. Referenced Documents

2.1 *ASTM Standards:*[2]

C 91 Specification for Masonry Cement
C 109/C 109M Test Method for Compressive Strength of Hydraulic Cement Mortars (Using 2-in. or [50-mm] Cube Specimens)
C 114 Test Methods for Chemical Analysis of Hydraulic Cement
C 115 Test Method for Fineness of Portland Cement by the Turbidimeter
C 125 Terminology Relating to Concrete and Concrete Aggregates
C 150 Specification for Portland Cement
C 185 Test Method for Air Content of Hydraulic Cement Mortar
C 187 Test Method for Normal Consistency of Hydraulic Cement
C 191 Test Methods for Time of Setting of Hydraulic Cement by Vicat Needle
C 204 Test Methods for Fineness of Hydraulic Cement by Air-Permeability Apparatus
C 219 Terminology Relating to Hydraulic Cement
C 230/C 230M Specification for Flow Table for Use in Tests of Hydraulic Cement
C 266 Test Method for Time of Setting of Hydraulic-Cement Paste by Gillmore Needles
C 305 Practice for Mechanical Mixing of Hydraulic Cement Pastes and Mortars of Plastic Consistency
C 451 Test Method for Early Stiffening of Hydraulic Cement (Paste Method)
C 595 Specification for Blended Hydraulic Cements
C 845 Specification for Expansive Hydraulic Cement
C 1157 Performance Specification for Hydraulic Cement
C 1506 Test Method for Water Retention of Hydraulic Cement-Based Mortars and Plasters
E 4 Practices for Force Verification of Testing Machines

2.2 *Other Documents:*

ACI 116R Cement and Concrete Terminology[3]

3. Terminology

3.1 *Definitions:*

3.1.1 *inspection*, *n*—a process of measuring, examining, testing, gaging, or using other procedures to ascertain the quality or state, detect errors or defects, or otherwise appraise materials, products, services, systems, or environments when compared to preestablished criteria.

3.1.2 Additional definitions may be found in Terminologies C 125 and C 219, Practices E 4, and ACI 116R.

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *evaluation authority*, *n*—an independent entity, apart from the organization being evaluated, that can provide an

[1] This practice is under the jurisdiction of ASTM Committee C01 on Cement and is the direct responsibility of Subcommittee C01.95 on Coordination of Standards.

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[2] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

[3] Available from American Concrete Institute (ACI), P.O. Box 9094, Farmington Hills, MI 48333-9094, http://www.aci-int.org.

***A Summary of Changes section appears at the end of this standard.**

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unbiased evaluation of the organization and shall have the capability to assess the technical activities of testing laboratories (see Discussion).

3.2.1.1 *Discussion*—One such evaluation authority is the Cement and Concrete Reference Laboratory (CCRL).[4] Laboratory inspection is broadened into accreditation programs by such independent authorities as the National Voluntary Laboratory Accreditation Program (NVLAP),[5] American Association for Laboratory Accreditation (A2LA)[6] AASHTO Accreditation Program (AAP),[7] and others established.

3.2.2 *laboratory technician*, *n*—an employee of the laboratory who is assigned to perform the actual testing operations primarily conducted in the laboratory.

3.2.3 *quality systems*, *n*—those internal procedures and practices that a laboratory utilizes to ensure continued compliance with applicable testing standards.

3.2.4 *subcontracting*, *n*—employing another organization to provide testing services that the laboratory contracted to provide.

3.2.5 *testing laboratory*, *n*—an organization that measures, examines, performs tests, or otherwise determines the characteristics or performance of materials or products. This may include organizations that offer commercial testing services, an in-house quality control function, an academic institution, or any other organization providing the specified testing services.

4. Significance and Use

4.1 The testing of hydraulic cement is an important element in obtaining quality construction. A testing laboratory must be selected with care.

4.2 A testing laboratory shall be deemed qualified to perform and report the results of its tests if the laboratory meets the requirements of this practice.

4.3 This practice provides guidance for evaluating the organization, personnel, facilities, and quality systems of the laboratory. This practice may be supplemented by criteria and requirements for particular projects.

5. Documentation of Organization

5.1 The following information shall be readily available for review:

5.1.1 A description of the organization, including the complete legal name and address of the main office and each laboratory location, names and positions of the principal officers and the individual in charge of the laboratory,

5.1.2 A description of the organization management structure, and

5.1.3 A listing of the range of services offered.

6. Human Resources

6.1 The manager of the laboratory shall be a chemist, materials analyst, or an engineer and a full-time employee of the organization having at least three years supervisory experience in the testing of hydraulic cement; however, a person with equivalent science-oriented education or experience having satisfactorily directed testing of hydraulic cement is acceptable.

7. Testing and Additional Requirements

7.1 *Testing Requirements*—The organization shall have the capability of performing tests associated with its range of services (see Note 2). The laboratory shall have the facilities and equipment required for preparing, storing, conditioning, and testing specimens.

NOTE 2—The range of services of a testing laboratory may involve either chemical testing or physical testing, or both. The laboratory need not perform all tests listed in the applicable ASTM specification, but rather have the required equipment and demonstrate the ability to perform the procedures within its reported range of services.

7.1.1 The laboratory shall use the latest version of each referenced ASTM standard within one year of its publication in the *Annual Book of ASTM Standards* except where an earlier version is specifically required.

7.1.2 Laboratory personnel shall have convenient access to applicable standards.

7.2 *Additional Requirements*—The following requirements apply to only those tests performed by the laboratory. They are intended to supplement certain provisions of the standard test methods.

7.2.1 Analytical balances and reference masses shall be checked at least annually and shall conform to the requirements of Test Methods C 114.

7.2.2 Flow tables shall be checked at least every 2½ years using the calibration material described in Specification C 230.

7.2.3 Compression machines shall be verified, in accordance with Practices E 4 at least annually to determine if indicated loads, with and without the maximum load indicator (when so equipped), are accurate to ±1.0 %.

7.2.4 Compression machine bearing blocks shall be checked for planeness in accordance with the requirements of Test Method C 109/C 109M at least annually using a straightedge and feeler stock and shall be refinished if found to be out of tolerance.

7.2.5 Air content measures (400 mL) shall be calibrated at least every 2½ years following the procedures described in Test Method C 185.

7.2.6 Wagner turbidimeter apparatus shall be calibrated at least every six months using the procedures described in Test Method C 115.

7.2.7 Cube molds and tampers shall be checked for conformance to the design and dimensional requirements of Test Method C 109/C 109M at least every 2½ years.

7.2.8 Vicat apparatus and vicat ring shall be inspected and checked for conformance to Test Methods C 187, C 191, and C 451 at least every 2½ years.

[4] CCRL, National Institute of Standards and Technology (NIST), 100 Bureau Dr., Stop 8618, Gaithersburg, MD 20899-8618; www.ccrl.us.

[5] NVLAP, Standards Services Division, National Institute of Standards and Technology (NIST), 100 Bureau Dr., Stop 2140, Gaithersburg, MD 20899-2140.

[6] American Association for Laboratory Accreditation (A2LA), 5301 Buckeystown Pike, Suite 350 Frederick, MD 21704; www.a2la2.net.

[7] Available from American Association of State Highway and Transportation Officials (AASHTO), 444 N. Capitol St., NW, Suite 249, Washington, DC 20001; www.transportation.org.

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7.2.9 Gillmore test apparatus shall be inspected and checked for conformance to the requirements of Test Method C 266 at least every 2½ years.

7.2.10 Mechanical mixing apparatus shall be inspected and checked for conformance to the requirements of Practice C 305 at least every 2½ years.

7.2.11 Air-permeability apparatus and related accessory equipment shall be calibrated and checked for conformance to Test Method C 204 at least every 2½ years.

7.2.11.1 Check determinations shall be made against standard or secondary standard reference samples every six months. If the results exceed the precision of the test method, the apparatus shall be recalibrated.

7.2.12 Water-retention apparatus and related equipment shall be checked for conformance to Test Method C 1506 at least every 2½ years.

8. Subcontracting

8.1 Subcontracting for the performance of part or all of a test method is permitted. When subcontracting is used the quality of the work provided must be ensured. The requirements for evaluation differ depending on the permanence of the subcontracting.

8.2 *Permanent Subcontracting*—When all or a portion of a test method is subcontracted on a permanent basis then the subcontracted organization must be subjected to separate evaluation according to this practice for the methods subcontracted. The laboratory shall retain a copy of this evaluation for review by the evaluation authority.

8.3 *Temporary Subcontracting*—When all or a portion of a test method is subcontracted on a temporary basis then the laboratory shall ensure the quality of the subcontracted work. The level and type of assurance will depend on the extent of the subcontracting (see Note 3). The laboratory shall retain records of this assurance for review by the evaluation authority.

NOTE 3—Some examples of assurance for different levels of temporary subcontracting are: (*1*) a review of calibrations records when the use of a piece of equipment is subcontracted; and (*2*) a satisfactory rating on a proficiency sample when a method is subcontracted. Other means of assurance are test results from a standard reference material or, in the case of chemical testing records of qualification testing.

9. Quality System

9.1 *Quality System Requirements*—The laboratory shall establish a quality system for ensuring the quality of services offered.

9.1.1 The laboratory shall maintain written documentation for the following:

9.1.1.1 Procedures for sampling, handling, and testing the hydraulic cement,

9.1.1.2 Procedures for training and evaluating laboratory personnel,

9.1.1.3 Procedures for calibrating and maintaining test equipment, and

9.1.1.4 Procedures for handling technical complaints from clients about results, procedures, or methods used.

9.1.2 The laboratory shall maintain current standard test methods and other pertinent reference material.

9.1.3 The laboratory shall participate in the appropriate CCRL Cement Proficiency Sample Program (see Note 4).

NOTE 4—The CCRL offers proficiency sample programs for physical and chemical testing of portland and blended cements and physical testing of masonry cement. The laboratory should participate in the program compatible with its scope.

9.1.4 *Internal Quality System Review*—The quality system shall contain a document describing the scope of internal quality system reviews, establishing the frequency of these reviews, identifying individuals responsible for the review, describing the distribution of reports to managements, procedures for handling deficiencies, and identifying the location of resulting records.

10. Laboratory Records and Reports

10.1 *Quality System Records*—The laboratory shall maintain records indicating compliance with the procedures described in their quality system documentation. Records shall be maintained for at least five years. The records shall include at least the following:

10.1.1 Results of all calibrations and verifications performed in the laboratory,

10.1.2 Traceability or accuracy of any in-house calibration or verification equipment used,

10.1.3 An inventory and description of all required test equipment,

10.1.4 Records on laboratory personnel that document work experience, education, on-the-job training, and action taken to ensure continued competence in performing the required test methods,

10.1.5 Records of audits and inspections by outside agencies and all reports or certifications, with applicable dates, of any evaluations or accreditations issued by an evaluating authority, and

10.1.6 Records of participation in the appropriate CCRL Cement Proficiency Sample Program.

10.2 *Test Report Records*—The laboratory shall maintain a system of documentation that permits verification of any test report issued. Each test report and supporting documentation shall be retained for at least three years. Corrections or additions to reports shall clearly reference the report being amended. Include in the test report or the supporting documentation the following information:

10.2.1 Name and address of the laboratory,

10.2.2 Identification of the report and the date issued,

10.2.3 Name of the client, if applicable,

10.2.4 Project identification, if applicable,

10.2.5 Sample identification,

10.2.6 Date of receipt of test samples,

10.2.7 Date(s) of test performance,

10.2.8 Identification of the standard test method used, and a notation of all known deviations from the test method observed during the testing of the sample being reported (see Note 5).

NOTE 5—Deviation from standard test methods may adversely affect results.

10.2.9 Identification of any standard test methods subcontracted and name of the organization that provided such services,

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10.2.10 Test results and other pertinent data required by this practice,

10.2.11 Identification of the person performing the tests, and

10.2.12 Name of the person in charge of the laboratory or their designee.

11. Laboratory Evaluation

11.1 *Laboratory Evaluation*—The laboratory shall have its facilities, personnel, equipment, and procedures inspected at intervals of approximately two years by an evaluation authority (see Discussion in 3.2.1) to confirm its ability to perform the required tests.

11.2 The evaluation authority, who performs the inspection of the laboratory, shall report to the manager of the laboratory on all applicable requirements of this practice including deficiencies that existed during the inspection. The laboratory manager is responsible for the correction of any deficiencies.

11.3 The manager of the laboratory shall report corrective actions taken on all inspection deficiencies when required by the evaluating authority for accreditation.

11.4 The evaluation authority providing the accreditation shall provide to the laboratory a statement of conformance when the laboratory evaluation report, including satisfactory correction of the deficiencies, has been accepted. The statement of conformance shall be evidence of the ability of the laboratory to conduct tests on cements in accordance with relevant standards. The report and statement of conformance shall be in such form that they may be used for public disclosure at the discretion of the laboratory.

12. Keywords

12.1 hydraulic cement; laboratory evaluation

SUMMARY OF CHANGES

Committee C01 has identified the location of selected changes to this practice since the last issue, C 1222 – 06, that may impact the use of this practice. (Approved June 1, 2009)

(*1*) Added new 9.1.4.

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Designation: C 1228 – 96 (Reapproved 2009)

Standard Practice for Preparing Coupons for Flexural and Washout Tests on Glass Fiber Reinforced Concrete[1]

This standard is issued under the fixed designation C 1228; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope

1.1 This practice covers preparation of test coupons to be used in tests of plant manufactured thin-section glass fiber reinforced concrete (GFRC).

1.2 The values stated in inch-pound units are to be regarded as standard. The values given in parentheses are mathematical conversions to SI units that are provided for information only and are not considered standard.

1.3 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

2. Referenced Documents

2.1 *ASTM Standards:*[2]

C 947 Test Method for Flexural Properties of Thin-Section Glass-Fiber-Reinforced Concrete (Using Simple Beam With Third-Point Loading)

C 1229 Test Method for Determination of Glass Fiber Content in Glass Fiber Reinforced Concrete (GFRC) (Wash-Out Test)

3. Significance and Use

3.1 Flexural strengths, as determined by Test Method C 947, are used for quality control and design of GFRC products and may be used to verify compliance with specifications and to collect data in research and development programs. It is, therefore, important that coupons be prepared according to a standard practice. The coupons are used to make test specimens for Test Method C 947 and for Test Method C 1229 to determine the amount of glass fiber reinforcement per unit volume of GFRC for quality control purposes.

4. Apparatus

4.1 *Form*—The form shall be rectangular in shape; made from wood, fiberglass reinforced plastic (FRP), GFRC, or steel with dimensions of ½ in. (13 mm) deep by 18 in. (450 mm) wide and 48 in. (1200 mm) long.

4.2 *Steel Trowel*, at least 20 in. (500 mm) long.

4.3 *Serrated Roller*, with handle.

4.4 *Strike-Off Bar (screed)*, at least 20 in. (500 mm) long, for leveling and thickness control of specimens.

5. Sampling

5.1 Sampling shall be in accordance with governing specifications.

6. Procedure

6.1 For plant manufactured product quality control purposes, spray the glass fiber reinforced material into the test form using the same method as used in production. The methods and conditions should be the same as for production materials except no mist coat or face mix should be used.

6.2 Trim off excess material from the sides of the form using a steel trowel.

6.3 Trowel surface smooth using a steel trowel.

6.4 See Fig. 1 for cutting layout for flexural test coupons and washout test coupons.

7. Curing

7.1 Cure the sample panel using the same methods and conditions as that used for production products.

8. Coding

8.1 Identify each sample board, and coupons.

9. Retained Samples

9.1 Retain samples as prescribed by Test Method C 947.

10. Keywords

10.1 coupons; flexural tests; glass fiber content; glass fiber reinforced concrete (GFRC); strength

[1] This practice is under the jurisdiction of ASTM C27 on Precast Concrete Products and is the direct responsibility of Subcommittee C27.40 on Glass Fiber Reinforced Concrete Made by the Spray-Up Process.

Current edition approved May 1, 2009. Published May 2009. Originally approved in 1993. Last previous edition approved in 2004 as C 1228 – 96(2004).

[2] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

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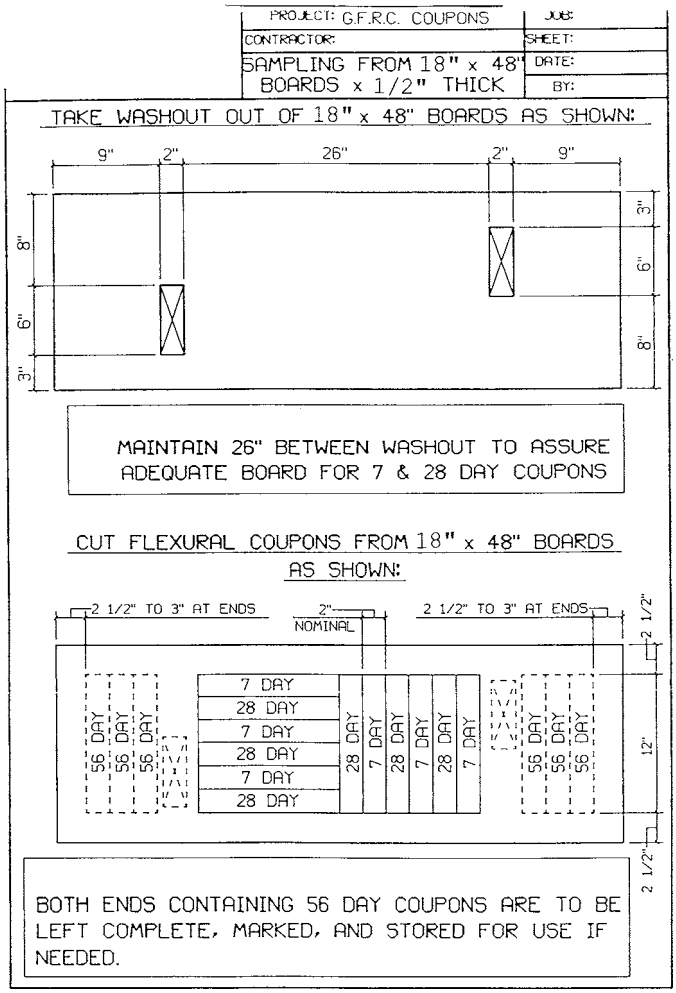

FIG. 1 Locations for Coupons Taken from 18 by 48 by ½-in. (450 by 1200 by 13-mm) GFRC Board

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Designation: C1231/C1231M – 10

Standard Practice for Use of Unbonded Caps in Determination of Compressive Strength of Hardened Concrete Cylinders[1]

This standard is issued under the fixed designation C1231/C1231M; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope*

1.1 This practice covers requirements for a capping system using unbonded caps for testing concrete cylinders molded in accordance with Practice C31/C31M or C192/C192M. *Unbonded neoprene caps of a defined hardness are permitted to be used for testing for a specified maximum number of reuses without qualification testing up to a certain concrete compressive strength level. Above that strength, level neoprene caps will require qualification testing. Qualification testing is required for all elastomeric materials other than neoprene regardless of the concrete strength.*

1.2 Unbonded caps are not to be used for acceptance testing of concrete with compressive strength below 1500 psi [10 MPa] or above 12 000 psi [85 MPa].

1.3 The values stated in either SI units or inch-pound units are to be regarded separately as standard. The values stated in each system may not be exact equivalents; therefore, each system shall be used independently of the other. Combining values from the two systems may result in non-conformance with the standard.

1.4 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.* (**Warning**—Concrete cylinders tested with unbonded caps rupture more violently than comparable cylinders tested with bonded caps. The safety precautions given in the Manual of Aggregate and Concrete Testing are recommended.[2])

2. Referenced Documents

2.1 *ASTM Standards:*[3]

C31/C31M Practice for Making and Curing Concrete Test Specimens in the Field

C39/C39M Test Method for Compressive Strength of Cylindrical Concrete Specimens

C192/C192M Practice for Making and Curing Concrete Test Specimens in the Laboratory

C617 Practice for Capping Cylindrical Concrete Specimens

D2000 Classification System for Rubber Products in Automotive Applications

3. Terminology

3.1 *Definitions of Terms Specific to This Standard:*

3.1.1 *pad*, *n*—an unbonded elastomeric pad.

3.1.2 *unbonded cap*, *n*—a metal retainer and an elastomeric pad.

4. Significance and Use

4.1 This practice provides for using an unbonded capping system in testing hardened concrete cylinders made in accordance with Practices C31/C31M or C192/C192M in lieu of the capping systems described in Practice C617.

4.2 The elastomeric pads deform in initial loading to conform to the contour of the ends of the cylinder and are restrained from excessive lateral spreading by plates and metal rings to provide a uniform distribution of load from the bearing blocks of the testing machine to the ends of the concrete or mortar cylinders.

5. Materials and Apparatus

5.1 Materials and equipment necessary to produce ends of the reference cylinders that conform to planeness requirements of Test Method C39/C39M and the requirements of Practice C617. This may include grinding equipment or capping materials and equipment to produce neat cement paste, high strength gypsum plaster, or sulfur mortar caps.

5.2 *Elastomeric Pads*:

5.2.1 Pads shall be ½ ± 1⁄16 in. [13± 2 mm] thick and the diameter shall not be more than 1⁄16 in. [2 mm] smaller than the inside diameter of the retaining ring.

5.2.2 Pads shall be made from polychloroprene (neoprene) meeting the requirements of Classification D2000 as follows:

[1] This practice is under the jurisdiction of ASTM Committee C09 on Concrete and Concrete Aggregates and is the direct responsibility of Subcommittee C09.61 on Testing for Strength.

Current edition approved Feb. 1, 2010. Published March 2010. Originally approved in 1993. Last previous edition approved in 2009 as C1231/C1231M–09. DOI: 10.1520/C1231_C1231M-10.

[2] Section on Safety Precautions, Manual of Aggregate and Concrete Testing, *Annual Book of ASTM Standards*, Vol. 04.02.

[3] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

***A Summary of Changes section appears at the end of this standard.**

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Shore A Durometer	Classification D2000 Line Call-Out
50	M2BC514
60	M2BC614
70	M2BC714

The tolerance on Shore A durometer hardness is ± 5. Table 1 provides requirements for use of caps made from material meeting the requirements of Classification D2000, above.

5.2.3 Other elastomeric materials that meet the performance requirements of qualification tests in Section 8 are permitted.

5.2.4 Elastomeric pads shall be supplied with the following information:

5.2.4.1 The manufacturer's or supplier's name,

5.2.4.2 The Shore A hardness, and

5.2.4.3 The applicable range of concrete compressive strength from Table 1 or from qualification testing.

5.2.5 The user shall maintain a record indicating the date the pads are placed in service, the pad durometer, and the number of uses to which they have been subjected.

5.3 *Retainers*, are a pair of metal fixtures used to provide support for and alignment of the neoprene pads and the cylinder ends (See Note 1 and Fig. 1). Each retainer (upper and lower) includes a (retaining) ring that is welded to or manufactured integrally with a base plate. The height of the retaining ring shall be 25 ± 3 mm [1.0 ± 0.1 in.]. The inside diameter of the retaining ring shall not be less than 102 % or greater than 107 % of the diameter of the cylinder. The thickness of the retaining ring shall be at least 12 mm [0.47 in.] for 150 mm [6 in.] diameter retainers and at least 9 mm [0.35 in.] for 100 mm [4 in.] diameter retainers. The surface of the base plate that contacts the bearing block of the testing machine shall be plane to within 0.05 mm [0.002 in.]. The thickness of the base plate shall be at least 12 mm [0.47 in.] for 150 mm [6 in.] retainers and at least 8 mm [0.3 in.] for 100 mm [4 in.] retainers. The bearing surfaces of the retainers shall not have gouges, grooves, protrusions, or indentations greater than 0.25 mm [0.010 in.] deep or greater than 32 mm^2 [0.05 $in.^2$] in surface area.

NOTE 1—Retainers made from steel and some aluminum alloys have been found acceptable.

6. Test Specimens

6.1 The specimens shall be either 6 by 12 in. [150 by 300 mm] or 4 by 8 in. [100 by 200 mm] cylinders made in accordance with Practices C31/C31M or C192/C192M. Neither end of a cylinder shall depart from perpendicularity to the axis by more than 0.5° (approximately equivalent to ⅛ in. in 12 in. [3 mm in 300 mm]). No individual diameter of a cylinder may differ from any other diameter by more than 2 %.

NOTE 2—One method of measuring the perpendicularly of ends of cylinders is to place a try square across any diameter and measure the departure of the longer blade from an element of the cylindrical surface. An alternative method is to place the end of the cylinder on a plane surface and support the try square on that surface.

6.2 Depressions under a straight edge measured with a round wire gage across any diameter shall not exceed 0.20 in. [5 mm]. If cylinder ends do not meet this tolerance, the cylinder shall not be tested unless irregularities are corrected by sawing or grinding.

TABLE 1 Requirements for Use of Polychloroprene(Neoprene) Pads

Compressive Strength,[A] psi [MPa]	Shore A Durometer Hardness	Qualification Tests Required	Maximum Reuses[B]
Less than 1500 [10]		Not permitted	
1 500 to 6 000 [10 to 40]	50	None	100
2 500 to 7 000 [17 to 50]	60	None	100
4 000 to 7 000 [28 to 50]	70	None	100
7 000 to 12 000 [50 to 80]	70	Required	50
Greater than 12,000 [80]		Not permitted	

[A] Compressive strength of concrete at age of testing as specified in Contract Documents. For acceptance testing, it is the specified compressive strength f_c'.

[B] Maximum number of reuses will be less if pads wear, crack or split. See 7.2.

7. Procedure

7.1 Unbonded caps are permitted to be used on one or both ends of a cylinder in lieu of a cap or caps meeting Practice C617, provided the caps meet the requirements of Section 5. Pad hardness shall be in accordance with Table 1. (See Note 3)

NOTE 3—The specified strength in the contract documents is for various stages of construction. This may include strength test requirements for formwork removal or release of prestress in addition to the test requirements for verification of specified compressive strength. Therefore, pad selection is based on the strength requirement for the designated stage of construction.

7.2 Examine both sides of pads for excessive wear or damage. Replace pads that have cracks or splits in their top or bottom surface that exceed ⅜ in. [10 mm] in length regardless of depth. Insert pad in the retainer before it is placed on the cylinder (Note 4).

NOTE 4—Some manufacturers recommend dusting the pads and the ends of the cylinders with corn starch or talcum powder prior to testing.

7.3 Center the unbonded cap or caps on the cylinder and place the cylinder on the lower bearing block of the testing machine. Carefully align the axis of the cylinder with the center of thrust of the testing machine by centering the upper retaining ring on the spherically seated bearing block. As the spherically seated block is brought to bear on the upper retaining ring, rotate its movable portion gently by hand so that uniform seating is obtained. After application of load, but before reaching 10 % of the anticipated specimen strength, check to see that the axis of the cylinder is vertical within a tolerance of ⅛ in. in 12 in. [3.2 mm in 300 mm] and that the ends of the cylinder are centered within the retaining rings. If the cylinder alignment does not meet these requirements, release the load, check compliance with 6.1, and carefully recenter the specimen. Reapply load and recheck specimen centering and alignment. A pause in load application to check cylinder alignment is permissible.

7.4 Complete the load application, testing, calculation, and reporting of results in accordance with Test Method C39/C39M (see Notes 5 and 6).

NOTE 5—Some users have reported damage to testing machines from the sudden release of energy stored in the elastomeric pads.

NOTE 6—Occasionally, unbonded capped cylinders may develop early cracking, but continue to carry increasing load. For this reason Test Method C39/C39M requires cylinders to be loaded until it is certain that they have been compressed beyond their ultimate capacity.

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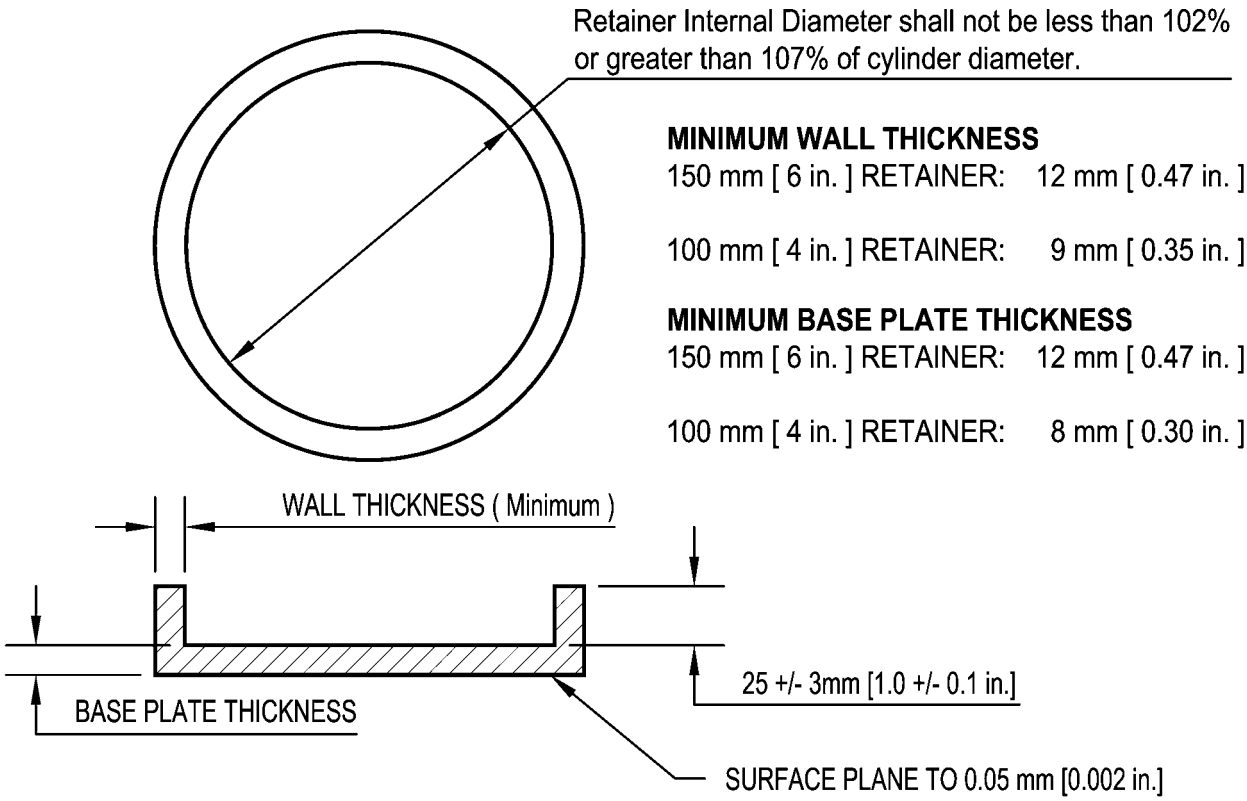

FIG. 1 Example of Retaining Ring and Base Plate

8. Qualification of Unbonded Capping Systems and Verification of Reuse of Pads

8.1 Table 1 specifies the conditions under which polychloroprene (neoprene) unbonded pads must be qualified under this section depending on the concrete strength and the Shore A hardness. Unbonded pads made of other elastomeric materials must be qualified using the procedures in this section.

8.2 When qualification tests are required they must be made by either the supplier or user of the unbonded pads. The user of the pads must retain a copy of the current qualification test report to demonstrate compliance with this practice. See X1.1.

8.3 The compressive strength of molded cylinders tested with unbonded caps shall be compared with that of companion cylinders tested with ends ground or capped to meet requirements of Test Method C39/C39M and Practice C617.

8.4 To be acceptable, tests must demonstrate that at a 95 % confidence level ($\alpha = 0.05$), the average strength obtained using unbonded caps is not less than 98 % of the average strength of companion cylinders capped or ground in accordance with 8.3.

8.4.1 When required, qualification tests in accordance with 8.5 shall be made on initial use of an unbonded cap at both the highest and lowest strength levels anticipated to establish an acceptable range of cylinder strength for use. In practice individual cylinders shall not have strengths more than 10 % greater than the high strength level or more than 10 % less than the low strength level qualified or specified in Table 1. Qualification tests shall be repeated whenever there is a change in the design or dimensions of the retaining rings, or when there is a change in pad composition or thickness, or the Shore A hardness changes by more than five units. Initial qualification tests shall include verification that after the specified maximum number of reuses the pads meet the requirements of 8.4.

8.4.2 When tests are made to establish a permissible number of reuses exceeding those in Table 1, only those tests or reuses which are within 2000 psi [14 MPa] of the highest strength level to be qualified will be included in the reuse count. Laboratories must maintain records of the number of times pads are reused.

NOTE 7—Pad life depends on the hardness and type of pad material, the strength of the concrete, the difference between the outside diameter of the cylinder and the inside diameter of the retaining ring, the unevenness and roughness of the ends of the cylinder, and other factors. Based on available information, scuffing or abrasion of the perimeter of the pad is normal, provided it does not reduce the thickness of the pad around the perimeter.

8.5 *Specimen Preparation for Qualification and Pad Reuse Testing*:

8.5.1 Pairs of individual cylinders shall be made from a sample of concrete and cured as nearly alike as possible: one cylinder per pair is to be tested after grinding or capping in accordance with 8.3 and the other is to be tested using the unbonded cap system.

8.5.2 A minimum of 10 pairs of cylinders shall be made at both the highest and lowest strength levels desired or anticipated (Note 8). The "strength level" is the average of the strengths of the 20 or more cylinders whose strengths are within a range of 1000 psi [7 MPa] (Note 9). More than one

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pair of cylinders can be made from a single concrete sample, but cylinders must come from a minimum of two samples made on different days for each concrete strength level (Note 10).

NOTE 8—If the Practice C617 capped and unbonded capped specimens produce equal strengths, the number of pairs of cylinders that will be needed to demonstrate compliance will range from 9 to more than 60 depending on the variability of test results. If the two capping systems produce equal strengths, about 10 % of laboratories will require more than 60 tests and 10 % of the laboratories will require 9 tests to demonstrate statistical compliance.

NOTE 9—Note that the range of strengths permitted in qualification testing to define the strength level is 1000 psi [7 MPa], but that in counting number of reuses only cylinders within a range of 2000 psi [14 MPa] are included in the reuse count.

NOTE 10—Cylinders for qualification tests can be from pairs of cylinders tested in routine laboratory operations and, in most instances, special trial batches should not be required for qualification tests.

9. Calculation

9.1 For each strength level, compute the difference in strength for each pair of cylinders, and compute the average strength of the cylinders with reference caps and the average strength of the cylinders with unbonded caps, as follows:

$$d_i = x_{pi} - x_{si} \quad (1)$$

$$\bar{x}_s = (x_{s1} + x_{s2} + x_{s3} \ldots + x_{sn})/n$$

$$\bar{x}_p = (x_{p1} + x_{p2} + x_{p3} \ldots + x_{pn})/n$$

where:

d_i = difference in strength of a pair of cylinders computed as the strength of unbonded capped cylinder minus the strength of the cylinder prepared according to Practice C617 (may be positive or negative),

x_{pi} = cylinder strength using unbonded cap,

x_{si} = cylinder strength using Practice C617,

n = number of pairs of cylinders tested for the strength level,

$\bar{x}_s$ = average strength of Practice C617 capped cylinders for a strength level, and

$\bar{x}_p$ = average strength of unbonded cap cylinders for a strength level.

9.2 Compute the average difference, $\bar{d}$, and standard deviation of the difference, s_d, for each strength level, as follows:

$$\bar{d} = (d_1 + d_2 \ldots + d_n)/n \quad (2)$$

$$s_d = [\Sigma(d_i - \bar{d})^2/(n-1)]^{1/2}$$

9.3 To comply with this practice the following relationship must be satisfied:

$$\bar{x}_p \geq 0.98\,\bar{x}_s + (ts_d)/(n)^{1/2} \quad (3)$$

where t is the value of "students t" for $(n-1)$ pairs at $\alpha = 0.05$ from the following table:

$(n-1)$	$t(\alpha = 0.05)^A$
9	1.833
14	1.761
19	1.729
100	1.662

[A] Use linear interpolation for other values of $(n-1)$ or refer to appropriate statistical tables.

10. Keywords

10.1 cap; compressive strength; concrete; concrete test; elastomeric; neoprene; pad cap; rubber; unbonded cap

APPENDIX

(Nonmandatory Information)

X1. SAMPLE REPORT AND CALCULATION

X1.1 *Sample Report:*

X1.1.1 *Pad Material*—Lot 3742, Shore A = 52, Thickness 0.51 in.

X1.1.2 *Retaining Ring*—Set A manufactured 1-87.

X1.1.3 Concrete Cylinders: Job 1207, Nos. 1–10, January 2 to 5, 1987.

X1.1.4 *Sulfur Mortar*—Lot 3420. Compressive Strength of 6985 psi [48.2 MPa].

X1.1.5 All Tests 28 days age.

X1.2 *Summary*—

xs = 3679 psi [25.35 MPa]:
xp = 3663 psi [25.26 MPa];
sd = 46.06 psi [0.328 MPa];
n = 10:
t = 1.833.

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X1.3 *Calculation*—Using equation in 9.3:

$$3663 >/= (0.98)(3679)+(1.833)(46.06)/(10)^{1/2}$$

$$3663 > 3632 \text{ (}\textit{system qualifies at}\text{ 3670 }\textit{psi}\text{)}$$

Metric:

$$25.26 >/= (0.98)(25.35) + (1.833)(0.328)/(10)^{1/2}$$

$$25.26 > 25.03 \text{ (}\textit{System Qualifies}\text{)}$$

Cylinder Pair	Neoprene Pad		Sulfur Cap		Difference, d	
	psi	MPa	psi	MPa	psi	MPa
1	3605	24.9	3580	24.7	25	0.20
2	3605	24.9	3690	25.4	-85	-0.50
3	3585	24.7	3595	24.7	-10	0.00
4	3570	24.6	3625	25.0	-55	-0.40
5	3625	25.0	3640	25.1	-15	-0.10
6	3660	25.2	3740	25.8	-80	-0.60
7	3750	25.9	3720	25.6	30	0.30
8	3725	25.7	3720	25.6	5	0.10
9	3700	25.5	3725	25.7	-25	-020
10	3805	26.2	3755	25.9	50	0.30
Average xp	3663	25.26	xs 3679	25.35	d -16	-0.090
Std. Dev.					sd 46.06	0.328

X1.4 *Keywords*—caps; capping cylinders; compressive strength; pads; strength; unbonded capping system

SUMMARY OF CHANGES

Committee C09 has identified the location of selected changes to this practice since the last issue, C1231/C1231M–09, that may impact the use of this practice. (Approved February 1, 2010)

(*1*) Revised Table 1 to clarify the basis for the required hardness of the neoprene pads.

(*2*) Revised 7.1 to provide an explicit statement in the procedure on the required hardness of the pads.

(*3*) Added new Note 3 to clarify what design strength should be used for pad selection.

Committee C09 has identified the location of selected changes to this practice since the last issue, C1231/C1231M–08a, that may impact the use of this practice. (Approved January 1, 2009)

(*1*) Revised the second sentence of Note 6 by adding reference to Test Method C39/C39M for the loading requirements.

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Designation: C 1240 – 05

Standard Specification for Silica Fume Used in Cementitious Mixtures[1]

This standard is issued under the fixed designation C 1240; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope*

1.1 This specification covers silica fume for use in concrete and other systems containing hydraulic cement.

1.2 In the cases of slurried or densified silica fume, perform the tests on the raw silica fume from which these products have been made.

1.3 The values stated in SI units are to be regarded as the standard. The values given in parentheses are for information only.

1.4 The following safety hazards caveat pertains only to the test methods portions, Sections 10-19, of this specification: *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.* Read the material safety data sheets for materials used.

1.5 The text of this standard references notes and footnotes that provide explanatory information. These notes and footnotes (excluding those in tables) shall not be considered as requirements of this standard.

2. Referenced Documents

2.1 *ASTM Standards:* [2]

C 109/C 109M Test Method for Compressive Strength of Hydraulic Cement Mortars (Using 2-in. or [50-mm] Cube Specimens)
C 114 Test Methods for Chemical Analysis of Hydraulic Cement
C 125 Terminology Relating to Concrete and Concrete Aggregates
C 183 Practice for Sampling and the Amount of Testing of Hydraulic Cement
C 185 Test Method for Air Content of Hydraulic Cement Mortar
C 219 Terminology Relating to Hydraulic Cement
C 311 Test Methods for Sampling and Testing Fly Ash or Natural Pozzolans for Use in Portland-Cement Concrete
C 430 Test Method for Fineness of Hydraulic Cement by the 45-μm (No. 325) Sieve
C 441 Test Method for Effectiveness of Pozzolans or Ground Blast-Furnace Slag in Preventing Excessive Expansion of Concrete Due to the Alkali-Silica Reaction
C 494 Specification for Chemical Admixtures for Concrete
C 670 Practice for Preparing Precision and Bias Statements for Test Methods for Construction Materials
C 1005 Specification for Reference Masses and Devices for Determining Mass and Volume for Use in the Physical Testing of Hydraulic Cements
C 1012 Test Method for Length Change of Hydraulic-Cement Mortars Exposed to a Sulfate Solution
C 1069 Test Method for Specific Surface Area of Alumina or Quartz by Nitrogen Adsorption
C 1157 Performance Specification for Hydraulic Cement
C 1437 Test Method for Flow of Hydraulic Cement Mortar

3. Terminology

3.1 *Definitions:*

[1] This specification is under the jurisdiction of ASTM Committee C09 on Concrete and Concrete Aggregates and is the direct responsibility of Subcommittee C09.24 on Supplementary and Cementitious Materials.

Current edition approved July 1, 2005. Published August 2005. Originally approved in 1993. Last previous edition approved in 2004 as C 1240-04.

[2] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

***A Summary of Changes section appears at the end of this standard.**

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3.1.1 *silica fume*—very fine pozzolanic material, composed mostly of amorphous silica produced by electric arc furnaces as a by-product of the production of elemental silicon or ferro-silicon alloys (also known as condensed silica fume and microsilica).

3.1.2 Other terms in this specification are defined in Terminologies C 125 and C 219.

4. Ordering Information

4.1 The purchaser shall specify any optional chemical or physical requirements.

5. Chemical Composition

5.1 Silica fume shall conform to the requirements for chemical composition prescribed in Table 1.

6. Physical Requirements

6.1 Silica fume shall conform to the physical requirements prescribed in Table 2. Optional physical requirements are given in Table 3.

7. Sampling

7.1 When the purchaser desires that the silica fume be sampled and tested to verify compliance with this specification, perform the sampling and testing in accordance with Practice C 183, modified as described in 7.3.

NOTE 1—Exercise caution in the interpretation of Practice C 183, since there is a difference between the continuous manufacture of hydraulic cement and the generation and collection of silica fume. To a great extent, storage is dictated by the design of the silica-fume collection system. The design of silica-fume collection systems may not have provided for sampling points and practices.

7.2 Practice C 183, as modified, is not designed for manufacturing quality control and is not required for manufacturer's certification.

7.3 The following modification of Practice C 183 is necessary to render it applicable to silica fume.

7.3.1 Replace the words "hydraulic cement" and "cement" with the words "silica fume" every time that they appear in the text.

7.3.2 All samples, whether grab or composite, shall have a mass of at least 1 kg (2 lb).

7.3.3 When compliance verification tests of silica fume are required to be made at a laboratory other than that of the silica-fume manufacturer or marketer, coordinate the silica-fume sampling schedule, sample transportation time, and sample testing schedule among the purchaser, manufacturer, and testing laboratory so that the test results will be available when the decision to accept or reject the silica fume must be made.

7.3.4 The section entitled "Sampling" is modified as follows:

TABLE 1 Chemical Requirements

SiO_2, min, %	85.0
Moisture content, max, %	3.0
Loss on ignition, max, %	6.0

TABLE 2 Physical Requirements

Oversize:	
Percent retained on 45-μm (No. 325), max, %[A]	10
Percent retained on 45-μm (No. 325), max variation from average, percentage points[B]	5
Accelerated pozzolanic strength activity index:[C]	
With portland cement at 7 days, min percent of control	105
Specific surface, min, m^2/g	15

[A] Exercise care to avoid retaining agglomerations of extremely fine material.

[B] The average shall consist of the ten preceding tests or all of the preceding tests if the number is less than ten.

[C] Accelerated pozzolanic strength activity index is not to be considered a measure of the compressive strength of concrete containing the silica fume. This is a measure of the reactivity of a given silica fume with a given cement and may vary with the source of both the silica fume and the cement.

TABLE 3 Optional Physical Requirements[A]

Uniformity requirements:	
When air-entraining concrete is specified, the quantity of air-entraining agent required to produce air content of 18.0 vol % of mortar shall not vary from the average established by the ten preceding tests or by all preceding tests if less than ten, by more than, %	20
Reactivity with cement alkalies:[B]	
Reduction of mortar expansion at 14 days, min, %	80
Sulfate resistance expansion,[C]	
(moderate resistance) 6 months, max, %	0.10
(high resistance) 6 months, max, %	0.05
(very high resistance) 1 year, max, %	0.05

[A] Will be made only at the request of the purchaser.

[B] The indicated tests for reactivity with cement alkalies shall not be requested unless the material is to be used with an aggregate that is regarded as deleteriously reactive with alkalies in hydraulic cement. The test for reduction of mortar expansion may be made using any high-alkali cement in accordance with Test Methods C 311, if the cement to be used in the work is not known or is not available at the time of the test. The test for mortar expansion should be performed by each of the high-alkali cements to be used in the work.

[C] Only one limit shall be specified.

7.3.4.1 Take two grab samples or two composite samples for the first 100 Mg (110 tons) of silica fume. Take a grab sample or a composite sample for each subsequent 100 Mg (110 tons) of silica fume, but not less than two samples shall be taken in any sampling program.

7.3.4.2 *From Bulk Storage at Points of Discharge*—Withdraw silica fume from the discharge openings in a steady stream until sampling is completed. In sampling bulk storage at points of discharge, while the silica fume is flowing through the openings, take samples at such intervals so that, at a minimum, the sampling requirements of 7.3.4.1 are met.

7.3.5 The section entitled "Amount of Testing" is modified by deleting the first paragraph, "General."

8. Frequency of Tests

8.1 Except for the tests listed in 8.2, make all chemical determinations and physical tests on composite samples representing no more than 400 Mg (440 tons) each. Prepare each composite sample by combining portions from the samples representing each 100 Mg (110 tons), so that each 100 Mg is represented equally.

8.2 Test for specific surface, density, and accelerated pozzolanic strength activity index using composite samples that represent 3200 Mg (3520 tons) or 3 months of production, whichever gives the highest frequency. Prepare each composite sample by combining portions from the samples representing

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each 400 Mg (440 tons) or 1 month, whichever gives the highest frequency, so that each sample is represented equally.

9. Preparation of Sample

9.1 Prepare composite samples for tests, as required in Section 8, by arranging all test samples in groups, with each group representing the number of megagrams required by the test or tests for which the composite sample is intended. From each of the samples in a group, take equal portions, sufficient in amount to form a composite sample large enough to permit making the required physical or chemical determinations.

9.2 Prior to testing, mix grab samples and composite samples thoroughly. A clean and dry laboratory concrete drum mixer provides adequate mixing for this purpose. Take care to limit the volume of silica fume in the drum mixer to the range of 10 to 50 % of the drum's total capacity. If necessary, secure a sheet of polyethylene film on the drum with an elastic tiedown to keep the material in the drum. Limit the mixing action to 5 ± 1 min.

9.2.1 When a small sample size precludes the use of a concrete mixer, use a heavy plastic bag, of a capacity at least five times larger than the sample volume, to mix the sample thoroughly. After placing the sample in the bag, close the bag by tying the bag opening tightly, and mix the material by rolling the bag around for 5 ± 1 min.

9.3 Take material for specific tests from a thoroughly mixed sample by using a sampling device (sampling tube, scoop, etc.) of appropriate size to make a test specimen. Make this test specimen from at least six random subsamples.

TEST METHODS—CHEMICAL ANALYSIS

10. Silicon Dioxide and Total Alkalies

10.1 *Reference Method*—Use the reference method in Test Methods C 114 for cements with insoluble residue greater than 1 %. Analysts performing sodium oxide and potassium oxide determinations shall observe the precautions outlined in the applicable section of Performance Specification C 1157 (refer to the section on Test Methods). Most pozzolans dissolve completely in lithium borate fluxes.

11. Moisture Content and Loss on Ignition

11.1 Follow the applicable provisions of Test Methods C 311.

TEST METHODS—PHYSICAL TESTS

12. Density

12.1 *Equipment*:

12.1.1 *Two 500-mL Volumetric Flasks*, Class A.

12.1.2 *Balance*, with an accuracy of at least 0.01 g.

12.1.3 *Constant Temperature Bath*, capable of being regulated within ±0.5 °C (1.0 °F).

12.2 *Deionized Water*.

12.3 *Procedure*:

12.3.1 Determine the density of the material as received, unless otherwise specified, as follows. If density determination on an ignited sample is required, first ignite the sample as described in the test for loss on ignition in the applicable section given in Test Methods C 114.

12.3.2 Determine the mass (W_f), of a 500-mL volumetric flask, to an accuracy of 0.01 g. Add 30 g of silica fume. Determine the mass of the flask and the contents (W_a) to the nearest 0.01 g. Add water to the flask to fill it one-half full, and shake it to ensure thorough wetting of the material. Fill to the mark with water. Remove air bubbles by shaking the flask at 15-min intervals until the liquid is free of air or by applying a vacuum to the flask. After all of the air bubbles are removed, place the flask in a constant temperature bath at 23 ± 0.5 °C until the flask and its contents reach a constant temperature. Remove the flask from the water bath; immediately add or remove water, at the same temperature, to the flask to get the meniscus on the mark. Wipe dry the exterior of the flask and determine the mass of the flask and its contents (W_s).

12.3.3 Empty, clean, and determine the mass of the 500-mL volumetric flask, used above, filled to the mark with water (W_t) stabilized at 23 ± 0.5 °C.

12.4 *Calculation*:

$$D_{sf} = \frac{(W_a - W_f)}{500\ \text{mL} - [(W_s - W_a)/D_w]} \quad (1)$$

where:

D_{sf} = density of silica fume, Mg/m^3,
W_f = mass of 500-mL volumetric flask, g,
W_a = mass of 500-mL volumetric flask plus approximately 30 g of silica fume, g,
W_s = mass of 500-mL volumetric flask plus silica fume plus water to the mark, g,
W_t = mass of 500-mL volumetric flask plus water to the mark, g, and
D_w = $(W_t - W_f)$/500-mL, Mg/m^3.

12.5 Report the average of two density determinations.

13. Oversize, Amount Retained When Wet-Sieved on a 45-μm (No. 325) Sieve

13.1 Use Test Method C 430. Calibrate the sieves in accordance with Test Method C 430.

NOTE 2—Oversize is used to determine the amount of contaminating material retained on the 45-μm sieve. See Appendix X2.

14. Specific Surface

14.1 Determine the specific surface by the BET, nitrogen adsorbtion method, in accordance with Test Method C 1069.[3]

15. Air Entrainment of Mortar

15.1 Follow the applicable provisions of Test Methods C 311, except use the following test mixture and equation for W_c:

	Test Mixture
Portland cement, g	300

[3] Manufacturers and examples of nitrogen adsorbtion instrumentation include Horiba Instruments, Inc., Irvine, CA, 5A-9600; Micromeritics Instrument Corporation, Norcross Georgia, FlowSorb-II 2300; Quantachrome Corporation, Boynton Beach, FL, Quantasorb Jr.; and JUWE Laborgerate Service GmbH, Korschenbroich, Germany, Stroehlein AREAmeter II. NIST SRM® 2696, Silica Fume, is available for use in comparison and evaluation of laboratory equipment and procedures.

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Silica fume, g	30
20–30 Standard Ottawa sand, g	1170
Water, mL, sufficient to give a flow of 80 to 95 %	Y
Neutralized Vinsol resin solution, mL, sufficient to produce an air content of 18 ± 3 %	Z

$$W_c = \frac{300 + 1170 + 30 + (300 \times P \times 0.01)}{300/3.15 + 1170/2.65 + (30/D) + [(300 \times P \times 0.01)/1]} \quad (2)$$

Then calculate:

$$\text{Air content, volume \%} = 100[1 - (W_a/W_c)]W_a = W/400 \quad (3)$$

where:

W_a = actual mass per unit of volume of mortar as determined by Test Method C 185, g/mL,

W = mass of the specified 400 mL of mortar (see Test Method C 185), g,

W_c = theoretical mass per unit volume, calculated on an air-free basis and using the values for density and quantities of the materials in the mixture, g/mL,

P = percent of mixing water plus Vinsol resin solution based on mass of cement, and

D = density of silica fume used in the mixture, Mg/m^3.

15.2 Determine the flow in accordance with the applicable provisions of Test Method C 109/C 109M.

16. Accelerated Pozzolanic Strength Activity Index with Portland Cement

16.1 Use the applicable section on strength activity index with portland cement of Test Methods C 311, except change to reflect testing at constant water to cementitious materials ratio. Prepare test specimens from the batch proportions below, molding three cubes from both the control mix and the test mix.

16.1.1 *Control Mixture*:

16.1.1.1 500 g of portland cement,

16.1.1.2 1375 g of graded standard sand, and

16.1.1.3 242 mL of water.

16.1.2 *Test Mixture*:

16.1.2.1 450 g of portland cement,

16.1.2.2 50 g of silica fume,

16.1.2.3 1375 g of graded standard sand, and

16.1.2.4 242 mL of water.

16.1.2.5 *X* grams of dry high-range water reducer, meeting Specification C 494 Type F, required to produce a flow of 100 to 115 %. Add the high-range water reducer directly to the mixing water in the mixing bowl. Then add the cement or the cement-silica fume mixture and start the mixing cycle.

16.1.3 Determine the flow in accordance with the applicable provisions of Test Method C 1437.

16.1.4 *Storage of Specimens*—After 24 h of initial curing in the moist room (23 ± 2 °C and relative humidity of not less than 95 %), place the cubes in airtight glass containers and store at 65 ± 2°C for six days.

16.1.5 Determine the compressive strength, as specified in Test Method C 109/C 109M, of the three specimens of the control mixture and the three specimens of the test mixture at 7 days after molding.

17. Reactivity with Cement Alkalies

17.1 Determine the reduction of mortar expansion in accordance with Test Method C 441, except that the amount of silica fume in the test mixture shall be 10 % by mass of cementitious material.

18. Sulfate Resistance

18.1 Determine sulfate resistance according to Test Method C 1012, except that the amount of silica fume used in the test mixture is 10 % by mass of cementitious material.

19. Bulk Density

19.1 The bulk density of silica fume is defined as the mass of a unit volume of loose silica fume.

19.2 This test method covers determination of the bulk density of silica fume, as silica fume is transferred from one container to another with controlled minimum compaction. Its particular usefulness is in connection with identifying material form (as produced or densified), silo or truck storage capacity, material handling and transportation characteristics.

19.3 *Equipment*:

19.3.1 *Balance*, meeting Specification C 1005, with a sensitivity of 0.1 g.

19.3.2 *Vibrating Table*[4], Table top, electromagnetic vibrating table, with a controlled low-amplitude that does not exceed 1 mm linear vibration. Approximate deck size is 175 × 250 mm with a 5 kg capacity. The amplitude of the vibration shall be capable of being regulated to suit the characteristics of the material being handled.

19.3.3 *Stainless Steel Beaker*, of known volume, not less than 1 L calibrated to the nearest ±1 mL. Without a spout.

19.4 *Procedure*:

19.4.1 Determine the mass of the clean dry beaker to the nearest 1 g.

19.4.2 Fill the beaker with silica fume and compact by use of the vibrating table at a mid-range setting for 15 s, adding material as needed.

19.4.3 Screed or strike off the measure, with a straight edge or spatula, to produce a flat, even surface, that is level with rim or edge of the beaker. Wipe off any excess silica fume that may adhere to the sides.

19.4.4 Place the filled measure on the balance and determine the mass of the silica fume to the nearest 1 g.

19.5 *Calculation*:

19.5.1 Divide the net mass of the silica fume in grams by the volume of the container in milliliters. Multiply by 1000 to express the density in kilograms per cubic meter. To convert the value in kilograms per cubic meter to pounds per cubic foot, divide by 16.01846.

[4] The sole source of supply of the vibrating table known to the committee at this time is the Syntron Paper Jogger, Model J-1, manufactured by F.M.C. Corp., 57 Cooper Ave., Homer City, PA 15748. If you are aware of alternative suppliers, please provide this information to ASTM International Headquarters. Your comments will receive careful consideration at a meeting of the responsible technical committee,[1] which you may attend.

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20. Report

20.1 Report the following information:
20.1.1 SiO_2 content, %,
20.1.2 Moisture content, %,
20.1.3 Loss on ignition, %,
20.1.4 Oversize, % retained,
20.1.5 Bulk density, kg/m^3,
20.1.6 Density, Mg/m^3,
20.1.7 Name of manufacturer and brand, if applicable,
20.1.8 Accelerated Pozzolanic Strength Activity Index,
20.1.9 Specific surface, m^2/g, and
20.1.10 Total alkalies, as equivalent Na_2O, %.

20.2 Report the following information when specifically requested by the purchaser:
20.2.1 The quantity of air-entraining agent compared to the 10 preceding tests, %,
20.2.2 Reduction of mortar expansion, %, and
20.2.3 Sulfate resistance expansion, %.

21. Precision and Bias

21.1 *Precision*:
21.1.1 *Accelerated Pozzolanic Strength Activity Index Test*:
21.1.1.1 *Single-Operator Precision*—The precision of this test will be evaluated using Practice C 670.
21.1.1.2 *Multilaboratory Precision*—The precision of this test will be evaluated using Practice C 670.
21.1.2 *Density Test*:
21.1.2.1 *Single-Operator Precision*—The single-operator standard deviation among single test results (a test result is defined in this specification as the average of two separate measurements) has been found to be 0.035 Mg/m^3.[5] Therefore, results of two properly conducted tests by the same operator should not differ by more than 0.099 Mg/m^3[5] on the same silica fume.
21.1.2.2 *Multilaboratory Precision*—The multilaboratory standard deviation among single test results (a test result is defined in this specification as the average of two separate measurements) has been found to be 0.047 Mg/m^3.[5] Therefore, results of two properly conducted tests in different laboratories on the same silica fume should not differ by more than 0.132 Mg/m^3 of their average.[5]
21.1.3 *Bulk Density*:
21.1.3.1 *Precision*—The precision of this test method will be evaluated using Practice C 670.
21.1.3.2 *Bias*—Since there is no accepted reference material suitable for determining any bias that might be associated with this test method, no statement on bias is being made.
21.2 *Bias*—Since there is no accepted reference material suitable for determining the bias for the procedures for measuring the accelerated pozzolanic strength activity index and the density, no statement on bias is being made.

22. Rejection and Retesting

22.1 The purchaser has the right to reject material that fails to conform to the requirements of this specification. Rejection shall be reported to the producer or supplier promptly and in writing. In case of dissatisfaction with the results of the tests, the producer or supplier is not prohibited from making a claim for retesting.

23. Certification

23.1 When specified in the purchase order or contract, the purchaser shall be furnished certification that samples have been tested as directed in this specification and the specified requirements have been met. When specified in the purchase order or contract, a report of the test results shall be furnished.

24. Packaging and Package Marking

24.1 When silica fume is delivered in packages, the name, and brand, if applicable, of the manufacturer or distributor and the mass of the silica fume contained therein shall be marked plainly on each package. Similar information shall be provided in the shipping invoices accompanying the shipment of packaged or bulk silica fume in dry or slurried forms. All packages shall be in good condition at the time of inspection.

25. Storage and Inspection

25.1 Silica fume shall be stored in such a manner as to permit easy access for the proper inspection and identification of each shipment. Facilities for inspection and sampling shall be provided at the point from which the material is to be shipped.

[5] These measurements represent, respectively, the (1s) and (d2s) limits in accordance with Practice C 670.

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APPENDIXES

(Nonmandatory Information)

X1. SILICA CONTENT

X1.1 Since the quantity of amorphous silica is one of the primary characteristics that determine the pozzolanic activity of silica fume, determination of the total silicon content is important. Gravimetric ["wet method"] determinations can be accomplished using sodium carbonate (Na_2CO_3) fusion as described in Test Methods C 114 and similar procedures. Instrumental methods successfully used for determination of total silicon in high silica materials include X-ray fluorescence spectrometry, inductively coupled plasma, optical emission spectrometry, and atomic absorption spectrophotometry. Silica Fume SRM® 2696 is available from the National Institute of Standards and Technology, for use in evaluating chemical and instrumental methods of analysis of silica fume used in conjunction with product specifications. Because silica (SiO_2) is required in this specification to be at least 85 % by mass of the silica fume, additional silica reference materials, such as SRM® 1413 high alumina sand [82.77 %] and silica flour [99.9 %], may be suitable for use with instrumental methods of analysis. Analysts should note that the gravimetric method determines all chemical forms of silicon in the material as silica (SiO_2), whereas the instrumental test methods determine all chemical forms of silicon in the material as total silicon (Si), which is reported as SiO_2. Typically, it is assumed that all or nearly all of the Si that is present in silica fume is SiO_2.

X2. OVERSIZE

X2.1 The 45-μm (No. 325) sieve specification is to be used to determine the amount of foreign material present. Since silica fume is much finer than cement or fly ash, the particles will all pass through the sieve except for foreign material. Extremely fine materials tend to form agglomerations; good judgment must be exercised to differentiate between easily dispersible agglomerates and foreign materials.

X3. PROBLEM OF MIXTURE PROPORTIONING FOR VARIOUS TEST MIXTURES

X3.1 Such test methods as accelerated pozzolanic strength activity index with portland cement, reactivity with cement alkalies, and sulfate resistance require mixtures where the silica fume being tested replaces a given amount of cement. For specification purposes, 10 % by mass replacement of cement by silica fume will be used rather than that which is stated in the present methods. Water-to-cementitious materials ratio will be replaced by a flow of between 100 and 115 %. As the percent replacement with silica fume increases, the mixture becomes unworkable, and either more water is necessary or a water reducer is necessary to have a workable mixture. By limiting the mixtures to 10 % by mass replacement, the addition of water to a certain flow is a viable alternative, even though the addition of water reducer would probably produce a higher strength. Since this is a specification, the interest is in comparing material under similar conditions, rather than in maximum strength.

X4. SULFATE RESISTANCE

X4.1 Satisfactory reductions of expansion in laboratory mixtures have been obtained with silica fume replacement levels of 5 to 15 %. Each source of silica fume must be tested with high-C_3A portland cement to establish appropriate replacement levels for adequate sulfate resistance.

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SUMMARY OF CHANGES

Committee C09 has identified the location of selected changes to this specification since the last issue, C 1240 – 04, that may impact the use of this specification. (Approved July 1, 2005)

(*1*) Revised 8.2.
(*2*) Revised X1.1.
(*3*) Revised old Note 3 and moved it to Footnote 3.

Committee C09 has identified the location of selected changes to this specification since the last issue, C 1240 – 03a, that may impact the use of this specification. (Approved June 1, 2004)

(*1*) Revised 20.1.10.

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Designation: C 1245/C 1245M – 06

Standard Test Method for Determining Bond Strength Between Hardened Roller Compacted Concrete and Other Hardened Cementitious Mixtures (Point Load Test)[1]

This standard is issued under the fixed designation C 1245/C 1245M; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope*

1.1 This test method is intended for testing roller-compacted concrete specimens and covers determination of the relative bond between layers of roller-compacted concrete or other hardened concrete in multiple-lift forms of construction. It is applicable to all types of layered concrete where the total depth is sufficient to meet the minimum specimen length and diameter requirements of this test method. This test method is not intended to provide tensile strength results of the material tested.

1.2 The values stated in SI units, shown in brackets, or inch-pound units are to be regarded separately as standard. The values stated in each system may not be exact equivalents; therefore, each system shall be used independently of the other, without combining values in any way. Combining values from the two systems may result in non-conformance with the standard.

1.3 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

2. Referenced Documents

2.1 *ASTM Standards:* [2]

C 39/C 39M Test Method for Compressive Strength of Cylindrical Concrete Specimens

C 42/C 42M Test Method for Obtaining and Testing Drilled Cores and Sawed Beams of Concrete

C 125 Terminology Relating to Concrete and Concrete Aggregates

C 192/C 192M Practice for Making and Curing Concrete Test Specimens in the Laboratory

C 670 Practice for Preparing Precision and Bias Statements for Test Methods for Construction Materials

C 1176 Practice for Making Roller-Compacted Concrete in Cylinder Molds Using a Vibrating Table

C 1435/C 1435M Practice for Molding Roller-Compacted Concrete in Cylinder Molds Using a Vibrating Hammer

D 1557 Test Methods for Laboratory Compaction Characteristics of Soil Using Modified Effort (56,000 ft-lbf/ft^3 (2,700 kN-m/m^3))

3. Terminology

3.1 Refer to Terminology C 125 for definitions of terms used in this test method.

4. Significance and Use

4.1 This test method is used to measure the effectiveness of bonding roller-compacted concrete to other roller-compacted concrete or other hardened cementitious mixtures by using a point load test at the joint. Bond strength is determined using drilled cores or cast cylindrical specimens in which the bond surface is essentially normal to the longitudinal axis at approximately the mid-length of the specimen. A splitting tensile stress normal to the bond surface is produced by applying a point load at the joint.

4.2 This test method may be used either for laboratory investigation by casting individual composite cylinders or by coring prototype structures or assemblies (Test Method C 42/C 42M).

5. Apparatus

5.1 *Testing Machine*—The testing machine shall conform to the requirements of Test Method C 39/C 39M.

5.2 *Testing Apparatus*—The testing apparatus shall be constructed of steel and allow the testing of both 4 and 6-in. [100 and 150-mm] diameter specimens. The test schematic is given in Fig. 1. The testing apparatus shall permit the positioning of a specimen such that the joint of the bonded surfaces is oriented as closely as possible parallel to the direction of loading. Figs. 2-9 provide the information necessary to construct the apparatus for 4 and 6-in. [100 and 150-mm] diameter specimens. Anvil rods (Fig. 3 and Fig. 5) shall have a hardness

[1] This test method is under the jurisdiction of ASTM Committee C09 on Concrete and Concrete Aggregates and is the direct responsibility of Subcommittee C09.45 on Roller Compacted Concrete.

Current edition approved July 1, 2006. Published August 2006. Originally approved in 1993. Last previous edition approved in 2003 as C 1245/C 1245M – 03.

[2] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

***A Summary of Changes section appears at the end of this standard.**

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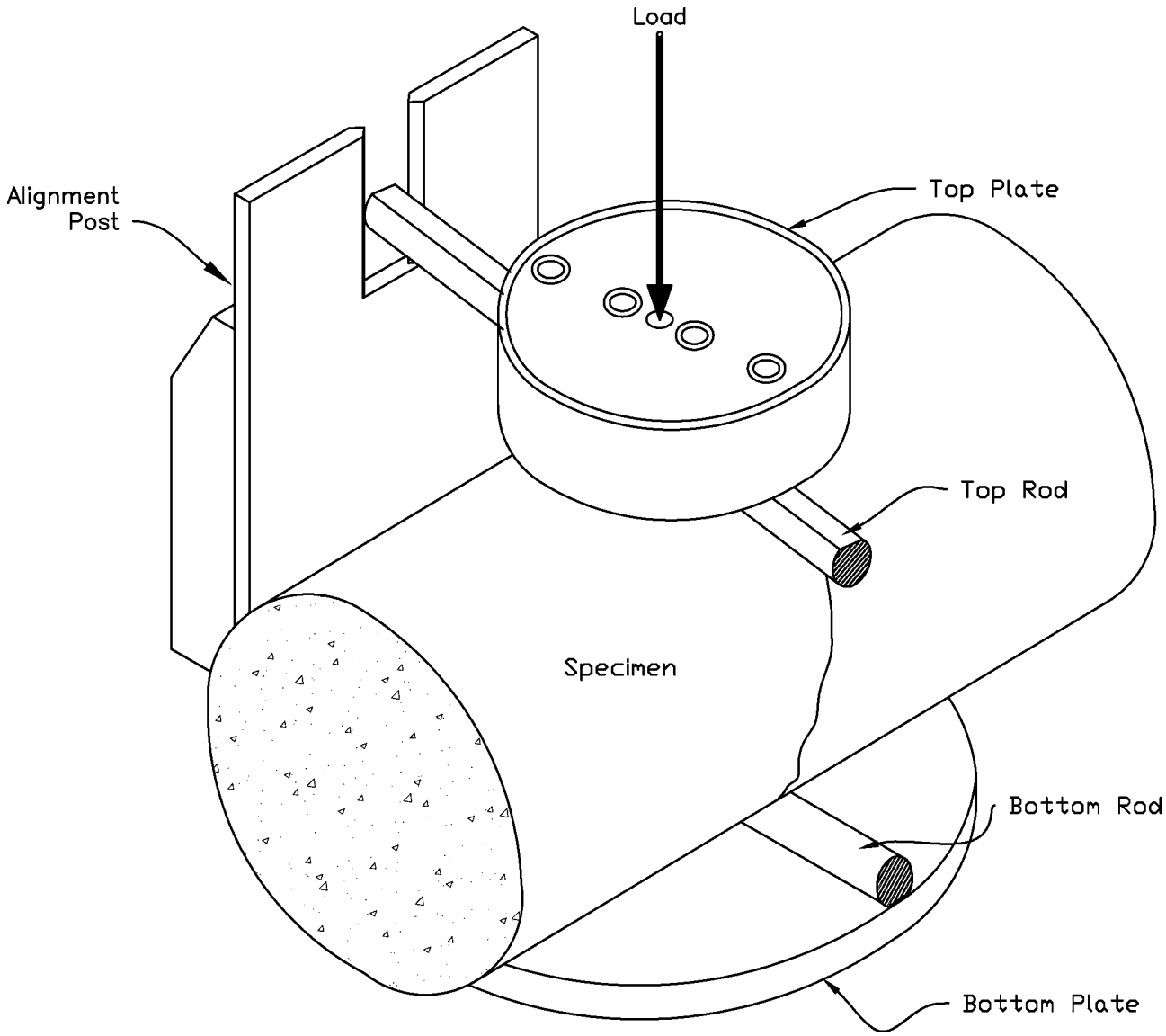

FIG. 1 Schematic of Loading Method

of not less than 55 HRC (Rockwell hardness number of 55 on the C scale) and shall be plane on the bearing surfaces to within ±0.001 in. [0.025 mm]. The alignment post shall ensure that the anvil rods are kept parallel to each other in the vertical plane. The system is easily adaptable to most testing machines.

6. Test Specimens

6.1 Test specimens shall be cores or cast cylinders 4 or 6 ± 0.25 in. [100 or 150 ± 5 mm] in diameter. Cast cylinders in accordance with Practice C 1176, Practice C 1435, or Test Method D 1557. Cut each core and cast each cylinder to ensure that the plane best describing the bond surface is oriented at 90 ± 15° to the long axes of the specimens.

6.2 Cure molded test specimens in accordance with Practice C 192/C 192M (laboratory specimens). Drilled cores shall be moisture conditioned in accordance with Test Method C 42/C 42M.

NOTE 1—Test results are not affected significantly by specimen surfaces obtained with normal coring operations. The ends of cores need not be trimmed.

NOTE 2—Where the bond surface undulates grossly, that is, the surface has a local texture exceeding 0.5 in. [13 mm] in amplitude, 6-in. [150-mm] diameter cores are preferable. No information is available on the relative results of 6-in. [150-mm] versus 4-in. [100-mm] diameter specimens.

7. Procedure

7.1 *Measurements*—Determine the diameter of the test specimens by averaging three diameters measured on the bond surface. Visually identify the bond surface by color, texture, or material contrasts. Measure diameters to the nearest 0.01 in. [0.25 mm] with calipers, whenever possible, but at least to the nearest 0.1 in. [2.5 mm]. Determine the length of each section of the bonded specimens to the nearest 0.1 in. [2.5 mm], and use these lengths to determine the section length-to-diameter ratios. Specimens must have a minimum length-to-diameter ratio of 1.2 if the bond plane is at mid-length (within ±0.25 in. [6 mm]) of the specimen. If the bond plane is not at mid-length

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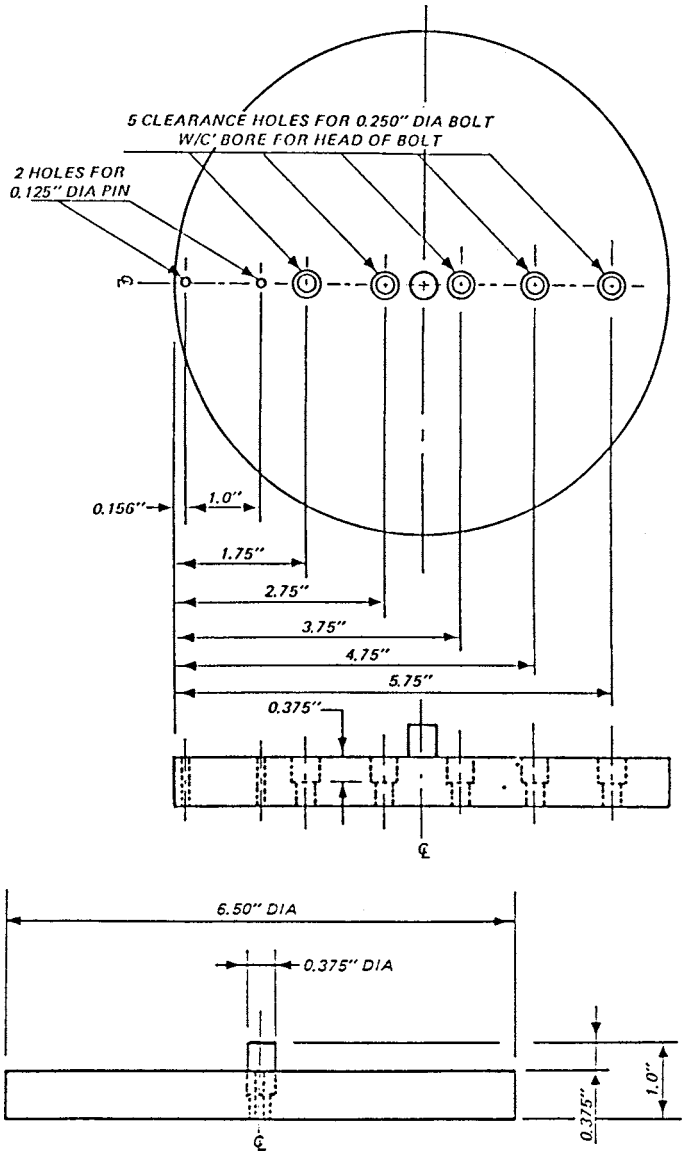

FIG. 2 Base Plate

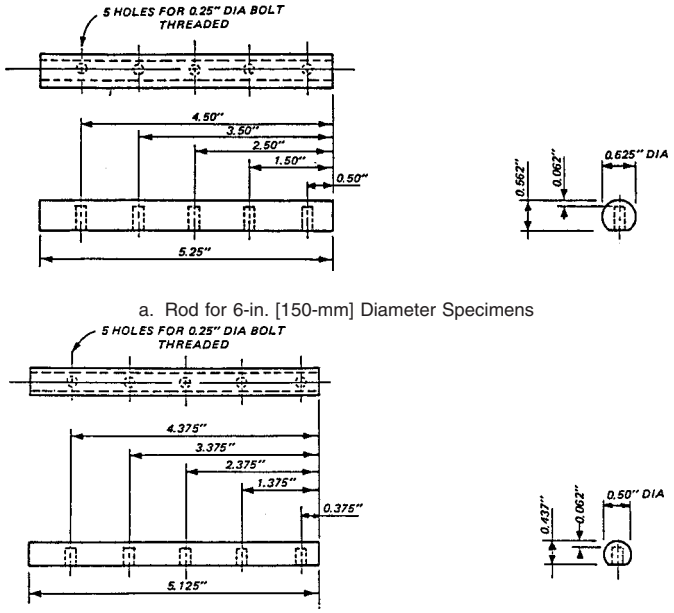

FIG. 3 Bottom Anvil Rods

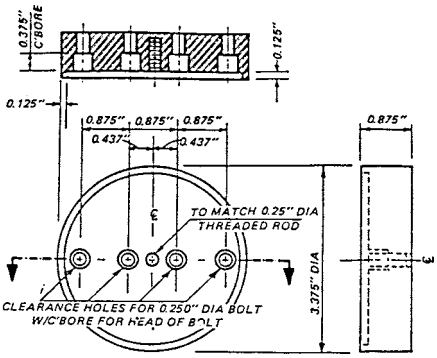

FIG. 4 Top Plate

of the specimen, the section on each side of the bond plane shall be of a length at least 0.6 the diameter. Where the bond surface is irregular or undulating, mark on the specimen a line representing a plane extending through and along the approximate average bearing of the bond surface, and measure the length from this line.

NOTE 3—Many drilled cores will not be smooth enough to justify the measurement of diameters closer than to the nearest 0.1 in. [2.5 mm].

7.2 *Positioning*—Assemble and position the apparatus in the testing machine. Place the specimen on the bottom plate with the joint in contact with the anvil rods (see Fig. 1). The longer anvil rods (Fig. 3a and Fig. 5a) and the longer alignment post (Fig. 9) are used to test 6-in. [150-mm] diameter specimens. The shorter anvil rods (Fig. 3b and Fig. 5b) and the shorter alignment post (Fig. 8) are used to test 4-in. [100-mm] diameter specimens.

7.2.1 Zero the load-indicating mechanism. Position the specimen so that the bond surface is parallel to the upper and lower anvil rods (see Fig. 1). This is best accomplished by positioning the specimen by hand while gently bringing the top anvil into contact with the specimen. Alternatively, the specimen may be supported with modeling clay or pieces of polystyrene. Where the bond surface is irregular or undulating, align the anvil rods along the approximate average bearing of the bond surface. Bring the anvil rods in contact with the bond surface at the contact point on the circumference of the specimen.

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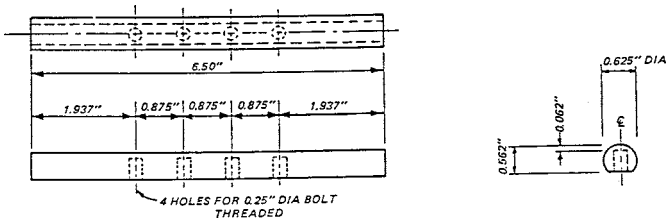
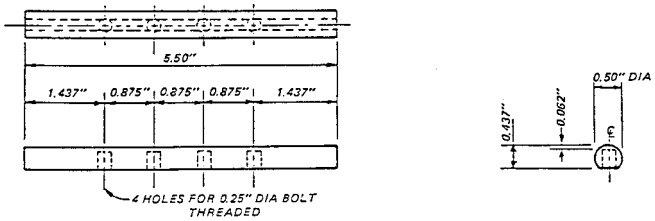


a. Rod for 6-in. [150-mm] Diameter Specimens



b. Rod for 4-in. [101-mm] Diameter Specimens

FIG. 5 Top Anvil Rods

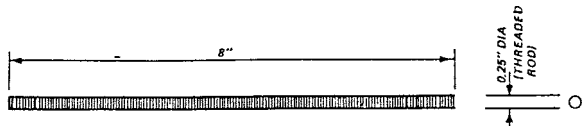


FIG. 6 Threaded Rod for Attachment of Top Plate

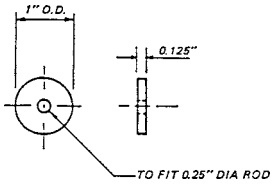


FIG. 7 Washer for Threaded Rod

7.3 *Loading*—Do not preload the specimen. Apply the load at a uniform rate within the range of 150 to 200 psi/min [1 to 1.4 MPa/min] until the specimen fails. Record the maximum load applied.

8. Calculation

8.1 Calculate the strength of the bond as follows:

$$f_{tb} = \frac{P}{D^2}$$

where:

f_{tb} = bond strength, psi [MPa],
P = maximum applied load, lbf [N], and
D = average specimen diameter at bond surface, in. [mm].

9. Report

9.1 Report the following information:

9.1.1 Date of testing.

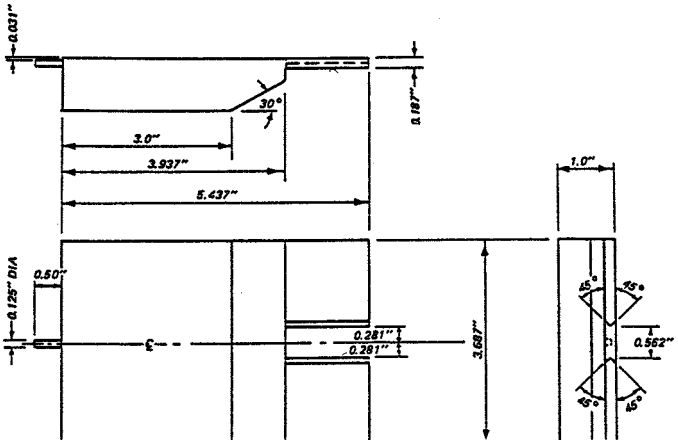


FIG. 8 Alignment Post for 4-in. [100-mm] Diameter Specimens

9.1.2 Specimen identification and if cored, the location of the core.

9.1.3 Details of the materials comprising the specimens, such as the following:

9.1.3.1 Mixture proportions of the concretes and mortars;

9.1.3.2 Details of fabrication including the practice or test method used to cast or mold cylinders;

9.1.3.3 Details of bonding techniques;

9.1.3.4 Age, when tested;

9.1.3.5 Specimen size including diameter and length of each layer material and whether a cast cylinder or drilled core was used; and

9.1.3.6 Any other information necessary to describe the production or features of the specimens.

9.1.4 Record of curing and moisture condition of the specimens at the time of test.

9.1.5 Any special treatment or prior testing performed on the specimens.

9.1.6 Strength of the bond to the nearest 10 psi [0.1 MPa].

9.1.7 Mode of failure:

9.1.7.1 Whether bond failure or aggregate failure, or both, were observed in the plane of failure;

9.1.7.2 Should the fracture occur along the original bond surface, the nature of the surface such as texture (smooth or rough), appearance (glossy or dull, undulating or flat), and detailed descriptions of discoloration, foreign objects or materials, loose or dusty material in voids, and the suspected presence and condition, or absence, of any bonding improvement agent;

9.1.7.3 Alternatively, should the plane of fracture occur partially or totally within the concrete layers adjacent to the bond surface, the percentage of the total area subjected to this type of failure versus the percentage area where failure occurred at the bond surface; and

9.1.7.4 Any unexpected features.

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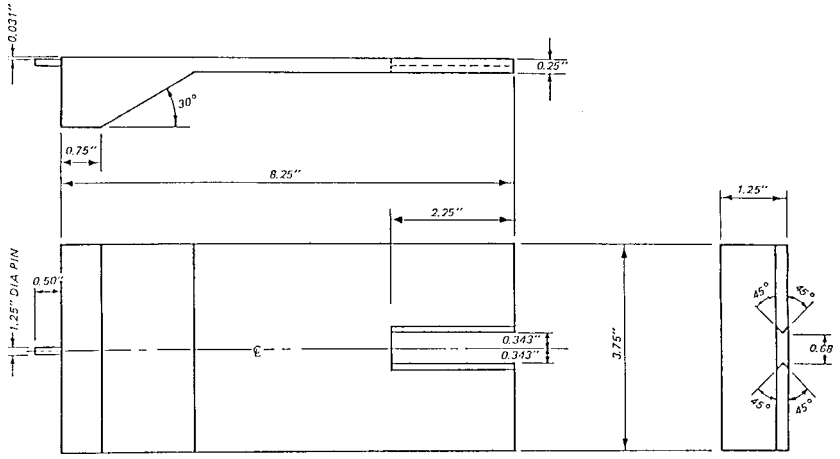

FIG. 9 Alignment Post for 6-in. [150-mm] Diameter Specimens

10. Precision and Bias

10.1 *Precision*—Precision of this test method was calculated from results published in Saucier,[3] which compared tensile strength of bonds and unbonded concrete for five mixtures of varying proportions. These data only represent within laboratory data for a single laboratory. A report of this analysis is on file at ASTM International Headquarters, as Research Report RR: C09-1025.[4]

10.1.1 The single-laboratory single-batch standard deviation for splitting tensile strength of unbonded concrete cores has been found to be 23 psi [0.16 MPa][5] in 95 % of the cases. Therefore, results of tests on two cores taken from the same batch of concrete should differ by no more than 106 psi [0.73MPa][5] in 95 % of cases.

10.1.2 The single-laboratory single-batch standard deviation for splitting tensile bond strength of cores obtained from a layered specimen has been found to be 38 psi [0.26 MPa][5] in 95 % of the cases. Therefore, results of tests on two cores taken from the same batch of concrete should differ by no more than 106 psi [07.3 MPa] in 95 % of cases.

10.2 *Bias*—This test method has no bias because there is no standard material on which to estimate this property.

11. Keywords

11.1 bond strength; bonding agents; concrete bonding; roller-compacted concretes

[3] Saucier, K. L. "No-Slump Roller Compacted Concrete (RCC) for Use in Mass Concrete Construction," Technical Report SL-84-17, U.S. Army Research and Development Center, 3909 Halls Ferry Rd., Vicksburg, MS 39180, 1984.

[4] Supporting data have been filed at ASTM International Headquarters and may be obtained by requesting Research Report RR: C09-1025.

[5] These numbers represent, respectively, the (ls) and (d2s) limits as described in Practice C 670.

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TABLE 1 Metric Equivalent for Figs. 2-9

in.	mm
0.031	0.8
0.062	1.6
0.125	3.2
0.156	4.0
0.187	4.7
0.25	6.4
0.281	7.1
0.343	8.7
0.375	9.5
0.437	11
0.50	13
0.562	14
0.625	16
0.687	17
0.75	19
0.875	22
1.0	25
1.25	32
1.375	35
1.437	36
1.50	38
1.75	44
1.937	49
2.25	57
2.375	60
2.50	65
2.75	70
3.0	75
3.375	85
3.43	87
3.50	90
3.687	94
3.75	95
3.937	100
4.375	110
4.50	115
4.75	120
5.437	138
5.50	140
5.75	145
6.50	165
8.0	200
8.25	205

SUMMARY OF CHANGES

Committee C09 has identified the location of selected changes to this test method since the last issue, C 1245/C 1245M – 03, that may impact the use of this test method. (Approved July 1, 2006)

(*1*) Replaced Fig. 1 with a new schematic.

(*2*) Deleted Fig. 2, a photo entitled "Test Specimen in Testing Machine" and renumbered all subsequent figures.

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Designation: C 1252 – 06

Standard Test Methods for Uncompacted Void Content of Fine Aggregate (as Influenced by Particle Shape, Surface Texture, and Grading)[1]

This standard is issued under the fixed designation C 1252; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope*

1.1 These test methods cover the determination of the loose uncompacted void content of a sample of fine aggregate. When measured on any aggregate of a known grading, void content provides an indication of that aggregate's angularity, sphericity, and surface texture compared with other fine aggregates tested in the same grading. When void content is measured on an as-received fine-aggregate grading, it can be an indicator of the effect of the fine aggregate on the workability of a mixture in which it may be used.

1.2 Three procedures are included for the measurement of void content. Two use graded fine aggregate (standard grading or as-received grading), and the other uses several individual size fractions for void content determinations:

1.2.1 *Standard Graded Sample (Test Method A)*—This test method uses a standard fine aggregate grading that is obtained by combining individual sieve fractions from a typical fine aggregate sieve analysis. See the section on Preparation of Test Samples for the grading.

1.2.2 *Individual Size Fractions (Test Method B)*—This test method uses each of three fine aggregate size fractions: *(a)* 2.36 mm (No. 8) to 1.18 mm (No. 16); *(b)* 1.18 mm (No. 16) to 600 µm (No. 30); and *(c)* 600 µm (No. 30) to 300 µm (No. 50). For this test method, each size is tested separately.

1.2.3 *As-Received Grading (Test Method C)*—This test method uses that portion of the fine aggregate finer than a 4.75-mm (No. 4) sieve.

1.2.4 See the section on Significance and Use for guidance on the method to be used.

1.3 The values stated in SI units shall be regarded as the standard.

1.4 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

2. Referenced Documents

2.1 *ASTM Standards:* [2]

B 88 Specification for Seamless Copper Water Tube

B 88M Specification for Seamless Copper Water Tube [Metric]

C 29/C 29M Test Method for Bulk Density ("Unit Weight") and Voids in Aggregate

C 117 Test Method for Materials Finer than 75-µm (No. 200) Sieve in Mineral Aggregates by Washing

C 125 Terminology Relating to Concrete and Concrete Aggregates

C 128 Test Method for Density, Relative Density (Specific Gravity), and Absorption of Fine Aggregate

C 136 Test Method for Sieve Analysis of Fine and Coarse Aggregates

C 670 Practice for Preparing Precision and Bias Statements for Test Methods for Construction Materials

C 702 Practice for Reducing Samples of Aggregate to Testing Size

C 778 Specification for Standard Sand

D 75 Practice for Sampling Aggregates

2.2 *ACI Document:*

ACI 116R Cement and Concrete Terminology[3]

3. Terminology

3.1 Terms used in these test methods are defined in Terminology C 125 or ACI 116R.

4. Summary of Test Method

4.1 A nominal 100-mL calibrated cylindrical measure is filled with fine aggregate of prescribed grading by allowing the sample to flow through a funnel from a fixed height into the measure. The fine aggregate is struck off and its mass is determined by weighing. Uncompacted void content is calculated as the difference between the volume of the cylindrical

[1] These test methods are under the jurisdiction of ASTM Committee C09 on Concrete and Concrete Aggregates and are the direct responsibility of Subcommittee C09.20 on Normal Weight Aggregates.

Current edition approved Nov. 1, 2006. Published November 2006. Originally approved in 1993. Last previous edition approved in 2003 as C 1252 – 03.

[2] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

[3] Available from American Concrete Institute (ACI), P.O. Box 9094, Farmington Hills, MI 48333-9094, http://www.aci-int.org.

***A Summary of Changes section appears at the end of this standard.**

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measure and the absolute volume of the fine aggregate collected in the measure. Uncompacted void content is calculated using the dry relative density (specific gravity) of the fine aggregate. Two runs are made on each sample and the results are averaged.

4.1.1 For a graded sample (Test Method A or Test Method C) the percent void content is determined directly, and the average value from two runs is reported.

4.1.2 For the individual size fractions (Test Method B), the mean percent void content is calculated using the results from tests of each of the three individual size fractions.

5. Significance and Use

5.1 Test Methods A and B provide percent void content determined under standardized conditions which depends on the particle shape and texture of a fine aggregate. An increase in void content by these procedures indicates greater angularity, less sphericity, or rougher surface texture, or combination thereof. A decrease in void content results is associated with more rounded, spherical, or smooth-surfaced fine aggregate, or a combination thereof.

5.2 Test Method C measures the uncompacted void content of the minus 4.75-mm (No. 4) portion of the as-received material. This void content depends on grading as well as particle shape and texture.

5.3 The void content determined on the standard graded sample (Test Method A) is not directly comparable with the average void content of the three individual size fractions from the same sample tested separately (Test Method B). A sample consisting of single size particles will have a higher void content than a graded sample. Therefore, use either one method or the other as a comparative measure of shape and texture, and identify which test method has been used to obtain the reported data. Test Method C does not provide an indication of shape and texture directly if the grading from sample to sample changes.

5.3.1 The standard graded sample (Test Method A) is most useful as a quick test which indicates the particle shape properties of a graded fine aggregate. Typically, the material used to make up the standard graded sample can be obtained from the remaining size fractions after performing a single sieve analysis of the fine aggregate.

5.3.2 Obtaining and testing individual size fractions (Test Method B) are more time consuming and require a larger initial sample than using the graded sample. However, Test Method B provides additional information concerning the shape and texture characteristics of individual sizes.

5.3.3 Testing samples in the as-received grading (Test Method C) may be useful in selecting proportions of components used in a variety of mixtures. In general, high void content suggests that the material could be improved by providing additional fines in the fine aggregate or more cementitious material may be needed to fill voids between particles.

5.3.4 The dry relative denstiy (specific gravity) of the fine aggregate is used in calculating the void content. The effectiveness of these test methods of determining void content and its relationship to particle shape and texture depends on the relative density (specific gravity) of the various size fractions being equal, or nearly so. The void content is actually a function of the volume of each size fraction. If the type of rock or minerals, or its porosity, in any of the size fractions varies markedly it may be necessary to determine the specific gravity of the size fractions used in the test.

5.4 Void content information from Test Methods A, B, or C will be useful as an indicator of properties such as: the mixing water demand of hydraulic cement concrete; flowability, pumpability, or workability factors when formulating grouts or mortars; or, in bituminous concrete, the effect of the fine aggregate on stability and voids in the mineral aggregate; or the stability of the fine-aggregate portion of a base course aggregate.

6. Apparatus

6.1 *Cylindrical Measure*—A right cylinder of approximately 100-mL capacity having an inside diameter of approximately 39 mm and an inside height of approximately 86 mm made of drawn copper water tube meeting the requirements of Specification B 88 , Type M or B 88M, Type C. The bottom of the measure shall be metal at least 6 mm thick, shall be firmly sealed to the tubing, and shall be provided with means for aligning the axis of the cylinder with that of the funnel. See Fig. 1.

6.2 *Funnel*—The lateral surface of the right frustum of a cone sloped 60 ± 4° from the horizontal with an opening of 12.7 ± 0.6-mm diameter. The funnel section shall be a piece of metal, smooth on the inside and at least 38 mm high. It shall have a volume of at least 200 mL or shall be provided with a supplemental glass or metal container to provide the required volume. See Fig. 2.

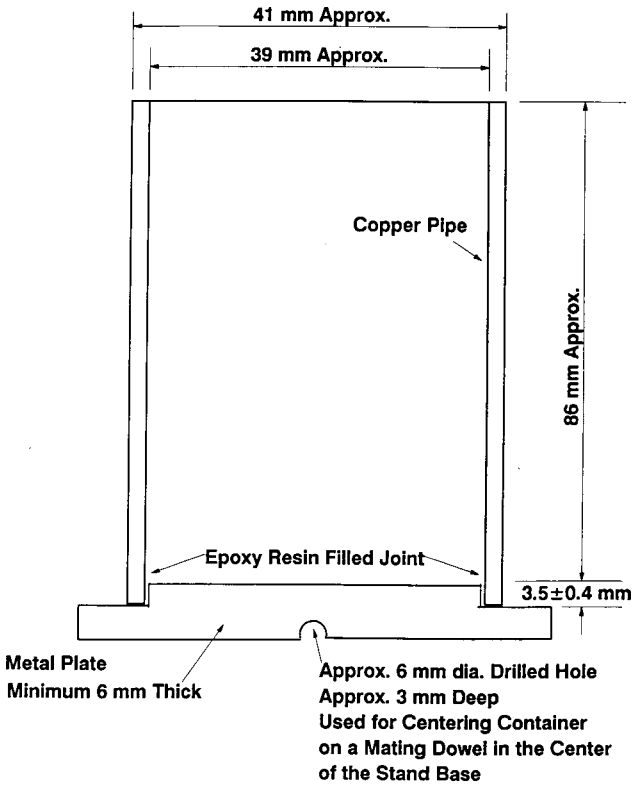

FIG. 1 Nominal 100-mL Cylindrical Measure

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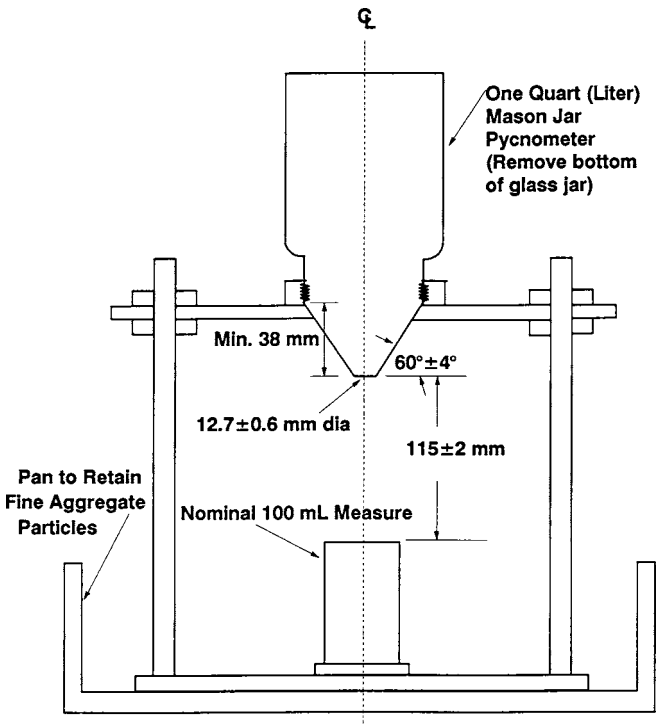

Section Through Center of Apparatus

FIG. 2 Suitable Funnel Stand Apparatus with Cylindrical Measure in Place

NOTE 1—Pycnometer top C9455[4] is satisfactory for the funnel section, except that the size of the opening has to be enlarged and any burrs or lips that are apparent should be removed by light filing or sanding before use. This pycnometer top must be used with a suitable glass jar with the bottom removed (Fig. 2).

6.3 *Funnel Stand*—A three- or four-legged support capable of holding the funnel firmly in position with the axis of the funnel colinear (within a 4° angle and a displacement of 2 mm) with the axis of the cylindrical measure. The funnel opening shall be 115 ± 2 mm above the top of the cylinder. A suitable arrangement is shown in Fig. 2.

6.4 *Glass Plate*—A square glass plate approximately 60 by 60 mm with a minimum 4-mm thickness used to calibrate the cylindrical measure.

6.5 *Pan*—A metal or plastic pan of sufficient size to contain the funnel stand and to prevent loss of material. The purpose of the pan is to catch and retain fine aggregate particles that overflow the measure during filling and strike off.

6.6 *Metal Spatula*, with a blade approximately 100 mm long, and at least 20 mm wide, with straight edges. The end shall be cut at a right angle to the edges. The straight edge of the spatula blade is used to strike off the fine aggregate.

6.7 *Scale or Balance*, accurate and readable to ±0.1 g within the range of use, capable of weighing the cylindrical measure and its contents.

7. Sampling

7.1 Obtain the sample(s) used for this test in accordance with Practices D 75 and Practice C 702, or from sieve analysis samples used for Test Method C 136, or from aggregate extracted from a bituminous concrete specimen. For Methods A and B, wash the sample over a 150-µm (No. 100) or 75-µm (No. 200) sieve in accordance with Test Method C 117 and then dry and sieve into separate size fractions in accordance with the procedures of Test Method C 136. Maintain the necessary size fractions obtained from one (or more) sieve analysis in a dry condition in separate containers for each size. For Method C, dry a split of the as-received sample in accordance with the drying procedure in Test Method C 136.

8. Calibration of Cylindrical Measure

8.1 Apply a light coat of grease to the top edge of the dry, empty cylindrical measure. Weigh the measure, grease, and glass plate. Fill the measure with freshly boiled, deionized water at a temperature of 18 to 24 °C. Record the temperature of the water. Place the glass plate on the measure, being sure that no air bubbles remain. Dry the outer surfaces of the measure and determine the combined mass of measure, glass plate, grease, and water by weighing. Following the final weighing, remove the grease and determine the mass of the clean, dry, empty measure for subsequent tests.

8.2 Calculate the volume of the measure as follows:

$$V = \frac{1000\,M}{D}$$

where:

V = volume of cylinder, mL,
M = net mass of water, g, and
D = density of water, kg/m^3(see table in Test Method C 29/C 29M for density at the temperature used.)

Determine the volume to the nearest 0.1 mL.

NOTE 2—If the volume of the measure is greater than 100.0 mL, it may be desirable to grind the upper edge of the cylinder until the volume is exactly 100.0 mL to simplify subsequent calculations.

9. Preparation of Test Samples

9.1 *Test Method A—Standard Graded Sample*—Weigh out and combine the following quantities of fine aggregate which have been dried and sieved in accordance with Test Method C 136.

Individual Size Fraction	Mass, g
2.36 mm (No. 8) to 1.18 mm (No. 16)	44
1.18 mm (No. 16) to 600 µm (No. 30)	57
600 µm (No. 30) to 300 µm (No. 50)	72
300 µm (No. 50) to 150 µm (No. 100)	17
	190

The tolerance on each of these amounts is ±0.2 g.

9.2 *Test Method B—Individual Size Fractions*—Prepare a separate 190-g sample of fine aggregate, dried and sieved in accordance with Test Method C 136, for each of the following size fractions:

[4] The sole source of supply of the apparatus known to the committee at this time is Hogentogler and Co., Inc., 9515 Gerwig, Columbia, MD 21045. If you are aware of alternative suppliers, please provide this information to ASTM International Headquarters. Your comments will receive careful consideration at a meeting of the responsible technical committee,[1] which you may attend.

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Individual Size Fraction	Mass, g
2.36 mm (No. 8) to 1.18 mm (No. 16)	190
1.18 mm (No. 16) to 600 µm (No. 30)	190
600 µm (No. 30) to 300 µm (No. 50)	190

The tolerance on each of these amounts is ±1 g. Do not mix these samples together. Each size is tested separately.

9.3 *Test Method C—As Received Grading*—Pass the sample (dried in accordance with Test Method C 136) through a 4.75-mm (No. 4) sieve. Obtain a 190 ± 1-g sample of the material passing the 4.75-mm (No. 4) sieve for test.

9.4 *Relative Density (Specific Gravity) of Fine Aggregate*—If the dry relative density (specific gravity) of fine aggregate from the source is unknown, determine it on the minus 4.75-mm (No. 4) material in accordance with Test Method C 128. Use this value in subsequent calculations unless some size fractions differ by more than 0.05 from the relative density (specific gravity) typical of the complete sample, in which case the relative density (specific gravity) of the fraction (or fractions) being tested must be determined. An indicator of differences in relative density (specific gravity) of various particle sizes is a comparison of relative densities (specific gravities) run on the fine aggregate in different gradings. Relative density (specific gravity) can be run on gradings with and without specific size fractions of interest. If relative density (specific gravity) differences exceed 0.05, determine the relative density (specific gravity) of the individual 2.36-mm (No. 8) to 150-µm (No. 100) sizes for use with Method A or the individual size fractions for use with Test Method B either by direct measurement or by calculation using the relative density (specific gravity) data on gradings with and without the size fraction of interest. A difference in relative density (specific gravity) of 0.05 will change the calculated void content about 1 %.

10. Procedure

10.1 Mix each test sample with the spatula until it appears to be homogeneous. Position the jar and funnel section in the stand and center the cylindrical measure as shown in Fig. 2. Use a finger to block the opening of the funnel. Pour the test sample into the funnel. Level the material in the funnel with the spatula. Remove the finger and allow the sample to fall freely into the cylindrical measure.

10.2 After the funnel empties, strike off excess heaped fine aggregate from the cylindrical measure by a single rapid pass of the spatula with the width of the blade vertical keeping the straight part of its edge horizontal and in light contact with both sides of the top of the measure. Until this operation is complete, exercise care to avoid vibration or any disturbance that could cause compaction of the fine aggregate in the cylindrical measure (Note 3). Brush adhering grains from the outside of the container and determine the mass of the cylindrical measure and contents to the nearest 0.1 g. Retain all fine aggregate particles for a second test run.

NOTE 3—After strike-off, the cylindrical measure may be tapped lightly to compact the sample to make it easier to transfer the container to the scale or balance without spilling any of the sample.

10.3 Recombine the sample from the retaining pan and cylindrical measure and repeat the procedure. Average the results of two runs. See Section 11.

10.4 Record the mass of the empty measure. Also, for each run, record the mass of the measure and fine aggregate.

11. Calculation

11.1 Calculate the uncompacted voids for each determination as follows:

$$U = \frac{V - (F/G)}{V} \times 100$$

where:

V = volume of cylindrical measure, mL,
F = net mass of fine aggregate in measure, g (gross mass minus the mass of the empty measure),
G = dry relative density (specific gravity) of fine aggregate, and
U = uncompacted voids in the material, %.

11.2 For the standard graded sample (Test Method A) calculate the average uncompacted voids for the two determinations and report the results as U_s.

11.3 For the individual size fractions (Test Method B) calculate as follows:

11.3.1 First, the average uncompacted voids for the determinations made on each of the three size-fraction samples:

U_1 = uncompacted voids, 2.36 mm (No. 8) to 1.18 mm (No. 16), %,
U_2 = uncompacted voids, 1.18 mm (No. 16) to 600 µm (No. 30), %, and
U_3 = uncompacted voids, 600 µm (No. 30) to 300 µm (No. 50), %.

11.3.2 Second, the mean uncompacted voids (U_m) including the results for all three sizes:

$$U_m = (U_1 + U_2 + U_3)/3$$

11.4 For the as-received grading (Test Method C) calculate the average uncompacted voids for the two determinations and report the result as U_R.

12. Report

12.1 Report the following information for the standard graded sample (Test Method A):

12.1.1 Uncompacted voids (U_s), % to the nearest one tenth of a percent (0.1 %), and

12.1.2 Relative density (specific gravity) value used in the calculations.

12.2 Report the following percent voids to the nearest one tenth of a percent (0.1 %) for the individual size fractions (Test Method B):

12.2.1 Uncompacted voids for size fractions: *(a)* 2.36 mm (No. 8) to 1.18 mm (No. 16) (U_1); *(b)* 1.18 mm (No. 16) to 600 µm (No. 30) (U_2); and *(c)* 600 µm (No. 30) to 300 µm (No. 50) (U_3),

12.2.2 Mean uncompacted voids (U_m), and

12.2.3 Relative density (specific gravity) value(s) used in the calculations, and whether the relative density (specific gravity) value(s) were determined on a graded sample or the individual-sized fractions used in the test.

12.3 Report the following information for the as-received sample (Test Method C):

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12.3.1 Uncompacted voids (U_R), % to the nearest one tenth of a percent (0.1 %).

12.3.2 Relative density (specific gravity) value used in the calculation.

13. Precision and Bias

13.1 *Precision*—Criteria for judging the acceptability of test results obtained by this test method are given as follows:

NOTE 4—The figures in Column 2 are the standard deviations that have been found to be appropriate for the materials and conditions of test described in Column 1. The figures given in Column 3 are the limits that should not be exceeded by the difference between the results of two properly conducted tests.

Material and Type Index	Standard Deviation[A]	Acceptable Range of Two Results[A]
Single-operator precision:		
Graded standard sand[B]	0.13 %	0.37 %
Manufactured fine aggregate[C]	0.33 %	0.94 %
Multilaboratory precision:		
Graded standard sand[B]	0.33 %	0.93 %
Manufactured fine aggregate[C]	1.1 %	3.1 %

[A] These numbers represent, respectively, the (1s) and (d2s) limits as described in Practice C 670.

[B] These estimates of precision are based on "graded standard sand" as described in Specification C 778, which is considered rounded, and is graded from 600 µm (No. 30 sieve) to 150 µm (No. 100 sieve), and may not be typical of other fine aggregates.

[C] These estimates of precision are based on results from the AASHTO Materials Reference Laboratory (AMRL) Proficiency Sample Program. The data are based on the analyses of 103 paired test results from 103 laboratories. The tests were conducted in accordance with Method C—As Received Grading on a manufactured fine aggregate.

NOTE 5—Additional precision information using multiple aggregate types, versus one material above, is available in Research Report RR: C09-1019[5], prepared by the Georgia Department of Transportation and titled *Fine Aggregate Angularity Round Robin Testing—Precision Statements*.

13.2 *Bias*—Since there is no accepted reference material suitable for determining the bias for the procedures in these test methods, bias has not been determined.

14. Keywords

14.1 angularity; fine aggregate; particle shape; sand; surface texture; void content

[5] Supporting data have been filed at ASTM International Headquarters and may be obtained by requesting Research Report RR: C09-1019.

SUMMARY OF CHANGES

Committee C09 has identified the location of selected changes to these test methods since the last issue, C 1252 – 03, that may impact the use of these test methods. (Approved November 1, 2006)

(*1*) Revised 10.2.

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Designation: C 1260 – 07

Standard Test Method for Potential Alkali Reactivity of Aggregates (Mortar-Bar Method)[1]

This standard is issued under the fixed designation C 1260; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope*

1.1 This test method permits detection, within 16 days, of the potential for deleterious alkali-silica reaction of aggregate in mortar bars.

1.2 The values stated in SI units are to be regarded as standard. The values in inch-pound units are shown in parentheses, and are for informational purposes only.

1.3 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.* A specific precautionary statement is given in the section on Reagents.

2. Referenced Documents

2.1 *ASTM Standards:* [2]

C 109/C 109M Test Method for Compressive Strength of Hydraulic Cement Mortars(Using 2-in. or [50-mm] Cube Specimens)

C 125 Terminology Relating to Concrete and Concrete Aggregates

C 127 Test Method for Density, Relative Density (Specific Gravity), and Absorption of Coarse Aggregate

C 128 Test Method for Density, Relative Density (Specific Gravity), and Absorption of Fine Aggregate

C 150 Specification for Portland Cement

C 151 Test Method for Autoclave Expansion of Hydraulic Cement

C 295 Guide for Petrographic Examination of Aggregates for Concrete

C 305 Practice for Mechanical Mixing of Hydraulic Cement Pastes and Mortars of Plastic Consistency

C 490 Practice for Use of Apparatus for the Determination of Length Change of Hardened Cement Paste, Mortar, and Concrete

C 511 Specification for Mixing Rooms, Moist Cabinets, Moist Rooms, and Water Storage Tanks Used in the Testing of Hydraulic Cements and Concretes

C 670 Practice for Preparing Precision and Bias Statements for Test Methods for Construction Materials

C 856 Practice for Petrographic Examination of Hardened Concrete

D 1193 Specification for Reagent Water

E 11 Specification for Wire Cloth and Sieves for Testing Purposes

3. Terminology

3.1 *Definitions:*

3.1.1 *relative density (OD), n*—as defined in Test Methods C 127 or C 128, for coarse and fine aggregates, respectively.

3.2 For definitions of other terms relating to concrete or aggregates, see Terminology C 125.

4. Significance and Use

4.1 This test method provides a means of detecting the potential of an aggregate intended for use in concrete for undergoing alkali-silica reaction resulting in potentially deleterious internal expansion. It is based on the NBRI Accelerated Test Method (**1-4**).[3] It is especially useful for aggregates that react slowly or produce expansion late in the reaction. However, it does not evaluate combinations of aggregates with cementitious materials nor are the test conditions representative of those encountered by concrete in service.

4.2 Because the specimens are exposed to a NaOH solution, the alkali content of the cement is not a significant factor in affecting expansions.

4.3 When excessive expansions (see Appendix X1) are observed, it is recommended that supplementary information be developed to confirm that the expansion is actually due to alkali-silica reaction. Sources of such supplementary information include: (1) petrographic examination of the aggregate

[1] This test method is under the jurisdiction of ASTM Committee C09 on Concrete and Concrete Aggregates and is the direct responsibility of Subcommittee C09.26 on Chemical Reactions.

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[2] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

[3] The boldface numbers in parentheses refer to a list of references at the end of the text.

***A Summary of Changes section appears at the end of this standard.**

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(Guide C 295) to determine if known reactive constituents are present; (2) examination of the specimens after tests (Practice C 856) to identify the products of alkali reaction; and (3) where available, field service records can be used in the assessment of performance.

4.4 When it has been concluded from the results of tests performed using this test method and supplementary information that a given aggregate should be considered potentially deleteriously reactive, the use of mitigative measures such as low-alkali portland cement, mineral admixtures, or ground granulated blast-furnace slag should be evaluated (see last sentence of 4.1).

5. Apparatus

5.1 The apparatus shall conform to Specification C 490, except as follows:

5.2 *Sieves*—Square hole, woven-wire cloth sieves, shall conform to Specification E 11.

5.3 *Mixer, Paddle, and Mixing Bowl*—Mixer, paddle, and mixing bowl shall conform to the requirements of Practice C 305, except that the clearance between the lower end of the paddle and the bottom of the bowl shall be 5.1 ± 0.3 mm (0.20 ± 0.01 in.).

5.4 *Tamper and Trowel*—The tamper and trowel shall conform to Test Method C 109/C 109M.

5.5 *Containers*—The containers shall be of such a nature that the bars can be totally immersed in either the water or 1N NaOH solution. The containers shall be made of material that can withstand prolonged exposure to 80 °C (176 °F) and must be resistant to a 1N NaOH solution (see Note 1). The containers must be so constructed that when used for storing specimens, the loss or gain of moisture is prevented by tight-fitting covers, by sealing, or both (see Note 2). The bars in the solution must be placed and supported so that the solution has access to the entire surface of the bar; therefore, it should be ensured that the specimens do not touch the sides of the container or each other. The specimens, if stood upright in the solution, shall not be supported by the metal gauge stud.

NOTE 1—The NaOH solution will corrode glass or metal containers.

NOTE 2—Some microwave-proof food storage containers made of polypropylene or high-density polythylene have been found to be acceptable.

5.6 *Oven, or Water Bath*—A convection oven or water bath with temperature control maintaining 80.0 ± 2.0 °C (176 ± 3.6 °F).

6. Reagents

6.1 *Sodium Hydroxide (NaOH)*—USP or technical grade may be used, provided the Na^+ and OH^- concentrations are shown by chemical analysis to lie between 0.99N and 1.01N.

6.2 *Purity of Water*—Unless otherwise indicated, references to water shall be understood to mean reagent water conforming to Type IV of Specification D 1193.

6.3 *Sodium Hydroxide Solution*—Each litre of solution shall contain 40.0 g of NaOH dissolved in 900 mL of water, and shall be diluted with additional distilled or deionized water to obtain 1.0 L of solution. The volume proportion of sodium hydroxide solution to mortar bars in a storage container shall be 4 ± 0.5 volumes of solution to 1 volume of mortar bars. The volume of a mortar bar may be taken as 184 mL. Include sufficient test solution to ensure complete immersion of the mortar bars.

6.3.1 **Warning**—Before using NaOH, review: (1) the safety precautions for using NaOH; (2) first aid for burns; and (3) the emergency response to spills, as described in the manufacturer's Material Safety Data Sheet or other reliable safety literature. NaOH can cause very severe burns and injury to unprotected skin and eyes. Suitable personal protective equipment should always be used. These should include full-face shields, rubber aprons, and gloves impervious to NaOH. Gloves should be checked periodically for pin holes.

7. Conditioning

7.1 Maintain the temperature of the molding room and dry materials at not less than 20 °C (68 °F) and not more than 27.5 °C (81.5 °F). The temperature of the mixing water, and of the moist closet or moist room, shall not vary from 23 °C (73.4 °F) by more than 1.7 °C (3 °F).

7.2 Maintain the relative humidity of the molding room at not less than 50 %. The moist closet or room shall conform to Specification C 511.

7.3 Maintain the storage oven or water bath in which the specimens are stored in the containers at a temperature of 80.0 ± 2.0 °C (176 ± 3.6 °F).

8. Sampling and Preparation of Test Specimens

8.1 *Selection of Aggregate*—Process materials proposed for use as fine aggregate in concrete as described in the section on Preparation of Aggregate with a minimum of crushing. Process materials proposed for use as coarse aggregate in concrete by crushing to produce as nearly as practical a graded product from which a sample can be obtained. Grade the sample as prescribed in Table 1. The sample shall represent the composition of the coarse aggregate as proposed for use.

8.1.1 When a given quarried material is proposed for use both as coarse and as fine aggregate, test it only by selection of an appropriate sample crushed to the fine aggregates sizes, unless there is reason to expect that the coarser size fractions have a different composition that the finer sizes and that these differences might significantly affect expansion due to reaction with the alkalies in cement or from the environment of service. In this case test the coarser size fractions in a manner similar to that employed in testing the fine aggregate sizes.

8.2 *Preparation of Aggregate*—Grade all aggregates to which this test method is applied in accordance with the requirements given in Table 1. Crush aggregates in which sufficient quantities of the sizes specified in Table 1 do not exist

TABLE 1 Grading Requirements

Sieve Size		Mass, %
Passing	Retained on	
4.75 mm (No. 4)	2.36 mm (No. 8)	10
2.36 mm (No. 8)	1.18 mm (No. 16)	25
1.18 mm (No. 16)	600 µm (No. 30)	25
600 µm (No. 30)	300 µm (No. 50)	25
300 µm (No. 50)	150 µm (No. 100)	15

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until the required material has been produced. In the case of aggregates containing insufficient amounts of one or more of the larger sizes listed in Table 1, and if no larger material is available for crushing, the first size in which sufficient material is available shall contain the cumulative percentage of material down to that size as determined from the grading specified in Table 1. When such procedures are required, make a special note thereof in the test report. After the aggregate has been separated into the various sieve sizes, wash each size with a water spray over the sieve to remove adhering dust and fine particles from the aggregate. Dry the portions retained on the various sieves and, unless used immediately, store each such portion individually in a clean container provided with a tight-fitting cover.

8.3 *Selection and Preparation of Cement*:

8.3.1 *Reference Cement*—Use a portland cement meeting the requirements of Specification C 150 (Note 3). In addition, the autoclave expansion in Test Method C 151 shall be less than 0.20 %.

NOTE 3—The alkali content of the cement has been found to have negligible (**3**) or minor (**6**) effects on expansion in this test.

8.3.2 *Preparation of Cement*—Pass cement for use in this test through an 850-µm (No. 20) sieve to remove lumps before use.

8.4 *Preparation of Test Specimens*:

8.4.1 *Number of Specimens*—Make at least three test specimens for each cement-aggregate combination.

8.4.2 *Preparation of Molds*—Prepare the specimen molds in accordance with the requirements of Practice C 490 except, the interior surfaces of the mold shall be covered with a release agent (see Note 4). A release agent will be acceptable if it serves as a parting agent without affecting the time of setting of the cement and without leaving any residue that will inhibit the penetration of water into the specimen.

NOTE 4—TFE-fluorocarbon tape complies with the requirements for a mold release agent.

8.4.3 *Proportioning of Mortar*—Proportion the dry materials for the test mortar using 1 part of cement to 2.25 parts of graded aggregate by mass for aggregates with a relative density (OD) at or above 2.45. For aggregates with a relative density (OD) below 2.45, determine the aggregate proportion as follows:

$$\textit{Aggregate proportion} = 2.25 \times D/2.65$$

where:

D = relative density (OD) of test aggregate.

8.4.3.1 For aggregates with a relative density (OD) equal to or greater than 2.45, the quantities of dry materials to be mixed at one time in the batch of mortar for making three specimens shall be 440 g of cement and 990 g of aggregate made up by recombining the portions retained on the various sieves in the grading prescribed in Table 1 (8.2). Use a water-cement ratio equal to 0.47 by mass (see Note 5).

8.4.3.2 For aggregates with a relative density (OD) less than 2.45, the quantities of dry materials to be mixed at one time in the batch of mortar for making three specimens shall be 440 g of cement and mass of aggregate shall be 440 g multiplied by the aggregate proportion determined in 8.4.3. This aggregate mass shall be made up by recombining the portions retained on the various sieves in the grading prescribed in Table 1 (8.2). Use a water-cement ratio equal to 0.47 by mass (see Note 5).

NOTE 5—Ruggedness tests indicated that mortar bar expansions were less variable at a fixed water to cement ratio than when gaged to a constant flow (**3**).

8.4.4 *Mixing of Mortar*—Mix the mortar in accordance with the requirements of Practice C 305.

8.4.5 *Molding of Test Specimens*—Mold test specimens within a total elapsed time of not more than 2 min and 15 s after completion of the original mixing of the mortar batch. Fill the molds with two approximately equal layers, each layer being compacted with the tamper. Work the mortar into the corners, around the gauge studs, and along the surfaces of the mold with the tamper until a homogeneous specimen is obtained. After the top layer has been compacted, cut off the mortar flush with the top of the mold and smooth the surface with a few strokes of the trowel.

9. Procedure

9.1 *Initial Storage and Reading*—Place each mold in the moist cabinet or room immediately after molds have been filled. The specimens shall remain in the molds for 24 ± 2 h. Remove the specimens from the molds and, while they are being protected from loss of moisture, properly identify and make an initial comparatory reading. Make and record the initial and all subsequent readings to the nearest 0.002 mm. Place the specimens made with each aggregate sample in a storage container with sufficient tap water to totally immerse them. Seal and place the containers in an oven or water bath at 80.0 ± 2.0 °C (176 ± 3.6 °F) for a period of 24 h.

9.2 *Zero Readings*—Remove the containers from the oven or water bath one at a time. Remove other containers only after the bars in the first container have been measured and returned to the oven or water bath. The time elapsed between removal and return of the specimens to the oven or water bath shall not exceed 10.0 min. Remove the bars one at a time from the water and dry their surface with a towel paying particular attention to the two metal gauge studs. Take the zero reading (see Note 6) of each bar immediately after drying, and read as soon as the bar is in position. Complete the process of drying and reading within 15 ± 5 s of removing the specimen from the water. After readings, leave the specimen on a towel until comparatory readings have been taken on the remainder of the bars. Place all specimens made with each aggregate sample in a container with sufficient 1N NaOH, at 80.0 ± 2.0 °C (176 ± 3.6 °F) for the samples to be totally immersed. Seal the container and return it to the oven or water bath.

NOTE 6—The reference bar should be read prior to each set of specimens since the heat from the mortar bars may cause the length of the comparator to change.

9.3 *Subsequent Storage and Measurement*—Make subsequent comparator readings of the specimens periodically, with at least three intermediate readings, for 14 days after the zero reading, at approximately the same time each day. If readings are continued beyond the 14-day period, take at least one

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reading per week. The procedure is identical to that described in the section on Zero Readings except that the specimens are returned to their own container after measurement.

10. Calculation

10.1 Calculate the difference between the zero comparatory reading of the specimen and the reading at each period to the nearest 0.001 % of the effective gauge length and record as the expansion of the specimen for that period. Report the average expansion of the three specimens of a given cement-aggregate combination to the nearest 0.01 % as the expansion for the combination for a given period.

11. Report

11.1 Report the following information:

11.1.1 Type and source of aggregate,

11.1.2 Type and source of portland cement,

11.1.3 Autoclave expansion and alkali content of cement as percent potassium oxide (K_2O), sodium oxide (Na_2O), and calculated sodium oxide (Na_2O) equivalent (Na_2O_{eq}= $\%Na_2O + 0.658 \times \%K_2O$),

11.1.4 Average length change in percent at each reading of the specimens,

11.1.5 Any relevant information concerning the preparation of aggregates, including the grading of the aggregate when it differs from that given in 8.2,

11.1.6 Any significant features revealed by examination of the specimens during and after test,

11.1.7 Amount of mixing water expressed as mass percent of cement,

11.1.8 A graph of the length change data from the time of the zero reading to the end of the 16 day period.

12. Precision and Bias

12.1 *Within-Laboratory Precision*—It has been found that the average within-laboratory coefficient of variation for materials with an average expansion greater than 0.1 % at 14 days is 2.94 % **(5)** (Note 7). Therefore, the results of two properly conducted tests within the same laboratory on specimens of a sample of aggregate should not differ by more than 8.3 % (Note 7) of the mean expansion.

12.2 *Multi-Laboratory Precision*—It has been found that the average multilaboratory coefficient of variation for materials with an average expansion greater than 0.1 % at 14 days is 15.2 % **(5)** (Note 7). Therefore, the results of two properly conducted tests in different laboratories on specimens of a sample of aggregate should not differ by more than 43 % (Note 7) of the mean expansion.

NOTE 7—These numbers represent, respectively, the (1s %) and (d2s %) limits as described in Practice C 670.

12.3 *Bias*—Since there is no accepted reference material for determining the bias of this test method, no statement on bias is being developed.

13. Keywords

13.1 aggregate; alkali-silica reactivity; length change; mortar; sodium hydroxide

APPENDIX

(Nonmandatory Information)

X1. INTERPRETATION OF TEST RESULTS

X1.1 There is good agreement in the published literature **(1,2,7-10)** for the following expansion limits:

X1.1.1 Expansions of less than 0.10 % at 16 days after casting are indicative of innocuous behavior in most cases (see Note X1.1).

X1.1.2 Expansions of more than 0.20 % at 16 days after casting are indicative of potentially deleterious expansion (see 4.3).

X1.1.3 Expansions between 0.10 and 0.20 % at 16 days after casting include both aggregates that are known to be innocuous and deleterious in field performance. For these aggregates, it is particularly important to develop supplemental information as described in 4.3. In such a situation, it may also be useful to take comparator readings until 28 days **(8,10)**.

NOTE X1.1—Some granitic gneisses and metabasalts have been found to be deleteriously expansive in field performance even though their expansion in this test was less than 0.10 % at 16 days after casting **(10)**. With such aggregate, it is recommended that prior field performance be investigated. In the absence of field performance data, mitigative measures should be taken as discussed in 4.4.

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REFERENCES

(1) Oberholster, R. E., and Davies, G.," An Accelerated Method for Testing the Potential Alkali Reactivity of Siliceous Aggregates." *Cement and Concrete Research*, Vol 16, 1986, pp. 181–189.

(2) Davies, G., and Oberholster, R. E., "Use of the NBRI Accelerated Test to Evaluate the Effectiveness of Mineral Admixtures in Preventing the Alkali-Silica Reaction," *Cement and Concrete Research*, Vol 17, 1987, pp. 97–107.

(3) Davies, G., and Oberholster, R. E., "An Interlaboratory Test Programme on the NBRI Accelerated Test to Determine the Alkali-Reactivity of Aggregates," National Building Research Institute, CSIRO, Special Report BOU 92-1987, Pretoria, RSA, 1987, 16 pp.

(4) Oberholster, R. E., "Alkali Reactivity of Siliceous Rock Aggregates: Diagnosis of the Reaction, Testing of Cement and Aggregate and Prescription of Preventative Measures," *Alkali in Concrete, Research and Practice*, Copenhagen, 1983, Danish Concrete Association, pp. 419–433.

(5) Rogers, C.A., "Multi-laboratory Study of the Accelerated Mortar Bar Test (ASTM Test Method C 1260) for Alkali-Silica Reaction," *Cement, Concrete, and Aggregates*, Vol 21, 1999, pp. 185–194.

(6) Hooton, R. D.," Interlaboratory Study of the NBRI Rapid Test Method and CSA Standardization Status," *Report EM-92*, Ontario Ministry of Transport, March 1990, pp. 225–240.

(7) Hooton, R. D., and Rogers, C. A., "Evaluation of Rapid Test Methods for Detecting Alkali-Reactive Aggregates," *Proceedings,* Eighth International Conference on Alkali-Aggregate Reaction, Kyoto, 1989, pp. 439–444.

(8) Hooton, R. D.," New Aggregate Alkali-Reactivity Test Methods," *Report MAT-91-14*, Ontario Ministry of Transportation, November 1991.

(9) Fournier, B., and Berube, M. A., "Application of the NBRI Accelerated Mortar Bar Test to Siliceous Carbonate Aggregates Produced in the St. Lawrence Lowlands, Part 2: Proposed Limits, Rates of Expansion, and Microstructure of Reaction Products," *Cement and Concrete Research*, Vol 21, 1991, pp. 1069–1082.

(10) Hooton, R. D., and Rogers, C. A., "Development of the NBRI Rapid Mortar Bar Test Leading to its Use in North America," *Proceedings*, Ninth International Conference on AAR in Concrete, London, 1992, pp. 461–467.

SUMMARY OF CHANGES

Committee C09 has identified the location of selected changes to this test method since the last issue, C 1260 – 05a, that may impact the use of this test method. (Approved June 1, 2007)

(*1*) Revised 1.1.

(*2*) Revised 8.4.3, 8.4.3.1, and 8.4.3.2.

Committee C09 has identified the location of selected changes to this test method since the last issue, C 1260 – 05, that may impact the use of this test method. (Approved December 15, 2005)

(*1*) Revised the Referenced Documents section.
(*2*) Added a Terminology section.
(*3*) Revised 8.4.3 and added new 8.4.3.1 and 8.4.3.2.

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Designation: C 1264 – 05

Standard Specification for Sampling, Inspection, Rejection, Certification, Packaging, Marking, Shipping, Handling, and Storage of Gypsum Panel Products[1]

This standard is issued under the fixed designation C 1264; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope

1.1 This specification covers sampling; inspection; rejection; certification; packaging and marking; and shipping, handling, and storage of gypsum panel products.

2. Sampling

2.1 When specified by the purchase agreement, samples of gypsum panel products shall be taken at the place of manufacture or at the destination. If the samples are taken at the destination, such samples shall be taken within 24 h of the receipt of the material.

2.2 At least 0.25 % of the number of gypsum panel products in a shipment, but not less than three gypsum panel products, shall be so selected as to be representative of the shipment and shall constitute a sample for the purpose of tests by the purchaser or user.

3. Inspection

3.1 Inspection of the gypsum panel products shall be agreed upon between the purchaser and the producer or supplier as part of the purchase agreement.

4. Rejection

4.1 Rejection of gypsum panel products that fails to conform to the requirements of the specification shall be reported to the producer or supplier promptly and in writing. The notice of rejection shall contain a statement documenting how the gypsum panel products has failed to conform to the requirements of the specification.

5. Certification

5.1 When specified in the purchase agreement, a producer's or supplier's report shall be furnished at the time of shipment certifying that the product is in compliance with the ASTM specification referencing this specification.

6. Packaging and Marking

6.1 Unless otherwise specified in the purchase agreement, each gypsum panel product or package shall have legibly marked thereon the following: the thickness, the name of the producer or supplier, the brand name, if any, and the ASTM specification for the product.

7. Shipping, Handling, and Storage

7.1 Gypsum panel products shall be shipped so as to be kept dry.

7.2 Gypsum panel products shall be stored so as to be kept dry, preferably inside a building. Gypsum panel products shall be neatly stacked flat with care taken to prevent sagging or damage to edges, ends, and surfaces.

7.3 Where necessary to store gypsum panel products outside, it shall be stacked flat, off the ground, supported on a level platform, and fully protected from weather and direct sunlight exposure.

8. Keywords

8.1 certification; gypsum; gypsum panel products; handling; inspection; marking; packaging; rejection; sampling; shipping; storage

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[1] This specification is under the jurisdiction of ASTM Committee C11 on Gypsum and Related Building Materials and Systems and is the direct responsibility of Subcommittee C11.01 on Specifications and Test Methods for Gypsum Products.

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Designation: C 1271 – 99 (Reapproved 2006)

Standard Test Method for X-ray Spectrometric Analysis of Lime and Limestone[1]

This standard is issued under the fixed designation C 1271; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope

1.1 This test method covers the X-ray emission spectrometric analysis of limestone, quicklime, hydrated lime, and hydraulic lime using wavelength dispersive instruments.

1.2 The values stated in SI units are to be regarded as the standard.

1.3 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.* Specific precautionary statements are given in Section 10.

2. Referenced Documents

2.1 *ASTM Standards:* [2]

C 25 Test Methods for Chemical Analysis of Limestone, Quicklime, and Hydrated Lime

C 50 Practice for Sampling, Sample Preparation, Packaging, and Marking of Lime and Limestone Products

C 51 Terminology Relating to Lime and Limestone (as used by the Industry)

E 50 Practices for Apparatus, Reagents, and Safety Considerations for Chemical Analysis of Metals, Ores, and Related Materials

E 135 Terminology Relating to Analytical Chemistry for Metals, Ores, and Related Materials

E 305 Practice for Establishing and Controlling Spectrochemical Analytical Curves[3]

E 456 Terminology Relating to Quality and Statistics

E 691 Practice for Conducting an Interlaboratory Study to Determine the Precision of a Test Method

E 1060 Practice for Interlaboratory Testing of Spectrochemical Methods of Analysis

E 1361 Guide for Correction of Interelement Effects in X-Ray Spectrometric Analysis

2.2 *NIST Documents:*[4]

ANSI-NIST Handbook 114

NIST Standards Catalog

3. Terminology

3.1 *Definitions:*

3.1.1 *emission spectroscopy*—unless otherwise specified, for definitions of terms used in this test method pertaining to emission spectroscopy, refer to Terminology E 135.

3.1.2 *lime*—unless otherwise specified, for definitions of terms used in this test method pertaining to lime, refer to Terminology C 51.

3.1.3 *statistical*—unless otherwise specified, for definitions of terms used in this test method pertaining to statistics, refer to Terminology E 456.

4. Summary of Test Method

4.1 A briquetted powder specimen or a fused-glass disk specimen is irradiated by a high-energy X-ray beam. The secondary X rays produced are dispersed by means of crystals, and the intensities are measured by suitable detectors at selected wavelengths. Data are collected based on the time required to reach a fixed number of counts, total count for a fixed time, or integration of voltage for a fixed time. Concentrations of the elements are determined by relating the measured radiation of unknown specimens to analytical curves prepared from reference materials of known composition.

5. Significance and Use

5.1 This procedure is suitable for manufacturing control and verifying that the product meets specifications. It provides rapid, multi-element determinations with sufficient accuracy to ensure product quality and minimize production delays. The analytical performance data included may be used as a benchmark to determine whether similar X-ray spectrometers provide equivalent precision and accuracy, or whether the performance of a particular X-ray spectrometer has changed.

6. Interferences

6.1 Interelement effects or matrix effects may exist for some of the elements listed. One way to compensate for these effects

[1] This test method is under the jurisdiction of ASTM Committee C07 on Lime and is the direct responsibility of Subcommittee C07.05 on Chemical Tests.

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[2] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

[3] Withdrawn.

[4] Available from National Institute of Standards and Technology (NIST), 100 Bureau Dr., Stop 3460, Gaithersburg, MD 20899-3460.

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is to prepare a series of calibration curves to cover the designated concentration ranges. The composition of the specimen being analyzed must match closely the composition of the reference materials used to prepare the calibration curve. Mathematical corrections, derived from empirical relationships or fundamental parameter calculations, may be used alternatively. Any of these are acceptable, providing that the analytical accuracy required by this test method is achieved.

6.2 Calcium is the primary component of the matrix analyzed by this test method. The analyst must be aware of all possible interferences and matrix effects of this element. Orders of all wavelengths may cause interference, for example, the effect of CaKβ1 (2nd order) on PKα1.

6.3 Contamination from the grinding apparatus is an ever-present source of interference of which the analyst must always be cognizant. For example, stainless steel will impart iron, chrome, and nickel to the prepared sample.

6.4 Spectral interferences from the X-ray tube may also occur, for example, line overlap from CrKβ1 on MnKα1 caused by a chrome target tube.

7. Apparatus

7.1 *Specimen Preparation Equipment*:

7.1.1 *Jaw Crusher*, for initial crushing of lumps.

7.1.2 *Plate Grinder or Pulverizer*, with one static and one rotating disk for further grinding.

7.1.3 *Rotary Disk Mill or Shatter Box*, with hardened grinding containers and timer control for final grinding.

7.2 *Briquetting Equipment*:

7.2.1 *Briquetting Press*, capable of providing pressures up to 550 MPa (80 000 psi). The press shall be equipped with a mold assembly that provides a briquet compatible with the X-ray specimen holder.

7.3 *Fusion Equipment*:

7.3.1 *Furnace or Gas Burners*, with a timer, capable of heating the sample and flux to at least 1000 °C and homogenizing the melt.

7.3.2 *Fusion Crucibles*:

7.3.2.1 *Vitreous Carbon or Graphite*, 20 to 30-mL capacity, with a flat bottom 30 to 35 mm in diameter.

7.3.2.2 *Platinum/Gold*, 95 % platinum/5 % gold alloy, 30 to 35-mL capacity.

7.3.2.3 *Platinum/Gold Casting Dish*, 95 % platinum/5 % gold alloy, 30 to 35-mL capacity, with a flat bottom 30 to 35 mm in diameter.

7.3.3 *Polishing Wheel*, suitable for polishing the fusion disk to obtain a uniform surface for irradiation. The analyst should be aware at all times of possible contamination from the polishing media used for surfacing the disk (6.3).

7.4 *Excitation Source*:

7.4.1 *X-Ray Tube Power Supply*, providing constant potential or rectified power of sufficient energy to produce secondary radiation of the specimen for the elements specified. The generator may be equipped with a line voltage regulator and current stabilizer.

7.4.2 *X-Ray Tubes*, with targets of various high-purity elements, capable of continuous operation at required potentials and currents, and that will excite the elements to be determined.

7.5 *Spectrometer*, designed for X-ray emission analysis and equipped with specimen holders and a specimen chamber. The chamber may contain a specimen spinner, and it must be equipped for vacuum operation.

7.5.1 *Analyzing Crystals*—Flat or curved crystals with optimized capability for diffraction of the wavelengths of interest.

7.5.2 *Collimator*, for limiting the characteristic X rays to a parallel bundle when flat crystals are used in the instrument. A collimator is not necessary for curved crystal optics.

7.5.3 *Detectors*, sealed or gas flow, proportional type, Geiger counters, scintillation counters or equivalent.

7.5.4 *Vacuum System*, providing for the determination of elements whose radiation is absorbed by air (atomic number below 20). The system shall consist of at least one vacuum pump, gage, and electrical controls to provide automatic pumpdown of the optical path and maintain a controlled pressure, usually 13 Pa or less.

7.6 *Measuring System*, consisting of electronic circuits capable of counting or integrating pulses received from the detectors. The counts, count rate, or integrated voltages may be displayed on meters, recorders, digital counters, or voltmeters. The counts, count rates, or integrated voltages can also be presented to a computer or programmable calculator for conversion to percent concentration. Pulse height analyzers may be required to provide more accurate measurements for some measurements.

8. Reagents and Materials

8.1 *Purity and Concentration of Reagents*—The purity and concentration of chemical reagents shall conform to the requirements prescribed in Practices E 50.

8.2 *Binders*—Various binders have been used successfully to prepare briquettes suitable for presentation to the instrument. As a general rule, the binder should not contain an element that will be determined. In addition, the sample to binder ratio must be present in the analytical sample as in the reference materials that were used to establish the calibration.

8.3 *Fluxes*—Various fluxes have been used successfully to prepare fusion disks. The flux must be capable of dissolving or dispersing the analyzed elements in an homogeneous and reproducible fashion in the melt. The prepared disks must then be suitable for presentation to the instrument.

8.4 *Detector Gas (P-10)*, consisting of a mixture of 90 % argon and 10 % methane for use with gas flow proportional counters only.

9. Reference Materials

9.1 Certified reference materials are available from the National Institute for Standards and Technology (NIST) and other international certification agencies. Refer to Test Methods C 25 for a current listing.

9.2 Reference materials with matrixes similar to that of the test specimen and containing varying amounts of the elements to be determined may be used provided that they have been analyzed in accordance with ASTM standard test methods.

9.3 Standard additions method or spiked samples may also be used to create standards for which appropriate reference

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materials are not available for an element desired to be analyzed. The matrix material must match that of the test specimen.

10. Safety Precautions

10.1 Occupational health and safety standards for ionizing radiation shall be observed at all X-ray emission spectrometer installations. It is also recommended that operating and maintenance personnel follow the guidelines of safe operating procedures given in current handbooks and publications from the original equipment manufacturer, NIST, U.S. Government Printing Office, or similar handbooks on radiation safety. See NIST Standards Catalog and ANSI-NIST Handbook 114.

10.2 *Personnel*—X-ray equipment shall be used only under the guidance and supervision of a responsible, qualified person.

10.3 *Monitoring Devices*—Either film badges or dosimeters shall be worn by all operating and maintenance personnel. Periodic radiation surveys of the equipment for leaks and excessive scattered radiation shall be made by a qualified person using an ionization chamber detector to meet local, state, and federal radiation standards. The personal film badge survey record, the radiation survey record, and an equipment maintenance record shall be available upon request.

10.4 Special precautions for operators and maintenance personnel shall be posted at the equipment site.

10.5 Radiation caution signs shall be posted near the X-ray equipment and at all entrances to the radiation area.

10.6 Fail-Safe "X-ray on" warning lights shall be used on the equipment.

11. Sampling

11.1 Gross sample is to be taken in accordance with Methods C 50.

11.2 Sample preparation is to be performed in accordance with Methods C 50 and Test Methods C 25.

11.3 Special preparation may be required to grind the analytical sample finer than is required in 11.2.

12. Preparation of Reference Materials and Test Specimens

12.1 Treat reference materials and specimens exactly the same way throughout the procedure. Either briquetted powder or fused disk specimens may be used.

13. Preparation of Apparatus

13.1 Prepare and operate the spectrometer in accordance with the manufacturer's instructions, using the parameters given in Table 1. Once established, control all instrument parameters closely to ensure repeatable analyses.

14. Calibration and Standardization

14.1 *Calibration (Preparation of Analytical Curves)*—Select a sufficient number of reference materials to cover the concentration ranges of the elements sought. Average duplicate intensity measurements of each reference material, and establish a calibration curve for each element in accordance with Practice E 305. Establish the curve by a least squares or multiple regression fit of the X-ray intensity measurements versus the corresponding weight percent concentrations of the element in the reference materials.

TABLE 1 Analytical Lines and Crystals

Element	Wavelength, A	Crystals
Sodium	11.91	TLAP, multilayer
Magnesium	9.889	ADP, TLAP, RAP, multilayer
Aluminum	8.338	PET, EDdT, RAP
Silicon	7.126	PET, EDdT, RAP, InSb
Phosphorus	6.155	Ge, PET
Sulfur	5.373	Ge, PET, NaCl
Chlorine	4.729	PET, Ge
Potassium	3.742	LiF 200, PET
Calcium	3.359	LiF 200, PET
Titanium	2.750	LiF 200, LiF 220
Manganese	2.103	LiF 200, LiF 220
Iron	1.937	LiF 200, LiF 220
Strontium	0.8766	LiF 200, LiF 220
Barium	2.775	LiF 200, LiF 220
Lead	1.175	LiF 200, LiF 220

14.2 *Standardization (Analytical Curve Adjustment)*—Verify that the calibration curve for each element has not drifted using a control reference material. Drift is indicated by a change in counts that exceeds the normal variation of counts for that element. A change of 1 % or greater usually signifies that the calibration curve for that element has drifted and should thus be adjusted. Re-measure the reference materials to verify that acceptable analyses are obtained after the adjustments are made.

15. Procedure

15.1 *Excitation*—Introduce the specimen into the specimen chamber, using care not to contaminate the surface to be excited. Produce the secondary fluorescence using the equipment used in 7.4.

15.2 *Radiation Measurements*—Obtain and record the counting rate measurement for each element. Either fixed count or fixed time modes may be used. A predetermined minimum count rate is obtainable only after unacceptable long counting times for lime materials, with the exception of the major oxides (Si, Fe, Al, Ca, and Mg). A minimum counting time of 60 s is acceptable.

15.3 *Spectral Interferences*—Some X-ray spectrometers will not resolve radiation completely from several line overlaps. Care must therefore be exercised in these cases. Alternate wavelengths without interference may be used. Otherwise, mathematical calculations must be used to correct for the interferences.

NOTE 1—If a goniometer is used, the setting for the 2 θ peak must be determined experimentally within each laboratory. Periodic checks to verify the setting are advisable.

15.4 *Replicate Measurements*—Make a minimum of two measurements on each test specimen. The performance of an X-ray spectrometer is not improved significantly by making multiple measurements on the same surface of the same specimen; however, for those elements not having sufficient counts in the predetermined time, the statistics near the detection limit will improve with multiple exposures. Confidence in the accuracy of analysis will also improve by analyzing more than one specimen.

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16. Calculation of Results

16.1 Determine the concentration of the various elements using the radiation measurements for the test specimen and the appropriate analytical curves.

16.2 If mathematical corrections must be made to correct the concentrations for interelement effects, any one of a number of correction procedures may be used. Refer to the equipment manufacturer's manual for the instrument being used. Computers are normally interfaced to the X-ray spectrometers in laboratories using such correction systems. Refer to Guide E 1361 for a guide to interelement corrections.

NOTE 2—With computer-controlled X-ray spectrometers that convert output signals automatically to percent concentrations and make interelement corrections, calculated results are usually printed without operator involvement.

17. Precision and Bias

17.1 *Precision*—An acceptable number of laboratories tested this test method in accordance with Practice E 1060. Precision data are provided in the annex.

17.1.1 *Repeatability (R1)*—Calculations for within-laboratory precision are listed in the annex.

17.1.2 *Reproducibility (R2)*—Calculations for between-laboratory precision are listed in the annex.

17.2 *Bias (Accuracy)*—Bias data calculated in accordance with Practice E 1060 are included in the annex.

18. Keywords

18.1 chemical analysis; hydrated lime; hydraulic lime; limestone; quicklime; wavelength dispersive; X-ray spectrometric

ANNEX

(Mandatory Information)

A1. HIGH CALCIUM LIMESTONE BY THE BRIQUETTE METHOD

A1.1 *Summary of Test Method*:

A1.1.1 A briquetted powder specimen of high calcium limestone is prepared and irradiated as directed in Test Method C 1271.

A1.2 *Provisions*:

A1.2.1 There are no special provisions in the test method that are not referred to in Test Method C 1271.

A1.3 *Precision and Bias*:

A1.3.1 *Round Robin*—An interlaboratory study, consistent with the guidelines of Practice E 691, was conducted in 1997. Five high calcium limestone materials were analyzed by eight laboratories performing replicate measurements on four briquettes.

A1.3.2 *Precision*—The relative precision of this test method, characterized by repeatability (S_r and r) and reproducibility (S_R and R) has been determined for the materials and elements to be:

A1.3.2.1 Silicon as % Silicon Dioxide (% SiO_2):

Material	Average	S_r	S_R	r	R
S-1143	0.054	0.012	0.022	0.034	0.062
S-1145	0.156	0.009	0.048	0.026	0.133
S-1142	0.627	0.011	0.070	0.032	0.197
S-1141	0.875	0.026	0.084	0.071	0.234
S-1144	1.866	0.062	0.091	0.174	0.254

A1.3.2.2 Iron as % Ferric Oxide (% Fe_2O_3):

Material	Average	S_r	S_R	r	R
S-1143	0.0244	0.0013	0.0156	0.0038	0.0436
S-1145	0.0359	0.0018	0.0067	0.0050	0.0188
S-1141	0.1357	0.0023	0.0062	0.0064	0.0173
S-1142	0.1917	0.0021	0.0168	0.0058	0.0469
S-1144	0.8792	0.0137	0.0388	0.0383	0.1087

A1.3.2.3 Aluminum as % Aluminum Oxide (% $A1_2O_3$):

Material	Average	S_r	S_R	r	R
S-1143	0.0463	0.0015	0.0259	0.0042	0.0724
S-1145	0.0736	0.0040	0.0330	0.0111	0.0924
S-1142	0.1142	0.0030	0.0321	0.0083	0.0899
S-1141	0.1159	0.0036	0.0330	0.0102	0.0924
S-1144	0.4404	0.0163	0.0444	0.0457	0.1244

A1.3.2.4 Calcium as % Calcium Oxide (% CaO):

Material	Average	S_r	S_R	r	R
S-1144	53.347	0.150	0.295	0.421	0.826
S-1141	53.683	0.159	0.428	0.446	1.199
S-1142	54.304	0.127	0.359	0.356	1.006
S-1145	55.599	0.110	0.371	0.307	1.039
S-1143	55.837	0.143	0.284	0.401	0.794

A1.3.2.5 Magnesium as % Magnesium Oxide (% MgO):

Material	Average	S_r	S_R	r	R
S-1143	0.176	0.015	0.085	0.042	0.238
S-1145	0.216	0.006	0.085	0.017	0.237
S-1144	0.637	0.007	0.024	0.021	0.067
S-1142	0.919	0.010	0.039	0.028	0.109
S-1141	1.406	0.049	0.106	0.138	0.298

A1.3.2.6 Manganese as % Manganese (% Mn):

Material	Average	S_r	S_R	r	R
S-1145	0.0024	0.0003	0.0016	0.0009	0.0044
S-1143	0.0035	0.0003	0.0015	0.0009	0.0041
S-1142	0.0170	0.0036	0.0046	0.0101	0.0128
S-1141	0.0248	0.0003	0.0021	0.0007	0.0059
S-1144	0.0900	0.0004	0.0196	0.0011	0.0550

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A1.3.3 *Repeatability*—The difference in absolute value between test results of the averages of two briquettes of the same sample, carried out separately and consecutively, in the same laboratory by the same operator using the same apparatus, may be expected to occur with a probability of approximately 0.95 (95 % confidence level). The repeatability limit for this test method is the following:

Silicon as % Silicon Dioxide (% SiO_2)	0.009 + 0.081 *x*
Iron as % Ferric Oxide (% Fe_2O_3)	0.0015 + 0.0411 *x*
Aluminum as % Aluminum Oxide (% Al_2O_3)	0.1038 *x*
Calcium as % Calcium Oxide (% CaO)	0.386
Magnesium as % Magnesium Oxide (% MgO)	0.0751 *x*
Manganese as % Manganese (% Mn)	0.0027

where: *x* is the average of test results from two briquettes.

A1.3.4 *Reproducibility*—The difference in absolute value of replicate determinations, carried out in different laboratories using samples taken at random from a single sample prepared from the same bulk sample after the last stage of reduction, may be expected to occur with a probability of approximately 0.95 (95 % confidence level). The reproducibility limit for this test method is the following:

Silicon as % Silicon Dioxide (% SiO_2)	0.109 + 0.093 *x*
Iron as % Ferric Oxide (% Fe_2O_3)	0.0227 + 0.0963 *x*
Aluminum as % Aluminum Oxide (% Al_2O_3)	0.0768 + 0.1104 *x*
Calcium as % Calcium Oxide (% CaO)	0.973
Magnesium as % Magnesium Oxide (% MgO)	0.1781 + 0.0174 *x*
Manganese as % Manganese (% Mn)	0.588 *x*

where: *x* is the average of test results.

A1.3.5 *Bias*—Certified reference materials are used for the calibration of this test method. No bias is expected for the method.

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Designation: C 1278/C 1278M – 07a

Standard Specification for Fiber-Reinforced Gypsum Panel[1]

This standard is issued under the fixed designation C 1278/C 1278M; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope*

1.1 This specification covers fiber-reinforced gypsum panels described in 1.1.1-1.1.4.

1.1.1 *Interior Fiber-Reinforced Gypsum Panels* are designed to be used for walls, ceilings, or partitions and affords a suitable surface to receive decoration.

1.1.2 *Water-Resistant Fiber-Reinforced Gypsum Backing Panels* are designed primarily to be used as a base for the application of ceramic or plastic tile on walls or ceilings. This product is also suitable for decoration.

1.1.3 *Exterior Fiber-Reinforced Gypsum Soffit Panels* are designed for use on exterior soffits and carport ceilings that are completely protected from contact with liquid water.

1.1.4 *Water-Resistant Exterior Fiber-Reinforced Gypsum Sheathing Panels* are designed for use as sheathing on buildings.

1.1.5 *Interior Fiber-Reinforced Gypsum Underlayment Panels* are designed for use as a base for application of finished flooring materials.

1.1.6 *Fiber-Reinforced Gypsum Board Panels* are designed for use in roofing systems.

1.2 Specifications applicable to all fiber-reinforced gypsum panels are located in Sections 1-4 and 11-13 except as modified by applicable product sections. Specifications applicable to specific panels are located in the following sections:

Interior Fiber-Reinforced Gypsum Panels	5
Water-Resistant Fiber-Reinforced Gypsum Backing Panels	6
Exterior Fiber-Reinforced Gypsum Soffit Panels	7
Water-Resistant Exterior Fiber-Reinforced Gypsum Sheathing Panels	8
Interior Fiber-Reinforced Gypsum Underlayment Panels	9
Fiber-Reinforced Gypsum Roof Board Panels	10

1.3 The values stated in either inch-pound units or SI (metric) are to be regarded separately as the standard. Within the text, the SI units are shown in brackets. The values stated in each system shall be used independently of the other. Values from the two systems shall not be combined.

1.4 The text of this specification references notes and footnotes that provide explanatory material. These notes and footnotes shall not be considered as requirements of the standard.

2. Referenced Documents

2.1 *ASTM Standards:* [2]

C 11 Terminology Relating to Gypsum and Related Building Materials and Systems

C 22/C 22M Specification for Gypsum

C 473 Test Methods for Physical Testing of Gypsum Panel Products

C 645 Specification for Nonstructural Steel Framing Members

C 1264 Specification for Sampling, Inspection, Rejection, Certification, Packaging, Marking, Shipping, Handling, and Storage of Gypsum Panel Products

D 1037 Test Methods for Evaluating Properties of Wood-Base Fiber and Particle Panel Materials

E 84 Test Method for Surface Burning Characteristics of Building Materials

E 96/E 96M Test Methods for Water Vapor Transmission of Materials

E 119 Test Methods for Fire Tests of Building Construction and Materials

3. Terminology

3.1 *Definitions*—Definitions of terms shall be in accordance with Terminology C 11.

3.1.1 *nominal thickness*, *n*—the manufacturer-stated fractional value of thickness of the gypsum panel product expressed in decimal value to the nearest one-thousandth (0.001) of an inch.

4. Materials and Manufacture

4.1 Fiber-reinforced gypsum panels shall consist essentially of gypsum with fibers dispersed throughout.

4.1.1 *Gypsum*—Specification C 22/C 22M.

[1] This specification is under the jurisdiction of ASTM Committee C11 on Gypsum and Related Building Materials and Systems and is the direct responsibility of Subcommittee C11.01 on Specifications and Test Methods for Gypsum Products.

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[2] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

***A Summary of Changes section appears at the end of this standard.**

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4.1.2 *Fibers*—Cellulose, derived from paper, paperboard stock, wood, or other organic material.

4.2 The back surface of foil-backed fiber-reinforced gypsum panels shall in addition be covered with aluminum foil.

4.3 Water-resistant fiber-reinforced gypsum panels shall be treated with a material that imparts water resistance throughout.

4.4 Fiber-reinforced gypsum panels, type X (special fire-resistant) designates fiber-reinforced gypsum panels complying with this specification that provide not less than 1-h fire resistance rating for panels ⅝-in. [15.9-mm] thick or ¾-h fire resistance rating for panels ½-in. [12.7-mm] thick, applied parallel with and on each side of load bearing 2 by 4 wood studs spaced 16 in. [406 mm] on center with 6d coated nails, 1⅞-in. [48-mm] long, 0.0915-in. [2.3-mm] diameter shank, ¼-in. [6.4-mm] diameter heads, spaced 7 in. [178 mm] on center with fiber-reinforced gypsum panel joints staggered 16 in. [406 mm] on each side of the partition and tested in accordance with Test Methods E 119.

NOTE 1—Consult producers for independent test data on assembly details and fire resistance ratings for other types of construction. See fire test reports or listings from recognized fire testing laboratories for assembly particulars, materials, and ratings.

4.5 Fiber-reinforced gypsum panels shall have a flame spread index of not more than 25 when tested in accordance with Test Method E 84.

4.6 *Physical Properties, Dimensions, and Tolerances of Gypsum Panel*:

4.6.1 Specimens shall be taken from samples obtained in accordance with Specification C 1264.

4.6.1.1 Specimens shall be tested in accordance with Test Methods C 473.

4.6.2 *Core, End, and Edge Hardness*—The specimens shall have an average hardness of not less than 20 lbf [90 N] when tested in accordance with Method B.

4.6.3 *Edges and Ends*—The edges and ends shall be straight.

4.6.4 *Length*—The nominal length shall be from 6 to 24 ft [1830 to 7320 mm], with a tolerance of ± ¼ in. [6 mm] from the specified length.

4.6.5 *Tapered Edge Depth*—The average thickness of the edge of recessed or tapered edge shall be not less than 0.020 in. [0.51 mm] but not more than 0.090 in. [2.29 mm] less than the average thickness of the fiber-reinforced gypsum panel.

5. Interior Fiber-Reinforced Gypsum Panels

5.1 *Physical Properties of Interior Fiber-Reinforced Gypsum Panels*:

5.1.1 *Flexural Strength*—The specimens shall be tested face up and face down. The average breaking load shall be not less than the following:

Thickness, in. [mm]	Method B, lbf [N]
½ [12.7]	110 [490]
⅝ [15.9]	155 [690]

5.1.2 *Humidified Deflection*—The specimens shall have an average deflection of not more than the following:

Thickness, in. [mm]	Deflection, eighths of an inch, [mm]
½ [12.7]	3 [10]
⅝ [15.9]	2 [6]

5.1.3 *Nail Pull Resistance*—The specimens shall have an average nail pull resistance of not less than the following:

Thickness, in. [mm]	Method B, lbf [N]
½ [12.7]	120 [535]
⅝ [15.9]	145 [645]

5.2 *Dimensions and Tolerances of Interior Fiber-Reinforced Gypsum Panel*:

5.2.1 Specimens shall be taken from samples in accordance with Specification C 1264.

5.2.1.1 Specimens shall be tested in accordance with Test Methods C 473.

5.2.2 *Thickness*—The thickness shall be ½ or ⅝ in. [12.7 or 15.9 mm] with tolerances of ± 0.015 in. [± 0.40 mm], and with a local tolerance of ± 0.030 in. [± 0.80 mm].

5.2.3 *Width*—The width shall be up to 54 in. [1370 mm], with a tolerance of 3⁄32 in. [3 mm] under the specified width.

5.2.4 *End Squareness*—Corners shall be square with a tolerance of ± ⅛ in. [± 3 mm] in the full width of the panel.

5.3 *Edges*—The edges shall be either square, beveled, featured, tapered, or featured and tapered.

5.4 *Foil-Backed Fiber-Reinforced Gypsum Panels*:

5.4.1 Foil-backed fiber-reinforced gypsum panels shall meet all of the requirements for fiber-reinforced gypsum panels. In addition, aluminum foil shall be bonded to the back surface.

5.4.2 When tested in accordance with Test Methods E 96/E 96M, the permeance of foil-backed fiber-reinforced gypsum panels shall be not more than 0.30 perm [17 ng/Pa·s·m^2] (Desiccant Method) for the condition of 50 % relative humidity on the face of the panel and 0 % relative humidity on the foil-covered back side of the panel.

6. Water-Resistant Fiber-Reinforced Gypsum Backing Panels

6.1 *Physical Properties of Water-Resistant Fiber-Reinforced Gypsum Backing Panels*:

6.1.1 *Flexural Strength*—The specimens shall be tested face up and face down. The average breaking load shall be not less than the following:

Thickness, in. [mm]	Method B, lbf [N]
½ [12.7]	110 [490]
⅝ [15.9]	155 [690]

6.1.2 *Humidified Deflection*—The specimens shall have an average deflection of not more than the following:

Thickness, in. [mm]	Deflection, eighths of an inch, [mm]
½ [12.7]	3 [10]
⅝ [15.9]	2 [6]

6.1.3 *Nail Pull Resistance*—The specimens shall have an average nail pull resistance of not less than the following:

Thickness, in. [mm]	Method B, lbf [N]
½ [12.7]	120 [535]
⅝ [15.9]	145 [645]

6.1.4 *Water Resistance*—The specimens shall have an average water absorption of not more than 5 weight percentage after 2-h immersion.

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6.1.5 *Surface Water Absorption*—The specimens shall have an average face surface water absorption of not more than 1.6 g after two hours of elapsed time.

6.2 *Dimensions and Tolerances of Water-Resistant Fiber-Reinforced Gypsum Backing Panel*:

6.2.1 Specimens shall be taken from samples obtained in accordance with Specification C 1264.

6.2.1.1 Specimens shall be tested in accordance with Test Methods C 473.

6.2.2 *Thickness*—The nominal thickness shall be ½ or ⅝ in. [12.7 or 15.9 mm] with tolerances of ± 1/64 in. [± 0.4 mm], and with a local tolerance of ± 1/32 in. [± 0.8 mm].

6.2.3 *Width*—The width shall be up to 54 in. [1370 mm], with a tolerance of 3/32 in. [3 mm] under the specified width.

6.2.4 *End Squareness*—Corners shall be square with a tolerance of ± ⅛ in. [± 3 mm] in the full width of the panel.

6.3 *Edges*—The edges shall be either square, beveled, featured, tapered, or featured and tapered.

7. Exterior Fiber-Reinforced Gypsum Soffit Panels

7.1 *Physical Properties of Exterior Fiber-Reinforced Gypsum Soffit Panels*:

7.1.1 *Flexural Strength*—The specimens shall be tested face up and face down. The average breaking load shall be not less than the following:

Thickness, in. [mm]	Method B, lbf [N]
½ [12.7]	110 [490]
⅝ [15.9]	155 [690]

7.1.2 *Humidified Deflection*—The specimens shall have an average deflection of not more than the following:

Thickness, in. [mm]	Deflection, eighths of an inch, [mm]
½ [12.7]	3 [10]
⅝ [15.9]	2 [6]

7.1.3 *Nail Pull Resistance*—The specimens shall have an average nail pull resistance of not less than the following:

Thickness, in. [mm]	Method B, lbf [N]
½ [12.7]	120 [535]
⅝ [15.9]	145 [645]

7.2 *Dimensions and Tolerances of Exterior Fiber-Reinforced Gypsum Soffit Panel*:

7.2.1 Specimens shall be taken from samples obtained in accordance with Specification C 1264.

7.2.1.1 Specimens shall be tested in accordance with Test Methods C 473.

7.2.2 *Thickness*—The nominal thickness shall be ½ or ⅝ in. [12.7 or 15.9 mm] with tolerances in the thickness of ± 1/64 in. [± 0.4 mm], and with a local tolerance of ± 1/32 in. [± 0.8 mm].

7.2.3 *Width*—The width shall be up to 54 in. [1370 mm], with a tolerance of 3/32 in. [3 mm] under the specified width.

7.2.4 *End Squareness*—Corners shall be square with a tolerance of ± ⅛ in. [± 3 mm] in the full width of the panel.

7.3 *Edges*—The edges shall be either square, beveled, featured, tapered, or featured and tapered.

8. Water-Resistant Exterior Fiber-Reinforced Gypsum Sheathing Panels

8.1 *Physical Properties of Water-Resistant Exterior Fiber-Reinforced Gypsum Sheathing Panels*:

8.1.1 *Flexural Strength*—The specimens shall be tested face up and face down. The average breaking load shall be not less than the following:

Thickness, in. [mm]	Method B, lbf [N]
½ [12.7]	110 [490]
⅝ [15.9]	155 [690]

8.1.2 *Humidified Deflection*—The specimens shall have an average deflection of not more than the following:

Thickness, in. [mm]	Deflection, eighths of an inch, [mm]
½ [12.7]	3 [10]
⅝ [15.9]	2 [6]

8.1.3 *Nail Pull Resistance*—The specimens shall have an average nail pull resistance of not less than the following:

Thickness, in. [mm]	Method B, lbf [N]
½ [12.7]	120 [535]
⅝ [15.9]	145 [645]

8.1.4 *Water Resistance of Water-Resistant Exterior Fiber-Reinforced Gypsum Sheathing Panel*—The specimens shall have an average water absorption of not more than 10 weight percentage after 2-h immersion.

8.2 *Dimensions and Tolerances of Water-Resistant Exterior Fiber-Reinforced Gypsum Sheathing Panels*:

8.2.1 Specimens shall be taken from samples obtained in accordance with Specification C 1264.

8.2.1.1 Specimens shall be tested in accordance with Test Methods C 473.

8.2.2 *Thickness*—The nominal thickness shall be from ½ or ⅝ in. [12.7 or 15.9 mm] with tolerances of ± 1/32 in. [± 0.8 mm], and with a local tolerance of ± 1/16 in. [± 1.6 mm].

8.2.3 *Width*—The nominal width shall be 24 or 48 in. [610 or 1220 mm], with a tolerance of ⅛ in. [3.2 mm] under the specified width.

8.2.4 *End Squareness*—Corners shall be square with a tolerance of ± ⅛ in. [± 3 mm] in the full width of the panel.

8.3 *Edges*—The edges shall be either square or V-tongue and groove.

9. Interior Fiber-Reinforced Gypsum Underlayment Panels

9.1 *Physical Properties of Interior Fiber-Reinforced Gypsum Underlayment Panels*:

9.1.1 *Flexural Strength*—The specimens shall be tested face up and face down. The average breaking load shall be not less than the following:

Thickness, in. [mm]	Method B, lbf [N]
¼ [6.4]	40 [175]
⅜ [9.5]	70 [310]
½ [12.7]	110 [490]

9.1.2 *Nail Pull resistance*—The specimens shall have an average nail pull resistance of not less than the following:

Thickness, in. [mm]	Method B, lbf [N]
¼ [6.4]	70 [310]
⅜ [9.5]	90 [400]
½ [12.7]	120 [535]

9.2 *Dimensions and Tolerances of Interior Fiber-Reinforced Gypsum Underlayment Panels*:

9.2.1 Specifications shall be taken from samples in accordance with Specification C 1264.

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9.2.2 *Thickness*—The nominal thickness shall be ¼ , ⅜ , or ½ in. [6.4, 9.5, or 12.7 mm] with tolerance of ± 0.015 in. [± 0.4 mm], and with a local tolerance of ± 0.030 in. [± 0.8 mm].

9.2.3 *End Squareness* —Corners shall be square with a tolerance of ± 0.125 in. [± 3 mm] in the full width of the panel.

9.3 *Edges*—Edges shall be square.

9.4 *Water Absorption*

9.4.1 Specimens shall be tested in accordance with Test Methods C 473.

9.4.2 Water absorption shall not exceed 10 %.

9.5 *Thickness Swelling*

9.5.1 Specimens shall be tested in accordance with Thickness Swelling in Test Methods D 1037.

9.5.2 The specimens shall have an average thickness swelling of no more than the following:

Thickness, in. [mm]	Method A and B
¼ [6.4]	1 %
⅜ [9.5]	1 %
½ [12.7]	1 %

10. Fiber-Reinforced Gypsum Roof Board Panels

10.1 *Physical Properties of Fiber-Reinforced Gypsum Roof Board Panels*:

10.1.1 *Flexural Strength*—The specimens shall be tested face up and face down. The average breaking load shall be not less than the following:

Thickness, in. [mm]	Method B, lbf [N]
¼ [6.4]	40 [175]
⅜ [9.5]	70 [310]
½ [12.7]	110 [490]
⅝ [15.9]	155 [690]

10.1.2 *Nail Pull resistance*—The specimens shall have an average nail pull resistance of not less than the following:

Thickness, in. [mm]	Method B, lbf [N]
¼ [6.4]	70 [310]
⅜ [9.5]	90 [400]
½ [12.7]	120 [535]
⅝ [15.9]	145 [645]

10.2 *Dimensions and Tolerances of Fiber-Reinforced Gypsum Roof Deck Cover Board Panels*:

10.2.1 Specifications shall be taken from samples in accordance with Specification C 1264.

10.2.2 *Thickness*—The nominal thickness shall be ¼ , ⅜ , ½ , ⅝ in. [6.4, 9.5, 12.7, 15.9 mm] with tolerance of ± 0.030 in. [± 0.4 mm], and with a local tolerance of ± 0.015 in. [± 0.8 mm].

10.2.3 *End Squareness*—Corners shall be square with a tolerance of ± ⅛ in. [± 3 mm] in the full width of the panel.

10.3 *Edges*—Edges shall be square.

10.4 *Water Absorption*

10.4.1 Specimens shall be tested in accordance with Test Methods C 473.

10.4.2 Water absorption shall not exceed 10 %.

11. Finish and Appearance

11.1 The surfaces of the fiber-reinforced gypsum panels shall be true and free from imperfections that would render the panels unfit for use with or without decoration.

12. Sampling, Inspection, Rejection, Certification, Packaging, Marking, Shipping, Handling, and Storage

12.1 Shall be in accordance with Specification C 1264.

13. Keywords

13.1 ceiling; fiber-reinforced gypsum panels; foil-backed; FRGP; gypsum; gypsum panel products; partition; sheathing; soffit; type X; wall; water-resistant

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APPENDIXES

(Nonmandatory Information)

This Appendix gives general information and also suggestions for inclusions to be made elsewhere by the specifier. They are not part of this specification.

The definition of type X as given in 4.4 and the alternate definition given in this appendix, are intended only as a test to define the gypsum board as meeting the requirements of type X. These tests do not indicate a preferred application, nor do they limit the use of the product in other fire-rated assemblies.

All gypsum panel products for which type X is defined, except gypsum lath and gypsum shaftliner board, use the same test for type X products, therefore the type X designation indicates a consistent level of fire resistance.

X1. ALTERNATE DEFINITION FOR TYPE X

X1.1 Fiber-reinforced gypsum panels, type X (special fire-resistant) designates fiber-reinforced gypsum panels providing a greater fire resistance than regular fiber-reinforced gypsum panels of the same thickness. Type X (special fire-resistant) fiber-reinforced gypsum panels, when tested in accordance with Test Methods E 119, shall provide the following minimum fire resistance ratings for the assemblies described:

X1.1.1 One hour for a ⅝-in. [15.9-mm] thickness applied to a partition in a single layer application on each side of 3⅝-in. [92-mm] deep non-loadbearing galvanized steel studs complying with Specification C 645 spaced 24 in. [610 mm] on center. The ⅝-in. [15.9-mm] thick fiber-reinforced gypsum panels 48-in. [1220-mm] wide shall be attached using 1-in. [25-mm] long drywall screws spaced 8 in. [203 mm] on center along the edges and ends, and 12 in. [305 mm] along intermediate studs. All joints shall be oriented parallel to and located over studs and staggered on opposite sides of the assembly, and

X1.1.2 Two hours for a ½-in. [12.7-mm] thickness applied to a partition in a double layer application on each side of 2½-in. [64-mm] deep non-loadbearing galvanized steel studs complying with Specification C 645 spaced 24 in. [610 mm] on center. The base layer 48-in. [1220-mm] wide shall be attached using 1-in. [25-mm] long drywall screws spaced 12 in. [305 mm] on center along panel edges, ends and along intermediate studs. Joints shall be oriented parallel to and located over studs and staggered on opposite sides of the assembly. The face layer 48-in. [1220-mm] wide shall be attached using 1⅝-in. [41-mm] long drywall screws spaced 12 in. [305 mm] along panel edges, ends and along intermediate studs. Joints shall be oriented parallel to and located over studs, offset 24 in. [610 mm] from the base layer joints, and staggered on opposite sides of the assembly.

X2. INSTALLATION RECOMMENDATIONS

X2.1 Installation guidelines for Interior Fiber-Reinforced Gypsum Underlayment Panels are outlined in manufacturer literature. For more information on best installation practice contact Tile Council of North America.

X2.2 Installation guidelines for Fiber-Reinforced Gypsum Roof Board Panels may be obtained by contacting National Roofing Council of America.

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SUMMARY OF CHANGES

Committee C11 has identified the location of selected changes to this specification since the last issue, C 1278/C 1278M – 07, that may impact the use of this specification. (Approved September 15, 2007)

(*1*) Definitions and specifications were revised or added under existing Sections 1 and 2, and new Sections 9, 10, and Appendix X2 (subsequent sections were renumbered) to add Interior Fiber-Reinforced Gypsum Underlayment Panels and Fiber-Reinforced Gypsum Roof Board Panels to this specification.

Committee C11 has identified the location of selected changes to this specification since the last issue, C 1278/C 1278M – 06, that may impact the use of this specification. (Approved August 1, 2007)

(*1*) Revised Sections 5 and 8 to remove ¼ in., 5⁄16 in., and ⅜ in. Interior Fiber-Reinforced Gypsum Panels and ⅜ in. Water-Resistant Exterior Fiber-Reinforced Gypsum Panels from this specification.

Committee C11 has identified the location of selected changes to this specification since the last issue, C 1278/C 1278M – 03$^{\epsilon 1}$, that may impact the use of this specification. (Approved November 1, 2006)

(*1*) Added new 3.1.1.

(*2*) Revised 5.2.2.

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Designation: C 1280 – 09

Standard Specification for Application of Gypsum Sheathing[1]

This standard is issued under the fixed designation C 1280; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope*

1.1 This specification covers the minimum requirements for and methods of application of gypsum sheathing for use as a substrate for exterior wall cladding.

1.2 Details of construction for a specific assembly to achieve the required fire resistance shall be obtained from reports of fire-resistance tests, engineering evaluations, or listings from recognized fire testing laboratories.

1.2.1 This specification shall govern where it is more stringent (size or thickness of framing and size and spacing of fasteners) than the fire-rated construction.

1.3 Where sound control is required for a gypsum sheathing assembly, the details of construction shall be in accordance with the acoustical test report of an assembly that has met the required acoustical value(s).

1.3.1 This specification shall govern where it is more stringent (size or thickness of framing and size and spacing of fasteners) than the sound-rated construction.

1.4 Where resistance to racking loads or shear is required for a gypsum sheathing assembly, the details of construction shall be in accordance with the racking or shear test report of an assembly that has met the required racking or shear value(s).

1.4.1 This specification shall govern where it is more stringent (size or thickness of framing and size and spacing of fasteners) than the racking or shear-tested construction.

1.5 The values stated in inch-pound units are to be regarded as standard. The values given in parentheses are mathematical conversions to SI units that are provided for information only and are not considered standard.

1.6 The text of this standard references footnotes which provide explanatory material. These footnotes shall not be considered as requirements of the standard.

1.7 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

2. Referenced Documents

2.1 *ASTM Standards:*[2]

C 11 Terminology Relating to Gypsum and Related Building Materials and Systems

C 954 Specification for Steel Drill Screws for the Application of Gypsum Panel Products or Metal Plaster Bases to Steel Studs from 0.033 in. (0.84 mm) to 0.112 in. (2.84 mm) in Thickness

C 955 Specification for Load-Bearing (Transverse and Axial) Steel Studs, Runners (Tracks), and Bracing or Bridging for Screw Application of Gypsum Panel Products and Metal Plaster Bases

C 1002 Specification for Steel Self-Piercing Tapping Screws for the Application of Gypsum Panel Products or Metal Plaster Bases to Wood Studs or Steel Studs

C 1007 Specification for Installation of Load Bearing (Transverse and Axial) Steel Studs and Related Accessories

C 1063 Specification for Installation of Lathing and Furring to Receive Interior and Exterior Portland Cement-Based Plaster

C 1396/C 1396M Specification for Gypsum Board

2.2 *U.S. Department of Commerce Publication:*

PS20 American Softwood Lumber Standard[3]

3. Terminology

3.1 *Definitions:* Definitions shall be in accordance with Terminology C 11.

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *exterior cladding*, *n*—a permanent material or system that impedes the transmission of environmental elements to the sheathing.

3.2.2 *fastener*, *n*—nails, staples, or screws used for application of the sheathing.

3.2.3 *framing member*, *n*—studs, headers, bracing, and blocking that serve to receive the sheathing.

[1] This specification is under the jurisdiction of ASTM Committee C11 on Gypsum and Related Building Materials and Systems and is the direct responsibility of Subcommittee C11.03 on Specifications for the Application of Gypsum and Other Products in Assemblies.

Current edition approved May 1, 2009. Published May 2009. Originally approved in 1994. Last previous edition approved in 2007 as C 1280 – 07.

[2] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

[3] Available from Standardization Documents Order Desk, Bldg. 4 Section D, 700 Robbins Ave., Philadelphia, PA 19111-5094, Attn: NPODS.

***A Summary of Changes section appears at the end of this standard.**

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3.2.4 *horizontal application*, *n*—a synonym for *perpendicular application.*

3.2.5 *parallel application*, *n*—gypsum sheathing applied with the edges parallel to the framing members; a synonym for *vertical application.*

3.2.6 *perpendicular application*, *n*—gypsum sheathing applied with the edges at right angles to the framing members; a synonym for *horizontal application.*

3.2.7 *require*, *v*—to mandate by a force outside this specification, such as a building code, project specification, contract, or purchase order.

3.2.8 *specified*, *adj*—pertaining to a mandatory requirement of this specification or a referenced requirement.

3.2.9 *specify*, *v*—to mandate by an obligation of this standard or a referenced document.

3.2.10 *vertical application*, *n*—synonym for *parallel application.*

3.2.11 *weather resistive barrier*, *n*—a temporarily exposed protective membrane that is intended to impede the penetration of environmental elements until the installation of a permanent exterior cladding.

4. Exposure After Installation

4.1 Gypsum sheathing board is a substrate that shall be covered by an exterior cladding or other weather-resistive barrier and is not intended for long-term exposure. It shall not be exposed to the elements for more than 30 days after it has been installed. Gypsum sheathing shall be covered with a weather-resistive barrier within 30 days if the exposure time will be more than 30 days.

NOTE 1—Some building codes require an additional weather-resistive barrier. The exterior face paper of the sheathing shall be dry prior to application of the additional weather-resistive barrier.

5. Materials and Manufacture

5.1 *Gypsum Sheathing*—Specification C 1396/C 1396M.

5.1.1 *Type X (Special Fire-Resistant) Gypsum Sheathing*—Gypsum sheathing that provides a greater degree of fire resistance than regular gypsum sheathing as defined in Specification C 1396/C 1396M.

5.2 *Fasteners*—Fasteners shall be as described in 5.2.1 through 5.2.3. The fastener length shall be not less than that specified in Table 1.

5.2.1 *Nails*—Nails shall be not less than 12-gauge galvanized, 7⁄16-in. (11.1-mm) diameter head.

5.2.2 *Screws*:

TABLE 1 Minimum Fastener Lengths

Framing Type	Fastener Type	Sheathing Thickness, in. (mm)	Minimum Fastener Length, in. (mm)
Wood	nails	½ (12.7)	1½ (38)
		⅝ (15.9)	1¾ (45)
	screws	½ (12.7)	1¼ (32)
		⅝ (15.9)	1¼ (32)
	staples	½ (12.7)	1½ (38)
		⅝ (15.9)	1¾ (45)
Steel	screws	½ (12.7)	1 (25)
		⅝ (15.9)	1¼ (32)

5.2.2.1 Screws for fastening gypsum sheathing to wood framing members, and to steel framing members less than 0.033 in. (0.84 mm) in thickness, shall meet the requirements of Specification C 1002.

5.2.2.2 Screws for fastening gypsum sheathing to steel framing members from 0.033 to 0.112 in. (0.84 to 2.84 mm) in thickness shall meet the requirements of Specification C 954.

5.2.2.3 Trim-head screws shall not be permitted for the attachment of gypsum sheathing.

5.2.2.4 Screws for fastening self-furred metal lath over gypsum sheathing as described in 8.2.7 shall be as specified in Specification C 1063.

5.2.3 *Staples*—Staples shall be of galvanized steel, not less than 16-gauge, 7⁄16-in. (11.1-mm) wide crown outside measurement. Legs shall have divergent points.

5.3 *Framing Members*:

5.3.1 *Wood Framing*—Wood framing members shall conform to PS20.

5.3.2 *Steel Framing*—Load-bearing steel framing shall meet the requirements of Specification C 955.

6. Substrate, Surface Preparation

6.1 The maximum spacing for framing members for gypsum sheathing shall be not more than 24 in. (610 mm) on center on walls.

6.1.1 Wood framing shall be straight and true, attached securely following accepted engineering practices and as required for the intended design. The surfaces to which abutting edges or ends of gypsum sheathing are to be attached shall be not less than 1½-in. (38-mm) wide. The bearing surface shall be not less than ¾ in. (19 mm) for internal corners or angles.

6.1.2 Load-bearing metal framing members shall be of the proper size and design for their intended use and shall be installed in accordance with Specification C 1007.

7. Framing Alignment

7.1 Framing members shall be installed so that the surface will be in an even plane, unless otherwise specified, after the gypsum sheathing has been applied.

8. Cutting and Application of Gypsum Sheathing

8.1 *Cutting Gypsum Sheathing*:

8.1.1 The gypsum sheathing shall be cut by scoring and breaking or by sawing, working from the face side. The face paper shall be cut with a sharp knife or other suitable tool when cutting by scoring. The gypsum sheathing shall be broken by snapping the gypsum sheathing in the reverse direction or by cutting the back paper with a knife or suitable tool.

8.1.2 The cut edges and ends of gypsum sheathing shall be trimmed to obtain neat fitting joints when installed.

8.1.3 Holes for pipes, fixtures, or other small openings shall be scored on the face paper before removing the cutout with a saw or special tool designed for this purpose.

8.1.4 Where gypsum sheathing meets projecting surfaces, the gypsum sheathing shall be scribed and cut neatly.

8.2 *Application of Gypsum Sheathing*:

8.2.1 Gypsum sheathing shall be fitted snugly around all window and door openings.

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8.2.1.1 Sheathing joints shall be offset a minimum of 4 in. (100 mm) from the edge of any opening.

8.2.1.2 Gypsum sheathing shall be flashed at openings so that water intrusion will not contact the sheathing.

8.2.2 All vertical end and edge joints shall abut over the centers of framing members and shall be offset a minimum of one framing space between adjacent rows of gypsum sheathing.

8.2.3 *Control Joints*:

8.2.3.1 Control joints shall be provided in wall runs exceeding 30 ft (9100 mm) in length. The distance between control joints shall be not more than 30 ft (9100 mm).

8.2.3.2 Control joints shall be installed in walls wherever there is a building construction joint or where required.

8.2.3.3 The location of the control joints shall be as required by either the building design or the exterior cladding specified.

8.2.3.4 Control joints, other accessories, and metal plaster base shall be fastened through gypsum sheathing to framing members.

8.2.4 Gypsum sheathing, 4-ft (1220-mm) wide, shall be applied either parallel or perpendicular to framing members.

8.2.4.1 Square edge gypsum sheathing applied perpendicular to framing members shall be covered with a weather-resistive barrier, or horizontal joints shall be sealed.

8.2.5 Tongue and groove gypsum sheathing shall be applied with the long dimension perpendicular to framing members, with the grooved edges down, interlocking the tongue of the panel below without forcing.

8.2.6 Fasteners shall be spaced not more than 8 in. (203 mm) on center along vertical ends or edges and intermediate supports. The length of fasteners shall be as indicated in Table 1.

8.2.6.1 Fasteners shall be located not less than ⅜ in. (9.5 mm) from the ends and edges of the gypsum sheathing.

8.2.6.2 Gypsum sheathing shall be held tight against the framing when driving fasteners.

8.2.6.3 Fasteners shall be driven so that the heads are at or slightly below the surface of the gypsum sheathing without breaking the face paper or fracturing the core.

8.2.6.4 Screws shall be driven without stripping the framing member around the screw shank.

8.2.6.5 Staples shall be driven with the crown parallel to the framing member.

8.2.7 *Application of Gypsum Sheathing Under Self-Furred Metal Lath*—Where fire resistance or shear resistance is not required, and when metal lath and portland cement plaster are to be applied as the exterior cladding over gypsum sheathing installed over framing members spaced not more than 16 in. (406 mm) on center, and the metal lath shall be installed in accordance with Specification C 1063 within 24 h after the gypsum sheathing, the gypsum sheathing shall be permitted to be applied as specified in 8.2.7.1 and 8.2.7.2, and fastening of the gypsum sheathing shall be completed with the attachment of the self-furred metal lath.

8.2.7.1 For 2-ft (610-mm) wide sheathing installed in accordance with 8.2.5, vertical ends of gypsum sheathing shall be fastened in accordance with 8.2.6. Gypsum sheathing shall be fastened in place at each intermediate stud with a minimum of two fasteners per board spaced not more than 2 in. (50 mm) from opposite edges.

8.2.7.2 For 4-ft (1220-mm) wide sheathing installed in accordance with 8.2.4, vertical ends or edges of gypsum sheathing shall be fastened in accordance with 8.2.6. Gypsum sheathing shall be fastened in place at each intermediate stud with fasteners spaced not more than 24 in. (610 mm) on center.

9. Keywords

9.1 exterior walls; gypsum; sheathing

SUMMARY OF CHANGES

Committee C11 has identified the location of selected changes to this specification since the last issue, C 1280 – 04, that may impact the use of this specification. (Approved May 1, 2009)

(*1*) Added new paragraphs 5.2.2.3 and 5.2.2.4.

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Designation: C 1293 – 08b

Standard Test Method for Determination of Length Change of Concrete Due to Alkali-Silica Reaction[1]

This standard is issued under the fixed designation C 1293; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope*

1.1 This test method covers the determination of the susceptibility of an aggregate or combination of an aggregate with pozzolan or slag for participation in expansive alkali-silica reaction by measurement of length change of concrete prisms.

1.2 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.* (**Warning**—Fresh hydraulic cementitious mixtures are caustic and may cause chemical burns to skin and tissue upon prolonged exposure.[2])

1.3 The values stated in SI units are to be regarded as the standard. No other units of measurement are included in this standard. When combined standards are cited, the selection of measurement system is at the user's discretion subject to the requirements of the referenced standard.

2. Referenced Documents

2.1 *ASTM Standards:*[3]

C 29/C 29M Test Method for Bulk Density ("Unit Weight") and Voids in Aggregate
C 33 Specification for Concrete Aggregates
C 125 Terminology Relating to Concrete and Concrete Aggregates
C 138/C 138M Test Method for Density (Unit Weight), Yield, and Air Content (Gravimetric) of Concrete
C 143/C 143M Test Method for Slump of Hydraulic-Cement Concrete
C 150 Specification for Portland Cement
C 157/C 157M Test Method for Length Change of Hardened Hydraulic-Cement Mortar and Concrete
C 192/C 192M Practice for Making and Curing Concrete Test Specimens in the Laboratory
C 227 Test Method for Potential Alkali Reactivity of Cement-Aggregate Combinations (Mortar-Bar Method)
C 289 Test Method for Potential Alkali-Silica Reactivity of Aggregates (Chemical Method)
C 294 Descriptive Nomenclature for Constituents of Concrete Aggregates
C 295 Guide for Petrographic Examination of Aggregates for Concrete
C 490 Practice for Use of Apparatus for the Determination of Length Change of Hardened Cement Paste, Mortar, and Concrete
C 494/C 494M Specification for Chemical Admixtures for Concrete
C 511 Specification for Mixing Rooms, Moist Cabinets, Moist Rooms, and Water Storage Tanks Used in the Testing of Hydraulic Cements and Concretes
C 618 Specification for Coal Fly Ash and Raw or Calcined Natural Pozzolan for Use in Concrete
C 702 Practice for Reducing Samples of Aggregate to Testing Size
C 856 Practice for Petrographic Examination of Hardened Concrete
C 989 Specification for Ground Granulated Blast-Furnace Slag for Use in Concrete and Mortars
C 1240 Specification for Silica Fume Used in Cementitious Mixtures
C 1260 Test Method for Potential Alkali Reactivity of Aggregates (Mortar-Bar Method)
D 75 Practice for Sampling Aggregates

2.2 *CSA Standards:*[4]

CSA A23.2-14A Potential Expansivity of Aggregates (Procedure for Length Change due to Alkali-Aggregate Reaction in Concrete Prisms at 38 °C)
CSA A23.2-27A Standard Practice to Identify Degree of Alkali-Reactivity of Aggregates and to Identify Measures to Avoid Deleterious Expansion in Concrete
CSA A23.2-28A Standard Practice for Laboratory Testing

[1] This test method is under the jurisdiction of Committee C09 on Concrete and Concrete Aggregates and is the direct responsibility of Subcommittee C09.26 on Chemical Reactions.

Current edition approved Dec. 1, 2008. Published January 2009. Originally approved in 1995. Last previous edition approved in 2008 as C 1293 – 08a.

[2] Section on Safety Precautions, *Manual of Aggregate and Concrete Testing*, *Annual Book of ASTM Standards*, Vol. 04.02.

[3] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

[4] Available from Canadian Standards Association (CSA), 5060 Spectrum Way, Mississauga, ON L4W 5N6, Canada, http://www.csa.ca.

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to Demonstrate the Effectiveness of Supplementary Cementing Materials and Lithium-Based Admixtures to Prevent Alkali-Silica Reaction in Concrete

3. Terminology

3.1 Terminology used in this standard is as given in Terminology C 125 or Descriptive Nomenclature C 294.

4. Significance and Use

4.1 Alkali-silica reaction is a chemical interaction between some siliceous constituents of concrete aggregates and hydroxyl ions (**1**).[5] The concentration of hydroxyl ion within the concrete is predominantly controlled by the concentration of sodium and potassium (**2**).

4.2 This test method is intended to evaluate the potential of an aggregate or combination of an aggregate with pozzolan or slag to expand deleteriously due to any form of alkali-silica reactivity (**3**,**4**).

4.3 When testing an aggregate with pozzolan or slag, the results are used to establish minimum amounts of the specific pozzolan or slag needed to prevent deleterious expansion. Pozzolan or slag from a specific source can be tested individually or in combination with pozzolan or slag from other sources.

4.4 When selecting a sample or deciding on the number of samples for test, it is important to recognize the variability in lithology of material from a given source, whether a deposit of sand, gravel, or a rock formation of any origin. For specific advice, see Guide C 295.

4.5 This test method is intended for evaluating the behavior of aggregates in portland cement concrete with an alkali (alkali metal oxide) content of 5.25 kg/m^3 or in concrete containing pozzolan or slag with an alkali content proportionally reduced from 5.25 kg/m^3 Na_2O equivalent by the amount of pozzolan or slag replacing portland cement. This test method assesses the potential for deleterious expansion of concrete caused by alkali-silica reaction, of either coarse or fine aggregates, from tests performed under prescribed laboratory curing conditions that will probably differ from field conditions. Thus, actual field performance will not be duplicated due to differences in concrete alkali content, wetting and drying, temperature, other factors, or combinations of these (**5**).

4.6 Results of tests conducted on an aggregate as described herein should form a part of the basis for a decision as to whether precautions should be taken against excessive expansion due to alkali-silica reaction. Results of tests conducted on combinations of an aggregate with pozzolans or slag should form a part of the basis for a decision as to whether the specific pozzolan or slag, when used in the amount tested, was effective in preventing excessive expansion. These decisions should be made before a particular aggregate is used in concrete construction. Criteria to determine the potential deleteriousness of expansions measured in this test are given in Appendix X1.

4.7 When the expansions in this test method are greater than the limit shown in X1.2, the aggregate or combination of aggregate with the tested amount of pozzolan or slag is potentially alkali-reactive. Supplemental information should be developed to confirm that the expansion is actually due to alkali-silica reaction. Petrographic examination of the concrete prisms should be conducted after the test using Practice C 856 to confirm that known reactive constituents are present and to identify the products of alkali-silica reactivity. Confirmation of alkali-silica reaction is also derived from the results of the test methods this procedure supplements (see Appendix X1).

4.8 If the supplemental tests show that a given aggregate is potentially deleteriously reactive, additional studies may be appropriate to evaluate preventive measures in order to allow safe use of the aggregate. Preventive measures are mentioned in the Appendix to Specification C 33.

4.9 This test method does not address the general suitability of pozzolans or slag for use in concrete. These materials should comply with Specification C 618, Specification C 989, or Specification C 1240.

5. Apparatus

5.1 The molds, the associated items for molding test specimens, and the length comparator for measuring length change shall conform to the applicable requirements of Test Method C 157/C 157M and Practice C 490, and the molds shall have nominal 75-mm square cross sections.

5.2 The storage container options required to maintain the prisms at a high relative humidity are described in 5.2.1.

5.2.1 *Recommended Container*—The recommended containers are 19 to 22-L polyethylene pails with airtight lids and approximate dimensions of 250- to 270-mm diameter at bottom, 290 to 310 mm at top, by 355 to 480 mm high. Prevent significant loss of enclosed moisture due to evaporation with airtight lid seal. Place a perforated rack in the bottom of the storage container so that the prisms are 30 to 40 mm above the bottom. Fill the container with water to a depth of 20 ± 5 mm above the bottom. A significant moisture loss is defined as a loss greater than 3 % of the original amount of water placed at the bottom of the pail. Place a wick of absorbent material around the inside wall of the container from the top so that the bottom of the wick extends into the water (See Note 1).

5.2.2 *Alternative Containers*—Alternative storage containers may be used. Confirm the efficiency of the alternative storage container with an alkali-reactive aggregate of known expansion characteristics.[6] The expansion efficiency is confirmed when expansions at one year obtained using the alternative container are within 10 % of those obtained using the recommended container. Alternative storage containers must contain the required depth of water. When reporting results, note the use of an alternative container, if one is used, together with documentation proving compliance with the above.

[5] The boldface numbers in parentheses refer to the list of references at the end of this test method.

[6] The sole source of supply of non-reactive aggregates and alkali-silica reactive aggregates of known expansion characteristics **(6)** known to the committee at this time is The Petrographer, Engineering Materials Office, Ministry of Transportation, 1201 Wilson Ave., Downsview, Ontario, Canada, M3M1J8.. If you are aware of alternative suppliers, please provide this information to ASTM International Headquarters. Your comments will receive careful consideration at a meeting of the responsible technical committee [1], which you may attend.

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NOTE 1—Polypropylene geotextile fabric or blotting paper are suitable materials for use as the wick.

5.3 The storage environment necessary to maintain the 38.0 °C reaction accelerating storage temperature consistently and homogeneously is described in 5.3.1.

5.3.1 *Recommended Environment*—The recommended storage environment is a sealed space insulated so as to minimize heat loss. Provide a fan for air circulation so the maximum variation in temperature measured within 250 mm of the top and bottom of the space does not exceed 2.0 °C. Provide an insulated entry door with adequate seals so as to minimize heat loss. Racks for storing containers within the space are not to be closer than 30 mm to the sides of the enclosure and are to be perforated so as to provide air flow. Provide an automatically controlled heat source to maintain the temperature at 38.0 ± 2.0 °C (see Note 2). Record the ambient temperature and its variation within the space to ensure compliance.

NOTE 2—It has been found to be good practice to monitor the efficiency of the storage environment by placing thermocouples inside dummy concrete specimens inside a dummy container within the storage area. The storage room described in Test Method C 227 generally will be satisfactory.

5.3.2 *Alternative Storage Environment*—Use of an alternative storage environment is permitted. Confirm the efficiency of the alternative storage container with an alkali-reactive aggregate of known expansion characteristics.[6] The expansion efficiency is confirmed when expansions at one year obtained using the alternative storage environment are within 10 % of those obtained using the recommended environment. When reporting the results, note the use of an alternative storage environment, if one is utilized, together with documentation proving compliance with the above.

6. Reagents

6.1 *Sodium Hydroxide (NaOH)*—USP or technical grade may be used. (**Warning**—Before using NaOH, review: (*1*) the safety precautions for using NaOH; (*2*) first aid for burns; and (*3*) the emergency response to spills as described in the manufacturers Material Safety Data Sheet or other reliable safety literature. NaOH can cause severe burns and injury to unprotected skin and eyes. Always use suitable personal protective equipment including: full-face shields, rubber aprons, and gloves impervious to NaOH (Check periodically for pinholes.).)

6.2 *Water*:

6.2.1 Use potable tap water for mixing and storage.

7. Materials

7.1 *Cement*—Use a cement meeting the requirements for a Type I Portland cement as specified in Specification C 150. The cement must have a total alkali content of 0.9 ± 0.1 % Na_2O equivalent (Na_2O equivalent is calculated as percent Na_2O + 0.658 × percent K_2O). Determine the total alkali content of the cement either by analysis or by obtaining a mill run certificate from the cement manufacturer. Add NaOH to the concrete mixing water so as to increase the alkali content of the mixture, expressed as Na_2O equivalent, to 1.25 % by mass of cement (see Note 3).

NOTE 3—The value of 1.25 % Na_2O equivalent by mass of cement has been chosen to accelerate the process of expansion rather than to reproduce field conditions. At the 420 kg/m^3 cement content, this corresponds to an alkali level of 5.25 kg/m^3 .

7.2 *Aggregates*:

7.2.1 To evaluate the reactivity of a coarse aggregate, use a nonreactive fine aggregate. A nonreactive fine aggregate is defined as an aggregate that develops an expansion in the accelerated mortar bar, (see Test Method C 1260) of less than 0.10 % at 14 days (see X1.6 for interpretation of expansion data). Use a fine aggregate meeting Specification C 33 with a fineness modulus of 2.7 ± 0.2.

7.2.2 To evaluate the reactivity of a fine aggregate, use a nonreactive coarse aggregate. Prepare the nonreactive coarse aggregate according to 7.2.3.[6] A nonreactive coarse aggregate is defined as an aggregate that develops an expansion in the accelerated mortar bar (see Test Method C 1260) of less than 0.10 % at 14 days (see X1.6 for interpretation of expansion data). Use a coarse aggregate meeting Specification C 33. Test the fine aggregate using the grading as delivered to the laboratory.

7.2.3 Sieve the coarse aggregate and recombine in accordance with the requirements in Table 1. Select the Table 1 grading based on the as-received grading of the sample. Coarse aggregate fractions larger than 19.0-mm sieve are not to be tested as such. When petrographic examination using Guide C 295 reveals that the material making up the size fraction larger than the 19.0-mm sieve is of such a composition and lithology that no difference should be expected compared with the smaller size material, then no further attention need be paid to the larger sizes. If petrographic examination suggests the larger size material to have a different reactivity, the material should be studied for its effect in concrete according to one of the other alternative procedures described herein:

7.2.3.1 *Proportional Testing*—Crush material larger than the 19.0-mm sieve to pass the 19.0-mm sieve. The crushing operation shall be performed in a manner that minimizes production of material passing the 4.75-mm sieve. Grade this crushed material per the Table 1 grading, and add to the original mass of graded aggregate produced in 7.2.3 such that the ratio of crushed, graded, oversize aggregate to total graded aggregate equals the ratio of material retained on the 19.0-mm sieve to the total material retained above the 4.75-mm sieve (See Note 4).

NOTE 4—For example, if the material retained on the 19-mm sieve formed 25 % of the total material retained above the 4.75-mm sieve, then the mass of crushed and returned oversize material shall form 25 % of the total graded aggregate.

7.2.3.2 *Separated Size Testing*—Crush material larger than the 19.0-mm sieve to pass the 19.0-mm sieve, grade that material as per Table 1 and test in concrete as a separate aggregate.

TABLE 1 Grading Requirement

Sieve Size		Mass Fraction	
Passing	Retained	Coarse	Intermediate
19.0-mm	12.5-mm	⅓	. . .
12.5-mm	9.5-mm	⅓	½
9.5-mm	4.75-mm	⅓	½

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7.3 *Concrete Mixture Proportions*—Proportion the concrete mixture to the following requirements:

7.3.1 *Cementitious Materials Content*—420 ± 10 kg/m.[3]

7.3.1.1 When evaluating the susceptibility of an aggregate to expansive alkali-silica reaction, use cement as 100 % of the cementitious material.

7.3.1.2 When evaluating combinations of aggregate with pozzolan or slag, replace cement with the desired amount of pozzolan or slag on a percent by mass basis.

7.3.2 *Coarse Aggregate Content*—Use a dry mass of coarse aggregate per unit volume of concrete equal to 0.70 ± 0.02 of its dry-rodded bulk density as determined by Test Method C 29/C 29M for all classes of aggregates (for example, low density, normal, and high density).

7.3.3 *Water-Cementitious Materials Ratio (w/cm)*—Maintain *w/cm* in the range of 0.42 to 0.45 by mass. Adjust the *w/cm* within this range to give sufficient workability to permit satisfactory compaction of the concrete in the molds. If necessary to obtain sufficient workability within the specified *w/cm* range, use of a high-range water reducer (HRWR), meeting the requirements of Specification C 494/C 494M Type F is permitted. If, within the specified *w/cm* range, specimens representative of the concrete mixture cannot be fabricated due to excessive bleeding or segregation, the use of a viscosity-modifying admixture (VMA) is permitted. Report the *w/cm* ratio used and the amount, if any, of HRWR or VMA.

7.3.4 *Admixture (NaOH)*—Dissolve in the mixing water and add as required to bring the alkali content of the concrete mixture, expressed as Na_2O_e = % Na_2O + 0.658× % K_2O, up to 1.25 % by mass of cement (see Note 5). Use no other admixture in the concrete except as permitted in the section on *Water-Cementitious Materials Ratio*.

NOTE 5—Example calculations for determining the amount of NaOH to be added to the mixing water to increase the alkali content of the cement from 0.90 % to 1.25 %:

Example A (Cement Only)	
Cementitious materials content of 1 m^3 concrete	= 420 kg
Cement content of concrete	= 420 kg
Amount of alkali in the concrete	= 420 kg × 0.90 % = 3.78 kg
Specified amount of alkali in concrete	= 420 kg × 1.25 % = 5.25 kg
Amount of alkali to be added to concrete	= 5.25 kg – 3.78 kg = 1.47 kg

The difference (1.47 kg) is the amount of alkali, expressed as Na_2O equivalent, to be added to the mix water. Factor to convert Na_2O to NaOH: since

$$(Na_2O + H_2O \rightarrow 2\ NaOH)$$

Compound	Molecular Weight
Na_2O	61.98
NaOH	39.997

Conversion factor:

$$2 \times 39.997/61.98 = 1.291; \quad (1)$$

Amount of NaOH required in Example A:

$$1.47 \times 1.291 = 1.898\ kg/m^3 \quad (2)$$

Example B (20 % of cement is replaced by pozzolan)	
Cementitious materials content of 1 m^3 concrete	= 420 kg
Cement content of concrete (20 % by mass pozzolan)	= 420 kg × 0.8 = 336 kg
Amount of alkali in the concrete	= 336 kg × 0.90 % = 3.02 kg
Specified amount of alkali in concrete	= 336 kg × 1.25 % = 4.20 kg
Amount of alkali to be added to concrete	= 4.20 kg – 3.02 kg = 1.18 kg

The difference (1.18 kg) is the amount of alkali, expressed as Na_2O equivalent, to be added to the mix water.

Amount of NaOH required for Example B:

$$1.18 \times 1.291 = 1.523\ kg/m^3 \quad (3)$$

8. Sampling

8.1 Obtain the aggregate sample in accordance with Practice D 75 and reduce it to test portion size in accordance with Practice C 702.

9. Specimen Preparation

9.1 *Mixing Concrete*:

9.1.1 *General*—Mix concrete in accordance with the standard practice for making and curing concrete test specimens in the laboratory as described in Practice C 192/C 192M.

9.1.2 *Slump*—Measure the slump of each batch of concrete immediately after mixing in accordance with Test Method C 143/C 143M.

9.1.3 *Yield, and Air Content*—Determine the yield, and air content of each batch of concrete in accordance with Test Method C 138/C 138M. Concrete used for slump, yield, and air content tests may be returned to the mixing pan and remixed into the batch.

9.2 Prepare three specimens of the type required for concrete in Test Method C 157/C 157M from one batch of concrete (see Note 6).

NOTE 6—It has been found useful to cast an additional (4th) prism that can be removed from the test and used for petrographic examination at any time.

9.3 *Initial Conditioning*—Cure, store, and remove molds in accordance with Test Method C 157/C 157M.

10. Procedure

10.1 *Initial Comparator Reading*—Follow the procedure of Test Method C 157/C 157M, except do not place in saturated lime water. Make initial length reading at the time of removal from the mold at an age of 23.5 ± 0.5 h. Thereafter, keep the specimens at 38.0 ± 2 °C in storage containers in accordance with 5.2.

10.2 *Subsequent Comparator Readings*—Stand the specimen on end. Specimens shall not be in contact with water in the reservoir within the storage container. Seal the container and place container in a 38.0 ± 2 °C storage environment. At no time should the storage container be in contact with the walls or floor of the 38.0 ± 2 °C storage environment and there shall be an adequate flow of air around the container.

10.2.1 When the specimens are 7 days old, take a comparator reading after removal of the container and contents from the storage environment according to 10.2.2. Subsequent readings are required at the ages of 28 and 56 days, as well as 3, 6, 9, and 12 months when testing an aggregate for susceptibility to

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expansive alkali-silica reaction and additionally at 18 and 24 months when testing combinations of aggregates with pozzolans or slag. Additional readings beyond those required for the specific application are suggested at 6-month intervals.

10.2.2 Remove the containers holding the prisms from the 38.0 ± 2.0 °C temperature environment and place in a moist cabinet or moist room that is in compliance with Specification C 511 for a period 16 ± 4 h before reading.

10.3 Fabricate all specimens placed in a given storage container at the same time so that all specimens in that container are due for comparator reading at the same time.

10.4 Identify the specimens so as to place the specimens in the comparator with the same end up. After the comparator reading of the prism, replace the specimen in the storage container but invert the upper end as compared with the previous storage period. In this way the prisms are not stored through two consecutive storage periods with the same ends up.

11. Calculation

11.1 Calculate the change in length between the initial comparator reading of the specimen and the comparator reading at each time interval to the nearest 0.001 % of the effective gage length and record as the length change of the prism for that period. Calculate the average length change in percentage for the group of prisms at the age.

11.2 Data from at least three bars must be available at any age to constitute a valid test at that age.

12. Report

12.1 Report the following information:

12.1.1 Type and source of coarse and fine aggregates, and the coarse aggregate grading used,

12.1.2 Type and source of portland cement,

12.1.3 The alkali content of the cement as percent potassium oxide (K_2O), sodium oxide (Na_2O), and calculated percent NaO_e,

12.1.4 Type, source, and amount (percent by mass of cementitious material) of any pozzolan or slag used,

12.1.5 The amount, if any, of high-range water reducer or viscosity-modifying admixture used,

12.1.6 Concrete mixture proportions based on SSD aggregates, and corrected for yield,

12.1.7 The amount of sodium hydroxide (NaOH) added to the mixing water, expressed as percent sodium oxide (Na_2O) equivalent by mass of the cement,

12.1.8 The w/cm based on saturated, surface dry (SSD) aggregates,

12.1.9 The slump, with mass yield and air content of the concrete batched,

12.1.10 The average length change in percent at each reading of the prisms along with the individual length change in percentage for each prism,

12.1.11 Any significant features revealed by examination of the concrete prisms either during the test or at the end of the test (for example, cracks, gel formation, or peripheral reaction rims on aggregate particles), and

12.1.12 Type of storage container and 38.0 ± 2.0 °C storage environment used to store the concrete prisms if they differ from those specified in 5.2.1 and 5.3.1.

13. Precision and Bias

13.1 *Multi-Laboratory Precision*:

13.1.1 *Average Expansion Less Than 0.014 %*—The multi-laboratory standard deviation of a single test result (mean of measurements of three prisms) for average expansion less than 0.014 % has been found to be 0.0032 % (CSA A23.2-14A).[4] Therefore, results of two properly conducted tests in different laboratories on the same aggregate should not differ by more than 0.009 %, nineteen times out of twenty.

13.1.2 *Average Expansion Greater Than 0.014 %*—The multi-laboratory coefficient of variation of a single test result (mean of measurements of three prisms) for average expansion greater than 0.014 % has been found to be 23 % (CSA A23.2-14A).[4] Therefore, results of two properly conducted tests in different laboratories on the same aggregate should not differ from each other by more than 65 % of their average, nineteen times out of twenty.

13.2 *Within-Laboratory Precision*:

13.2.1 *Average Expansion Less Than 0.02 %*—For average expansions of less than 0.02 %, the multi-specimen, within-laboratory standard deviation has been found to be 0.0025 % (CSA A23.2-14A). Therefore, the range (difference between highest and lowest) of the three individual prism measurements used in calculating an average test result should not exceed 0.008 %, nineteen times out of twenty.

13.2.2 *Average Expansion Greater Than 0.02 %*—For average expansions of more than 0.02 %, the multi-specimen, within-laboratory coefficient of variation has been found to be 12 % (CSA A23.2-14A). Therefore, the range (difference between highest and lowest) of the three individual prism measurements used in calculating an average test result should not exceed 40 % of the average, nineteen times out of twenty.

13.3 *Bias*—Since there is no accepted reference material for determining the bias of this test method, no statement is being made.

14. Keywords

14.1 aggregate; alkali-silica reactivity; concrete; length change; pozzolan; slag

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APPENDIX

(Nonmandatory Information)

X1. Interpretation of Results

X1.1 The question of whether or not criteria based on the results obtained using this test method should be used for acceptance of materials for use as concrete aggregate will be dealt with, if deemed appropriate, in Specification C 33.

X1.2 Work has been reported from which it may be inferred that an aggregate might reasonably be classified as potentially deleteriously reactive if the average expansion of three concrete specimens is equal to or greater than 0.04 % at one year (**7**) (CSA A23.2-27A-00 Table 1).

X1.3 It is reasonable to conclude that the amount of pozzolan or slag used in combination with an aggregate is at least the minimum needed to prevent excessive expansion in field concrete if the average expansion is less than 0.04 % at two years (CSA A23.2-28A-02).

X1.4 A history of satisfactory field performance in concrete is the best method of evaluating the potential for an aggregate to cause premature deterioration of concrete due to alkali-silica reaction. When field performance of an aggregate in concrete is to be accepted, the following conditions should be met (**8**):

X1.4.1 The cement content and alkali content of the cement should be the same or higher in the field concrete than is proposed in the new structure.

X1.4.2 The concrete examined should be at least 10 years old.

X1.4.3 The exposure conditions of the field concrete should be at least as severe as those in the proposed structure.

X1.5 This test method supplements the results of other test methods. The results of the other test methods are usually reported before the results of this test method are available. Standards that this test method supplements include: Test Method C 227, Guide C 295, Test Method C 289, and Test Method C 1260. It is recommended that the relevant procedure(s) be performed concurrently with this test method and any discrepancies between the results explained. Care should be exercised in the interpretation of these other test method results (**9-14**).

X1.6 The use of this test method should especially be considered when other test methods may be inadequate. Some examples of such problems are as follows: The potential reactivity of various varieties of quartz may not be accurately determined by Test Method C 227 since the test method may produce a false-negative result (**3**). False-negative results are possible with a number of aggregates such as slow-late expanding argillaceous greywackes, strained quartz and microcrystalline quartz associated with strained quartz (**3,4,13**). False-negative results are also possible due to storage conditions (**9**), reactive aggregate levels far above or below pessimum (**3**) or insufficient alkali to accelerate the test (**3**). The potential reactivity of various varieties of quartz may not be accurately determined by Test Method C 1260 since the test method may produce a false-positive result with a number of marginally reactive aggregates (**13**). Test Method C 1260 may also give a false-negative result with aggregates suspected of containing deleterious strained quartz (**14**).

X1.7 If the data generated with other test methods and supplemented with information from this test method judge an aggregate to be "not potentially deleteriously alkali-silica reactive," no restrictions are usually required with the use of that aggregate in order to protect against expansion due to alkali-silica reaction (**7**) (see Note X1.1).

X1.8 Additional interlaboratory testing data is provided in Ref (**15**).

NOTE X1.1—In critical structures such as those used for nuclear containment or large dams, where slight expansions cannot be tolerated, a lower expansion limit may be required.

REFERENCES

(**1**) Diamond, S., "Alkali Reactions in Concrete-Pore Solution Effects," *Proceedings*, 6th International Conference on Alkali-Aggregate Reaction in Concrete, Copenhagen, Denmark, 1983, pp. 155–166.

(**2**) Diamond, S., "ASR—Another Look at Mechanisms," *Proceedings*, 8th International Conference on Alkali-Aggregate Reaction, Kyoto, Japan, 1989, pp. 83–94.

(**3**) Grattan-Bellew, P. E., "Test Methods and Criteria for Evaluating the Potential Reactivity of Aggregates," *Proceedings*, 8th International Conference on Alkali-Aggregate Reaction, Kyoto, Japan, 1989, pp. 279–294.

(**4**) Grattan-Bellew, P. E., "Microcrystalline Quartz, Undulatory Extinction and Alkali-Silica Reaction," *Proceedings*, 9th International Conference on Alkali-Aggregate Reaction in Concrete, Concrete Society, Slough, U.K., 1992, pp. 383–394.

(**5**) Rogers, C. A., and Hooton, R. D., "Comparison Between Laboratory and Field Expansion of Alkali-Carbonate Reactive Concrete," *Proceedings*, 9th International Conference on Alkali-Aggregate Reaction in Concrete, Concrete Society, Slough, U.K., 1992, pp. 877–884.

(**6**) Rogers, C. A., "General Information on Standard Alkali-Reactive Aggregates from Ontario, Canada," Ontario Ministry of Transportation, Engineering Materials Office, 1988, p. 59.

(**7**) Grattan-Bellew, P. E., "Reevaluation of Standard Mortar Bar and Concrete Prism Tests," *Materiaux et Constructions*, Vol 16, No. 94, 1983, pp. 243–250.

(**8**) British Cement Association, "The Diagnosis of Alkali-silica Reaction," British Cement Association, Crowthorne, Berks, RG1 6YS, United Kingdom, Second edition, 1992.

(**9**) Rogers, C. A., and Hooton, R. D., "Reduction in Mortar and Concrete Expansion with Reactive Aggregates Due to Leaching," *Cement, Concrete and Aggregates*, CCAGDP, Vol 13, 1991, pp. 42–49.

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(**10**) Bérubé, M. A., and Fournier, B., "Accelerated Test Methods for Alkali-Aggregate Reactivity," *Advances in Concrete Technology*, Malhotra, V. M., ed., Canada Communication Group, Ottawa, 1992, pp. 583–627.
(**11**) Sorrentino, D., Clément, J. Y., and Goldberg, J. M., "A New Approach to Characterize the Chemical Reactivity of the Aggregates," *Proceedings*, 9th International Conference on Alkali-Aggregate Reaction in Concrete, Concrete Society, Slough, U.K., 1992, pp. 1009–1016.
(**12**) Fournier, B., and Bérubé, M. A., "Application of the NBRI Accelerated Mortar Bar Test to Siliceous Carbonate Aggregates Produced in the St. Lawrence Lowlands (Quebec, Canada), Part 1: Influence of Various Parameters on the Test Results, *Cement and Concrete Research*, Vol 21, 1991, pp. 853–862.
(**13**) Hooton, R. D., "New Aggregate Alkali-Reactivity Test Methods," Ontario Ministry of Transportation, Research and Development Branch Report MAT-91-14, November, 1991.
(**14**) Kerrick, D. M., and Hooton, R. D., "ASR of Concrete Aggregate Quarried from a Fault Zone: Results and Petrographic Interpretation of Accelerated Mortar Bar Test," *Cement and Concrete Research*, Vol 22, 1992, pp. 949–960.
(**15**) Fournier, B. and Malhotra, V.M., "Interlaboratory Study on the CSA A 23.2-14A Concrete Prism Test for Alkali-Silica Reactivity in Concrete", *Proceedings*, 10th International Conference on Alkali-Aggregate Reaction in Concrete", CSIRO, Melbourne, Australia, 1996, pp. 302-309.

SUMMARY OF CHANGES

Committee C09 has identified the location of selected changes to this test method since the last issue, C 1293 – 08a, that may impact the use of this test method. (Approved December 1, 2008)

(*1*) Revised 1.3.
(*2*) Revised 7.2.3, 12.1.1, and Table 1.
(*3*) Deleted old 12.1.13.

Committee C09 has identified the location of selected changes to this test method since the last issue, C 1293 – 08, that may impact the use of this test method. (Approved February 1, 2008)

(*1*) Revised 1.3, 5.1, 7.2.3, and 7.2.3.1.
(*2*) Added new 12.1.13 and Note 4.
(*3*) Revised Table 1.
(*4*) Removed all informational inch-pound units throughout to conform to ASTM Form and Style.

Committee C09 has identified the location of selected changes to this test method since the last issue, C 1293 – 06, that may impact the use of this test method. (Approved January 15, 2008)

(*1*) Revised 7.3.2.

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Designation: C 1301 – 95 (Reapproved 2009)ε1

Standard Test Method for Major and Trace Elements in Limestone and Lime by Inductively Coupled Plasma-Atomic Emission Spectroscopy (ICP) and Atomic Absorption (AA)[1]

This standard is issued under the fixed designation C 1301; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

ε[1] NOTE—A units statement was added editorially as new paragraph 1.3 and subsequent paragraphs were renumbered in June 2009.

1. Scope

1.1 The following test method covers the use of inductively coupled plasma-atomic emission spectroscopy (ICP) and atomic absorption spectroscopy (AA) in the analysis of major and trace elements in limestone and lime (calcined limestone).

1.2 Table 1 lists some of the elements that can be analyzed by this test method and the preferred wavelengths. Also see U.S. EPA Methods 200.7 and 200.9.

1.3 The values stated in SI units are to be regarded as standard. No other units of measurement are included in this standard.

1.4 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

2. Referenced Documents

2.1 *ASTM Standards:*[2]

C 51 Terminology Relating to Lime and Limestone (as used by the Industry)

D 1193 Specification for Reagent Water

E 135 Terminology Relating to Analytical Chemistry for Metals, Ores, and Related Materials

E 863 Practice for Describing Atomic Absorption Spectrometric Equipment[3]

E 1479 Practice for Describing and Specifying Inductively-Coupled Plasma Atomic Emission Spectrometers

2.2 *U.S. EPA Standards:*

Methods for the Determination of Metals in Environmental Samples; U.S. EPA Methods 200.2, 200.7, and 200.9; Smoley, C. K., 1992[4]

Method 6010, Inductively Coupled Plasma Method, SW-846, Test Methods for Evaluating Solid Waste[5]

TABLE 1 Elements and Some Suggested Wavelengths[A]

Major Elements	ICP Wavelength, nm	AA Wavelength, nm
Calcium	317.933 (315.887)[B]	422.7
Magnesium	279.079 (285.213)	285.2
Silicon	251.611 (288.160)	251.6
Aluminum	308.215 (309.271)	309.3
Iron	259.940	248.3
Manganese	257.610	279.5
Sodium	588.995 (589.59)	589.0
Potassium	766.491	766.5
Phosphorus	214.914 (213.618)	...[C]
Strontium	421.552	460.7
Trace Elements	**ICP Wavelength, nm**	**AA Wavelength, nm**
Antimony	206.833	217.6
Arsenic	193.696	193.7
Barium	455.403 (493.409)	553.6
Beryllium	313.042	234.9
Boron	249.773	249.8
Cadmium	226.502 (228.80)	228.8
Chromium	267.716 (205.552)	357.9
Cobalt	228.616	240.7 (242.5)
Copper	324.754	324.8
Lead	220.353	217.0 (283.3)
Molybdenum	202.030 (203.844)	313.3
Nickel	231.604 (221.647)	232.0
Selenium	196.090	196.0
Silver	328.068	328.1
Sulfur	180.731 (180.669)	...[C]
Thallium	190.864	276.8
Tin	189.989	235.5 (286.3)
Vanadium	292.402	318.4
Zinc	213.856 (202.551)	213.9

[A] The suggested wavelengths may vary for your particular instrument.
[B] Numbers in parentheses are alternate wavelengths.
[C] Not recommended or not used.

[1] This test method is under the jurisdiction of ASTM Committee C07 on Lime and is the direct responsibility of Subcommittee C07.05 on Chemical Tests

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[2] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

[3] Withdrawn. The last approved version of this historical standard is referenced on www.astm.org.

[4] Available from CRC Press, 2000 Corporate Blvd., N. W., Boca Raton, FL 33431.

[5] Available from U.S. Government Printing Office, Washington, DC 20402.

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3. Terminology

3.1 *Definitions*—Definitions for terms used in this test method can be found in Terminologies C 51 and E 135.

3.2 *Additional Definitions:*

3.2.1 *total recoverable*, *n*—trace element concentration in an unfiltered sample after heating in acid.

3.2.2 *total digestion*, *n*—complete digestion of a sample, including silica and silicate minerals, using the fusion-flux method.

4. Summary of Test Method

4.1 A sample, digested by either fusion or acid, is atomized and passed into an excitation medium (a plasma in the case of ICP; a flame in the case of AA). The resulting ions are analyzed by atomic spectroscopy. Elemental concentrations are determined by graphically relating the emission/absorption at specific wavelengths for an unknown sample to analytical curves made from reference standards of known composition.

5. Significance and Use

5.1 The presence and concentration of elements in lime and limestone is important in determining product quality and its suitability for various uses. This test method provides a means of measuring the major and trace element concentration in lime and limestone.

6. Interferences

6.1 *Chemical*—Chemical interferences, most common in AA, arise from the formation of molecular compounds that cause absorbances at the wavelength of interest. This molecular band spectral overlap can be minimized by buffering the sample with matrix modifiers (a Lanthanum additive, for example), using standard additions techniques, matrix matching or by careful selection of operating conditions (for example, using a hotter nitrous oxide/acetylene flame, selecting an alternate wavelength).

6.2 *Physical*—Physical interferences are the result of the inconsistencies in the introduction of the sample into the instrument, namely the transport and atomization/nebulization of the sample. These inconsistencies are a function of changing viscosity and surface tension, and are found primarily in samples of high-dissolved solids or high-acid concentrations. Physical interferences can be reduced by diluting the sample and by the use of a peristaltic pump.

6.3 *Spectral*—Spectral interference, most common in ICP, consists of overlapping and unresolved peaks. Computer software, along with the analysis of the suspected interfering element, can compensate for this effect. Using an alternate wavelength is also a solution. Another spectral interference is caused by background, both stray light and continuous spectrum (continuous argon spectrum, for example). Background correction adjacent to the analyte line will correct background spectral interference.

7. Apparatus

7.1 *Spectrometer*.

7.1.1 *Inductively Coupled Plasma Emission Spectrometer (ICP)*—Either a scanning sequential or multi-element simultaneous type ICP, with resolution appropriate for the elements to be analyzed. The optical path may be in air, vacuum or an inert gas. A detailed description of an ICP is given in Practice E 1479.

7.1.2 *Atomic Absorption Spectrometer (AA)*—An atomic absorption spectrometer consisting of single or double beam optics, a monochromator, photomultiplier detector, adjustable slits, a wavelength range from 190 to 800 nm, and provisions for interfacing with either a strip chart recorder or a computer. A simultaneous background correction system is also recommended. A detailed description of an AA is given in Practice E 863.

7.1.2.1 *Hollow Cathode Lamps*—Single hollow cathode lamps, one for each element. Multi-element hollow cathode lamps can be used but spectral interferences are possible.

8. Reagents

8.1 *Purity of Reagents*—Reagents should conform to the specifications of the Committee on Analytical Reagents of the American Chemical Society as a minimum when such specifications are available.[6] The high sensitivity of both the ICP and AA may require reagents of high purity. It is recommended that the reagents be of sufficiently high purity so as not to lessen the accuracy of the determination.

8.2 *Purity of Water*—At minimum, water should conform to Type II of Specification D 1193.

8.3 *Stock Solutions*—Standard stock solutions may be purchased or prepared from high purity metals or metal salts (Method 6010, SW-846; EPA Methods 200.7 and 200.9). Salts should be dried at 105°C for 1 h, unless otherwise specified.

8.4 *Multi-element Calibration Standards*—ICP calibration is most often performed using multi-element calibration standards prepared from single element stock solutions. Prior to preparing the mixed standards, each stock solution should be analyzed separately to determine possible spectral interference or the presence of impurities. Standards are combined in such a way that they are chemically compatible (no precipitation occurs) and do not cause spectral interferences. An example of multi-element combinations is given in EPA Method 200.7.

8.5 *Interference Check Sample*—Interference check samples are made from single element stock solutions at a concentration level equal to that of the samples to be analyzed.

8.6 *Calibration Blank*—A calibration blank is prepared at the same acid strength as that of the samples to be analyzed; usually 5 or 10 %. To prepare a 10 % nitric acid calibration blank, add one volume of nitric acid to nine volumes of water. This same blank can be used as the rinse solution for flushing the system between standards and samples.

8.7 *Reagent Blank*—The reagent blank contains all the reagents in the same concentrations (including nitric acid) as the samples to be analyzed. The reagent blank is carried through the same processes as a sample for analysis.

[6] *Reagent Chemicals, American Chemical Society Specifications,* American Chemical Society, Washington, DC. For suggestions on the testing of reagents not listed by the American Chemical Society, see *Analar Standards for Laboratory Chemicals,* BDH Ltd., Poole, Dorset, U.K., and the *United States Pharmacopeia and National Formulary,* U.S. Pharmacopeial Convention, Inc. (USPC), Rockville, MD.

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8.8 *Nitric Acid*—High purity nitric acid is recommended.

8.9 *Lithium Tetraborate (Li2B4O7) Powder or Lithium Metaborate (LiBO2)) Powder.*

8.10 *Non-Wetting Agent*—Saturated solution of Hydrogen Bromide (HBr), Potassium Bromide (KBr) or Potassium Iodide (KI) as a non-wetting agent to prevent the flux from sticking to the crucible.

8.11 *Lanthanum Chloride (LaCl3) Powder*—Lanthanum is added to samples for AA analysis as a releasing agent (for Calcium) and ionization suppressant (for Aluminum). When added to the sample solution, Lanthanum will preferentially react with potential interferents and "release" the analyte. In addition, the Lanthanum will preferentially ionize relative to Aluminum, aiding in the number of ground state Aluminum atoms. A typical Lanthanum additive is prepared by dissolving 175 g LaCl3 in 1 L of water (equivalent to 100 g/L Lanthanum).

9. Preparation of Apparatus

9.1 Prepare and operate the spectrometer in accordance with the manufacturer's instructions. The present method assumes that good operating procedures are followed. Design differences between spectrometers make it impractical to specify the required steps in detail here.

10. Calibration and Standardization

10.1 Allow a warm-up time of at least 30 min. Operate the spectrometer according to the operation manual for the instrument.

10.2 Calibrate the instrument by aspirating the blank and standards. A 10 % by volume HNO_3 rinse solution is aspirated for a minimum of 60 s between each standard. Most new systems are controlled by computer. The computer will establish the slope, intercept and correlation coefficients for each element. Some suggested wavelengths are given in Table 1 and EPA Methods 200.2, 200.7, and 200.9.

10.3 A peristaltic pump is recommended for aspirating standards and samples. The peristaltic pump will reduce physical interferences caused by changes in specimen viscosity and concentration (transport processes).

11. Sample Preparation

11.1 *Major Elements*—Samples for major element analysis are prepared for total digestion using lithium tetraborate or lithium metaborate as a flux. Major elements include Calcium, Magnesium, Silicon, Aluminum, Iron, Manganese, Sodium and Potassium. Trace elements such as Lead, Arsenic, Selenium and Antimony will partially volatilize using this fusion method and it is therefore not recommended for trace element analysis.

11.1.1 Take a representative minus 100 mesh sample split and dry at 105°C for 2 h.

11.1.2 Weigh 0.25 g of dried sample in a graphite or platinum crucible. Then weigh 1.00 g of lithium metaborate in the crucible. Add a few drops of non-wetting agent if needed. Mix the sample and lithium metaborate (the flux) well. Cover the mixed sample-lithium metaborate with an additional 0.50 g of lithium metaborate. This will give a total sample-flux ratio of 1:6.

11.1.3 Place a lid (optional) on the crucible prepared in 11.1.2 and place in a muffle furnace at 1000°C for 30 min. Gently agitate the molten contents of the crucible at least once during the 30° min heating.

11.1.4 Add 12.5 mL of concentrated nitric acid and 40 mL of water to a clean 250 mL wide-mouth plastic bottle.

11.1.5 When the 30 min heating in 11.1.3 is complete, quickly pour molten contents of the crucible into the plastic bottle described in 11.1.4. The water will bubble and sizzle. Quickly put the lid on the plastic bottle and shake. To aid in digestion place the bottle in a warm ultrasonic bath.

11.1.6 The contents of the plastic bottle can either be quantitatively transferred to a 250 mL volumetric flask and diluted to volume or diluted to volume by weight (that is, 1 mL = 1 g) in the same 250 mL plastic bottle it was digested in. Keep in mind, however, that the standards need to be made in the same manner as the samples. Add 10 mL Lanthanum additive to samples for AA analysis (10 mL addition is part of the dilution to volume). Filtering is not necessary.

11.2 *Trace Elements*—Samples for trace element analysis are prepared using hydrochloric acid (1:5 or 1+4) and nitric acid (1:2 or 1+1). The trace elements concentrations determined by this method are termed "total recoverable" (that is, components not digested in hot acid are not recovered). Trace elements include, but are not limited to, Antimony, Arsenic, Barium, Beryllium, Boron, Cadmium, Chromium, Cobalt, Copper, Lead, Molybdenum, Nickel, Selenium, Silver, Strontium, Thallium, Tin, Vanadium, and Zinc.

11.2.1 Take a representative minus 100 mesh sample split and dry at 105°C for 2 h.

11.2.2 Weigh 1.00 g of dried sample and transfer to a clean beaker.

11.2.3 Add 10 mL of dilute hydrochloric acid (see 11.2) and 4 mL of dilute nitric acid (see 11.2). In the case of limestone, add the acids slowly so that the powdered sample will not splatter on the sides of the beaker during it's effervescent reaction with the acid. Cover the sample (a ribbed watch glass is best) and place on a hot plate. Heat at approximately 85°C for 30 min. Boiling should be kept to a minimum. After 30 min allow the sample to cool. Then quantitatively transfer the liquid and any undissolved residue to a 100 mL volumetric flask. Dilute to volume.

12. Procedure

12.1 Aspirate the specimens prepared in Section 11 into the AA or ICP using the same conditions used during calibration.

12.2 Analyze the instrument check standards, blanks and internal control samples at a 10 % or better frequency. The results on the instrument check standards are to be within 10 %, and the internal control specimens should fall within established limits of deviation. If the results exceed these limits, investigate the cause and take corrective action.

12.3 It is recommended that 10 % of the samples analyzed be duplicates. Process duplicates through the same dissolution and analysis procedures as any other sample. The results should fall within established limits of deviation. If the results exceed these limits, investigate the cause and take corrective action. The applicability of duplicate analysis data as a

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measure of analytical and sampling reproducibility assumes specimen homogeneity.

12.4 Analyze an interference check specimen at the beginning and the end of each specimen run or a minimum of twice per 8 h work shift, whichever is more frequent. This check specimen should contain, in relatively high concentration, those elements which are expected to be present at significant levels in the samples and which are known interfering species. All other elements should be present at relatively low levels in order to assess the quality of interference corrections.

12.5 Use the background and interference corrected data to calculate the concentration of each element. This calculation, including the dilution factor, is performed by the computer.

13. Precision and Bias

13.1 Participation in a round robin is anticipated.

14. Keywords

14.1 atomic absorption; atomic emission spectroscopy; digestion; dissolution; inductively coupled plasma; lime; limestone; spectrometer; trace elements

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Designation: C 1315 – 08

Standard Specification for Liquid Membrane-Forming Compounds Having Special Properties for Curing and Sealing Concrete[1]

This standard is issued under the fixed designation C 1315; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope*

1.1 This specification provides requirements for membrane-forming liquids suitable for use as curing compounds and sealers on freshly placed concrete and as sealers on hardened concrete. These membranes have special properties, such as, alkali resistance, acid resistance, adhesion-promoting qualities, and resistance to degradation by UV light.

NOTE 1—For liquid membrane-forming curing compounds specified primarily by their ability to retain water in newly placed concrete (and by drying time, and for white pigmented products, reflectance), see Specification C 309.

1.2 The values stated in SI units are to be regarded as the standard. (Inch pound units are shown in parentheses).

1.3 The following precautionary caveat pertains only to the test methods portion, Section 8, of this specification. *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

1.4 This is a performance specification. The allowable composition of products covered by this specification is limited by various local, regional, and national regulations. Issues related to air quality (solvent emission), worker exposure, and other hazards are not addressed here. It is the responsibility of the producers and users of these materials to comply with pertinent regulations.

Warning—Some VOC exempt solvents used to meet the regulations are extremely flammable with low auto ignition temperatures and rapid evaporation rates. Consult the manufacturer's product information sheet for important application and safety information.

2. Referenced Documents

2.1 *ASTM Standards:* [2]

C 156 Test Method for Water Retention by Liquid Membrane-Forming Curing Compounds for Concrete

C 309 Specification for Liquid Membrane-Forming Compounds for Curing Concrete

D 869 Test Method for Evaluating Degree of Settling of Paint

D 1308 Test Method for Effect of Household Chemicals on Clear and Pigmented Organic Finishes

D 1309 Test Method for Settling Properties of Traffic Paints During Storage

D 1544 Test Method for Color of Transparent Liquids (Gardner Color Scale)

D 1734 Practice for Making Cementitious Panels for Testing Coatings

D 2369 Test Method for Volatile Content of Coatings

D 2371 Test Method for Pigment Content of Solvent-Reducible Paints

D 3723 Test Method for Pigment Content of Water-Emulsion Paints by Low-Temperature Ashing

D 4541 Test Method for Pull-Off Strength of Coatings Using Portable Adhesion Testers

E 1347 Test Method for Color and Color-Difference Measurement by Tristimulus Colorimetry

G 154 Practice for Operating Fluorescent Light Apparatus for UV Exposure of Nonmetallic Materials

2.2 *Other Standard:*

ANSI A136.1–1992 Type I Organic Adhesives for Installation of Ceramic Tile[3]

3. Classification

3.1 The following types of liquid membrane-forming compounds are included:

3.1.1 *Type I*—Clear or translucent, and

[1] This specification is under the jurisdiction of ASTM Committee C09 on Concrete and Concrete Aggregates and is the direct responsibility of Subcommittee C09.22 on Materials Applied to New Concrete Surfaces.

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[2] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

[3] American National Standard Specifications for the Installation of Ceramic Tile, 1992, Tile Council of America, P.O. Box 1787, Clemson, SC 29633-1787.

***A Summary of Changes section appears at the end of this standard.**

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3.1.2 *Type II*—White pigmented.

3.2 The curing compound shall conform to one of the following classes:

3.2.1 *Class A* curing compounds conform to the requirements of 6.4.1, and are essentially non-yellowing,

3.2.2 *Class B* curing compounds conform to the requirements of 6.4.2, where moderate yellowing is not prohibited, and

3.2.3 *Class C* curing compounds are not restricted with regard to yellowing or darkening, and are for use where the color changes are acceptable.

NOTE 2—Polymer materials known to satisfy the durability requirements of this document include, but are not limited to, chlorinated rubbers, styrene-acrylate and styrene-butadiene copolymers. These polymers have demonstrated their durability by their ability to adhere to concrete and not be affected by the alkalies from cement.

NOTE 3—Pigmented colors other than white, or other special attributes, are beyond the scope of this specification and are subject to negotiation between the purchaser and the supplier.

4. Ordering Information

4.1 The purchaser shall include the following information in the purchase order when applicable:

4.1.1 Type and class of liquid membrane-forming compound to be furnished,

4.1.2 Rate of application to be used to determine conformance to this specification,

4.1.2.1 For Type I compounds if not specified, the liquid membrane-forming material shall be applied by uniform spraying at a rate of 7.4 m^2/L (300 ft^2/gal) for testing purposes.

4.1.2.2 For Type II compounds, if not specified, the liquid membrane-forming material shall be applied by uniform spraying at a rate of 5.0 m^2/L (200 ft^2/gal) for testing purposes.

NOTE 4—The application rate used for testing may or may not be the same as the rate used for field application. Many agencies use the same rate for field application on relatively smooth surfaces as the rate used for testing, while requiring a substantially greater application rate on deeply textured surfaces.

4.1.3 The intended method of application (for example: spraying, brushing, or by roller). If not specified, materials shall be of a sprayable consistency.

5. General Requirements

5.1 Type I liquid membrane-forming compound shall be clear or translucent and have a minimum of 25 % solids by mass when tested in accordance with 8.5.

5.2 Type II liquid membrane-forming compound shall consist of finely divided white pigment and vehicle integrally ready mixed for immediate use as is and have a minimum of 25 % vehicle solids by mass when tested in accordance with 8.6. The membrane-forming compound shall present a uniform white appearance when applied uniformly to a new concrete surface at the specified rate of application.

NOTE 5—Although this is a performance specification, a minimum vehicle solids content is specified in order to provide an approximately 0.025 mm (1 mil) thick dry film at the specified rate of application. This film thickness is considered necessary to achieve the desired characteristics.

5.3 Liquid membrane-forming compounds shall be of such a consistency that they can be readily applied by spraying, or by brushing or rolling, to form a uniform coating at temperatures above 4 °C (40 °F).

NOTE 6—For uniform application in the field on vertical concrete surfaces, the specified rate of application may be achieved by two coats, each applied at one half the normal rate with approximately 1 h drying time between coats or in accordance with manufacturer's recommendations.

5.4 Liquid membrane-forming compounds shall adhere to freshly-placed concrete that has stiffened or set sufficiently to resist marring during application. Liquid membrane-forming compounds shall also adhere to damp or dry, hardened concrete surfaces. In every case, the compound shall form a continuous film after application at the specified rate.

5.5 Liquid membrane-forming compounds shall not react deleteriously with concrete. Deleterious reactions are detected by scratching the surface of a mortar specimen used for the water-retention test with a knife or screwdriver, not less than 72 h after application, and comparing with the surface hardness similarly determined on a similar specimen that has been moist cured for one half the time. Any softening of the treated surface shall be considered sufficient cause for rejection of the compound.

5.5.1 Testing for deleterious reactions is not needed on a routine basis. However, it must be done when testing compounds of a new or unknown composition.

5.6 Liquid membrane-forming compounds shall be storable for at least 6 months without deterioration. Compounds of the water emulsion type shall not be exposed to freezing. Type II liquid membrane-forming compounds shall be capable of being mixed to a uniform consistency by stirring or agitation. When tested for long term settling, as is stated in 8.4, the compound shall have a rating of not less than 4.

6. Specific Characteristics

6.1 *Water Retention*—Liquid membrane-forming compounds, when tested in accordance with 8.1 shall restrict the loss of water to not more than 0.40 kg/m^2 in 72 h.

6.2 *Reflectance*—Type II liquid membrane-forming compounds, when tested in accordance with 8.2 shall exhibit a daylight reflectance of not less than 65 %. Reflectance properties are only for white pigmented materials.

6.3 *Drying Time*—Liquid membrane-forming compounds, when tested in accordance with 8.3 shall dry to touch in not more than 4 h.

6.4 *Ultraviolet Light (UV) Degradation-Yellowing*— When tested in accordance with 8.7.6, compounds shall be durable and remain as a complete film, free of blisters, peeling, or flaking on the surface of the mortar panel.

6.4.1 Class A Type I or Type II compounds shall have a color equal to or lighter than Gardner Color Standard No. 1 when tested in accordance with 8.7.6.

6.4.2 Class B Type I or Type II compounds shall have a color equal to or lighter than Gardner Color Standard No. 3 when tested in accordance with 8.7.6.

6.4.3 Class C shall not be tested for yellowing.

6.5 *Acid and Alkali Resistance*:

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6.5.1 The cured membrane, when tested in accordance with 8.7.7 for 48 h, shall not pin-hole, blister or disintegrate.

6.6 *Adhesion*—This requirement is to assure that the product being specified does not reduce the bonding effectiveness of adhesives commonly used to adhere flooring materials such as ceramic tile, resilient tile, wood flooring and carpet to concrete.

6.6.1 When tested in accordance with 8.8, surfaces coated with the membrane-forming compound shall pass the performance requirement of 8.8.5.

7. Sampling

7.1 Samples shall be taken either at the plant or warehouse prior to delivery, or at the point of delivery, at the option of the purchaser. If sampling is done prior to shipment, the inspector representing the purchaser shall have free access to the materials being sampled and shall be afforded all reasonable facilities for inspection and sampling.

7.2 Thoroughly shake or stir liquid membrane-forming compounds before taking a sample. Take one sample for each lot, batch, or other unit of production in a shipment. If the liquid membrane-forming compound is in mixing tanks or vats, one third of the sample shall represent the material coming from the tank at the beginning of the filling operation, one third shall represent the material coming at the middle of the filling operation, and one third shall represent the material coming at the end of the filling operation. If the liquid membrane-forming compound to be sampled is in containers, obtain a sample by taking a portion out of a number of containers equal in number to the next integer larger than the cube root of the total number of containers in the lot.

7.3 Seal all of the filled containers represented by the sample to prevent leakage, substitution or dilution. The sampling agency shall mark each container represented by the sample with a suitable identification mark for later identification and correlation.

8. Test Methods

8.1 *Water Retention Test*—Perform as per Test Method C 156. Unless otherwise specified by the manufacturer, use an application rate of 7.4 m^2/L (300 ft^2/gal) for Type I compounds and 5.0 m^2/L (200 ft^2/gal) for Type II compounds.

8.2 *Reflectance Test*—Using Test Method E 1347, determine the daylight reflectance of Type II membrane-forming compound on a mortar specimen after completion of the water retention test.

8.3 *Drying Time Test*:

8.3.1 *Scope*—This test method is used to determine the length of time for a liquid membrane-forming curing compound to dry to the touch.

8.3.2 *Significance and Use*—The ability of a liquid membrane-forming compound to dry in a suitable length of time enables the user the ability to perform other tasks on the concrete, such as sawing joints, and the like without lifting the membrane from the concrete by tracking.

8.3.3 *Procedure*—Apply the membrane-forming compound to a fresh mortar specimen at the specified rate of application and expose it to air at 23 ± 2 °C (73 ± 4 °F), 50 ± 10 % relative humidity and at an air velocity of approximately 180 m/min (600 ft/min) horizontally across the surface of the test specimen. Test the film with a finger using moderate pressure. Consider the film to be dry when the soft tacky condition no longer exists and the film feels firm.

8.3.4 *Precision and Bias*—The precision of the procedure for measuring the drying time of liquid membrane-forming compounds is being determined. The test method has no bias because there is not any acceptable reference material.

8.4 *Long Term Settling Test*—Use Test Method D 1309 for routine testing. In the case of dispute, use Test Method D 869.

8.5 *Solids Test (Type I)*—Test in accordance with Test Method D 2369.

8.6 *Vehicle Solids Test (Type II)*— Determine total nonvolatile content in accordance with Test Method D 2369, and pigment solids in accordance with Test Method D 2371 for solvent-borne products or Test Method D 3723 for water-borne products. Calculate percent vehicle solids as percent total solids minus percent pigment solids.

NOTE 7—This procedure is not satisfactory for water-borne products containing organic colorants or filler, or pigments which dehydrate or decompose below 230 °C (450 °F).

8.7 *UV Degradation, Yellowing, Acid, and Alkali Resistance*:

8.7.1 *Scope*—This procedure is used to evaluate the resistance of the membrane to the effects of UV radiation, acid, and alkali.

8.7.2 *Significance and Use*—Curing membranes are exposed to water and alkali in concrete and frequently are subjected to ultraviolet light, any or all of which can degrade some polymers. These tests are used to evaluate durable membranes. Polymers used in formulations to comply with these requirements are alkali and acid resistant and adhere well to concrete surfaces. As such, they are suitable for use under many latex and alkyd base paints and do not interfere with the adhesion of most resilient floor coverings, parquet wood floors, carpets or carpet tiles. The compounds are also suitable for sealing and protecting exterior concrete surfaces against the intrusion of water and some chemicals.

8.7.3 *Materials*—Five mortar panels, prepared as directed in Practice D 1734, 5 % aqueous sodium hydroxide by mass, 10 % aqueous hydrochloric acid by mass, and watch glasses.

8.7.4 *Equipment*—as described in Practice G 154, with UV-A 340 light source.

8.7.5 *Preparation of Specimens*—Coat five mortar panels at the rate of 7.4 m^2/L (300 ft^2/gal) and allow to dry for at least 24 h.

8.7.6 *Yellowing Resistance*:

8.7.6.1 Expose three of the panels for 336 h (2 weeks) in accordance with Practice G 154 with a test cycle consisting of alternating periods of 8 h UV radiation at 60 °C (140 °F) and 4 h condensation at 50 °C (122 °F).

8.7.6.2 *Interpretation of Results*—Compare the panels after the test period to the color of the Gardner Color Standards of Test Method D 1544. Report the results as lighter, the same, or darker than the designated color. Also report if the membrane was damaged or destroyed during the test.

8.7.7 *Alkali and Acid Resistance*:

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8.7.7.1 *Procedure*—Test the cured membrane on two panels as directed in Test Method D 1308 using the covered spot test method and 5 % aqueous sodium hydroxide solution on one panel and 10 % aqueous hydrochloric acid solution on the other panel.

8.7.7.2 *Interpretation of Results*—Report whether the membranes pinhole, disintegrate, blister or discolor.

8.7.7.3 *Precision and Bias*—No information is presented about the precision or bias of this test method since the result is non-quantitative.

8.8 *Adhesion*:

8.8.1 *Scope*—This test is used to determine if the membrane formed by the product being tested is compatible with tile adhesives of the types listed in 8.8.3.3 or other types as agreed upon between supplier and purchaser.

8.8.2 *Significance and Use*—Durable curing and sealing membranes are used to promote surface strength and prevent dusting of concrete. The subsequent adhesion of topcoats such as tile adhesives is sometimes affected positively or adversely by the membrane. This test method evaluates the bonding between the membrane and an adhesive.

8.8.3 *Apparatus*:

8.8.3.1 *Mortar Panels*—Three mortar panels for each adhesive to be tested, prepared according to Practice D 1734[4] (the test is run in triplicate).

8.8.3.2 *Test Apparatus* as described in Annex A2 of Test Method D 4541 with a 40-mm (1 9⁄16-in.) loading fixture (available from the manufacturer). (See Note 8.)

NOTE 8—The usual apparatus employs a 20-mm loading fixture. The 40-mm fixture permits measurements in the low range of forces required.

8.8.3.3 *Adhesives*—Ceramic tile adhesive shall meet the requirements of ANSI A136.1–1992. Adhesives for other systems shall be of a type recommended for the installation of materials of interest over concrete. No product specifications are currently in force for these other adhesives.

8.8.4 *Procedure*—For each adhesive to be tested, coat three mortar panels with the membrane-forming curing compound under test at the specified application rate and allow to dry 72 h at 23 ± 2 °C (73.5 ± 3.5 °F) 50 ± 10 % relative humidity. Apply the adhesive on each panel at the rate specified by the manufacturer to a 40-mm (1 9⁄16-in.) diameter area, affix the loading fixture, allow the adhesive to cure in accordance with the manufacturer's instructions, and determine the pull-off strength in accordance with Test Method D 4541. (See Note 9.)

NOTE 9—Pull-off strength results obtained using devices other than specified in Annex A2 of Test Method D 4541 may be different because the results depend on parameters of the specific test instrument.

8.8.5 *Interpretation of Results*—This test is a pass/fail determination. If the measured pull-off strength is greater than 0.50 MPa (70 psi) in at least two thirds of the trials, the membrane passes.

8.8.5.1 If the measured pull-off strength is less than 0.50 MPa (70 psi), examine the failure surface to determine if failure occurred in the adhesive/membrane bond or at other interfaces. Estimate the percent of adhesive and cohesive failure in accordance to their respective areas and locations within the test system.

8.8.5.2 The test system is described as consisting of: substrate (A, the mortar specimen); the coating under test (B, a C 1315 liquid membrane-forming curing compound); the adhesive (Y, e.g. tile or carpet adhesive); and the pull-off fixture (Z).

8.8.5.3 Designate cohesive failures by the layers within which they occur as A, B, or Y, and the percent of each.

8.8.5.4 Designate adhesive failures by the interfaces at which they occur as A/B, B/Y, or Y/Z, and the percent of each.

8.8.5.5 A result that is very different from most of the results, caused by a mistake in recording or calculating, or by circumstances involved in preparation of the test specimens, shall be dropped from the analysis of the test. Valid reasons for dropping results include misalignment of the apparatus, improper application of the adhesive, voids or inclusions in the adhesive and sliding or twisting the fixture during the cure of the adhesive.

8.8.5.6 Disregard any test where failure in the adhesive (Y), failure of the bond (Y/Z), or both represents more than 50 % of the area. If all tests result in failure of the adhesive (Y or YZ) at less than 0.50 MPa (70 psi) repeat the evaluation using a different adhesive. (See Note 10.)

NOTE 10—To avoid results of this type, an adhesive can be tested between two pull-off fixtures to establish its inherent pull-off strength prior to running the material evaluation.

8.8.5.7 If more than 20 % of the failure occurs in B, A/B and B/Y at less than 0.50 MPa (70 psi), the membrane is suspect and the trial fails.

8.8.6 *Precision and Bias*—Precision is being determined. The test method for measuring adhesion has no bias because the value of adhesion is defined only in terms of this test method.

9. Packaging and Package Marking

9.1 The liquid membrane-forming compound shall be delivered in the manufacturer's original, clean, and sealed containers. The manufacturer shall ensure that material in all containers is representative of the compound produced. Each container shall be marked with:

9.1.1 The name of the manufacturer,

9.1.2 The trade name of the compound,

9.1.3 The ASTM designation and type of compound,

9.1.4 The nominal percentage of nonvolatile material (Note 11), and

9.1.5 The manufacturer's lot or batch designation.

NOTE 11—The listing of the nominal percentage of nonvolatile materials by the manufacturer, and the reporting of this information on the identification accompanying the sample, will enable the testing agency to determine whether the compound in the containers was adequately stirred and the sample is reasonably representative of the membrane-forming compound produced. Type II membrane-forming compounds are especially prone to separation due to settling of the pigment.

[4] The sole commercial source of supply of the mortar panels known to the committee at this time is Masonry Test Block Company, 6389 Lawndale, Saginaw, MI 48004. If you are aware of alternative suppliers, please provide this information to ASTM International Headquarters. Your comments will receive careful consideration at a meeting of the responsible technical committee [1], which you may attend.

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10. Keywords

10.1 acid resistance; adhesion promoting; alkali resistance; curing compounds; liquid membrane-forming compounds; sealers; yellowing resistance

SUMMARY OF CHANGES

Committee C09 has identified the location of selected changes to this specification since the last issue, C 1315 – 07, that may impact the use of this specification. (Approved March 1, 2008)

(*1*) Revised paragraph 8.1.

Committee C09 has identified the location of selected changes to this specification since the last issue, C 1315 – 06, that may impact the use of this specification. (Approved June 1, 2007)

(*1*) Added new paragraph 1.4.

(*2*) Deleted old paragraphs 5.7 and 8.7, and old Footnote 4.

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Designation: C 1318 – 95 (Reapproved 2009)ε1

Standard Test Method for Determination of Total Neutralizing Capability and Dissolved Calcium and Magnesium Oxide in Lime for Flue Gas Desulfurization (FGD)[1]

This standard is issued under the fixed designation C 1318; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

ε[1] NOTE—A units statement was added editorially as new paragraph 1.4 and subsequent paragraphs were renumbered in June 2009.

1. Scope

1.1 This test method covers analysis of magnesian, dolomitic and high-calcium limes for total neutralizing capability and dissolved major oxides. Dissolved calcium and magnesium are the major species that neutralize acid under the conditions of the test.

1.2 The test conditions are chosen to measure the acid-neutralizing capacity of both calcium hydroxide and magnesium hydroxide contained in slaked lime. By controlling the neutralization pH at 6, magnesium hydroxide and magnesium oxide are titrated in addition to calcium hydroxide fraction.

1.3 This test method also determines the fraction of Mg ions present in the lime that will dissolve under lime flue gas desulfurization (FGD) conditions. Because the Mg^{++} ion alters FGD performance, it is important to know its concentration.

1.4 The values stated in SI units are to be regarded as standard. No other units of measurement are included in this standard.

1.5 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

2. Referenced Documents

2.1 *ASTM Standards:*[2]

C 25 Test Methods for Chemical Analysis of Limestone, Quicklime, and Hydrated Lime

C 50 Practice for Sampling, Sample Preparation, Packaging, and Marking of Lime and Limestone Products

C 51 Terminology Relating to Lime and Limestone (as used by the Industry)

3. Terminology

3.1 *Definitions*—Unless otherwise specified, for definitions of terms used in these test methods refer to Terminology C 51.

4. Summary of Test Method

4.1 Lime is slaked by boiling and is reacted with acid at a pH and residence time similar to those found in full-scale FGD reaction tanks.

4.2 A sample of lime is titrated with 1N hydrochloric acid, maintaining a pH of 6 for 30 min. After 30 min, the acid consumption is recorded. The total neutralizing capacity is calculated from the acid consumption and reported as CaO. Dissolved magnesium is determined by atomic absorption spectrometry or by EDTA titration and reported as percent dissolved Magnesium Oxide (as MgO).

5. Significance and Use

5.1 There are existing lime-based flue gas desulfurization units in operation that require a method to measure the oxides available for sulfur dioxide absorption. Dissolved magnesium oxide varies among limes depending on the limestone sources and calcination conditions.

6. Interferences

6.1 Any substance reacting with acid under the conditions of the test will contribute to the total oxide and dissolved oxide values.

[1] This test method is under the jurisdiction of ASTM Committee C07 on Lime and is the direct responsibility of Subcommittee C07.05 on Chemical Tests.

Current edition approved June 1, 2009. Published September 2009. Originally approved in 1995. Last previous edition approved in 2001 as C 1318 – 95(2001).

[2] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

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6.2 Magnesium in forms other than MgO, which dissolve under test conditions, may affect the dissolved MgO and total oxide value.

7. Apparatus

7.1 *Digital Readout pH Meter*, with combination electrode readable to 0.01 pH units, or an autotitrator with an automatic temperature compensator capable of titrating to a preset endpoint (Note 1).

NOTE 1—Use of an automatic titrator is recommended.

7.2 *Stirrers and Stir Bars*.

7.3 *Atomic Absorption Spectrometer*, if not using EDTA titration.

7.4 *Filtering Funnel*, Type AE glass fiber paper, volumetric flasks (size as needed), 500 mL volumetric flasks, and various Class A pipettes.

8. Reagents

8.1 *1.0 Normal Hydrochloric Acid*, standardize using procedures in Test Methods C 25, Section 28.

8.2 *Distilled Water*, CO_2 free.

8.3 *Calcium and Magnesium Standard Solutions* (commercially available or use methods in Test Methods C 25, Section 31).

8.4 *EDTA Standard Solution* (0.4 %), standardize according to Test Methods C 25, Section 31.5, Standardization of EDTA.

9. Sample Preparation

9.1 The sampling and grinding of any lime sample shall be carried out as rapidly as possible, so that the absorption of moisture and carbon dioxide is held to a minimum.

9.2 The sample as received at the laboratory shall be thoroughly mixed and a representative sample with minimum weight of 100 g shall be taken and pulverized to pass a No. 50 mesh sieve for analysis.

9.3 The prepared sample shall be stored in a tightly capped container.

10. Procedure

10.1 *Slaking of Lime Sample*:

10.1.1 Weigh rapidly 1.402 g of the finely pulverized sample and brush carefully into a 250 mL Erlenmeyer flask containing about 50 mL of CO_2 free water and immediately stopper the flask.

10.1.2 Remove the stopper. Swirl the flask, place on a hot plate and boil actively 1 min for complete slaking. Remove from the hot plate, stopper the flask loosely and place in a cold-water bath to cool to room temperature.

10.2 *Titration of Sample*:

10.2.1 Set the pH electrode, burette tip, and temperature sensing device in place, while maintaining agitation.

10.2.2 Begin the titration by adding standard 1.0 normal hydrochloric acid solution. Titrate to and maintain a pH of 6 within 0.4 pH units for 30 min (Note 2). Time begins from initial addition of acid.

NOTE 2—When doing a manual titration, the increment of acid addition may require the use of partial drops (suspend a small amount of titrant on the buret tip and wash into the titration flask with CO_2 free distilled water) to avoid exceeding the 0.4 unit limit of pH 6.

10.2.3 Record the amount of acid consumed after 30 min.

10.2.4 Filter the solution and rinse the flask thoroughly with CO_2 free distilled water.

10.2.5 Carefully transfer the solution to an appropriately sized volumetric flask, add approximately 10 mL of 1:1 hydrochloric acid, and dilute to volume.

10.3 *Determination of Dissolved Oxides*:

10.3.1 *Atomic Absorption*:

10.3.1.1 From the diluted solution make the required dilutions and determine the dissolved magnesium by standard atomic absorption spectroscopy techniques.

10.3.1.2 Calculate the dissolved magnesium as MgO according to 11.2.

10.3.2 *EDTA Titration*:

10.3.2.1 From the diluted solution pipette 20 mL of sample into a 500 mL Erlenmeyer flask and dilute with CO_2 free distilled water to an approximate volume of 100 mL.

10.3.2.2 Determine the total dissolved calcium according to Test Methods C 25, Paragraph 31.6.4. Record mL of EDTA required for titration.

10.3.2.3 Repeat 10.3.2 and determine the total dissolved oxides according to Test Methods C 25, Paragraph 31.6.5. Record mL of EDTA required for this titration.

11. Calculation of Results

11.1 *Percent Total Neutralizing Capability (TNC)*:

$$\%\ TNC\ (\text{as CaO}) = \frac{A \times B \times C_1}{W} \quad (1)$$

where:

A = mL HCl used in 10.2.3,
B = normality HCl,
C_1 = chemical factor = 2.804 (mequi of CaO/10), and
W = sample weight, g.

11.2 *Atomic Absorption*:

11.2.1 *Dilution Factor*:

$$\text{Dilution factor} = \text{Initial Volume (see 10.2.5)/Pipette volume for final dilution} \quad (2)$$

11.2.2 *Percent Dissolved Magnesium*:

$$\%\ \text{Dissolved Mg++ (as MgO)} = \frac{A \times B \times C_2 \times D}{W \times 1000} \quad (3)$$

where:

A = concentration of magnesium from AA, ppm Mg^{++},
B = dilution factor,
C_2 = chemical factor = 1.658 (MgO/Mg^{++}),
D = final dilution volume, mL, and
W = sample weight, g.

11.3 *EDTA Titration*:

11.3.1 *Dilution Factor*:

$$\text{Dilution factor} = \text{Initial Volume (see 10.2.5)/titration volume (20 mL)} \quad (4)$$

11.3.2 *Percent Dissolved Calcium*:

$$\%\ \text{Dissolved Ca++ (as CaO)} = \frac{A \times B \times C_3 \times D}{W \times 10} \quad (5)$$

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where:
A = mL of EDTA standard solution used,
B = dilution factor,
C_3 = chemical factor = 1.399 (CaO/Ca^{++}),
D = EDTA titer, mg Ca^{++}/mL EDTA, and
W = sample weight, g.

11.3.3 *Percent Total Dissolved Oxides (TDO)*:

$$\%\ TDO\ (\text{as CaO}) = \frac{A \times B \times C_3 \times D}{W \times 10} \quad (6)$$

where:
A = mL of EDTA standard solution used,
B = dilution factor,
C_3 = chemical factor = 1.399 (CaO/Ca^{++}),
D = EDTA titer, mg Ca^{++}/mL EDTA, and
W = sample weight, g.

11.3.4 *Percent Dissolved Magnesium*:

$$\%\ \text{Dissolved Mg++ (as MgO)} = (A - B) \times C_4 \quad (7)$$

where:
A = % total dissolved oxides,
B = % dissolved calcium, and
C_4 = chemical factor = 0.7188 (MgO/CaO).

12. Precision and Bias

12.1 The precision and bias of this test method have not been determined.

12.2 When sufficient data has been obtained and analyzed, a statement of precision will be provided.

12.3 The user is cautioned to verify by the use of reference materials, if available, that the bias of the test method is adequate for the contemplated use.

13. Keywords

13.1 dissolved calcium; dissolved magnesium; flue gas desulfurization (FGD); lime; pH determination; total neutralizing capability

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Designation: C 1328 – 05

Standard Specification for Plastic (Stucco) Cement[1]

This standard is issued under the fixed designation C 1328; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope

1.1 This specification covers two types of plastic cement for use in portland cement-based plasters for exterior (stucco) and interior application.

1.2 The values stated in SI units are to be regarded as the standard. Values in SI units shall be obtained by measurement in SI units or by appropriate conversion, using the Rules for Conversion and Rounding given in IEEE/ASTM SI 10, of measurements made in other units.

1.3 The text of this standard refers to notes and footnotes that provide explanatory material. These notes and footnotes (excluding those in tables and figures) shall not be considered as requirements of the standard.

1.4 The following safety hazards caveat pertains only to Sections 14 and 15. *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.* (**Warning—**Fresh hydraulic cementitious mixtures are caustic and may cause chemical burns to skin and tissue upon prolonged exposure.)[2]

2. Referenced Documents

2.1 *ASTM Standards:* [3]

C 109/C 109M Test Method for Compressive Strength of Hydraulic Cement Mortars (Using 2-in. or [50-mm] Cube Specimens)

C 151 Test Method for Autoclave Expansion of Hydraulic Cement

C 183 Practice for Sampling and the Amount of Testing of Hydraulic Cement

C 185 Test Method for Air Content of Hydraulic Cement Mortar

C 187 Test Method for Normal Consistency of Hydraulic Cement

C 188 Test Method for Density of Hydraulic Cement

C 219 Terminology Relating to Hydraulic Cement

C 266 Test Method for Time of Setting of Hydraulic-Cement Paste by Gillmore Needles

C 305 Practice for Mechanical Mixing of Hydraulic Cement Pastes and Mortars of Plastic Consistency

C 430 Test Method for Fineness of Hydraulic Cement by the 45-μm (No. 325) Sieve

C 511 Specification for Mixing Rooms, Moist Cabinets, Moist Rooms, and Water Storage Tanks Used in the Testing of Hydraulic Cements and Concretes

C 778 Specification for Standard Sand

C 926 Specification for Application of Portland Cement-Based Plaster

C 1506 Test Method for Water Retention of Hydraulic Cement-Based Mortars and Plasters

IEEE/ASTM SI 10 Standard for Use of the International System of Units (SI) (the Modernized Metric System)

3. Terminology

3.1 *Definitions*—Terms used in this specification are defined in Terminology C 219 and Specification C 926.

3.2 *Definition of Term Specific to This Standard:*

3.2.1 *plastic cement*—a hydraulic cement, primarily used in portland cement-based plastering construction, consisting of a mixture of portland or blended hydraulic cement and plasticizing materials (such as limestone or hydrated or hydraulic lime), together with other materials introduced to enhance one or more properties such as setting time, workability, water retention, and durability.

3.2.1.1 *Discussion*—The term "plastic" does not refer to the inclusion of one or more organic components in the cement. The cement is predominantly inorganic in chemical composition. The term "plastic" refers to the ability of the cement to impart to the plaster a high degree of workability, and for the

[1] This specification is under the jurisdiction of ASTM Committee C01 on Cement and is the direct responsibility of Subcommittee C01.11 on Masonry Cement.

Current edition approved September 15, 2005. Published October 2005. Originally approved in 1996. Last previous edition approved in 2003 as C 1328 – 03a.

[2] *Annual Book of ASTM Standards*, Vol 04.01. See the section on Safety Precautions in the Manual of Cement Testing.

[3] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

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plaster to remain workable or plastic for a period of time so that, after initial application and floating on the wall, it can be reworked to obtain both densification and desired texture.

4. Physical Properties

4.1 Plastic cement shall conform to the applicable requirements prescribed in Table 1.

5. Sampling

5.1 At the option of the purchaser, the cement shall be sampled and tested to verify compliance with this specification, sampling and testing shall be performed in accordance with Practice C 183.

5.2 Practice C 183 is not designed for manufacturing quality control and is not required for manufacturer's certification.

6. Temperature and Humidity

6.1 The temperature and relative humidity of the air in the vicinity of the mixing slab and dry materials, molds, base plates, and mixing bowl shall conform to the requirements of Test Method C 109/C 109M.

6.2 The moist cabinet or moist room shall conform to the requirements of Specification C 511.

7. Fineness

7.1 Determine the residue on the 45-μm (No. 325) sieve in accordance with Test Method C 430.

8. Normal Consistency

8.1 Determine normal consistency by the Vicat apparatus in accordance with Test Method C 187.

9. Autoclave Expansion

9.1 Determine the autoclave expansion in accordance with Test Method C 151. After molding, store the bars in the moist cabinet or room for 48 h ± 30 min before removal from the molds for measurement and testing in the autoclave. Calculate the difference in length of the test specimen before and after autoclaving to the nearest 0.01 % of the effective gage length, and report as the autoclave expansion of the plastic cement.

10. Time of Setting

10.1 Determine the time of setting by the Gillmore needle method in accordance with Test Method C 266.

11. Density

11.1 Determine the density of the plastic cement in accordance with Test Method C 188, using kerosine as the liquid. Use the density so determined in the calculation of the air content of the plaster.

12. Blended Sand

12.1 The sand shall be a blend of equal parts by weight of graded standard sand and standard 20–30 sand conforming to Specification C 778.

13. Preparation of Plaster

13.1 *Proportions for Plaster*—Plaster for air entrainment, compressive strength, and water retention tests shall be proportioned to contain 1620 g of sand and a mass of cement, in grams, as indicated in Table 2. The sand shall consist of 810 g of graded standard sand and 810 g of 20–30 standard sand (Note 1). The quantity of water, measured in millilitres, shall be such as to produce a flow of 110 ± 5, as determined by Test Method C 109/C 109M.

NOTE 1—Historically, field-mixed plaster has been proportioned by volume measured in increments or fractions of 1 ft^3. The comparable whole SI-unit volume to 1 ft^3 is 28 L. The specified plaster proportions approximate the 1:3 nominal proportions by volume, commonly specified for construction, on the basis of the following assumed mass and volume relationships:

The mass of dry sand in 28 L of loose damp sand is 36 k.
28 L of Type S Plastic (Stucco) cement has a mass of 35 kg.
28 L of Type M Plastic (Stucco) cement has a mass of 42 kg.

For example, the amount of cement needed to provide a 1:3 volume proportion of cement to sand using a Type S Plastic (Stucco) cement is:

TABLE 1 Physical Requirements

Plastic Cement Type	S	M
Fineness, residue on a 45-μm (No. 325) sieve, max,%	24	24
Autoclave expansion, max, %	1.0	1.0
Time of setting, Gillmore method:		
Initial set, minutes, not less than	90	90
Initial set, minutes, not more than	1000	1000
Compressive strength (average of three cubes):		
The compressive strength of mortar cubes, composed of 1 part cement and 3 parts blended sand (half graded standard sand and half standard 20–30 sand) by volume, prepared and tested in accordance with this specification, shall be equal to or higher than the values specified for the ages indicated below:		
7 days, MPa (psi)	9.0 (1300)	12.4 (1800)
28 days, MPa (psi)	14.5 (2100)	20.0 (2900)
Air content of mortar:		
Min, volume%	8	8
Max, volume %	20	20
Water retention value, min, %, of original flow	70	70

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TABLE 2 Cement in Laboratory Batch of Plastic

Plastic (Stucco) Cement Type	Mass of Cement, g
S	525
M	630

$$A = 1620 \times (C/B) = 1620 \times (35/108) = 525 \quad (1)$$

where:

A = number of grams of cement to be used in the mortar with 1620 g of sand,
B = $3 \times 36 = 108$ kg, the mass of dry sand in 84 (or 3×28) L of loose damp sand, and
C = mass of Type S Plastic (Stucco) cement per 28 L.

13.2 *Mixing of Plasters*—Mix the plaster in accordance with Practice C 305.

13.3 *Determination of Flow*—Determine the flow in accordance with Test Method C 109/C 109M.

14. Air Entrainment

14.1 *Procedure*—If the plaster has the correct flow, use a separate portion of the plaster for the determination of entrained air. Determine the mass of 400 mL of plaster in accordance with Test Method C 185.

14.2 *Calculation*—Calculate the air content of the plaster, and report it to the nearest 1 % as follows:

$$D = (W_1 + W_2 + V_w)/[(W_1/S_1) + (W_2/S_2) + V_w] \quad (2)$$

$$A = 100 - (W_m/4D)$$

where:

D = density of air-free plaster, g/cm^3,
W_1 = mass of cement, g,
W_2 = mass of sand, g,
V_w = mL-g of water used,
S_1 = density of cement, g/cm^3,
S_2 = density of standard sand, 2.65 g/cm^3,
A = volume percent of entrained air, and
W_m = mass of 400 mL of plaster, g.

15. Compressive Strength

15.1 *Test Specimens*:

15.1.1 *Molding*—Immediately after determining the flow and mass of 400 mL of plaster, return all of the plaster to the mixing bowl and remix for 15 s at the medium speed. Then mold the test specimens in accordance with Test Method C 109/C 109M, except that the elapsed time for mixing plaster, determining flow, determining air entrainment, and starting the molding of cubes shall be within 8 min.

15.1.2 *Storage*—Immediately after molding, store all test specimens in the molds on plane plates in a moist cabinet or moist room for 48 to 52 h in such a manner that the upper surfaces shall be exposed to the moist air. Then remove the cubes from the molds, and place them in the moist cabinet or moist room for 5 days in such a manner as to allow free circulation of air around at least five faces of the specimens. At the age of 7 days, immerse the cubes for the 28-day tests in saturated lime water in storage tanks of noncorrodible materials.

15.2 *Procedure*:

15.2.1 Test the cube specimens immediately after their removal from the moist cabinet or moist room for 7-day specimens, and immediately after their removal from storage water for all other specimens. If more than one specimen at a time is removed from the moist cabinet or moist room for 7-day tests, cover these cubes with a damp cloth until the time of testing.

15.2.2 The remainder of the testing procedure shall conform to Test Method C 109/C 109M.

16. Water Retention

16.1 Water retention shall be determined in accordance with the procedures in Test Method C 1506, except wherever the term "mortar" is used, read "plaster."

17. Storage

17.1 The cement shall be stored in such a manner as to permit easy access for the proper inspection and identification of each shipment, and in a suitable weathertight building that will protect the cement from dampness and minimize warehouse set.

18. Inspection

18.1 Adequate facilities shall be provided to the purchaser for the necessary inspection and sampling.

18.2 All packages shall be in good condition at the time of inspection.

19. Rejection

19.1 At the option of the purchaser, the cement shall be rejected if it fails to meet any of the requirements of this specification.

19.2 At the option of the purchaser, packages more than 2 % below the mass marked thereon shall be rejected. At the option of the purchaser, the entire shipment represented shall be rejected if the average mass of packages in any shipment as shown by weighing 50 packages taken at random is less than that marked on the packages.

19.3 At the option of the purchaser, cement remaining in storage prior to shipment for a period greater than six months after testing shall be retested and, at the option of the purchaser, shall be rejected if it fails to meet any of the requirements of this specification.

20. Manufacturer's Certification

20.1 Upon request of the purchaser in the contract or order, a manufacturer's report shall be furnished at the time of shipment stating the results of the tests made on samples of the material taken during production or transfer and certifying that the applicable requirements of this specification have been met.

21. Packaging and Package Marking

21.1 When plastic cement is delivered in packages, the brand, name of the manufacturer, net mass of the package in kg (see Note 2) shall be indicated plainly thereon. Similar information shall be provided in the shipping documents accompanying the shipment of plastic cement in bulk.

NOTE 2—To facilitate the change to SI units, a standard SI package size

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of 35 Kg for Type S and 42 Kg for Type M will provide convenient mass increments reasonably similar to the traditional 77- and 94-lb packages.

22. Keywords

22.1 plaster; plastic cement; portland cement-based plaster; stucco

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Designation: C 1329 – 05

Standard Specification for Mortar Cement[1]

This standard is issued under the fixed designation C 1329; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope

1.1 This specification covers three types of mortar cement for use where mortar for masonry is required.

1.2 The values stated in SI units are to be regarded as the standard. Values in SI units shall be obtained by measurement in SI units or by appropriate conversion, using the Rules for Conversion and Rounding given in IEEE/ASTM SI 10, of measurements made in other units.

1.3 The text of this standard refers to notes and footnotes which provide explanatory material. These notes and footnotes (excluding those in tables and figures) shall not be considered as requirements of the standard.

1.4 The following safety hazards caveat pertains only to Section 16. *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.* (**Warning—**Fresh hydraulic cementitious mixtures are caustic and may cause chemical burns to skin and tissue upon prolonged exposure.[2])

2. Referenced Documents

2.1 *ASTM Standards:* [3]

C 91 Specification for Masonry Cement

C 109/C 109M Test Method for Compressive Strength of Hydraulic Cement Mortars (Using 2-in. or [50-mm] Cube Specimens)

C 151 Test Method for Autoclave Expansion of Hydraulic Cement

C 183 Practice for Sampling and the Amount of Testing of Hydraulic Cement

C 185 Test Method for Air Content of Hydraulic Cement Mortar

C 187 Test Method for Normal Consistency of Hydraulic Cement

C 188 Test Method for Density of Hydraulic Cement

C 219 Terminology Relating to Hydraulic Cement

C 266 Test Method for Time of Setting of Hydraulic-Cement Paste by Gillmore Needles

C 305 Practice for Mechanical Mixing of Hydraulic Cement Pastes and Mortars of Plastic Consistency

C 430 Test Method for Fineness of Hydraulic Cement by the 45-μm (No. 325) Sieve

C 511 Specification for Mixing Rooms, Moist Cabinets, Moist Rooms, and Water Storage Tanks Used in the Testing of Hydraulic Cements and Concretes

C 778 Specification for Standard Sand

C 1357 Test Methods for Evaluating Masonry Bond Strength

C 1506 Test Method for Water Retention of Hydraulic Cement-Based Mortars and Plasters

IEEE/ASTM SI 10 Standard for Use of the International System of Units (SI): The Modern Metric System

3. Terminology

3.1 *Definitions*—Terms used in this specification are defined in Terminology C 219.

3.2 *Definition of Term Specific to This Standard:*

3.2.1 *mortar cement*—a hydraulic cement, primarily used in masonry construction, consisting of a mixture of portland or blended hydraulic cement and plasticizing materials (such as

[1] This specification is under the jurisdiction of ASTM Committee C01 on Cement and is the direct responsibility of Subcommittee C01.11 on Masonry Cement.

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[2] *Annual Book of ASTM Standards*, Vol 04.01. See the section on Safety Precautions in the Manual of Cement Testing.

[3] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

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limestone or hydrated or hydraulic lime), together with other materials introduced to enhance one or more properties such as setting time, workability, water retention, and durability.

3.2.1.1 *Discussion*—Mortar cement is similar to masonry cement in use and function (See Specification C 91). However, this specification requires lower air contents and includes a flexural bond strength requirement.

4. Classification

4.1 Mortar cements are classified as Type N, S, or M, according to the physical requirements prescribed in Table 1.

5. Physical Properties

5.1 Mortar cement shall conform to the applicable requirements prescribed in Table 1 for its classification.

6. Sampling

6.1 At the option of the purchaser, the cement shall be sampled and tested to verify compliance with this specification, sampling and testing shall be performed in accordance with Practice C 183.

6.2 Practice C 183 is not designed for manufacturing quality control and is not required for manufacturer's certification.

7. Temperature and Humidity

7.1 The temperature and relative humidity of the air in the vicinity of the mixing slab and dry materials, molds, base plates, and mixing bowl shall conform to the requirements of Test Method C 109/C 109M.

7.2 The moist cabinet or moist room shall conform to the requirements of Specification C 511.

8. Fineness

8.1 Determine the residue on the 45-μm (No. 325) sieve in accordance with Test Method C 430.

9. Normal Consistency

9.1 Determine the normal consistency by the Vicat apparatus in accordance with Test Method C 187.

10. Autoclave Expansion

10.1 Determine the autoclave expansion in accordance with Test Method C 151. After molding, store the bars in the moist cabinet or room for 48 h ± 30 min before removal from the molds for measurement and testing in the autoclave. Calculate the difference in length of the test specimen before and after autoclaving to the nearest 0.01 % of the effective gage length, and report as the autoclave expansion of the mortar cement.

11. Time of Setting

11.1 Determine the time of setting by the Gillmore needle method in accordance with Test Method C 266.

12. Density

12.1 Determine the density of the mortar cement in accordance with Test Method C 188, using kerosine as the liquid. Use the density so determined in the calculation of the air content of the mortars.

13. Blended Sand

13.1 The sand shall be a blend of equal parts by weight of graded standard sand and 20–30 standard sand conforming to Specification C 778.

14. Preparation of Mortar

14.1 *Proportions for Mortar*—Mortar for air entrainment, compressive strength, and water retention tests shall be proportioned to contain 1620 g of sand and a mass of cement, in grams, as indicated in Table 2. The sand shall consist of 810 g of graded standard sand and 810 g of 20-30 standard sand (Note 1). The quantity of water, measured in millilitres, shall be such as to produce a flow of 110 ± 5 as determined by Test Method C 109/C 109M.

NOTE 1—Historically, field-mixed mortar has been proportioned by volume measured in increments or fractions of 1 ft^3. The comparable whole SI-unit volume to 1 ft^3 is 28 L. The specified mortar proportions approximate the 1:3 nominal proportions by volume, commonly specified for construction, on the basis of the following assumed mass and volume relationships:

The mass of dry sand in 28 L of loose damp sand is 36 kg.
28 L of Type N mortar cement has a mass of 32 kg.
28 L of Type S mortar cement has a mass of 34 kg.
28 L of Type M mortar cement has a mass of 36 kg.

For example, the amount of cement needed to provide a 1:3 volume proportion of cement to sand using a Type N mortar cement is calculated as follows:

TABLE 1 Physical Requirements

Mortar Cement Type	N	S	M
Fineness, residue on a 45-μm (No. 325) sieve, max, %	24	24	24
Autoclave expansion, max, %	1.0	1.0	1.0
Time of setting, Gillmore method:			
Initial set, minutes, not less than	120	90	90
Initial set, minutes, not more than	1000	1000	1000
Compressive strength (average of three cubes):			
The compressive strength of mortar cubes, composed of 1 part cement and 3 parts blended sand (half graded standard sand and half standard 20–30 sand) by volume, prepared and tested in accordance with this specification, shall be equal to or higher than the values specified for the ages indicated below:			
7 days, MPa (psi)	3.5 (500)	9.0 (1300)	12.4 (1800)
28 days, MPa (psi)	6.2 (900)	14.5 (2100)	20.0 (2900)
Flexural bond strength			
28 days, min, MPa (psi)	0.5 (70)	0.7 (100)	0.8 (115)
Air content of mortar:			
Min, volume %	8	8	8
Max, volume %	17	15	15
Water retention value, min, %, of original flow	70	70	70

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TABLE 2 Cement in Laboratory Batch of Mortar

Mortar Cement Type	Mass of Cement, g
N	480
S	510
M	540

$$A = 1620 \times (C/B) = 1620 \times (32/108) = 480 \quad (1)$$

where:

A = number of grams of cement to be used in the mortar with 1620 g of sand,
B = 3 × 36 = 108 kg, the mass of dry sand in 84 (or 3 × 28) L of loose damp sand, and
C = mass of Type N mortar cement per 28 L.

14.2 *Mixing of Mortars*—Mix the mortar in accordance with Practice C 305.

14.3 *Determination of Flow*—Determine the flow in accordance with Test Method C 109/C 109M.

15. Air Entrainment

15.1 *Procedure*—If the mortar has the correct flow, use a separate portion of the mortar for the determination of entrained air. Determine the mass of 400 mL of mortar in accordance with Test Method C 185.

15.2 *Calculation*—Calculate the air content of the mortar, and report it to the nearest 1 % as follows:

$$D = (W_1 + W_2 + V_w)/[(W_1/S_1) + (W_2/S_2) + V_w]A = 100 - (W_m/4D) \quad (2)$$

where:

D = density of air-free mortar, g/cm^3,
W_1 = mass of cement, g,
W_2 = mass of sand, g,
V_w = mL-g of water used,
S_1 = density of cement, g/cm^3,
S_2 = density of standard sand, 2.65 g/cm^3,
A = volume percent of entrained air, and
W_m = mass of 400 mL of mortar, g.

16. Compressive Strength

16.1 *Test Specimens*:

16.1.1 *Molding*—Immediately after determining the flow and mass of 400 mL of mortar, return all of the mortar to the mixing bowl and remix for 15 s at the medium speed. Then mold the test specimens in accordance with Test Method C 109/C 109M, except that the elapsed time for mixing mortar, determining flow, determining air entrainment, and starting the molding of cubes shall be within 8 min.

16.1.2 *Storage*—Immediately after molding, store all test specimens in the molds on plane plates in a moist cabinet or moist room for 48 to 52 h in such a manner that the upper surfaces shall be exposed to the moist air. Then remove the cubes from the molds, and place them in the moist cabinet or moist room for 5 days in such a manner as to allow free circulation of air around at least five faces of the specimens. At the age of 7 days, immerse the cubes for the 28-day tests in saturated lime water in storage tanks of noncorrodible materials.

16.2 *Procedure*:

16.2.1 Test the cube specimens immediately after their removal from the moist cabinet or moist room for 7-day specimens, and immediately after their removal from storage water for all other specimens. If more than one specimen at a time is removed from the moist cabinet or moist room for 7-day tests, cover these cubes with a damp cloth until the time of testing.

16.2.2 The remainder of the testing procedure shall conform to Test Method C 109/C 109M.

17. Water Retention

17.1 Water retention shall be determined in accordance with the procedures in Test Method C 1506.

18. Flexural Bond Strength

18.1 Flexural bond strength shall be determined in accordance with the test method for laboratory prepared specimens of Test Methods C 1357, except sand shall be a blend of equal mass of graded and standard 20-30 sand conforming to Specification C 778 and mortar shall be proportioned to contain mass of cement in kg equal to 0.20 times the net mass in kg printed on the bag and 22.0 kg of sand. The flexural bond strength of mortar cement shall be determined as the average gross area flexural bond strength of 30 joints minus 1.28 times the standard deviation of the sample.

19. Storage

19.1 The cement shall be stored in such a manner as to permit easy access for proper inspection and identification of each shipment, and in a suitable weathertight building that will protect the cement from dampness and minimize warehouse set.

20. Inspection

20.1 Adequate facilities shall be provided to the purchaser for the necessary inspection and sampling.

20.2 All packages shall be in good condition at the time of inspection.

21. Rejection

21.1 At the option of the purchaser, the cement shall be rejected if it fails to meet any of the requirements of this specification.

21.2 At the option of the purchaser, packages more than 2 % below the mass marked thereon shall be rejected. At the option of the purchaser, the entire shipment shall be rejected if the average mass of packages in any shipment, as shown by weighing 50 packages taken at random, is less than that marked on the packages.

21.3 At the option of the purchaser, cement remaining in storage prior to shipment for a period greater than six months after testing shall be retested and, at the option of the purchaser, shall be rejected if it fails to meet any of the requirements of this specification.

22. Manufacturer's Certification

22.1 Upon request of the purchaser in the contract or order, a manufacturer's report shall be furnished at the time of

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shipment stating the results of the tests made on samples of the material taken during production or transfer and certifying that the applicable requirements of this specification have been met.

23. Packaging and Package Marking

23.1 When mortar cement is delivered in packages, the brand, name of the manufacturer, type of mortar cement, and net mass of the package in kilograms (Note 2) shall be indicated plainly thereon. Similar information shall be provided in the shipping documents accompanying the shipment of mortar cement in bulk.

NOTE 2—To facilitate the change to SI units, a standard metric package size of 32 kg for Type N, 34 kg for Type S, and 36 kg for Type M will provide convenient mass increments reasonably similar to the traditional 70–, 75–, and 80–lb packages.

24. Keywords

24.1 flexural bond strength; masonry; mortar; mortar cement

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Designation: C 1355/C 1355M – 96 (Reapproved 2006)

Standard Specification for Glass Fiber Reinforced Gypsum Composites[1]

This standard is issued under the fixed designation C 1355/C 1355M; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope

1.1 This specification covers glass fiber reinforced gypsum (GRG) composites having minimum properties and quality suitable to allow the production of GRG parts for non-loading bearing, thin section, ornamental shapes for architectural embellishment of interior building construction.

1.2 The values stated in either inch-pound units or SI (metric) are to be regarded separately as standard. Within the text, the SI units are shown in brackets. The values stated in each system shall be independent of the other. Values from the two systems shall not be combined.

1.3 The text of this standard references footnotes which provide explanatory material. These footnotes shall not be considered as requirements of the standard.

2. Referenced Documents

2.1 *ASTM Standards:* [2]

C 11 Terminology Relating to Gypsum and Related Building Materials and Systems

C 472 Test Methods for Physical Testing of Gypsum, Gypsum Plasters and Gypsum Concrete

C 473 Test Methods for Physical Testing of Gypsum Panel Products

C 947 Test Method for Flexural Properties of Thin-Section Glass-Fiber-Reinforced Concrete (Using Simple Beam With Third-Point Loading)

D 256 Test Methods for Determining the Izod Pendulum Impact Resistance of Plastics

D 578 Specification for Glass Fiber Strands

D 696 Test Method for Coefficient of Linear Thermal Expansion of Plastics Between -30°C and 30°C with a Vitreous Silica Dilatometer

D 2583 Test Method for Indentation Hardness of Rigid Plastics by Means of a Barcol Impressor

E 84 Test Method for Surface Burning Characteristics of Building Materials

E 136 Test Method for Behavior of Materials in a Vertical Tube Furnace at 750°C

3. Terminology

3.1 *Definitions:* Definitions of terms shall be in accordance with Terminology C 11.

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *GRG composite*, *n*—a thin section laminate made from the combination of alpha gypsum cement, glass fiber, additives and water.

3.2.2 *GRG part*, *n*—an individual molded component used as architectural embellishment.

4. Materials and Manufacture

4.1 *Materials*:

4.1.1 *Alpha Gypsum Cement*—Alpha-calcium sulfate hemihydrate-plaster which is noncombustible, has a low water demand, neutral (pH) or low alkalinity, and a purity of not less than 90 % by weight of $CaSO_4 \cdot 2H_2O$.

4.1.2 *"E" Glass Fiber*—Chopped glass fiber strands or continuous strand mats of calcia-alumina silicate glasses conforming to Specification D 578.

4.1.3 *Water*—Potable water.

4.1.4 *Additives*—In accordance with the alpha gypsum cement manufacturer's specifications.

4.2 *Manufacturer's Certification of Raw Materials*:

4.2.1 *Alpha Gypsum Cement*—Each lot of alpha gypsum cement shall be certified to be in compliance with 4.1 and 5.1.

4.2.2 *Glass Fiber Reinforcement*—Each lot of glass fiber reinforcement shall be certified to be in compliance with Specification D 578.

4.3 *Composite Preparation*:

4.3.1 Prepare a flat, rectangular composite of sufficient size to obtain specimens required in 5.2. The composite prepared shall be the same formula as the intended GRG part.

5. Mechanical Properties

5.1 *Neat Alpha Gypsum Cement*:

[1] This specification is under the jurisdiction of ASTM Committee C11 on Gypsum and Related Building Materials and Systems and is the direct responsibility of Subcommittee C11.01 on Specifications and Test Methods for Gypsum Products.

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[2] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

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5.1.1 Normal Consistency shall be not more than 30 when tested in accordance with Test Methods C 472.

5.1.2 Compressive Strength shall be not less than 6000 psi (41.4 MPa) when tested in accordance with Test Methods C 472.

5.1.3 Hardness shall be not less than 33 Barcol when tested in accordance with Test Method D 2583.

5.2 *Composite*:

5.2.1 *Specimen Preparation*

5.2.1.1 *Flexural Strength*—Average Flexural Yield (FY) shall be not less than 1200 psi (8.3 MPa) and an average Flexural Ultimate (FU) shall be not less than 2500 psi (17.2 MPa) when tested in accordance with Test Method C 947, using a crosshead speed of 0.08 in./min (2 mm/min). Specimens shall be conditioned to a constant weight in accordance with Test Methods C 473.

5.2.1.2 *Impact Resistance*—Average impact resistance shall be not less than 3 ft-lb (4 j) when tested in accordance with Test Methods D 256, Test Method A (Izod-unnotched method).

5.2.1.3 *Hardness*—Average hardness shall be not less than 50 Barcol when tested in accordance with Test Methods D 2583. Specimens shall be conditioned according to Test Methods C 473.

5.2.1.4 *Coefficient of Linear Thermal Expansion*—Coefficient of linear thermal expansion shall be not more than 11.1 $\times$ 10^{-6} in./in. °F (20.0 $\times$ 10^{-6} mm/mm °C) when tested in accordance with Test Method D 696.

5.2.1.5 *Humidified Deflection*—Average humidified deflection shall be not more than ⅛ in. (3 mm) when tested on a 3⁄16 in. specimen (5 mm) in accordance with Test Methods C 473.

5.2.1.6 *Surface Burning Characteristics*—Flame spread index shall be 0 and smoke developed index shall be less than 10 when tested in accordance with Test Method E 84.

5.2.1.7 *Behavior at 750 °C*—Shall pass all criteria when tested in accordance with Test Method E 136.

5.2.1.8 *Nail Pull Resistance*—Shall be not less than 110 lbf (489 N) when tested on a 3⁄16 in. specimen (5 mm) in accordance with Test Methods C 473 (Method B).

6. Samples Taken at the Point of Manufacture

6.1 When specified by the purchase agreement, samples of the GRG composite shall be taken at the place of manufacture and tested for compliance with 5.2.

7. Number of Tests and Retests

7.1 The number of tests and type of tests to be performed shall be part of the purchase agreement. Data from prior tests showing compliance with Section 5 are permitted to be supplied by the producer showing compliance with the specified requirements.

8. Inspection

8.1 Inspection of the GRG composite shall be agreed upon between the purchaser and the producer or the supplier as part of the purchase agreement.

9. Rejection and Rehearing

9.1 GRG composite that fails to conform to the requirements of this specification shall be reported to the producer or the supplier promptly and in writing. In case of dissatisfaction with the results of the test, the producer or supplier, shall be permitted to make a claim for a hearing to retest.

10. Certification

10.1 When specified in the purchase agreement, a producer's or supplier's report certifying that the GRG composite is in compliance with this specification, shall be furnished at the time of shipment.

11. Quality Assurance

11.1 Testing for compliance with this specification is required whenever glass fiber reinforced gypsum formulae are initially established.

11.2 Additional testing for compliance with this specification is required whenever constituent materials are added or deleted.

11.3 Each producer's test specimens shall be representative of actual production procedures and materials.

12. Keywords

12.1 alpha gypsum cement; glass fiber reinforced gypsum; glass fiber reinforced gypsum composite; GRG; GRG composite

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Designation: C 1356 – 07

Standard Test Method for Quantitative Determination of Phases in Portland Cement Clinker by Microscopical Point-Count Procedure[1]

This standard is issued under the fixed designation C 1356; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope*

1.1 This test method covers a systematic procedure for measuring the percentage volume of the phases in portland cement clinker by microscopy.

1.2 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

1.3 The values stated in SI units are to be regarded as the standard.

2. Referenced Documents

2.1 *ASTM Standards:* [2]

C 150 Specification for Portland Cement

C 219 Terminology Relating to Hydraulic Cement

C 670 Practice for Preparing Precision and Bias Statements for Test Methods for Construction Materials

D 75 Practice for Sampling Aggregates

D 3665 Practice for Random Sampling of Construction Materials

3. Terminology

3.1 *Definitions:*

3.1.1 *clinker phase*, *n*—a physically and chemically distinct optically identifiable portion of the clinker sample, including both principal phases (alite, belite, aluminate, and ferrite), minor phases (for example, free lime, periclase, and alkali sulfates), and voids.

3.1.1.1 *Discussion*—Voids, though not a phase in the sense of being a crystalline compound, are a distinct, identifiable portion of a clinker microstructure.

3.1.2 *voids*, *n*—isolated or interconnected open areas in the clinker, also called pores.

3.2 *Principal Clinker Phases:*[3]

3.2.1 *alite*, *n*—crystalline tricalcium silicate (C_3S), modified in composition and crystal structure by incorporation of foreign ions; the crystals are pseudo-hexagonal with well-defined faces, though less regular shapes commonly occur.

3.2.2 *aluminate*, *n*—tricalcium aluminate (C_3A) modified in composition and crystal structure by incorporation of a substantial proportion of foreign ions; aluminate forms cubic crystals when relatively pure, and forms identifiable elongated crystals commonly called "alkali aluminate" when in solid solution with significant amounts of potassium or sodium, or both.

3.2.3 *belite*, *n*—crystalline dicalcium silicate (C_2S), modified in composition and crystal structure by incorporation of foreign ions; belite usually occurs as rounded crystals marked by striations formed by cross sections of lamellae, and may occur as single crystals or in clusters.

3.2.4 *ferrite*, *n*—a solid solution of approximate composition tetracalcium aluminoferrite (C_4AF) modified in composition by variation in the Al/Fe ratio and by substantial incorporation of foreign ions; ferrite is characterized by high reflectivity in polished sections and is normally the only strongly colored compound among the principal clinker phases.

3.2.4.1 *Discussion*—Aluminate and ferrite form most of the interstitial material between the silicate crystals and, under certain conditions of cooling, may not be easily identifiable or resolved by ordinary light microscopy.

3.3 *Minor Clinker Phases:*

3.3.1 *alkali sulfates*, *n*—sodium sulfate, potassium sulfate, and double sulfates such as calcium langbeinite (K_2SO_4–$2CaSO_4$).

3.3.2 *free lime*, *n*—calcium oxide (C) found mostly as round crystals.

3.3.3 *periclase*, *n*—crystalline form of free magnesium oxide (M), that has not been taken up in solid solution with other phases.

3.4 For definitions of other terms relating to hydraulic cements, refer to Terminology C 219.

[1] This test method is under the jurisdiction of ASTM Committee C01 on Cement and is the direct responsibility of Subcommittee C01.23 on Compositional Analysis.

Current edition approved June 1, 2007. Published July 2007. Originally approved in 1996. Last previous edition approved in 2001 as C 1356 – 96(2001).

[2] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

[3] C = CaO, S = SiO_2, A = Al_2O_3, F = Fe_2O_3, $\bar{S}$ = SO_3, M = MgO, N = Na_2O, and K = K_2O in cement chemistry notation.

***A Summary of Changes section appears at the end of this standard.**

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4. Summary of Test Method

4.1 The test method consists of the preparation and microscopical examination of a specimen produced by encapsulating clinker in a mounting medium and sectioning the specimen so as to expose the interior of particles for visual examination. Polishing the section surface and treating it with etchants to highlight specific phases complete the preparation. During microscopical examination phases are identified and their proportions determined by a point-count procedure. In this procedure, the specimen is moved in uniform increments on a microscope stage, and phases falling under the cross hairs of the eyepiece are identified and counted (**1-5**).

5. Significance and Use

5.1 This test method provides a relatively simple and reliable microscopical means of measuring the phase abundance of portland cement clinker (Note 1). Microscopical point counting provides a direct measure of the clinker phase composition in contrast to the calculated Bogue phase composition (Note 2).

NOTE 1—This test method utilizes a reflected light microscope. Related methods such as transmitted light microscopy, scanning electron microscopy, and automated imaging techniques may also be used for clinker analysis but are not presently included in this test method.

NOTE 2—This test method allows direct determination of the proportion of each individual phase in portland-cement clinker. This test method is intended to provide an alternative to the indirect estimation of phase proportion using the equations in Specification C 150 (footnote C in Table number 1 and footnote B in Table number 2).

5.2 This test method assumes the operator is qualified to operate a reflected light microscope and the required accessories, is able to correctly prepare polished sections and use necessary etchants, and is able to correctly identify the constituent phases.

5.3 This test method may be used as part of a quality control program in cement manufacturing as well as a troubleshooting tool. Microscopic characterization of clinker phases may also aid in correlating cement properties and cement performance in concrete, to the extent that properties and performance are a function of phase composition.

6. Apparatus

6.1 Reflected light microscope.

6.2 Mechanical stage with stepping increments ranging from 0.05 to 2.0 mm (to enable analysis of clinkers of different average crystal sizes) and vernier scales graduated in both X and Y directions.

6.3 Microscope objectives of magnification 5×, 10×, 20×, and 40× or other magnifications suitable for the task.

NOTE 3—The use of reflected light with oil immersion is optional. It is highly recommended for study of finely crystalline aluminate and ferrite which typically form the ground mass in which the silicates occur. Reflected light objective lenses with magnification up to 100× designed for use in oil-immersion are required.

6.4 Assorted eyepieces (5×, 10×, 20×) which when combined with the objectives described in 6.3 will provide magnifications up to 800×.

6.5 Eyepiece reticles (graticulae) with a linear grid pattern containing 9, 16, or 25 intersections.

6.6 Eyepiece micrometer for measuring dimensions of the object under investigation and calibrated for each magnification.

6.7 Stage micrometer for the calibration of the eyepiece micrometer.

6.8 Light source that provides uniform and consistent illumination of the field and light of constant intensity.

6.9 Counting (tallying) device capable of recording up to ten categories of data.

6.10 Crushing device capable of reducing sample particle size to between 1 and 4 mm.

6.11 Riffle sample splitter to reduce sample from initial volume to approximately 100 g.

6.12 Wire cloth sieves with openings suitable for sieving the entire clinker sample to broadly define the model size class, and sieves with 1-mm and 4-mm square openings to concentrate particles of recommended size for specimen preparation.

6.13 Vacuum impregnation device to force epoxy into clinker voids. (Vacuum bell jar or desiccator connected to a vacuum pump.)

6.14 Curing oven, hot plate, slide warmer, or ultraviolet light may be used to accelerate the epoxy hardening.

6.15 Thin, diamond-rimmed wafering saw for sectioning the encapsulated clinker.

6.16 Glass grinding (lapping) plates (300 mm × 300 mm × 5 mm) required only if the mechanical system is not equipped to handle the final grinding with alumina powder.

6.17 Ultrasonic cleaning device (optional) to clean the sample prior to, between, and after polishing steps.

7. Reagents and Materials

7.1 Consumable grinding (lapping) and polishing supplies. After the encapsulated specimen has been cut with the saw, all or most of the following grinding and polishing steps are required: 120-, 320-, and 600-grit silicon carbide grinding papers or equivalent and 5 μm, 0.3μ m, and 0.05 μm alumina polishing powders or their equivalent. Diamond grinding discs, silicon carbide paper, or polishing cloths and alumina polishing powder may be used. Various types of polishing cloths may be used to produce a nearly flat clinker surface or a relief surface to aid in identification of periclase (**1**).[4]

7.2 Sample cups (with volumes ranging from 10 to 20 mL) to contain epoxy-clinker mix during hardening.

7.3 Epoxy resin and hardener for encapsulation of the clinker. Low viscosity resin will facilitate penetration into clinker voids. When hardened it should have an abrasive resistance close to that of the clinker to minimize relief during polishing. It should be resistant to substances used for washing and etching.

7.4 Isopropyl alcohol (2-propanol) for washing the specimen and for use in the ultrasonic cleaner. Propylene glycol is suitable as a lubricant for the saw blade.

7.5 Immersion oil with an index of refraction of 1.51 if reflected light immersion-oil technique is used.

[4] The boldface numbers in parentheses refer to the list of references at the end of this standard.

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7.6 Etching material to highlight different phases for counting. (See Appendix X3.)

8. Sampling

8.1 Take samples of portland-cement clinker in accordance with the applicable provisions of Practices D 75 and D 3665 so as to be representative of the quantity of material with which testing is concerned (see Appendix X1).

8.2 Sieve the initial sample to obtain clinker particles representing approximately 70 % of the clinker particle size distribution, centered about the mode. This particle size interval represents a size range of approximately two standard deviations, one on each side of the mode, and is herein defined as the "bulk mode" (M_b), the combined material between the extremes of the particle size distribution. State the sieve sizes used. If either extreme of the particle size distribution is to be studied, the selected portion shall be identified as non-modal, and the percentages retained or passing standard sieves shall be stated. The recommended size fraction for microscopical analysis is 2 to 4 mm. Therefore, that portion of the initial clinker sample representing the bulk mode shall be crushed, sieved, and riffled to provide approximately 100 g. Whole clinkers may be encapsulated to study the phase distribution within clinker nodules.

9. Preparation of Sample Specimen

9.1 Polished sections shall be polished to a fineness such that grinding pits and scratches have been eliminated (see Appendix X1).

9.2 Etching of the clinker surface may be used to facilitate identification of clinker phases **(1)**; additional information may be found in the Appendix X1.

10. Counting Procedure

10.1 Choose the microscope magnification such that adjacent reticle grid points do not fall on the same crystal, except for a few unusually large crystals. Magnification from 200× to 500× will accommodate most clinkers. Reticles with multiple grid points are recommended. Single crosshair reticles are not suitable.

10.2 Choose the stepping interval such that an entirely different field of view is observed after each step.

10.3 Attach a mechanical stage to the microscope. The mechanical stage may be an electrically driven specimen carriage connected to an automatic electronic counter or a simple hand-operated carriage and counter. Place a small amount of soft modeling clay on a standard, petrographic glass slide (27 mm × 46 mm) and level the sample thereon. Either use a commercial leveling device or use a small spirit level to adjust the mount while pressing it firmly into the clay. A tissue paper between the polished section and the leveling device or spirit level prevents surface scratches. Place the glass slide with attached clay and leveled mount on the mechanical stage. Check the accuracy of leveling by observing the focus at several points on the polished surface. Move to a starting point (the initial field of view from which data will be taken) at the edge of the mount and record the position in the X-Y coordinate system, using the graduated scales on the mechanical stage.

10.4 Use a tally sheet or a counting device to record the phases as required. The observer should not keep a mental tally of any data because of possible bias. Identify and record each phase under the grid intersections. In some cases, the aluminate and ferrite quantities may be combined and labeled "matrix". Move the mechanical stage a distance of one stepping interval in the chosen X or Y direction to bring another field into view. The phases under the grid points are identified, counted, and the mechanical stage advanced one stepping interval to an adjacent field of view. This procedure is continued until a range of 3000-4000 points are recorded.

At the clinker periphery, some of the reticle points may fall on the encapsulating epoxy that surrounds the clinker particle. Count only points within the clinker, and disregard the reticle points over epoxy at the clinker periphery. Thus, the clinker void space (porosity), if determined in the point count, does not include cavities on the surface of the clinker particle. As one steps over irrelevant areas (such as epoxy exterior to the clinker or severally damaged portions of the polished surface that obscure the phase identification) the count is temporarily suspended until a suitable clinker surface again falls under the reticle grid points. Artifacts (for example, blot marks, residual liquids) on the section surface are not to be counted. If the identity of the phase is obscured by the area formed by the grid intersection, one should consistently use a specified corner of the intersection where the phase can be clearly observed.

When the edge of the mount is reached at the end of a line of traverse, the mount is translated one stepping interval perpendicular to that line and counting continues in the opposite direction, or the mount is repositioned to a point at the original starting boundary to keep the same direction of travel. As one progresses along the lines of traverse the data are accumulated until 3000–4000 points (N) are recorded.

11. Calculation of Results

11.1 Calculate the volume fraction of each phase in the sample by dividing the number of points counted for that phase by the total number of points counted. This number multiplied by 100 yields the phase content in volume per cent.

11.2 The number of points to be counted is to be between 3000 and 4000 **(2).** The absolute error at the 96 % confidence interval has been shown to be:

$$\delta = 2.0235 \sqrt{\frac{P(100 - P)}{N}} \quad (1)$$

where:

δ = absolute measuring error in percentage for a given constituent,
P = phase percentage, and
N = total number of points counted.

Therefore for any error percentage deemed acceptable and expected value of P, the required number of points, N, can be calculated:

$$N = \left(\frac{2.0235}{\delta}\right)^2 \times (100 - P)P \quad (2)$$

If an estimate of P is not available, the above equation takes on a maximum when $P = 50$. Using this value will provide a conservative estimate for the number of points required.

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11.3 To express phase abundance in terms of mass fraction, multiply phase volume fractions by their respective mass density (see Table 1) and normalize the totals to 100 %.

12. Reporting Results

12.1 The report of the point count results to microscopically determine the phase percentages in portland cement clinker should include the following information:

12.1.1 Identify the source of the samples, including sampling location and type of sample.

12.1.2 State how the sample was treated. If the sample was sieved, give the sieve designation size for the final sample. Indicate the type of each etchant used and etch time.

12.1.3 State the number of data points and percentages of each determined phase.

TABLE 1 Mass Densities in g/cm³ for Clinker Phases (7)

Phase	Density
alite	3.18
belite	3.31
aluminate	3.03
ferrite	3.73
free lime	3.35
periclase	3.58
alkali sulfate	2.66

13. Precision and Bias

13.1 *Within-Laboratory Precision*—Single operator values of the one-sigma limit in percent (1S %), defined in accordance with Practice C 670 determined for volume fraction determination by point count analysis (see Note 4) have been found to be 0.71 % (1S) (**6**). Therefore, results of two properly conducted tests by the same operator on the same material should not differ by more than 2.58 % (D2S) from the average of the two results.[5]

NOTE 4—These levels of precision are based on data from the NIST RM Clinker certificate data. A bias statement is not available as these data are used to establish the phase abundance compositions of the RM clinkers.

13.2 A multi-laboratory round robin is planned to generate data for use in a precision and bias statement in accordance with Practice C 670.

14. Keywords

14.1 alite; aluminate; belite; ferrite; periclase; portland-cement clinker; reflected light microscopy

[5] Supporting data pertaining to this precision statement have been filed at ASTM International Headquarters and may be obtained by requesting Research Report RR: C01-1005.

APPENDIXES

(Nonmandatory Information)

X1. SAMPLING

X1.1 The task of obtaining a representative clinker sample for microscopical examination from the stream of material leaving the kiln presents special problems, and the solution depends greatly on local conditions. When sampling from a conveyor belt, an entire cross section of the material should be taken. When the sample is collected from material in free fall, for example at the end of the conveyor belt or at the discharge of a bucket elevator, all the particles falling during the sampling operation shall be included, and sampling devices and containers shall be of sufficient volume to contain the resulting amount. One litre is recommended for the initial clinker sample.

X1.2 If continuous sampling of a clinker flow is impractical, samples representing more extended periods of operation shall be composites of two of more grab samples obtained according to X1.1. The period of time covered and the frequency of sampling will depend on local conditions and the purpose of the test, but the procedure for obtaining each individual grab sample shall be identical.

X1.3 Material judged atypical for the period, the process, or the equipment under study (kiln dust, kiln coating, etc.) may be removed prior to microscopical examination, but the removal of such material should be noted.

X2. SAMPLE IMPREGNATION AND POLISHING

X2.1 Label a sample cup with the sample identification (a tag may also be embedded in the epoxy) and coat the interior with a mold release agent. Place 10 to 20 g of the clinker sample in the cup and add low-viscosity epoxy resin previously mixed with the hardener. Place the sample cup under the vacuum jar and operate the vacuum pump to obtain adequate penetration of the resin. Break the vacuum several times to permit atmospheric pressure to force the epoxy into the material.

X2.2 Cure the epoxy as recommended by the manufacturer in an oven at a temperature not higher than 70°C. Some epoxies will harden rapidly at room temperature or under ultraviolet light.

X2.3 Remove the specimen from the cup and, if necessary, label with a diamond engraver or indelible pen.

X2.4 Cut the encapsulation with the diamond-rimmed wafering saw to expose the clinker particle cross sections.

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Preparation liquids retained in clinker voids may interfere with etching and staining; therefore, a second application of vacuum impregnated epoxy on the polished surface may be necessary. A cyanoacrylate resin, smeared over the polished surface, may be used. The encapsulation is then reground and polished.

X2.5 Grind the exposed surface by lapping with each of the selected grinding media (see 7.1), beginning with the coarsest, for 2 to 4 min each. Use propylene glycol, isopropanol, or other liquids as lubricants during grinding. After each step, wash the surface with a forceful spray of isopropyl alcohol. Do not use water in cutting, grinding, polishing, or cleaning the encapsulated clinkers.

X2.6 Polish the surface with each of the chosen polishing media, beginning with the coarsest, for 2 to 4 min. Wash the surface after each polishing step with a forceful isopropyl alcohol spray. Clean the specimen ultrasonically after the last wash, using isopropyl alcohol as the cleaning fluid. Rinse again with the alcohol spray. Dry the surface with a forced warm air current. Blotting is not recommended because of the production of blot marks.

X3. ETCHES AND STAINS

X3.1 Certain liquids or vapors applied to the polished surface will produce a preferential phase coloration. One versatile liquid is nital (1 mL nitric acid in 99 mL isopropyl alcohol). Other commonly used stains and etchants are hydrofluoric acid vapor, potassium hydroxide, distilled water, aqueous ammonium chloride, dimethyl ammonium citrate, and others. Details of various etches and stains, immersion times, and techniques are given in Ref (**1**)**.** The choice of etchant, etch time, and temperature of etchant can affect results. Therefore, these choices should be consistent for all specimens prepared for point counting. (**Warning**—Appropriate safety precautions must be observed when preparing and using stains and etchants. Review all Material Safety Data Sheets and always use suitable personal protective equipment including eye protection, apron, and gloves.)

X3.2 For aluminate and free-lime coloration, the application of distilled water at 40 °C for 5 s with the specimen at room temperature, or 0.1 molar KOH for 20 to 30 s is recommended. The polished surface can also be placed on a water-saturated, clean, low-nap polishing cloth for 2 to 3 s and then quickly washed with a forceful isopropyl alcohol spray. This technique produces a structure etch on the silicates. The polishing cloth may be attached to a rotating wheel or may be stationary on a glass plate.

X3.3 For a clear differentiation of the silicates, alite and belite, a 6- to 8-s immersion in nital is recommended, quickly followed by an alcohol spray wash. One may choose to carry out a high magnification point count (550× or more) on the water-stained matrix, followed by a relatively low-magnification point count (approximately 300×) of the silicates on a nital-etched surface.

REFERENCES

(**1**) Campbell, D. H., *Microscopical Examination and Interpretation of Portland Cement and Clinker*, Portland Cement Association, Skokie, Illinois, 1986, 128 pp.

(**2**) Hofmanner, F., *Microstructure of Portland Cement Clinker*, Holderbank Management & Consulting Ltd., Switzerland, 1973, 48 pp.

(**3**) Fundal, E., *Microscopy of Cement Raw Mix and Clinker*, F. L. Smidth, Review 25, 1980, 15 pp.

(**4**) Chayes, F., *Petrographic Modal Analysis, An Elementary Statistical Appraisal*, John Wiley and Sons, Inc., New York, 1956, 113 pp.

(**5**) Brown, L. S., *Microscopical Study of Clinkers*, in Long-Time Study of Cement Performance in Concrete, Portland Cement Association R&D Bulletin 26, 1948, pp. 877–923.

(**6**) Kanare, H. M., *Production of Portland Cement Clinker Phase Abundance Standard Reference Materials*, Construction Technology Laboratories Final Report, Project No. CRA012-840, 1987, 32 pp.

(**7**) ICDD/JCPDS Powder Diffraction File, International Centre for Diffraction Data, Newton Square, PA.

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SUMMARY OF CHANGES

Committee C01 has identified the location of selected changes to this test method since the last isse, C 1356 – 96(2001), that may impact the use of this test method. (Approved June 1, 2007)

(*1*) Added new paragraph 3.4.

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Designation: C 1362 – 09

Standard Test Method for Flow of Freshly Mixed Hydraulic-Cement Concrete[1]

This standard is issued under the fixed designation C 1362; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope*

1.1 This test method covers determination of the flow of a sample of freshly mixed concrete, either in the field or in the laboratory.

1.2 This test method is applicable to concrete having coarse aggregate up to 37.5 mm in size. If the coarse aggregate is larger than 37.5 mm in size, the test method is applicable when the fraction of concrete larger than 37.5 mm is removed in accordance with Practice C 172.

1.3 The values stated in SI units are to be regarded as standard. No other units of measurement are included in this standard.

1.4 The text of this standard references notes and footnotes that provide explanatory information. These notes and footnotes (excluding those in tables and figures) shall not be considered as requirements of this standard.

1.5 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.* (**Warning**—Fresh hydraulic cementitious mixtures are caustic and may cause chemical burns to skin and tissue upon prolonged exposure.[2])

2. Referenced Documents

2.1 *ASTM Standards:*[3]

C 172 Practice for Sampling Freshly Mixed Concrete

C 670 Practice for Preparing Precision and Bias Statements for Test Methods for Construction Materials

3. Summary of Test Method

3.1 A flow apparatus comprising an outer partially perforated hollow tube and an inner calibrated floating rod is inserted into a sample of freshly mixed concrete to a preset level and held in place by a collar floater. A portion of the concrete is allowed to flow into the hollow tube through its perforations for a period of 40 s. The inner floating rod is then lowered onto the concrete surface that has penetrated the hollow tube. The height of the concrete in the hollow tube is read from the scale on the upper portion of the floating rod protruding from the top of the hollow tube. With increasing fluidity of the concrete a higher flow reading is obtained on a scale from zero to one hundred divisions.

4. Significance and Use

4.1 This test method permits a rapid assessment of the flow and consistency of freshly mixed concrete (see Note 1).

4.2 This test method also provides information on the change in flow and consistency, with time, of concrete containing superplasticizer admixtures.

4.3 This test method can be used to measure the uniformity characteristics of flow and consistency of freshly mixed concrete and its change with time.

NOTE 1—This test method may not be appropriate for use in evaluating gap-graded aggregate concrete.

5. Apparatus

5.1 Details of the apparatus are shown in Fig. 1. The apparatus consists of (*1*) measuring rod, (*2*) scale datum, (*3*) hollow tube with round holes and longitudinal slots, (*4*) holding pin, (*5*) collar floater, and (*6*) tube point.

5.2 Measuring rod is a hollow tube, 13 mm in outside diameter, 336 mm long with a wall thickness of 1.5 mm and it is capped at both ends with a cap 15 mm in outside diameter. A scale datum is 45 mm in outside diameter and 25 mm wide and fabricated to fit hollow tube and accommodate measuring rod. Hollow tube has an outside diameter of 33 mm, and it is 310 mm long with a wall thickness of 4 mm and has 16 round holes, 9.4 mm in diameter, and 4 longitudinal slots, 9.4 mm wide by 50 mm long, which are distributed around the circumference of the tube as shown in Fig. 1. A pin which is a rivet, 3.2 mm in diameter, protrudes 3.2 mm inside tube. Collar floater, made of a plate 5 mm thick, has an outside diameter of 90 mm and inside diameter of 33 mm, is connected to hollow tube. Tube point is machined from a rod stock and fashioned into a conical shape. It is secured to the bottom end of hollow tube, and it is used to facilitate the insertion of the assembly

[1] This test method is under the jurisdiction of ASTM Committee C09 on Concrete and Concrete Aggregates and is the direct responsibility of Subcommittee C09.60 on Testing Fresh Concrete.

Current edition approved June 1, 2009. Published July 2009. Originally approved in 1997. Last previous edition approved in 2004 as C 1362–04.

[2] Section on Safety Precautions, Manual of Aggregate and Concrete Testing, *Annual Book of ASTM Standards*, Vol 04.02

[3] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

***A Summary of Changes section appears at the end of this standard.**

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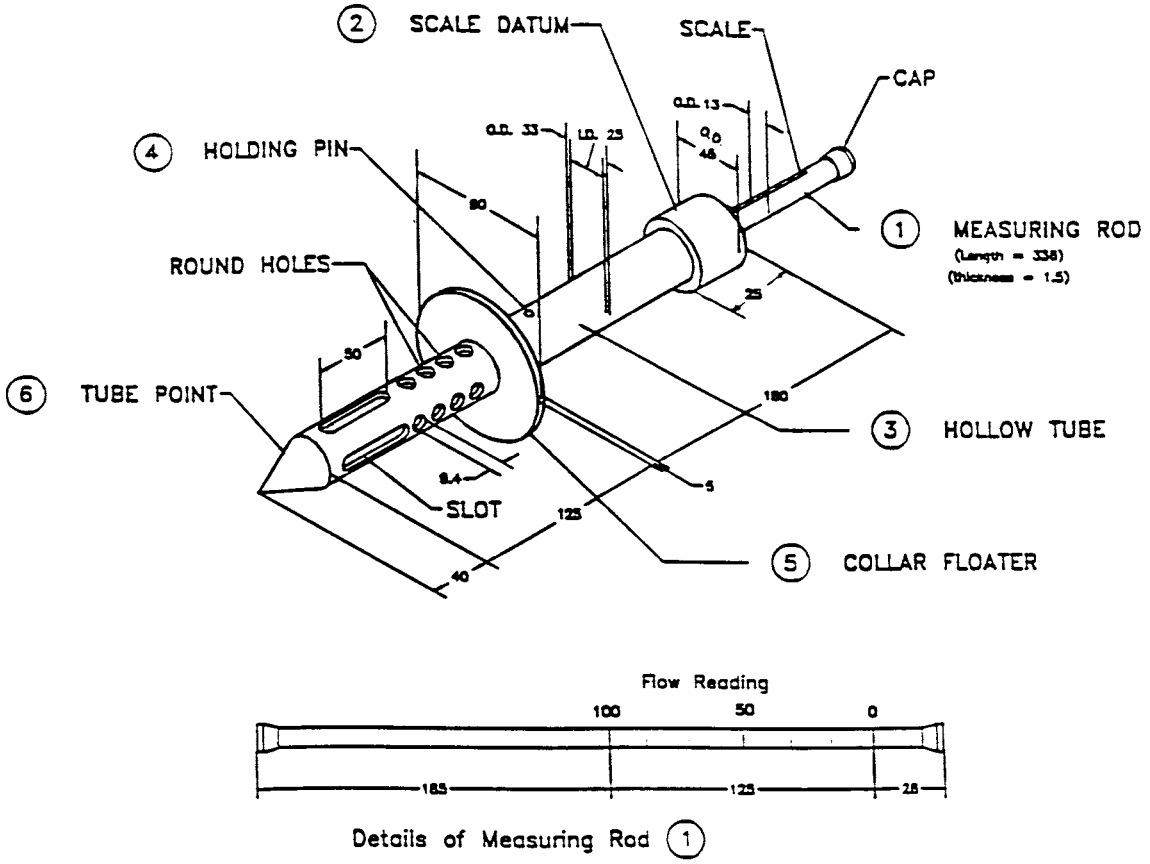

FIG. 1 Apparatus for Flow Test

into the fresh concrete. All individual dimensions shall have a tolerance of ±1 % of their value. Make all parts of the apparatus of non-corrosive materials that are not affected by chemicals found in the fresh concrete.

6. Sampling

6.1 Determine the flow either as the concrete is placed in the forms prior to any manipulation or in a suitable container such as a can, a hopper, a pail, or a wheelbarrow. The sample of concrete from which determination of flow is made shall be representative of the entire batch. Obtain the sample in accordance with the requirements of Practice C 172.

7. Procedure

7.1 Bring the surface of the concrete to a smooth and level condition. Use a small wood float or screed, but work the surface as little as possible to avoid formation of mortar layers. The minimum depth of concrete at testing shall be 175 mm, and the distance from the tube to the nearest edge of the level surface of the concrete on which the flow or consistency is to be determined shall be a minimum of 75 mm. During the flow measurement protect the concrete against vibration, jarring, or agitation. Wet the apparatus, and shake off all excess water. Raise the measuring rod, and let it rest on the pin inside the apparatus. Insert the apparatus slowly and vertically downward until the collar floater rests at the surface of the concrete. Do not rotate the apparatus while inserting it into the concrete. After 40 s of complete insertion lower the measuring rod slowly until it rests on the surface of the concrete that entered into the hollow tube. Read and record the level of the measuring rod to the nearest division in percent on the scale which represents the flow of the concrete.

8. Report

8.1 Record the flow in terms of the number of divisions of 1 % on the scale; if more than one test reading is taken on the same concrete, report the average to the nearest division in percent.

9. Precision and Bias [4]

9.1 *Precision*—Based on data from 150 tests, with a flow of 10 to 90 % the pooled standard deviation is 8 %[4] for a single operator using the same test device. Therefore, the range of two tests on the same material should not exceed 23 %.[4]

[4] Supporting data have been filed at ASTM International Headquarters and may be obtained by requesting Research Report RR: C09-1011.

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NOTE 2—These numbers represent, respectively, the (1 s %) and (d2s %) limits as defined in Practice C 670.

9.2 *Bias*—This test method has no bias because the values determined can be defined only in terms of this test method.

10. Keywords

10.1 concrete; consistency; flow; fluidity; fresh concrete; uniformity

SUMMARY OF CHANGES

Committee C09 has identified the location of selected changes to this test method since the last issue, C 1362 – 04, that may impact the use of this test method. (Approved June 1, 2009)

(*1*) Revised 1.3.

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Designation: C 1365 – 06

Standard Test Method for Determination of the Proportion of Phases in Portland Cement and Portland-Cement Clinker Using X-Ray Powder Diffraction Analysis[1]

This standard is issued under the fixed designation C 1365; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope*

1.1 This test method covers direct determination of the proportion by mass of individual phases in portland cement or portland-cement clinker using quantitative X-ray (QXRD) analysis. The following phases are covered by this standard: alite (tricalcium silicate), belite (dicalcium silicate), aluminate (tricalcium aluminate), ferrite (tetracalcium aluminoferrite), periclase (magnesium oxide), gypsum (calcium sulfate dihydrate), bassanite (calcium sulfate hemihydrate), anhydrite (calcium sulfate), and calcite (calcium carbonate).

1.2 This test method specifies certain general aspects of the analytical procedure, but does not specify detailed aspects. Recommended procedures are described, but not specified. Regardless of the procedure selected, the user shall demonstrate by analysis of certified reference materials (CRM's) that the particular analytical procedure selected for this purpose qualifies (that is, provides acceptable precision and bias) (see Note 1). The recommended procedures are ones used in the round-robin analyses to determine the precision levels of this test method.

NOTE 1—A similar approach was used in the performance requirements for alternative methods for chemical analysis in Test Methods C 114.

1.3 The values stated in SI units shall be regarded as the standard.

1.4 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.* For specific hazards, see Section 9.

2. Referenced Documents

2.1 *ASTM Standards:* [2]

C 114 Test Methods for Chemical Analysis of Hydraulic Cement
C 150 Specification for Portland Cement
C 183 Practice for Sampling and the Amount of Testing of Hydraulic Cement
C 219 Terminology Relating to Hydraulic Cement
C 670 Practice for Preparing Precision and Bias Statements for Test Methods for Construction Materials
E 29 Practice for Using Significant Digits in Test Data to Determine Conformance with Specifications
E 691 Practice for Conducting an Interlaboratory Study to Determine the Precision of a Test Method

3. Terminology

3.1 *Definitions are in accordance with Terminology C 219.*

3.2 *Phases* (**1**):[3]

3.2.1 *alite*, *n*—tricalcium silicate (C_3S)[4] modified in composition and crystal structure by incorporation of foreign ions; occurs typically between 30 to 70 % (by mass) of the portland-cement clinker; and is normally either the M_1 or M_3 crystal polymorph, each of which is monoclinic.

3.2.2 *alkali sulfates*, *n*—arcanite (K_2SO_4) may accommodate Na^+, $Ca2^+$, and CO_3 in solid solution, aphthitalite (K_{4-x},Na_x)SO_4 with x usually 1 but up to 3), calcium langbeinite ($K_2Ca_2[SO_4]_3$) may occur in clinkers high in K_2O, and thenardite (Na_2SO_4) in clinkers with high Na/K ratios (**1**).

3.2.3 *aluminate*, *n*—tricalcium aluminate (C_3A) modified in composition and sometimes in crystal structure by incorporation of a substantial proportion of foreign ions; occurs as 2 to 15 % (by mass) of the portland-cement clinker; is normally cubic when relatively pure and orthorhombic or monoclinic when in solid solution with significant amounts of sodium (**2**).

3.2.4 *anhydrite*, *n*—calcium sulfate ($C\overline{S}$) and is orthorhombic (see Note 2).

NOTE 2—Calcium sulfate is added to the clinker during grinding to control setting time, strength development, and volume stability. Several phases may form as a result of dehydration of gypsum. The first 1.5

[1] This test method is under the jurisdiction of ASTM Committee C01 on Cement and is the direct responsibility of Subcommittee C01.23 on Compositional Analysis.
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[2] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

[3] The boldface numbers in parentheses refer to the list of references at the end of this standard.

[4] When expressing chemical formulae, C = CaO, S = SiO_2, A = Al_2O_3, F = Fe_2O_3, M = MgO, $\overline{S}$ = SO_3, and H = H_2O.

***A Summary of Changes section appears at the end of this standard.**

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molecules of water are lost between 0 and 65 °C with minor changes in structure; and, above 95 °C, the remaining 0.5 molecules of water are lost transforming the structure to the metastable γ polymorph of anhydrite (sometimes referred to as 'soluble anhydrite') and subsequently the orthorhombic form (**3**).

3.2.5 *bassanite*, *n*—calcium sulfate hemihydrate ($C\bar{S}H_{1/2}$) and is monoclinic.

3.2.6 *belite*, *n*—dicalcium silicate (C_2S) modified in composition and crystal structure by incorporation of foreign ions; occurs typically as 15 to 45 % (by mass) of the portland-cement clinker as normally the β polymorph, which is monoclinic. In lesser amounts, other polymorphs can be present.

3.2.7 *calcite*, *n*—calcium carbonate is trigonal and may be present in a cement as an addition or from carbonation of free lime.

3.2.8 *ferrite*, *n*—tetracalcium aluminoferrite solid solution of approximate composition $C_2(A,F)$ modified in composition by variation in the Al/Fe ratio and by substantial incorporation of foreign ions as $C_4A_XF_{2-X}$ where $0 < x < 1.4$; constituting 5 to 15 % (by mass) of a portland-cement clinker; and is orthorhombic.

3.2.9 *free lime*, *n*—free calcium oxide (C); cubic (see Note 3).

NOTE 3—Free lime (CaO) may be present in clinker and cement but readily hydrates to form portlandite ($Ca(OH)_2$). Portlandite may carbonate to form calcium carbonate, generally as calcite. Heat-treating a freshly-ground sample to 600 °C is useful to convert any portlandite back to free lime but will also dehydrate the hydrous calcium sulfate phases (gypsum and bassanite) to anhydrite.

3.2.10 *gypsum*, *n*—calcium sulfate dihydrate ($C\bar{S}H_2$) and is monoclinic .

3.2.11 *periclase*, *n*—free magnesium oxide (M); cubic.

3.3 *Definitions of Terms Specific to This Standard:*

3.3.1 *Certified Reference Material (CRM)*, *n*—a material whose properties (in this case phase abundance, XRD peak position or intensity, or both) are known and certified (see Note 4).

NOTE 4—NIST Standard Reference Material (SRM®) Clinkers 2686, 2687, and 2688 are suitable CRMs for qualification.[5]

3.3.2 *diffractometer*, *n*—the instrument, an X-ray powder diffractometer, for determining the X-ray diffraction pattern of a crystalline powder.

3.3.3 *phase*, *n*—a homogeneous, physically distinct, and mechanically separable portion of a material, identifiable by its chemical composition and crystal structure.

3.3.3.1 *Discussion*—Phases in portland-cement clinker and cements that are included in this test method are four major phases (alite, belite, aluminate, and ferrite) and one minor phase (periclase).

3.3.3.2 *Discussion*—Precision values are provided for additional phases (gypsum, bassanite, anhydrite, arcanite, and calcite). Values for these constituents may be provided using this method but are considered informational until suitable certified reference materials for qualification are available.

[5] Portland cement clinker SRM's® from the Standard Reference Material Program, National Institute of Standards and Technology.

3.3.4 *qualification*, *n*—process by which a QXRD procedure is shown to be valid.

3.3.5 *Rietveld analysis*, *n*—process of refining crystallographic and instrument variables to minimize differences between observed and calculated X-ray powder diffraction patterns for one or more phases, estimating their relative abundance.

3.3.6 *standardization*, *n*—process of determining the relationship between XRD intensity and phase proportion for one or more phases (see Note 5).

NOTE 5—In the literature of X-ray powder diffraction analysis, the standardization process has been commonly referred to as calibration; however, we have determined that standardization is a more accurate term.

3.3.6.1 *Discussion*—Rietveld analysis uses crystal structure models to calculate powder diffraction patterns of phases that serve as the reference patterns. The pattern-fitting step seeks the best-fit combination of selected pattern intensities to the raw data. The relative pattern intensities along with the crystallographic attributes of each phase are used to calculate relative abundance. The standardization approach uses powdered samples of pure phases to assess the relationship between diffraction intensity ratios and mass fraction ratios of two or more constituents; and is referred to here as the traditional method.

3.3.7 *X-ray diffraction (XRD)*, *n*—the process by which X-rays are coherently scattered by electrons in a crystalline material.

4. Background

4.1 This test method assumes general knowledge concerning the composition of cement and portland-cement clinker. Necessary background information may be obtained from a number of references (**1, 4**).

4.2 This test method also assumes general expertise in XRD and QXRD analysis. Important background information may be obtained from a number of references (**5-10**).

5. Summary

5.1 This test method covers direct determination of the proportion by mass of individual phases in cement or portland-cement clinker using quantitative X-ray powder diffraction analysis. The following phases are covered by this standard: alite (tricalcium silicate, C_3S), belite (dicalcium silicate C_2S), aluminate (tricalcium aluminate, C_3A), ferrite (tetracalcium aluminoferrite, C_4AF), periclase (magnesium oxide, M), arcanite (potassium sulfate, ($K\bar{S}$)), gypsum (calcium sulfate dihydrate, ($C\bar{S}H_2$)), bassanite (calcium sulfate hemihydrate, ($C\bar{S}H_{1/2}$)), anhydrite (calcium sulfate ($C\bar{S}$)), and calcite (calcium carbonate, $CaCO_3$.

A QXRD test procedure includes some or all of the following: *(a)* specimen preparation; *(b)* data collection and phase identification; *(c)* standardization (for the standardization approach); *(d)* collecting a set of crystal structure models for refinement (for the Rietveld approach); *(e)* use of an internal or external standard (to correct for various effects on intensity besides phase proportion); *(f)* analysis of the sample (in which the powder diffraction pattern is measured and/or the intensity

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of selected XRD peaks or patterns are measured); and *(g)* calculation of the proportion of each phase.

5.2 This test method does not specify details of the QXRD test procedure. The user must demonstrate by analysis of certified reference materials that the particular analytical procedure selected for this purpose provides acceptable levels of precision and bias. Two recommended procedures (the Rietveld approach and the traditional approach used to determine the acceptable levels of precision and bias) are given in Appendix X1 and Appendix X2.

6. Significance and Use

6.1 This test method allows direct determination of the proportion of some individual phases in cement or portland-cement clinker. Thus it provides an alternative to the indirect estimation of phase proportion using the equations in Specification C 150 (Annex A1).

6.2 This test method assumes that the operator is qualified to operate an X-ray diffractometer and to interpret X-ray diffraction spectra.

6.3 This test method may be used as part of a quality control program in cement manufacturing.

6.4 This test method may be used in predicting properties and performance of hydrated cement and concrete that are a function of phase composition.

6.5 QXRD provides a bulk analysis (that is, the weighted average composition of several grams of material). Therefore, results may not agree precisely with results of microscopical methods.

7. Apparatus

7.1 *X-Ray Diffractometer*—The X-ray diffractometer allows measurement of the X-ray diffraction pattern from which the crystalline phases within the sample may be qualitatively identified and the proportion of each phase may be quantitatively determined. X-ray diffractometers are manufactured commercially and a number of instruments are available. The suitability of the diffractometer for this test method shall be established using the qualification procedure outlined in this test method.

8. Materials

8.1 *Standardization Phases*—The use of standardization phases is recommended for establishing the intensity ratio/mass ratio relationships when using the traditional quantitative method. These phases must usually be synthesized **(12, 13)**.

8.2 *CRM Clinker*—The use of three CRM clinkers is required to qualify the QXRD procedure.

8.3 *Internal Standard*—The use of an internal standard is recommended for the standardization approach. Suitable materials include chemical reagents (see 8.4) or CRM's (see Appendix X1).

8.4 *Reagent Chemicals*—Reagent grade chemicals, if used either as an internal standard or during chemical extraction of certain phases, shall meet the specifications of the Committee on Analytical Reagents of the American Chemical Society where such specifications are available.[6] Other grades may be used, provided it is first ascertained that the chemical is sufficiently pure to permit its use without lessening the accuracy of the determination.

9. Hazards

9.1 The importance of careful and safe operation of an X-ray diffractometer cannot be overemphasized. X-rays are particularly hazardous. An X-ray diffractometer must be operated safely to avoid serious injury or death. The X-rays are generated by high voltages, perhaps as high as 55 kV peak, requiring care to avoid serious electric shock. Klug and Alexander **(6)** (pp. 58–60) state, "*The responsibility for safe operation rests directly on the individual operator*" (italics are theirs).

10. Sampling and Sample Preparation

10.1 Take samples of cement in accordance with the applicable provisions of Practice C 183. Take samples of portland-cement clinker so as to be representative of the material being tested.

10.2 Prepare samples as required for the specific analytical procedure (see Appendix X2).

11. Qualification and Assessment

11.1 *Qualification of Test Procedure*:

11.1.1 When analytical data obtained in accordance with this test method are required, any QXRD test procedure that meets the requirements described in this section may be used.

11.1.2 Prior to use for analysis of cement or portland-cement clinker, qualify the QXRD test procedure for the analysis. Maintain records that include a description of the QXRD procedure and the qualification data (or, if applicable, re-qualification data). Make these records available to the purchaser if requested in the contract or order.

11.1.3 If more than one X-ray diffractometer is used in a specific laboratory for the same analysis, even if the instruments are substantially identical, qualify each separately.

11.1.4 If more than one procedure is used to mount specimens for QXRD, the use of each procedure shall constitute a separate test procedure and each procedure shall be qualified separately.

11.1.5 Qualification shall consist of replicate determinations of the three SRM® clinkers, re-mounting the specimen for each analysis, (see Note 6) for the proportions of C_3S, C_2S, C_3A (cubic and orthorhombic), C_4AF, and M using the desired QXRD procedure (see Note 7).

NOTE 6—Prior to qualification, it may be convenient to carry out a preliminary assessment in which one or more mixtures of synthetic phases are analyzed. Such a preliminary assessment should produce no more than the permissible variation described in 11.2.

[6] *Reagent Chemicals, American Chemical Society Specifications* , American Chemical Society, Washington, DC. For suggestions on the testing of reagents not listed by the American Chemical Society, see *Analar Standards for Laboratory Chemicals*, BDH Ltd., Poole, Dorset, U.K., and the *United States Pharmacopeia and National Formulary*, U.S. Pharmacopeial Convention, Inc. (USPC), Rockville, MD.

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NOTE 7—It is recommended that at least two replicate analyses be carried out, but three determinations may be used for assessing permissible variation.

11.2 *Permissible Variation*:

11.2.1 The values of permissible variation were computed from the within-laboratory standard deviation values obtained in round robin analyses of mixtures of SRM® clinkers and synthetic phases (see 14.2).

11.2.1.1 *Discussion*—Qualification limits in Table 2 are prediction intervals (95 %) for a future mean and are designed to bracket values of a mean of k (=2,3,4) future measurements of the relevant phases. The intervals are based upon the performance of the 11 round robin participants.

11.2.2 Replicate analyses shall differ from each other by no more than the within-lab repeatability value shown in Table 1.

11.2.3 The mean result shall differ from the known value by no more than the value shown in Table 2 for the particular number of replicates.

11.2.4 *Known Values*—The known values of each phase in the SRM® clinkers provided by NIST was determined using quantitative X-ray powder diffraction and optical microscopy (**11**).

11.3 *Partial Results*:

11.3.1 QXRD procedures that provide acceptable results for some phases but not for others shall be used only for those phases for which acceptable results are obtained. However, it is not expected that a QXRD procedure would provide acceptable results for some phases and not for others, and such a result may indicate that the procedure is not, in fact, valid.

11.4 *Assessing the Diffractometer*:

11.4.1 The procedures described in the Annex shall be used to assess the diffractometer. Note that assessment is different from qualification or re-qualification.

11.4.2 The diffractometer shall be assessed each month that this test method is used.

11.4.3 The diffractometer shall be assessed after any substantial modification in the instrument (see Note 8).

NOTE 8—Substantial modification of the diffractometer includes changing the X-ray tube, changing a detector, adding or removing a monochromator, and realignment.

11.4.4 QXRD procedure shall be assessed upon receipt of evidence that the test procedure is not providing data in accordance with the permissible variation.

TABLE 1 Permissible Maximum Difference Between Replicate Values (percent of clinker or cement)[A]

	Repeatability Within-Lab		Reproducibility Between-Lab	
	s-within	d2s-within	s-between	d2s-between
alite	0.74	2.04	2.27	6.30
belite	0.64	1.77	1.40	3.87
aluminate	0.47	1.31	0.79	2.19
ferrite	0.49	1.36	0.89	2.47
periclase	0.23	0.63	0.50	1.39
arcanite	0.22	0.60	0.34	0.94
gypsum	0.21	0.59	0.59	1.65
bassanite	0.39	1.08	0.58	1.60
anhydrite	0.27	0.74	0.64	1.77
calcite	0.99	2.73	0.50	1.50

[A] As described in Practice C 670.

TABLE 2 Permissible Maximum Difference Between Mean Value and Known Value (Mass percent) Expressed at a 95 % Confidence Level for the Mean of a Selected Number of Replicates (k) = 2, 3, 4[A]

Phase	2 replicates	3 replicates	4 replicates
alite	5.93	4.91	4.31
belite	3.70	3.06	2.69
aluminate	2.14	1.77	1.55
ferrite	2.46	2.04	1.79
periclase	0.77	0.64	0.56
arcanite	0.85	0.70	0.61
gypsum	1.55	1.28	1.12
bassanite	1.52	1.26	1.11
anhydrite	1.67	1.38	1.21
calcite	0.68	0.56	0.49

[A] Computed from within-laboratory standard deviation using 95 % confidence interval and 30 df.

11.5 *Re-qualification of QXRD Procedure*:

11.5.1 If assessment shows that the X-ray diffractometer is not properly aligned (as discussed in Annex A1), it shall be realigned following the manufacturer's instructions. When subsequent assessment shows that the X-ray diffractometer is properly aligned (or was not properly aligned when the QXRD procedure was previously qualified), qualification of the QXRD procedure shall be repeated.

12. Recommended Procedure

12.1 For required analytical data see Section 11 and the recommended QXRD procedures described in Appendix X1.

13. Report

13.1 Report the following information:

13.1.1 The phase and its proportion, and which method (Rietveld or standardization) was used. Round figures to the number of significant places required in the report only after calculations are completed, in order to keep the final results substantially free of calculation errors. Follow the rounding procedure outlined in Practice E 29.

14. Precision and Bias

14.1 *Analysis*—A round-robin analysis by Rietveld refinement of the SRM® clinkers with calcium sulfate and calcium carbonate additions has been carried out following experimental procedures described in Appendix X1. An earlier cooperative standardization of mixtures of synthetic phases and a round-robin analysis[7] of the RM clinkers have been carried out (**12, 13**) following the experimental procedures described in Appendix X2 (see Note 9). Results were analyzed statistically according to Practices E 691 and C 670 to determine precision levels.

NOTE 9—Analysis of clinker is likely to include variance in addition to that found in analysis of mixtures of synthetic phases.

14.1.1 The precision values are all expressed as percentage points by mass relative to the total clinker or cement.

[7] SRM's from the Standard Reference Material Program, National Institute of Standards and Technology are Certified Reference Materials.

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14.2 *Precision*—The within-laboratory standard deviation and the between-laboratory standard deviation for all phases are given in Table 1, representing pooled results from the four test mixtures. The within-laboratory standard deviation for each phase is reported as 's-within.' Results of two properly conducted tests by the same operator should not vary more than d2s-within in 95 % of comparisons, where d2s-within = $1.96 \cdot \sqrt{2} \cdot_{swithin}$. The multi-laboratory standard deviation for each phase is reported as 's-between.' Results of two properly conducted tests on the same clinker or cement by two different laboratories should not differ from each other by more than d2s-between in 95 % of comparisons, where d2s-between $=1.96 \cdot \sqrt{2} \cdot_{sbetween}$.

14.3 *Bias*—The difference between the estimate of true mean phase concentration and the accepted reference values.

14.4 *Discussion*—Eleven laboratories participated in a co-operative round-robin analysis of mixtures of four separate reference materials. Reference values were that of the SRM® clinkers adjusted for the known amounts of added calcium sulfates and calcite. Taylor (**1**) concluded that the four major phases in portland-cement clinker may be determined using QXRD with an absolute accuracy of 2 to 5 percentage points (by mass) for alite and belite and 1 to 2 percentage points (by mass) for aluminate and ferrite. The SRM® clinkers do not contain gypsum, bassanite, anhydrite or calcite so these data are provided for informational purposes. The qualification requires assessment of certified phases in the clinker SRMs® only. As new SRMs® become available, additional phase qualifications will be added to the test method. There is insufficient data to estimate method bias at this time.

15. Keywords

15.1 alite; alkali sulfate; aluminate; belite; cement; clinker; diffractometer; ferrite; periclase; phase analysis; quantitative X-ray powder diffraction analysis; QXRD; Rietveld analysis; X-ray powder diffraction; XRD

ANNEX

(Mandatory Information)

A1. ASSESSING THE X-RAY DIFFRACTOMETER

A1.1 *Introduction*—This Annex provides a procedure for assessing the diffractometer to assure the validity of the QXRD procedure over a long period of time (several years or longer). A QXRD analysis of portland cement and portland-cement clinker is made particularly difficult by the fact that individual clinker phases used for standardization are not stable over long periods of time, because they hydrate easily, and are not easily synthesized. Thus it is difficult to assess standardizations directly by reanalysis of one or more standardization specimens. In addition, it is not desirable to repeat the standardization unless absolutely necessary. A more reasonable strategy is to use an external standard to assess the diffractometer and to decide when it is necessary to re-qualify a particular procedure. This Annex provides a procedure for assessing the diffractometer to assure the validity of the QXRD procedure over a long period of time (several years or longer).

A1.2 *Overview*:

A1.2.1 As long as certain aspects of the procedure are not changed, the relationship between peak intensity ratio and mass ratio is assumed to be universal (that is, valid over an indefinite period of time, even after changes in the diffractometer such as realignment and replacement of the X-ray tube, and transferable from one diffractometer to another).

A1.2.2 The requirements for the QXRD standardization to be universal are: *(1)* specimens are free from preferred orientation, primary extinction, and microabsorption, *(2)* the irradiated volume of the specimen is constant and independent of scattering angle, *(3)* monochromator polarization effects are corrected, *(4)* integrated peak intensity is used, *(5)* when using an internal standard, standardization and analyses are carried out with an internal standard from the same lot because differences in the particle size distribution between lots of the same material can cause significant difference in peak intensity, and *(6)* standardization and analyses are carried out with the diffractometer in proper geometric alignment.

A1.2.3 If analyses are carried out using only the instrument on which the standardization was carried out, then it is necessary only that preferred orientation, extinction, microabsorption, irradiated volume, and integrated peak intensity are reproducible. In that case, the standardization is valid (though not universal, in that it cannot be transferred from one diffractometer to another) as long as methods of specimen preparation, specimen mounting, and data collection are suitable and are not changed. For example, thus the use of a variable divergence slit for traditional standardization-based analyses is acceptable, because it provides reproducible irradiated volume (see Note A1.1).

NOTE A1.1—Variable divergence slits maintain a fixed irradiated area on the specimen surface. For lower angle regions, they keep the beam from spreading beyond the specimen, while at higher angles they provide a larger irradiated area (and so, volume) than do fixed slit systems. However, Rietveld analysis requires the constant volume provided by a fixed divergence slit. Therefore, data collected with a variable slit needs to be transformed to fixed slit by multiplying by $\sin\Theta$ (**7**).

A1.3 *Terminology*:

A1.3.1 *extinction*—a decrease in intensity during diffraction due to interference by successive crystal planes.

A1.3.1.1 *Discussion*—Extinction is affected by the crystallite size and is negligible for specimens ground to a particle diameter of 5 or 10 μm.

A1.3.2 *irradiated volume*—the volume of specimen that produces XRD signal.

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A1.3.2.1 *Discussion*—Irradiated volume is constant from specimen to specimen as long as the proper geometric alignment is maintained and the specimen is sufficiently thick.

A1.3.3 *microabsorption*—an increase or decrease in intensity produced by a combination of phases that differ in absorption coefficient.

A1.3.3.1 *Discussion*—Microabsorption is affected by the extent to which the absorption coefficients differ and by the crystallite size. For phases whose mass absorption coefficients differ by less than 100, microabsorption is not significant for specimens ground to a particle diameter of <10 μm.

A1.3.4 *pattern intensity measurements*—the scale factor for a diffraction pattern of an individual phase determined by a least-squares procedure on a point-by-point basis.

A1.3.5 *peak intensity measurements*—the integrated intensity of the particular diffraction peak.

A1.3.6 *preferred orientation*—the nonrandom orientation of grains relative to the specimen surface.

A1.3.6.1 *Discussion*—Preferred orientation causes major changes in intensity of certain XRD lines, and therefore may be a source of error in QXRD analysis. Preferred orientation is not thought to be a major problem with portland cement clinker phases because they do not typically cleave along crystallographic directions. Preferred orientation is reduced (but not prevented) by prolonged grinding. The mounting procedure must be one that reduces preferred orientation, such as the procedure as described by Klug and Alexander (**6**, pp. 372–374) or Bish and Post (**7**)

A1.4 *Alignment*:

A1.4.1 Loss of proper alignment causes systematic variations in peak intensity with 2θ angle, thus rendering the QXRD procedure invalid.

A1.4.2 In order to assess alignment, an external standard shall be analyzed each month that this test method is used. Measurements shall include peak position, intensity, and resolution (that is, peak width or the ratio of the peak to valley intensity of partially overlapping peaks) of two or more peaks at widely separated 2θ angles. Suitable external standards include SRM® 1976 or polished specimens of novaculite quartz or silicon (**7**).

A1.4.3 Proper alignment is indicated by all of the following: *(1)* correct peak position, *(2)* suitable peak intensity, *(3)* suitable ratio of peak intensity of one or more peaks, and *(4)* suitable peak resolution. These must all be determined for suitably intense peaks. The correct peak position is within 0.01°2θ (Cu Kα) of its nominal value; for the (101) line of novaculite quartz, this value is 26.64°2θ (Cu Kα). Suitable peak intensity depends on many aspects besides alignment and therefore must be determined for a particular diffractometer based on experience; 1000 counts per second per mA is a reasonable expected value for the (101) line of novaculite quartz. Suitable peak intensity ratio is within 5 % of the nominal value. Suitable peak resolution must likewise be determined for a particular diffractometer based on experience. A reasonable indication is provided by clear separation of the five quartz peaks [(122) α_1, (122) α_2, (203) α_1, (203) α_2 plus (301) α_1, and (301) α_2] that appear at about 68°2θ (Cu Kα) (**5**, p. 392–394). Another indication is provided by resolution of the (110) Kα1–2 doublet of tungsten that appears at about 40.4°2θ (Cu Kα); the valley between these peaks must be no greater than 0.5 times the intensity of the α_2 peak (**6**).

A1.4.4 NIST SRM® 1976 may be used for instrument sensitivity assessment (**16**). Certified relative intensities of diffraction peaks, by both peak height or peak area, may be used to assess and correct for instrument bias. Plotting the ratios of the observed to certificate relative intensities will allow assessment of instrument performance relative to a diffractometer deemed to be "in control." If the plot of intensity ratios is pattern-less and falls within the control limits, the diffractometer may be considered "in control."

A1.4.5 When a diffractometer is found to not be properly aligned, then it must be realigned according to the manufacturer's instructions.

APPENDIXES

(Nonmandatory Information)

X1. RIETVELD ANALYSIS OF X-RAY POWDER DIFFRACTION PATTERNS FROM CEMENTS

X1.1 *Introduction*—The Rietveld method employs a least-squares refinement to minimize the difference between a calculated and measured X-ray powder diffraction pattern based upon refinement of crystal structure, specimen, and instrument effects (**9**). The resulting refined crystal structure data for each phase include pattern intensity information used to calculate relative phase abundance. Chemical (solid solution) and structural properties (lattice parameters) of each phase may also be obtained. Crystal structure data describe the structure and chemical composition of crystalline phases that may occur in cements.

Quantitative phase determinations of cements and portland cement clinkers have been difficult to obtain from powder diffraction patterns because of the large number of phases and the large extent of diffraction peak overlap. Traditional peak area measurement approaches are relatively imprecise because of the difficulty in decomposing the highly-overlapped patterns. The advantages of the Rietveld method over these traditional standardization-based methods is the whole-pattern decomposition of simultaneous refinement of crystal structure data from X-ray powder diffraction patterns of multiple phases. This approach provides improved reproducibility in intensity measurement, accommodation of specimen displacement shifts in the pattern, adjustments in crystal lattice parameters affecting peak positions, and relative peak intensities affected by chemical substitution.

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The resulting set of relative phase scale factors, phase densities, and cell volumes are used to calculate relative phase abundance according to Eq X1.1:

$$W_p = \frac{S_p\,(ZMV)_p}{\sum_p [S_p\,(ZMV)_p]} \quad \text{(X1.1)}$$

where:

W_p = the mass fraction of phase p,
S_p = the Rietveld scale factor,
Z = the number of formula units per unit cell,
M = the mass of the formula unit, and
V = the unit cell volume.

X1.2 The minimum requirements for a successful analysis are *(1)* collection of accurate powder diffraction data by step scanning, *(2)* having crystal structure data that are close to the actual structures found in the specimens, and *(3)* a model that accurately reflects systematic errors in the pattern and peak shapes (**7**).

X1.3 Qualitative phase identification may be performed through the principal diagnostic peaks listed in Table X1.1, which lists peaks that are generally resolvable (not too highly overlapped) and unique. This approach is useful since the number of phases and the high degree peak overlap preclude traditional means for phase identification. Confirmation of each phase should be accomplished using the patterns from the ICDD reference database or some other reference patterns of pure phases.

X1.4 The following variables should be refined: *(1)* background, *(2)* specimen displacement, *(3)* individual phase scale (intensity), *(4)* individual phase lattice parameters, *(5)* alite preferred orientation (if necessary), and *(6)* individual phase peak shapes. Examination of the correlation matrix can generally identify variables with high correlation that may create difficulties in refining to the proper values.

X1.4.1 Suitable results can be achieved by refining only the variables listed in X1.4. Refinement of atom site occupancy (Fe–Al ratios) for the ferrite phase is possible but not necessary as the effect on phase fraction is generally small. In addition, the scale and site occupancy factors can be strongly-correlated. Refining preferred orientation for phases other than alite (lower-concentration phases) can create correlation problems that lead to incorrect refinements.

X1.5 Examination of the difference profile plot is considered the best means of assessing the progress of the refinement.

TABLE X1.1 Diagnostic Peaks and ICDD Entry Number for Common Cement Phases (15)

d-spacing (nm)	Two-Theta (CuKα)	Phase (rel. I)	ICDD No.
0.7627	11.593	gypsum (100)	33-311
0.7249	12.200	ferrite (45)	30-226
0.5997	14.759	bassanite (80)	41-224
0.4284	20.717	gypsum (100)	
0.4235	20.959	aluminate, cubic (6)	38-1429
0.4175	21.264	arcanite (28)	5-613
0.4158	21.352	arcanite (23)	
0.4079	21.770	aluminate, cubic (12)	
0.3799	23.397	gypsum (17)	
0.3670	24.231	aphthitalite (20)	20-928
0.3653	24.346	ferrite (16)	
0.3497	25.450	anhydrite (100)	37-1496
0.3468	25.666	bassanite (40)	
0.3313	26.889	langbeinite (95)	19-975
0.3271	27.241	langbeinite (80)	
0.3263	27.309	langbeinite (80)	
0.3225	27.637	langbeinite (100)	
0.3065	29.111	gypsum (75)	
0.3040	29.355	alite, triclinic (55)	31-301
0.3036	29.395	alite, monoclinic (40)	42-551
0.3025	29.504	alite, triclinic (65)	
0.3025	29.504	alite, monoclinic (75)	
0.3002	29.736	bassanite (80)	
0.3000	29.756	arcanite (77)	
0.2985	29.909	alite, triclinic (25)	
0.2974	30.022	alite, triclinic (18)	
0.2965	30.115	alite, triclinic (20)	
0.2961	30.157	alite, monoclinic (25)	
0.2940	30.378	aphthitalite (75)	
0.2902	30.785	arcanite (100)	
0.2880	30.960	arcanite (53)	
0.2886	31.026	langbeinite (18)	
0.2876	31.070	belite, β-form (21)	33-302
0.2838	31.497	aphthitalite (100)	
0.2784	32.124	ferrite (25)	
0.2714	32.976	aluminate, orthorhombic (65)	
0.2710	33.026	belite α-form (100)	23-1042
0.2698	33.178	aluminate, cubic (100)	
0.2692	33.254	aluminate, orthorhombic (100)	26-957
0.2644	33.875	ferrite (100)	
0.2610	34.330	belite, β-form (42)	
0.2405	37.360	free lime (100)	37-1497
0.2220	40.605	belite, α-form (40)	
0.2110	42.920	periclase (100)	4-829
0.1940	46.788	belite, α-form (60)	
0.1764	51.783	alite, monoclinic (55)	
0.1757	52.004	alite, monoclinic (30)	

Numerical measures of the degree of fit include the reliability factor (R values), representing some measure of the degree of agreement between the observed and calculated data. This value is dependent upon the quality of the experimental data and so, the plots are ultimately the best means to assess the quality of the fit. Additional discussion may be found in Bish and Post (**7**), Young (**9**), and McCusker (**10**).

X2. STANDARDIZATION-BASED QXRD PROCEDURES USED TO DETERMINE ACCEPTABLE LEVELS OF PRECISION AND BIAS

X2.1 *Introduction*—During development of the traditional procedure, a round-robin analysis of the RM clinkers was carried out to determine acceptable levels of precision and bias (**12, 13**). Details of the QXRD procedure were specified during this analysis. Although this test method does not include detailed QXRD procedures, the procedures used in the cooperative standardization and round robins described in Appendix X1 or Appendix X2 are recommended.

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X2.2 *Overview*—This QXRD procedure has a number of critical features: standardization using mixtures of synthetic phases, use of an internal standard, intensity measurement of a specified peak for each phase, measurement of peak area to determine intensity, grinding samples until at least 90 % (by mass) is smaller than 10 μm in diameter, and the use of chemical extractions in the analytical scheme (see Note X2.1).

NOTE X2.1—Alternative QXRD procedures may provide satisfactory precision and bias and thus be acceptable under this test method. An external standard may be used rather than an internal standard. Intensity of each phase may be measured using many peaks or even the entire pattern. Chemical extractions need not be used in the analytical scheme. The particular procedure described in this appendix simply constitutes a recommendation.

X2.3 *Standardization Mixtures*:

X2.3.1 Three standardization mixtures were prepared using cubic C_3A, orthorhombic C_3A, C_4AF, and M. These individual phases were obtained from the Construction Technology Laboratories, and procedures used to prepare these individual phases and standardization mixtures were described by Struble and Kanare (**12**).

X2.3.2 The proportions in each mixture are listed in Table X2.1. The phases in this standardization are the principal phases in a clinker that has been chemically extracted using maleic acid or salicylic acid (see X2.3.3).

X2.3.3 Standardization phases were ground such that at least 95 % (by mass) was finer than 10 μm and not more than 5 % were finer than 1 μm in diameter. This particle size was selected to minimize microabsorption preferred orientation and to avoid loss of X-ray intensity due to grinding to particle sizes <1 μm.

X2.4 *Internal Standard*:

X2.4.1 Participants were required to use an internal standard—a pure, stable material, 95 % of which is finer than 10 μm. One recommended material was SRM® 640c (silicon).[8] However, it should be noted that silicon intensity may be affected by particle size distribution. Also recommended were any one of the materials in SRM® 674.[8] Another suitable material is SRM® 676.[8]

X2.4.2 Standardization mixtures were mixed with the internal standard material in recommended proportions of 0.1200 g internal standard per 1.0000 g standardization or unknown mixture, corresponding to 0.0200 g internal standard per 1.0000 g clinker. These proportions assume that the standardization mixture and unknown mixtures represent 17 % (by mass) of a clinker.

X2.5 *Blending*—Components must be blended to provide homogeneous specimens. The recommended procedure was to blend each standardization mixture for approximately 10 min using a vibratory-type mill with approximately 5 mL of a nonaqueous solvent (see Note X2.2) for each gram of powder and with appropriate grinding media.

NOTE X2.2—Suitable solvents include cyclohexane or alcohol (ethanol, methanol, or 2-propanol). Alcohol often contains sufficient water to cause hydration, so this water must be removed (**17**).

X2.6 *Diffraction Procedures*—Participants were instructed to use their normal procedures for preparing specimens and for collecting diffraction patterns. Specimen preparation procedures should minimize preferred orientation. Procedures to collect diffraction patterns should provide reproducible peak intensity measurements (for example, slow scanning speeds and moderately large receiving-slit widths).

X2.7 *Peak Selection*—Participants were required to measure intensity of the peaks specified in Table X2.2 plus one or more peaks for the internal standard, though they were encouraged to measure additional peaks, as many as possible for each phase. Analysis using a manual diffractometer is probably limited to the few peaks in Table X2.2, whereas analysis using a computer-controlled diffractometer can utilize many peaks for each phase.

TABLE X2.2 Peaks Recommended for QXRD Analysis

Phase	hkl	*d*-spacing (nm)	Position (°2θ) using Cu Kα
Orthorhombic C_3A[A]	(113)	0.4210	21.1
Cubic C_3A	(023)	0.4236	21.0
	(213)	0.4083	21.8
C_4AF	(130)	0.3654	24.3
M	(200)	0.2106	42.9

[A] Note that the intensity of the (113) peak of orthorhombic C_3A must be corrected for any contribution from the (023) peak of cubic C_3A. The intensity of the (023) peak is calculated by multiplying the (213) peak by a correction factor. The correction factor is determined by measuring the intensity ration of the (023) peak to the (213) peak in a sample containing cubic C_3A and no orthorhombic C_3A.

X2.8 *C_3A Correction*—The intensity of the (113) peak of orthorhombic C_3A must be corrected for any contribution from the (023) peak of cubic C_3A. This (023) intensity contribution is calculated by multiplying the (213) peak by a correction factor, which is the intensity ratio of the (023) peak to the (213) peak for cubic C_3A using Sample A (which contains no orthorhombic C_3A).

X2.9 *Intensity Measurement*—Integrated intensity above the background must be measured for each peak. There are a number of procedures for measuring integrated intensity, and no specific procedure is required for this standardization.

X2.10 *Standardization Curve*—Once the standardization mixtures have been analyzed, standardization curves relating the measured intensity of each peak, relative to the intensity of the internal standard peak, to the known proportion of the

[8] In this test method, SRM clinkers refer specifically to SRM 2686, SRM 2687, and SRM 2688. These are available from the Standard Reference Material Program, National Institute of Standards and Technology.

TABLE X2.1 Proportion of Phases in Standardization Mixtures

Phase	Percent of Mixture			Percent of Clinker		
	A	B	C	A	B	C
Orthorhombic C_3A	0	51	7	0.00	8.67	1.19
Cubic C_3A	65	11	29	11.05	1.87	4.93
C_4AF	35	11	60	5.95	1.87	10.20
M	0	27	4	0.00	4.59	0.68

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phase must be developed. These curves may be prepared graphically or using accepted statistical procedures to determine the best-fitting curve. When an internal standard is used, it is assumed that the peak intensity is linearly related to the phase proportion. However under certain circumstances it may be found that the relationship is not linear, but is better described by some other mathematical function.

X2.11 *Analysis of Unknown Mixtures*—Two additional mixtures of the standardization phases were analyzed using the same QXRD procedures to provide a preliminary assessment of the standardization.

X2.12 *Analysis of Cement or Clinker*—The following procedures were followed during analysis of the SRM® clinkers and are recommended for analysis of any portland cement or portland-cement clinker.

X2.12.1 *Grinding*—The clinker samples were ground such that at least 95 % was finer than 10 µm and not more than 5 % was finer than 1 µm. The following procedure has been found to be suitable: grind using a tungsten carbide ring and puck mill, with approximately 5 drops ethylene glycol as a grinding aid, for 4 to 6 min. It is necessary to start with enough sample to provide sufficient powder for the specimen mount, considering that extraction of the calcium silicates will leave ca. 15 to 20 % (by mass) for XRD analysis.

X2.12.2 *Ignition*—In the case of analyzing portland cement for C_3A, C_4AF, and M, gypsum ($C\bar{S}H_2$) and hemihydrate ($C\bar{S}H_{1/2}$) must be converted to anhydrite ($C\bar{S}$) before QXRD analysis to eliminate interfering XRD peaks. This conversion can be carried out by igniting the cement for 30 min at 500 °C.

X2.12.3 *Blending with Internal Standard*—The ground sample was blended with the internal standard using the same procedure as used during the standardization. The recommended proportion was 0.0200 g internal standard per gram of clinker to approximate the 12 % (by mass) recommended for the standardization mixtures.

X2.12.4 *Extraction*—The calcium silicates were extracted chemically using salicylic acid or maleic acid and methanol using procedures described by Struble (**17**). This extraction was not quantitative; because the internal standard was added relative to unextracted clinker, the phase contents were determined relative to the un-extracted clinker.

X2.12.5 *XRD Analysis*—The clinkers were analyzed using the same procedures (for example, collection of the diffraction pattern, measurement of peak intensities, and calculation of phase proportions) that were used in the standardization.

REFERENCES

(**1**) Taylor, H. F. W., *Cement Chemistry*, 2nd edition, Thomas Telford, New York, 1997.
(**2**) Takeuchi, Y., Nishi, F., and Maki, I., *Zeit Krist*., 152, 1980, p. 259.
(**3**) Klein, C., *Manual of Mineralogy*, after J. D. Dana, 22th Edition John Wiley and Sons, New York, 2002.
(**4**) Lea, F. M., *The Chemistry of Cement and Concrete*, 3rd ed., Arnold, London, 1970, p. 727.
(**5**) Cullity, B. D., and Stock, S. R., *Elements of X-Ray Diffraction*, Prentice Hall, 2001.
(**6**) Klug, H. P., and Alexander, L. E., *X-Ray Diffraction Procedures for Polycrystalline and Amorphous Materials*, 2nd ed, John Wiley & Sons, New York, NY, 1974.
(**7**) Bish, D. L., and Post, J. E., eds., *Modern Powder Diffraction*, Reviews in Mineralogy, Vol 20, Mineralogical Society of America, Washington, DC, 1989.
(**8**) *Methods and Practices in X-Ray Powder Diffraction*, 3rd ed., International Centre for Diffraction Data, Newtown Square, PA, 1989.
(**9**) *The Rietveld Method*, Young, R. A., ed., Oxford University Press, 1993.
(**10**) McCusker, L. B., Von Dreele, R. B., Cox, D. E., Louer, D., and Scardi, P., "Rietveld Refinement Guidelines," *Jour. Appl. Cryst*. 32, 1999, pp. 36-50.
(**11**) Stutzman, P. E., and Leigh, S. L., "Phase Composition Analysis of the NIST Reference Clinkers by Optical Microscopy and X-Ray Powder Diffraction," *NIST Technical Note 1441*, 2002, p. 44.
(**12**) Struble, L., and Kanare, H., "Cooperative Calibration and Phases, Report 2," *Structural Research Series No. 556*, University of Illinois at Urbana-Champaign, 1990.
(**13**) Struble, L., "Quantitative Phase Analysis of Clinker Using X-Ray Diffraction," *Cement, Concrete and Aggregates*, Vol 13, No. 2, 1991, pp. 97–102.
(**14**) Stutzman, P. E., and Leigh, S. L., "Phase Analysis of Hydraulic Cements by X-Ray Powder Diffraction: Precision, Bias, and Qualification," NIST IR, in press, 2006.
(**15**) *The Powder Diffraction File*, International Centre for Diffraction Data, Newtown Square, PA.
(**16**) Certificate of Analysis, "Standard Reference Material 1976, Instrument Sensitivity Standard for X-ray Powder Diffraction," Standard Materials Reference Program, National Institute of Standards and Technology, Gaithersburg, MD.
(**17**) Struble, L., "The Effect of Water on Maleic Acid and Salicylic Acid Extractions," *Cement and Concrete Research*, Vol 15, 1985, pp. 631–636.

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SUMMARY OF CHANGES

Committee C01 has identified the location of selected changes to this test method since the last issue, C 1365 – 05, that may impact the use of this test method. (Approved December 15, 2006)

(*1*) The standard was extensively revised to include new development in X-ray powder diffraction analysis as well as provide for a more complete analysis, and to include a precision statement.

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Designation: C 1381/C 1381M – 97 (Reapproved 2008)ε1

Standard Specification for Molded Glass Fiber Reinforced Gypsum Parts[1]

This standard is issued under the fixed designation C 1381/C 1381M; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

ε[1] NOTE—The units statement in subsection 1.2 was corrected and the standard was changed to a dual designation editorially in July 2008.

1. Scope

1.1 This specification covers molded glass fiber reinforced gypsum (GRG) parts, which are nonload-bearing, thin-shell, ornamental shapes for architectural embellishment of interior building construction.

1.2 The values stated in either SI units or inch-pound units are to be regarded separately as standard. Within the text, the SI units are shown in brackets. The values stated in each system may not be exact equivalents; therefore, each system shall be used independently of the other. Combining values from the two systems may result in non-conformance with the standard.

1.3 The information presented refers to the molded surface of the part.

1.4 The text of this standard references footnotes, which provide explanatory material. These footnotes shall not be considered as requirements of the standard.

2. Referenced Documents

2.1 *ASTM Standards:* [2]

C 11 Terminology Relating to Gypsum and Related Building Materials and Systems

C 1355/C 1355M Specification for Glass Fiber Reinforced Gypsum Composites

3. Terminology

3.1 *Definitions*—Definitions of terms shall be in accordance with Terminology C 11.

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *control thickness*, *n*—the thickness of the GRG part where abutting other GRG parts, other products or at fastening points.

3.2.2 *embedments*, *n*—materials encapsulated into the part for the purpose of suspension, attachment, and stiffening.

3.2.3 *finish surface*, *n*—a surface against a mold.

3.2.4 *GRG part*, *n*—an individual molded component used as architectural embellishment.

3.2.5 *GRG product*, *n*—combination of GRG parts used as architectural embellishment.

3.2.6 *mock-up*, *n*—a presentation assembly of GRG parts defined by the purchase agreement.

3.2.7 *part thickness*, *n*—thickness of a part at any measurement point.

4. Materials and Manufacture

4.1 *Materials*—GRG parts shall be produced using the same materials used to make the composites in conformance with Specification C 1355/C 1355M.

4.2 *Manufacture*:

4.2.1 *GRG* parts shall be manufactured from the mixed slurry of alpha gypsum cement, potable water and additives, when used, and not less than 5 % by weight glass fiber reinforcement using either the hand lay-up or the spray-up process in a mold.

4.2.2 *GRG* parts shall be produced according to approved shop drawings.

4.2.3 Shop drawings shall specify part dimensions, quantities, recommended attachment points and methods, reinforcements, embedments, and tolerance.

5. Mechanical Properties

5.1 *GRG* parts shall be made from materials to make composites having properties in accordance with Specification C 1355/C 1355M.

6. Dimensions and Tolerances of GRG Parts

6.1 *Part Thickness*—The thickness of the GRG part shall be not less than 3⁄16 in. [5 mm].

6.2 *Control Thickness*, shall be not less than 5⁄16 in. [8 mm].

6.3 *Straightness*—At any point on a line generally along a plane, an edge, or a surface, the molded side of the part shall not vary from straight ± 1⁄8 in. in 8 linear ft [1 mm in 750 mm].

[1] This specification is under the jurisdiction of ASTM Committee C11 on Gypsum and Related Building Materials and Systems and is the direct responsibility of Subcommittee C11.01 on Specifications and Test Methods for Gypsum Products.

Current edition approved May 1, 2008. Published July 2008. Originally approved in 1998. Last previous edition approved in 2002 as C 1381 – 97(2002)ε1.

[2] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

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6.4 *Dimensions*, as specified in approved shop drawings, pertaining to the individual part.

6.4.1 *Overall Width*, ± ⅛ in. [3 mm].

6.4.2 *Dimensions Within the Overall Width*, ± 1⁄16 in. [2 mm].

6.4.3 *Overall Length*, ± ⅛ in. [3 mm].

6.4.4 *Dimensions Within the Overall Length*, ± 1⁄16 in. [2 mm].

7. Workmanship, Finish and Appearance

7.1 *GRG* parts shall be produced to quality, tolerances, and surface standards set within this specification.

7.2 The standard finished surface shall be suitable to receive flat paint.

7.3 Finishes with sheen, direct light or special lighting conditions require additional coats of primer, sanding and finishing by the installer or painter.

8. Sampling

8.1 When specified by the purchase agreement, samples of the GRG part shall be taken at the place of manufacture for measuring in accordance with Section 6.

8.2 *Mock-Up*—When specified by the purchase agreement, a mock-up shall be supplied.

9. Inspection

9.1 Inspection of the GRG parts shall be agreed upon between the purchaser and the supplier as part of the purchase agreement.

10. Rejection and Rehearing

10.1 Rejection of GRG parts that fail to conform to the requirements of this specification shall be reported in writing to the producer or supplier within 14 calendar days from receipt of parts and prior to installation.

11. Certification

11.1 When specified in the purchase agreement, the purchaser shall be furnished certification that samples representing each lot have been either tested or inspected as directed in this specification and the requirements have been met. When specified in the purchase agreement, a report of test results shall be furnished.

12. Quality Assurance

12.1 Each manufacturer's measuring of samples shall be representative of actual production procedures and materials. The GRG manufacturer shall certify that the materials are the same as those used to produce the composite according to C 1355/C 1355M.

13. Marking

13.1 Each GRG part shall be marked clearly according to the project shop drawings.

14. Packaging

14.1 Packaging shall ensure that the GRG parts arrive at the jobsite in good condition when handled and shipped according to industry operating standards.

15. Keywords

15.1 glass fiber reinforced gypsum; glass fiber reinforced gypsum composite; glass fiber reinforced gypsum parts; GRG; GRG composites; GRG parts

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Designation: C 1383 – 04

Standard Test Method for Measuring the P-Wave Speed and the Thickness of Concrete Plates Using the Impact-Echo Method[1]

This standard is issued under the fixed designation C 1383; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope*

1.1 This test method covers procedures for determining the thickness of concrete slabs, pavements, bridge decks, walls, or other plate-like structure using the impact-echo method.

1.2 The following two procedures are covered in this test method:

1.2.1 *Procedure A: P-Wave Speed Measurement*—This procedure measures the time it takes for the P-wave generated by a short-duration, point impact to travel between two transducers positioned a known distance apart along the surface of a structure. The P-wave speed is calculated by dividing the distance between the two transducers by the travel time.

1.2.2 *Procedure B: Impact-Echo Test*—This procedure measures the frequency at which the P-wave generated by a short-duration, point impact is reflected between the parallel (opposite) surfaces of a plate. The thickness is calculated from this measured frequency and the P-wave speed obtained from Procedure A.

1.2.3 Unless specified otherwise, both Procedure A and Procedure B must be performed at each point where a thickness determination is made.

1.3 The values stated in SI units are to be regarded as the standard.

1.4 The text of this standard references notes and footnotes that provide explanatory material. These notes and footnotes (excluding those in tables and figures) shall not be considered as requirements of the standard.

1.5 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

2. Referenced Documents

2.1 *ASTM Standards:* [2]

C 597 Test Method for Pulse Velocity Through Concrete

E 1316 Terminology for Nondestructive Examinations

3. Terminology

3.1 *Definitions:*

3.1.1 *acoustic impedance*—the product of P-wave speed and density that is used in computations of characteristics of stress wave reflection at boundaries.

3.1.2 *amplitude spectrum*—a plot of relative amplitude versus frequency that is obtained from the waveform using a Fourier transform technique.

3.1.3 *Fourier transform*—a numerical technique used to convert digital waveforms from the time domain to the frequency domain.

3.1.3.1 *Discussion*—The peaks in the amplitude spectrum correspond to the dominant frequencies in the waveform.

3.1.4 *impact-echo method*—a send-receive nondestructive test method based on the use of a short-duration mechanical impact to generate transient stress waves and the use of a broadband receiving transducer placed adjacent to the impact point.

3.1.4.1 *Discussion*—Waveforms are converted to the frequency domain and the resulting amplitude spectra are analyzed to obtain the dominant frequencies in the structure's response to the impact. These frequencies are used to determine the thickness of the structure or the presence of flaws.

3.1.5 *impact duration*—the time that the impactor used to generate stress waves is in contact with the test surface. Also referred to as contact time.

3.1.5.1 *Discussion*—The impact duration is a critical aspect in the success of the two procedures covered by this method. Recommended impact durations are given. In practice, the impact duration will depend on the type of impactor and the condition of the concrete at the point of impact. Smooth, hard

[1] This test method is under the jurisdiction of ASTM Committee C09 on Concrete and Concrete Aggregates and is the direct responsibility of Subcommittee C09.64 on Nondestructive and In-Place Testing.

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***A Summary of Changes section appears at the end of this standard.**

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surfaces will result in shorter impact durations than rough, soft surfaces. The user should verify that the impact durations are within the recommended ranges. An approximate measure of the impact duration can be obtained from the portion of the waveform corresponding to the surface wave arrival.[3] Fig. 1

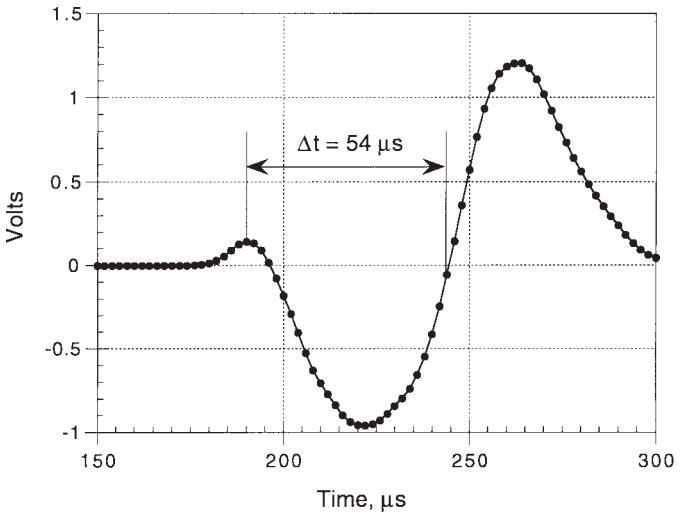

FIG. 1 Expanded View of Surface-Wave Portion of Waveform Showing the Width of the Surface Wave Signal as an Approximation of the Contact Time of the Impact

shows an example of the surface-wave portion of a waveform and the approximate contact time is indicated.

3.1.6 *P-wave*—the dilatational (longitudinal or primary) stress wave that causes particle displacement parallel to the direction of wave propagation. This wave produces normal stresses (tensile or compressive) as it propagates.

3.1.7 *P-wave speed*—the speed with which the P-wave propagates through a semi-infinite solid.

3.1.7.1 *Discussion*—The P-wave speed is the same as the compressional pulse velocity measured according to Test Method C 597.

3.1.8 *sampling frequency*—the rate at which the points that comprise the waveform are recorded; the inverse of the sampling interval, expressed in Hz or samples/s (also referred to as *sampling rate*).

3.1.9 *sampling period*—the duration of the waveform, which equals the number of points in the waveform multiplied by the sampling interval.

3.1.10 *sampling interval*—the time difference between any two adjacent points in the waveform.

3.1.11 *surface wave*—a stress wave in which the particle motion is elliptical and the amplitude of particle motion decreases rapidly with depth. Also known as *Rayleigh wave* (or *R-wave*).

3.1.12 *waveform*—a recorded signal from a transducer that is a plot of voltage versus time.

3.1.13 Refer to Terminology E 1316 for additional definitions, related to nondestructive ultrasonic examination, that are applicable to this test method.

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *apparent P-wave speed in a plate*[3,4]—a parameter that is 0.96 of the P-wave speed:

$$C_{p,\,plate} = 0.96\,C_p \tag{1}$$

where:

$C_{p,\,plate}$ = the apparent P-wave speed in a plate, m/s, and
C_p = the P-wave speed in concrete that is obtained from Procedure A, m/s.

3.2.1.1 *Discussion*—This parameter is used in thickness calculations in impact-echo measurements on plates. The P-wave speed in a material (concrete) is converted to the apparent P-wave speed in a plate that is used to calculate the plate thickness by the following equation:

$$T = \frac{C_{p,\,plate}}{2f} \tag{2}$$

where:

T = the thickness of the plate, m, and
f = the frequency of the P-wave thickness mode of the plate obtained from the amplitude spectrum, Hz.

3.2.2 *plate*—any prismatic structure where the lateral dimensions are at least six times the thickness.

3.2.2.1 *Discussion*—Minimum lateral dimensions are necessary to prevent plate modes[3] of vibration from interfering with the identification of the thickness mode frequency in the amplitude spectrum. The minimum lateral dimensions and acceptable sampling period are related, as explained in Note 11.

4. Significance and Use

4.1 This test method may be used as a substitute for, or in conjunction with, coring to determine the thickness of slabs, pavements, decks, walls, or other plate structures. There is a certain level of systematic error in the calculated thickness due to the discrete nature of the digital records that are used. The absolute systematic error depends on the plate thickness, the sampling interval, and the sampling period.

4.2 Because the wave speed can vary from point-to-point in the structure due to differences in concrete age or batch-to-batch variability, the wave speed is measured (Procedure A) at each point where a thickness determination (Procedure B) is required.

4.3 The maximum and minimum thickness that can be measured is limited by the details of the testing apparatus (transducer response characteristics and the specific impactor). The limits shall be specified by manufacturer of the apparatus, and the apparatus shall not be used beyond these limits. If test equipment is assembled by the user, thickness limitations shall be established and documented.

[3] Sansalone, M. and Streett, W.B., *Impact-Echo: Nondestructive Evaluation of Concrete and Masonry*, Bullbrier Press, Ithaca, NY and Jersey Shore, PA, 1997.

[4] Sansalone, M., Lin, J. M., and Streett, W. B., "A Procedure for Determining P-wave Speed in Concrete for Use in Impact-Echo Testing Using P-wave Speed Measurement Technique," *ACI Journal*, Vol. 94, No. 6, November–December 1997, pp. 531–539.

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4.4 This test method is not applicable to plate structures with overlays, such as a concrete bridge deck with an asphalt or portland cement concrete overlay. The method is based on the assumption that the concrete plate has the same P-wave speed throughout its depth.

4.5 Procedure A is performed on concrete that is air dry as high surface moisture content may affect the results.

4.6 Procedure B is applicable to a concrete plate resting on a subgrade of soil, gravel, permeable asphalt concrete, or lean portland cement concrete provided there is sufficient difference in acoustic impedance[3] between the concrete and subgrade or there are enough air voids at the interface to produce measurable reflections. If these conditions are not satisfied, the waveform will be of low amplitude and the amplitude spectrum will not include a dominant peak at the frequency corresponding to the thickness (Eq 2). If the interface between the concrete and subgrade is rough, the amplitude spectrum will have a rounded peak instead of a sharp peak associated with a flat surface.

4.7 The procedures described are not influenced by traffic noise or low frequency structural vibrations set up by normal movement of traffic across a structure.

4.8 The procedures are not applicable in the presence of mechanical noise created by equipment impacting (jack hammers, sounding with a hammer, mechanical sweepers, and so forth) on the structure.

4.9 Procedure A is not applicable in the presence of high amplitude electrical noise, such as may produced by a generator or some other source, that is transmitted to the data-acquisition system.

PROCEDURE A—P-WAVE SPEED MEASUREMENT

5. Summary of Procedure

5.1 An impact on the concrete surface is used to generate transient stress waves. These waves propagate along the surface of the concrete past two transducers, placed on a line through the impact point and at a known distance apart.

5.2 The time difference between the arrival of the P-wave (stress wave with highest speed) at each transducer is used to determine the P-wave speed by dividing the time difference (travel time) by the known distance between the transducers.

6. Apparatus [5]

6.1 *Impactor*—The impactor shall be spherical or spherically tipped. It shall produce an impact duration of 30 ± 10 μs with sufficient energy to produce surface displacements due to the P-wave that can be recorded by the two transducers (see Note 1). The impactor shall be positioned to strike on the centerline passing through the two transducers at a distance of 150 ± 10 mm from the first transducer.

NOTE 1—Hardened steel balls ranging from 5 to 8 mm in diameter and attached to steel spring rods have been found to produce suitable impacts.

6.2 *Transducers*—Two broadband transducers that respond to displacements normal to the surface. These transducers must be capable of detecting the small displacements that correspond to the arrival of the impact-generated P-wave traveling along the surface. A small contact area between the piezoelectric element and the concrete surface is required to record accurately the arrival of the P-wave (see Note 2). Use a suitable material to couple the transducer to the concrete.

NOTE 2—A commercially available displacement transducer made from a conical piezoelectric element with a tip diameter of 1.5 mm and the larger end attached to a brass backing block has been found suitable.[6] A lead sheet approximately 0.25 mm thick is a suitable coupling material for such a transducer.

6.2.1 Acceptable transducers shall be previously documented to produce accurate results for plate thicknesses similar to those being measured by this test method.

6.3 *Spacer Device*—A spacer device shall be provided to hold the transducers a fixed distance apart. It shall not interfere with the ability of the transducers to measure surface displacement. It shall be manufactured to minimize the possibility of P-wave transmission through it so as to prevent interference with measurement of the P-wave travel time. The transducer tips shall be placed about 300 mm apart. Measure and record to the nearest 1 mm the actual distance between the centers of the transducer tips.

NOTE 3—The accuracy of the measurement is affected if the distance between the tips of the two transducers is not known accurately. The materials and design of the spacer device should be chosen to minimize the change in separation of the transducers due to changes in temperature.

6.4 *Data-Acquisition System*—Hardware and software for acquiring, recording, and processing the output of the two transducers. This system can be a portable computer with a two-channel data-acquisition card, or it can be a portable two-channel waveform analyzer.

6.4.1 The sampling frequency for each channel shall be 500 kHz or higher (sampling interval of 2 μs or less). The system shall be capable of triggering on the signal from one of the recording channels.

6.4.2 The voltage range and voltage resolution of the data acquisition system shall be matched with the sensitivity of the transducers so that the arrival of the P-wave is determined accurately.

NOTE 4—For example, a computer data acquisition card with a voltage range of ±2.5 V and 12-bit resolution has been found to be suitable for the transducer described in Note 2.

6.4.3 The display system shall include cursors, including a corresponding readout of time and voltage, that can be positioned at the point in each waveform corresponding to the P-wave arrival.

6.4.4 The data-acquisition system shall be operated by a power source that does not produce electrical noise detectable by the transducers and data acquisition system when the system is set at the voltage sensitivity required to detect the arrivals of the P-wave.

NOTE 5—Battery-powered data acquisition systems have been found suitable.

[5] Suitable apparatus is available commercially.

[6] Proctor, T.M., Jr., "Some Details on the NBS Conical Transducer," *J. of Acoustic Emission*, Vol 1, No. 3, pp. 173–178.

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6.5 *Cables and Connectors*—To connect the transducers to the data acquisition system. Connectors shall be high quality and tightly connected to the cables. The cables shall be shielded to reduce electrical noise.

6.6 *Functionality Check Apparatus*—Apparatus to verify that all components of test system are functioning properly prior to the start of testing.

NOTE 6—This may include a reference test specimen whose impact response has been determined and can be compared with the output of the test system.

7. Preparation of Test Surface

7.1 The test surface shall be dry. Remove dirt and debris from the surface where the P-wave speed is to determined.

7.2 If the test surface is extremely rough so that it is difficult to achieve good contact between the transducer tips and the concrete, grind the surface so that good contact is achieved. Remove loose material prior to coupling the transducers to the surface.

NOTE 7—Surface roughness may be a problem when testing highway pavements with roughly textured or grooved surfaces. On new construction, curing compounds may have to be removed at test locations to permit proper coupling of the transducers and to obtain short duration impacts.

8. Procedure

8.1 Fig. 2 shows a schematic of the test set-up for Procedure A.

8.2 Assemble the apparatus (transducers, spacer device, impactor). Verify that the test system is functioning properly. Position the apparatus on the concrete surface, and position the impactor to strike on the line passing through the two transducers and at a distance of 150 ± 10 mm from the first (triggering) transducer. If testing on a grooved surface, test parallel to the grooves, so that the line through the transducers and the impactor does not cross a groove. If cracks are present, position the apparatus so that no cracks intersect the line passing through the impact point and the two transducers.

8.3 Ready the data-acquisition system with correct data acquisition parameters (sampling frequency, voltage range, triggering level, delay, and so forth).

NOTE 8—For some systems, it is advisable to set the data acquisition parameters so that about 100 points are recorded before the trigger point. This pre-trigger information permits an assessment of the baseline value in the waveform before P-wave arrival. Due to electrical noise, the signal may fluctuate before P-wave arrival, and knowing the amplitude of those fluctuations assists in identifying P-wave arrival.

8.4 Perform the impact. Examine the acquired waveforms. If the waveforms from both transducers are valid, store the data for subsequent analysis. If the P-wave arrivals cannot be identified with certainty, repeat the test at the same position or move to a different position to achieve good coupling between the transducers and concrete.

NOTE 9—Fig. 3 is an example to illustrate a valid set of waveforms with the arrows positioned at the points corresponding to the P-wave arrivals in each waveform. In this case the arrivals of the P-wave at the transducer locations are clearly identified by the rise of the waveforms above background levels. The calculated P-wave speed is 0.3/(0.000076) = 3950 m/s, which is a reasonable value.

9. Data Analysis and Calculations

9.1 Display on the screen of the data acquisition system the waveforms from the two transducers so that they are plotted against the same time axis.

9.2 Identify the arrival time of the direct P-wave in each waveform. The arrival of the P-wave is identified as the first point where the voltage changes from the base line value (see Fig. 3). Use the cursors to display the voltage and time readings at the points corresponding to the P-wave arrivals. Determine the time difference, Δt, between the arrival of the P-wave in

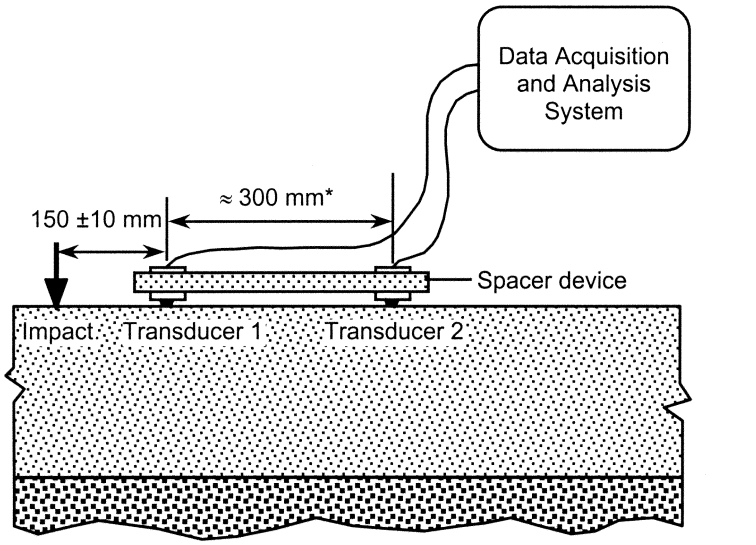

FIG. 2 Schematic of Testing Configuration for Procedure A

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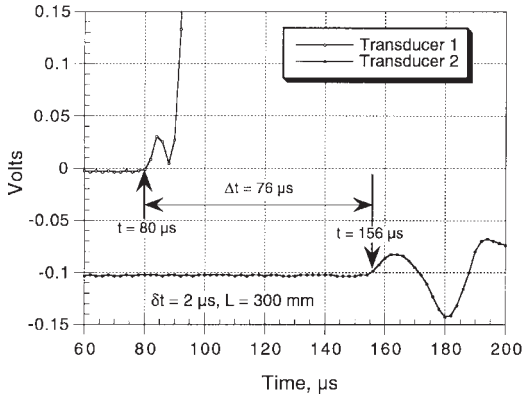

FIG. 3 Example of waveforms obtained using Procedure A (Only Early Part of Waveforms are Plotted)

each waveform. This time difference is the travel time. Automated detection of the P-wave arrivals in the waveforms is permitted provided the waveforms are stable (do not contain noise) before the P-wave arrivals.

9.3 Use the measured travel time, Δt, and measured spacing between the transducers, L, to calculate the P-wave speed:

$$C_p = \frac{L}{\Delta t} \tag{3}$$

9.4 Perform two replicates of the test at each test location. If the measured travel time is the same in both cases, then proceed to other test points. If the two travel times differ by one sampling interval or more, perform a third test and accept that travel time that repeats as the correct value. If two of the three measurements do not agree, ensure that the transducers are making good contact with the surface, and repeat the test.

9.5 Calculate the apparent P-wave speed in a plate using Eq 1.

9.6 *Alternative Procedure*—Under circumstances where maximum accuracy in measured thickened is not critical, the apparent P-wave speed in the concrete is permitted to be determined by direct calibration with measured thickness at points in the structure. Determine the thickness of the structure, determine the thickness frequency at the same point in accordance with Procedure B, and use Eq 2 to solve for the apparent wave speed. The purchaser of testing services and the testing agency shall agree on whether this alternative is permitted. They shall agree further on the number and location of calibration points and the method of determining concrete thickness. When this alternative procedure is used, the interpretation procedure in Section 15 is not applicable.

PROCEDURE B—IMPACT-ECHO TEST

10. Summary of Test Method

10.1 Impact on the surface of the concrete generates stress waves, of which the P-wave is of primary importance. The P-wave propagates into the plate and is reflected from the opposite surface.

10.2 Multiple reflections of the P-wave between the plate surfaces give rise to a transient thickness resonance with a frequency related to the plate thickness.

10.3 A receiving transducer, located adjacent to the impact point, records the surface displacement caused by the arrival of the reflected waves. The output of the transducer is captured as a time domain waveform.

10.4 The recorded waveform is transformed into the frequency domain using a Fourier transform technique and an amplitude spectrum is obtained. The thickness resonance produces one dominant peak in the spectrum, which can be readily identified. The frequency value of this peak is used in conjunction with the apparent P-wave speed obtained from Procedure A to calculate the thickness of the plate by using Eq 2.

11. Apparatus

11.1 *Impactor*—The impactor shall be spherical or spherically tipped. It shall deliver sufficient energy to a solid plate so that a well defined amplitude spectrum is obtained with a single predominant peak. The impact duration, t_c, must be less (see 3.1.5) than the round-trip travel time for a P-wave, that is:

$$t_c < \frac{2T}{C_p} \tag{4}$$

NOTE 10—Hardened steel balls with diameters ranging from 8 to 16 mm in diameter and attached to steel spring rods and spherically tipped mechanical impactors have been used as suitable impactors for typical highway pavements.

11.2 *Transducer*—A broadband transducer that responds to displacements normal to the surface. This transducer is the same as that described under Procedure A.

11.3 *Data-Acquisition System*—For acquiring, recording and processing the output of the transducer. This system can be the same as that described under Procedure A.

11.3.1 The typical sampling frequency is between 500 kHz (2 μs interval) and 250 kHz (4 μs interval).

11.3.2 The typical number of data points in the recorded waveform is 1024 or 2048.

11.3.3 The typical duration of the recorded waveform (the sampling period) is 4096 μs or 8192 μs.

NOTE 11—The sampling period is the product of the number of recorded points and the sampling interval. The inverse of the sampling period establishes the frequency interval in the amplitude spectrum obtained by the fast Fourier transform method. A sampling period of 4096 μs corresponds to a frequency interval of 244 Hz and a sampling period of 8192 μs corresponds to 122 Hz. A smaller frequency interval results in a more accurate thickness measurement. However, the sampling period should be chosen considering the lateral dimensions of the plate relative to the thickness of the plate. If the smaller lateral dimension is at least 20 times the thickness, a sampling period of 8192 μs may be used. If the smaller lateral dimension is at least 10 times the thickness, a sampling period of 4096 μs may be used. For smaller lateral dimensions, a shorter sampling period will have to be used, resulting in a greater uncertainty in the measured thickness. These limitations are necessary to assure that the waveform does not include motion associated with other modes of vibration that would interfere with the ability to identify the thickness frequency of the plate in the amplitude spectrum.

11.3.4 The voltage range for data acquisition shall be such that the amplitude of the waveform is sufficient to permit visual examination of its key features, such as the surface wave signal and the subsequent oscillations.

NOTE 12—A voltage range that is too high may result in a displayed

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waveform with small amplitude making it difficult to examine. A voltage range that is too low may result in clipping of the transducer signal. A digitizer with at least 12-bit resolution is recommended.

11.3.5 Software shall be provided for acquiring, recording, displaying, and analyzing data. The software shall compute the amplitude spectrum from the recorded waveform. The amplitude spectrum shall be displayed immediately after the waveform has been captured. A cursor for manually determining the thickness frequency shall be included. It is permitted to use software to determine the thickness frequency.

11.3.6 The data-acquisition system shall be operated by a power source that does not produce electrical noise that is detected by the transducer and data acquisition system when the system is set at the voltage range used for testing (see Note 5).

11.4 *Cables and Connectors*, as described under Procedure A.

11.5 *Functionality Check Apparatus*, as described under Procedure A.

12. Preparation of Test Surface

12.1 Remove dirt and debris from the surface where the thickness is to determined.

12.2 If the test surface is extremely rough so that it is difficult to achieve good contact between the transducer tip and the concrete, grind the surface so that good contact is achieved (see Note 7).

13. Procedure

13.1 Fig. 4 is a schematic of an impact-echo test on a plate.

13.2 Position the transducer on the concrete surface where thickness is to be measured. Position the impactor to strike at a distance less than 0.4 of the nominal plate thickness away from the transducer.

13.3 Ready the data-acquisition system with correct data acquisition parameters (sampling frequency, voltage range, triggering level, delay, and so forth). Data acquisition shall be triggered by the transducer signal or by an instrumented impact device. If necessary, establish data acquisition parameters by trial tests.

NOTE 13—For some systems, it is advisable to set the data acquisition parameters so that about 100 points are recorded before the trigger point. The initial portion of the waveform provides information on the contact time of the impact and can help identify invalid waveforms due to improper coupling, electrical noise, or other factors.

13.4 Perform the impact. Examine the acquired waveform and corresponding amplitude spectrum. In making a judgment about the validity of the waveform, examine whether the portion of the waveform corresponding to the surface wave is of the correct shape and that the surface wave is followed by periodic oscillations corresponding to multiple reflections between the plate boundaries. The amplitude spectrum of a valid waveform will have a single dominant peak at a frequency corresponding to the plate thickness.

NOTE 14—Fig. 5 shows an example of a valid time domain waveform and its corresponding amplitude spectrum for a test of a concrete slab on grade. The sampling interval is 4 μs and the number of points in the complete waveform (not shown) is 2048.

13.5 If a valid waveform and amplitude spectrum have been obtained, store the waveform and amplitude spectrum. Repeat the test to verify the results. If the results are repeatable and valid, move to the next test point. If the waveform and amplitude spectrum are not valid (see Note 15), check that the test surface is free of dust and debris and that the transducer is coupled properly to the test surface. Also check that the impact point is flat and free of debris, and that the correct size of impactor is being used. Repeat the test until a valid waveform and amplitude spectrum are obtained.

NOTE 15—Fig. 6 shows an example of invalid impact-echo test results. The waveform lacks periodic oscillations and the amplitude spectrum does not contain a single dominant peak.

14. Data Analysis

14.1 Determine the frequency of the high-amplitude peak in the amplitude spectrum.

14.2 Calculate the thickness of the plate using Eq 2.

15. Interpretation of Results (Systematic Errors)

15.1 There are systematic errors in determining the wave speed and the thickness of concrete plates because of the digital

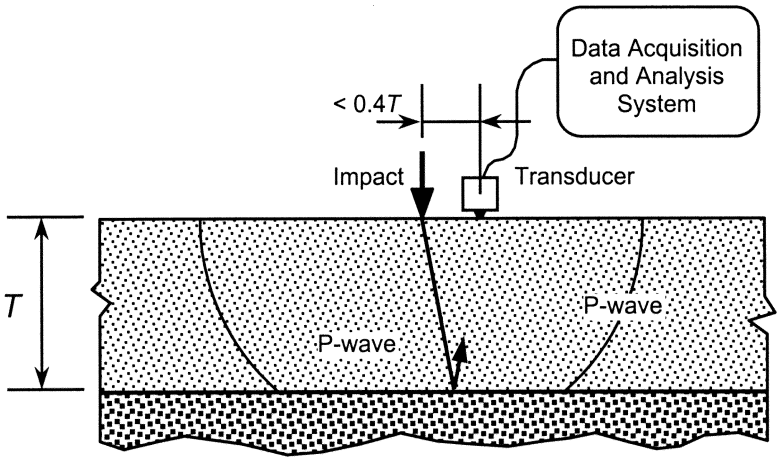

FIG. 4 Schematic of Testing Configuration for Impact-Echo Test (Procedure B)

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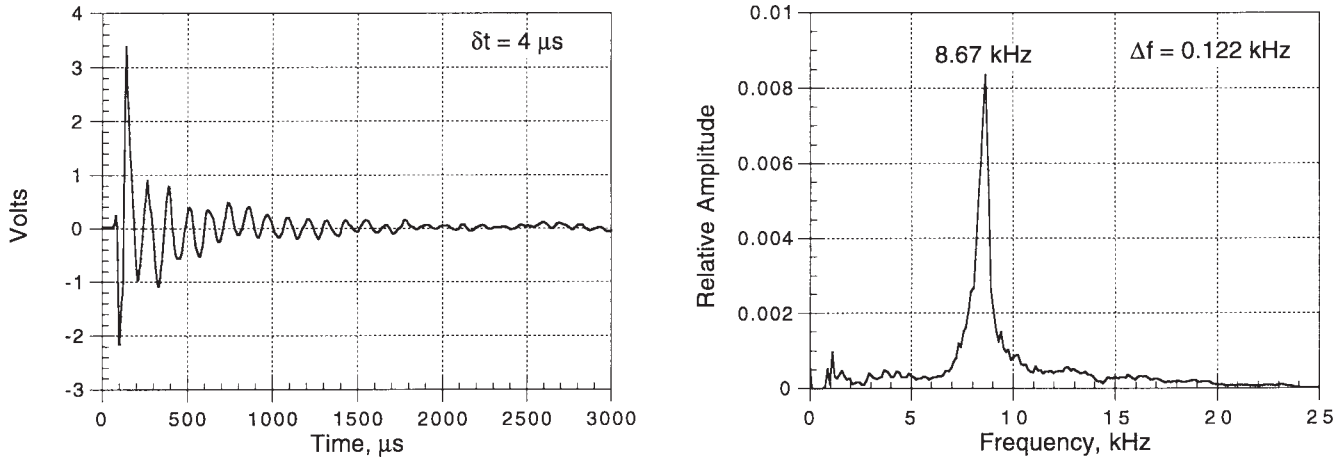

FIG. 5 Waveform and Amplitude Spectrum for a Valid Impact-Echo Test of 250-mm Thick Concrete Slab

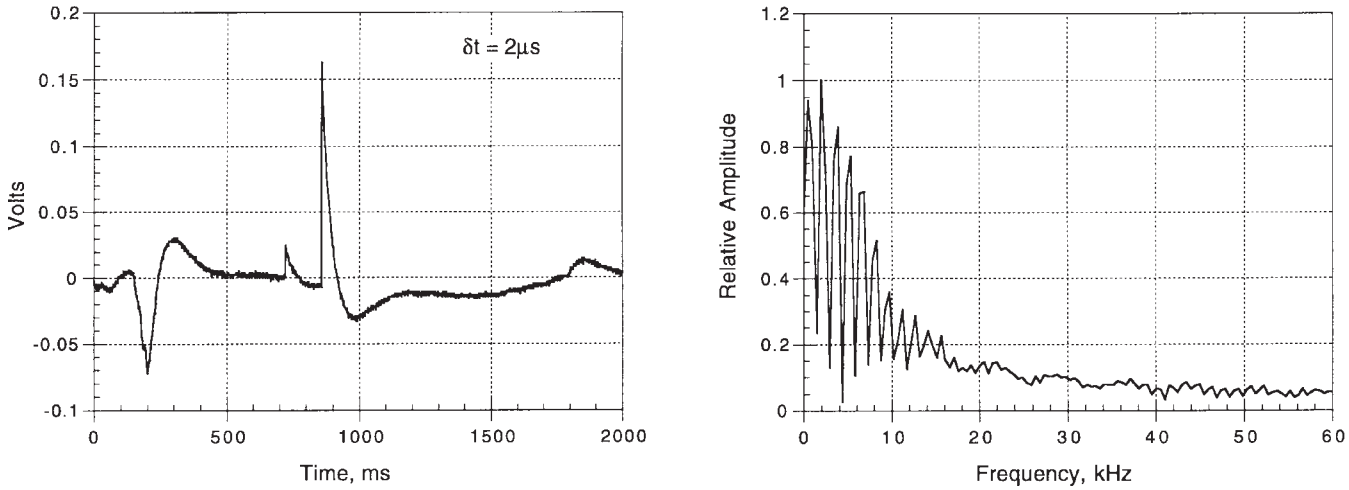

FIG. 6 Example of an Invalid Impact-Echo Test, the Waveform Does Not Display Periodic Oscillations and the Amplitude Spectrum does not have a Single Dominant Peak

nature of the waveforms and amplitude spectra. Thus there is an inherent systematic error in the computed P-wave speeds and plate thicknesses. The appendix provides derivations of the expressions for maximum systematic errors.

15.2 *Systematic Error in Procedure A*—The maximum systematic error in the calculated P-wave speed is given by:

$$e_p = \pm \frac{\delta t}{\Delta t} \tag{5}$$

where:

δt = sampling interval, and
Δt = measured P-wave travel time.

15.2.1 Eq 5 is based on the assumption that there is no electrical noise in the waveforms, so that the P-wave arrival can be identified easily. Fig. 7 shows the maximum systematic error due to the sampling interval as a function of the travel time. Report the P-wave speed calculated according to Eq 3 as follows:

$$C_p \pm e_p C_p \tag{6}$$

15.3 *Systematic Error in Procedure B*—The maximum systematic error in the calculated thickness due to frequency resolution is given by the following equation:

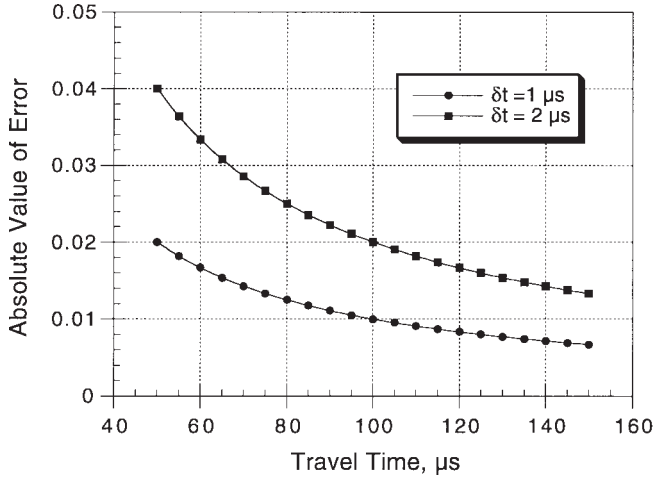

FIG. 7 Maximum Systematic Error Due to Sampling Interval as a Function of the Travel Time

$$e_f = \pm \frac{\Delta f}{2f} \tag{7}$$

where:

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Δf = the frequency interval in the amplitude spectrum, and
f = the frequency corresponding to the high amplitude peak in the amplitude spectrum.

15.3.1 Fig. 8 shows the maximum systematic error in the calculated thickness due to the frequency resolution as a function of the measured frequency. A higher frequency corresponds to a lower thickness, and there is less systematic error in the computed thickness as the thickness decreases.

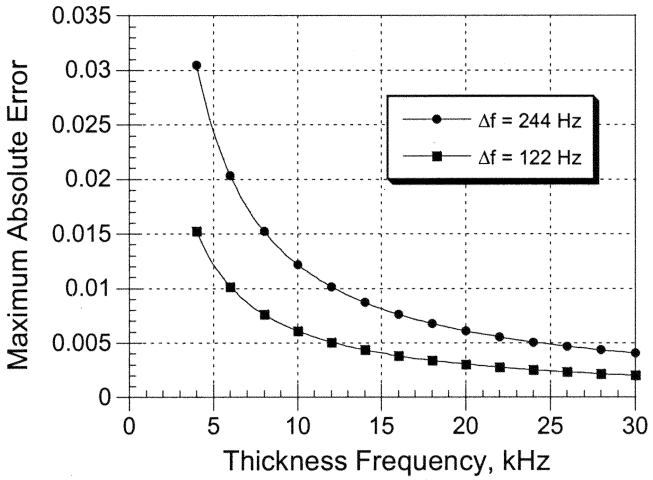

FIG. 8 Maximum Systematic Error Due to Frequency Interval as a Function of Thickness Frequency

15.4 *Combined Systematic Error*—An estimate of the maximum expected systematic error in the calculated thickness that accounts for both sources of error is given by the following equation:[7]

$$e = \sqrt{e_p^2 + e_f^2} \tag{8}$$

15.5 *Reporting Thickness*—Report plate thickness, which is calculated according to Eq 2, as follows:

$$T \pm eT \tag{9}$$

16. Report

16.1 Report the data acquisition parameters that were used. These include the sampling interval, the voltage range, the voltage resolution, the number of points in the waveform, and the frequency interval in the amplitude spectrum.

16.2 The location of each test point on the structure, a description of the condition of the test surface, and whether grinding was required.

16.3 For concrete slabs on grade, report the type of material supporting the slab, if known.

16.4 The P-wave speed in accordance with 15.2.1.

16.5 The plate thickness in accordance with 15.5.

16.6 If the alternative procedure in 9.6 was used to establish the apparent P-wave speed, provide the calibration data and report how the data were used to estimate concrete thickness.

17. Precision and Bias

17.1 The precision and bias of this test method are unknown at this time. Data comparing core lengths with pavement thicknesses obtained by an earlier version of this test method are given in the reference cited in footnote 3. That reference indicates that the differences in pavement thickness by measurement of cores and by this test method were within ±3 % for pavement thickness varying from 200 to 290 mm.

18. Keywords

18.1 concrete plate; impact-echo; nondestructive testing; P-wave speed; thickness measurement

[7] Ku, H.H., "Notes on the Use of Propagation of Error Formulas," *Journal of Research of the National Bureau of Standards—C. Engineering and Instrumentation*, Vol 70C, No.4, October-December 1966.

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APPENDIX

(Nonmandatory Information)

X1. SYSTEMATIC ERRORS

X1.1 General

X1.1.1 This test method is based on using digital sampling and digital signal analysis methods. As a result, the time-domain waveforms and amplitude spectra are composed of discrete points with fixed spacings that depend upon the data acquisition parameters. This results in systematic errors between the measured travel times or thickness frequencies and their true values. The following sections explain how to determine the maximum values of these systematic errors. Because of these systematic errors, the P-wave speeds and plate thicknesses obtained from this test method are reported as ranges of values.

X1.2 Systematic Error in P-Wave Speed

X1.2.1 Fig. X1.1 shows a schematic of the early part of the waveforms (voltage versus time) obtained from the two transducers in Procedure A. The solid circles represent the points recorded by the data acquisition system. The solid lines represent the true surface displacements as a function of time. The travel time is measured as the time difference Δt between the two points at which the voltages rises above the background values. The measured travel time differs from the true travel time $\Delta t'$. From Fig. X1.1, it can be shown that:

$$\Delta t = \Delta t' - \epsilon_1 + \epsilon_2 \tag{X1.1}$$

$$\Delta t' - \Delta t = \epsilon_1 - \epsilon_2 \tag{X1.2}$$

The relative error in the calculated P-wave speed due to the differences between the measured and true travel time can be expressed as follows:

$$e_p = \frac{C_p - C'_p}{C'_p} = \frac{\frac{L}{\Delta t} - \frac{L}{\Delta t'}}{\frac{L}{\Delta t'}} = \frac{\Delta t'}{\Delta t} - 1 = \frac{\Delta t' - \Delta t}{\Delta t} = \frac{\epsilon_1 - \epsilon_2}{\Delta t} \tag{X1.3}$$

The maximum absolute value of the error e_p occurs when either $\epsilon_1 = 0$ and $\epsilon_2 = \delta t$; or when $\epsilon_1 = \delta t$ and $\epsilon_2 = 0$. When $\epsilon_1 = 0$ and $\epsilon_2 = \delta t$:

$$e_p = \frac{-\delta t}{\Delta t} \tag{X1.4}$$

When $\epsilon_1 = \delta t$ and $\epsilon_2 = 0$:

$$e_p = \frac{+\delta t}{\Delta t} \tag{X1.5}$$

Therefore, the maximum systematic error in the P-wave speed due to sampling in the time domain is:

$$e_p = \pm \frac{\delta t}{\Delta t} \tag{X1.6}$$

X1.2.2 The above derivation assumes that the two waveforms are obtained by simultaneous sampling of the two channels. Fig. X1.2 is a schematic of the waveforms obtained by a data acquisition system that alternately samples the two channels. It can be shown that the maximum systematic error

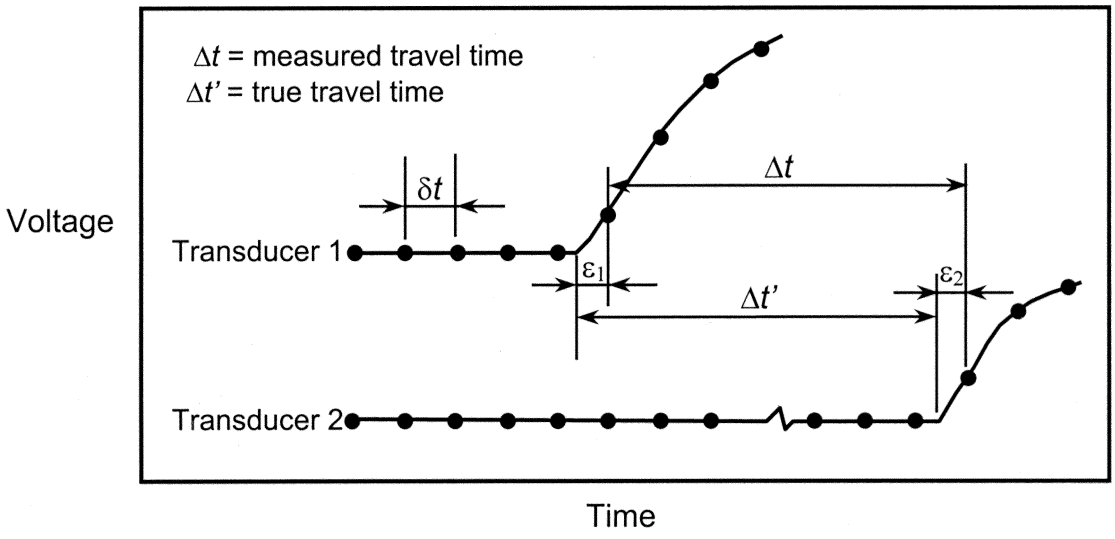

FIG. X1.1 Schematic of Early Part of Waveforms Obtained from Procedure A

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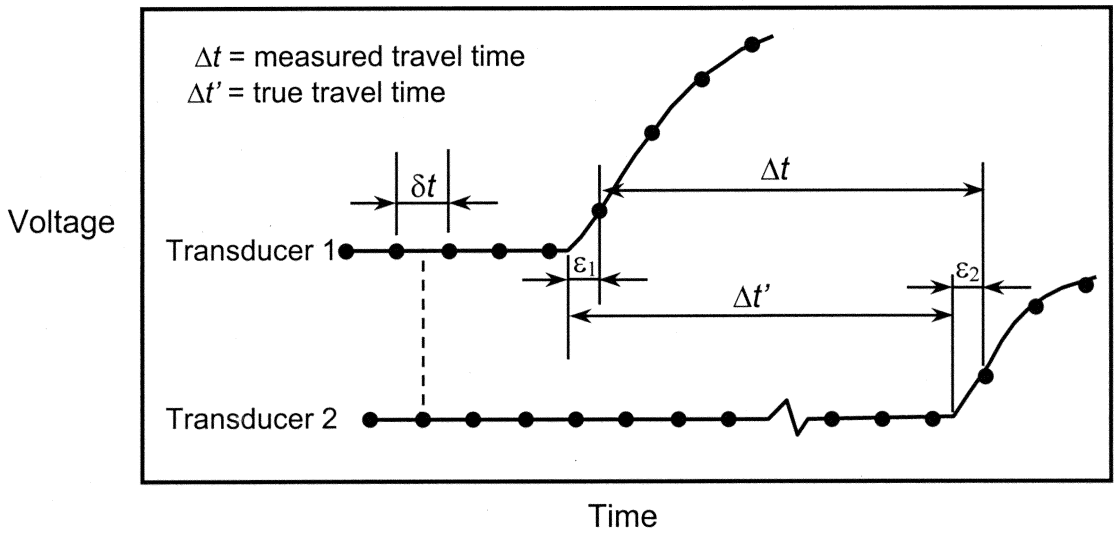

FIG. X1.2 Schematic of Early Part of Waveforms Obtained from Procedure A With a Data Acquisition System That Samples Each Channel Alternately

is the same as given by Eq X1.6 provided the sample interval δt is the time interval between adjacent points in each of the waveforms.

X1.3 Systematic Error in Thickness Due to Frequency Interval in the Amplitude Spectrum

X1.3.1 Fig. X1.3 is a schematic of the amplitude spectrum obtained from an impact-echo test of a solid plate. The high amplitude peak corresponds to the thickness frequency of the plate. The solid circles are the digital values displayed on the computer display, and the solid curve represents the true amplitude spectrum. The measured frequency f differs from the true frequency f'. This difference leads to a systematic error in plate thickness computed using the measured frequency.

X1.3.2 The relative error in the calculated plate thickness is related to the measured frequency and the true frequency as follows:

$$e_f = \frac{T - T'}{T'} = \frac{\frac{0.96\,C_p}{2f} - \frac{0.96\,C_p}{2f'}}{\frac{0.96\,C_p}{2f'}} = \frac{f'}{f} - 1 = \frac{f' - f}{f} \qquad \text{(X1.7)}$$

where:

T = calculated thickness based on measured thickness frequency, f, and

T' = calculated thickness based on true thickness frequency, f'.

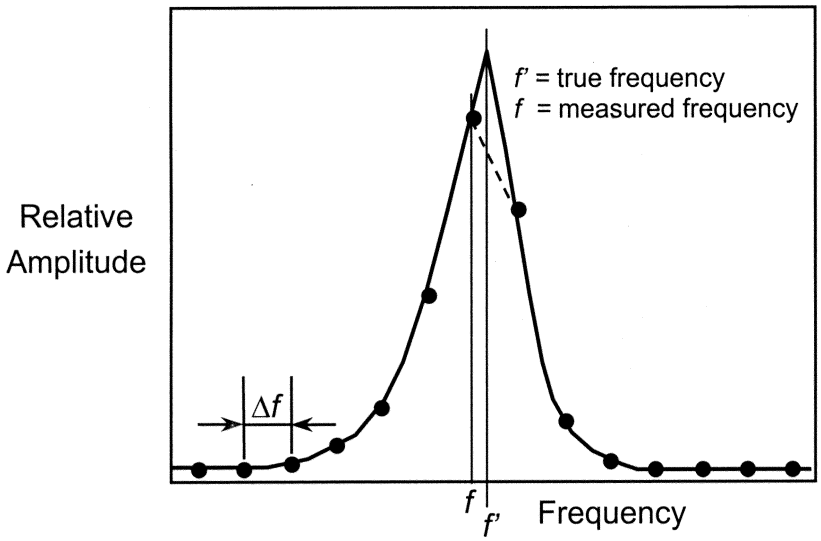

FIG. X1.3 Schematic of Amplitude Spectrum Resulting from an Impact-Echo (Procedure B) Test on a Solid Plate

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The absolute value of the maximum difference between f and f' is $\Delta f/2$. Therefore, the maximum systematic error in the calculated thickness due to the frequency interval in the amplitude spectrum is:

$$e_f = \pm \frac{\Delta f}{2f} \quad \text{(X1.8)}$$

X1.3.3 Eq X1.8 shows that systematic error in the calculated frequency is reduced by reducing the frequency interval Δf. As explained in Note 11 of this test method, the frequency interval is controlled by the duration of the waveform, that is, the record length. Thus, when doing the impact-echo test to measure plate thickness, use the longest record length that is practicable. However, the record length must not be too long, otherwise motions due to other plate modes, set up by reflections of the lateral boundaries, may contribute to the waveform. This is the intent of the guidelines in Note 11.

X1.4 Systematic Error in Calculated Thickness

X1.4.1 The thickness calculated from the P-wave speed and peak frequency includes two sources of systematic errors. The approach taken in this test method is to obtain the combined systematic error, e, as follows:

$$e = \sqrt{e_p^2 + e_f^2} \quad \text{(X1.9)}$$

X1.4.2 The relative error in the plate thickness due to the two sources of systematic error is as follows:

$$\frac{T - T'}{T'} = \pm e \quad \text{(X1.10)}$$

that can be rearranged as follows:

$$T' = \frac{T}{1 \pm e} \quad \text{(X1.11)}$$

For small values of $|e|$:

$$\frac{1}{1 \pm e} \approx 1 \pm e \quad \text{(X1.12)}$$

Therefore to account for the systematic error that is inherent in this test method, report the thickness calculated according to Eq 2 as follows:

$$T \pm T\,e \quad \text{(X1.13)}$$

SUMMARY OF CHANGES

Committee C09 has identified the location of selected changes to this standard since the last issue, C 1383 – 98a, that may impact its use. (Approved June 2004)

(1) Added the term “sampling frequency” under 3.1.
(2) Moved the last sentence in 6.6 to new Note 6.
(3) Added new Note 8 to explain the usefulness of pre-trigger data and removed mandatory requirement for pre-trigger data.
(4) Added a sentence to 9.2 to permit automated detection of P-wave arrivals when waveforms are not contaminated with noise.
(5) Added a new 9.6 to permit an alternative procedure for determining apparent P-wave speed when there is agreement between the seller and the purchaser of testing services.
(6) Added new Note 13 to explain the usefulness of pre-trigger data and removed mandatory requirement for pre-trigger data.
(7) Added 16.6 on reporting results when the alternative procedure is used.
(8) Provided information on reported differences between core lengths and slab thicknesses determined by this method.

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Designation: C 1385/C 1385M – 98 (Reapproved 2004)$^{\epsilon 1}$

Standard Practice for Sampling Materials for Shotcrete[1]

This standard is issued under the fixed designation C 1385/C 1385M; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

ϵ^1 NOTE—The title was changed to a dual designation editorially to reflect the existing measurements in the standard in September 2004.

1. Scope

1.1 This practice covers procedures for obtaining representative samples of materials to be shotcreted. The practice covers sampling from stationary and truck mixers, volumetric and continuous mixing equipment, and bag and bulk delivery.

1.2 The values stated in either inch-pound or SI units are to be regarded separately as standard. Within the text, the SI units are shown in brackets. The values stated in each system are not exact equivalents; therefore, each system shall be used independently of the other. Combining values from the two systems may result in nonconformance with this practice.

2. Significance and Use

2.1 This practice is used to obtain representative samples of materials delivered to the shotcrete machine. These samples are used to perform tests to determine compliance with the specifications under which the material is furnished.

3. Procedure

3.1 Composite samples are required by this practice, unless specifically made exempt by procedures governing the tests to be performed, such as tests to determine uniformity of consistency and mixer efficiency. Procedures used to select the specific test batches are not described in this practice, but it is recommended that random sampling be used to determine overall specification compliance.

3.2 The size of an individual sample shall be a minimum of 25 lb [12 kg], the size of the composite sample shall be a minimum of 75 lb [35 kg]. The composite sample shall be large enough to perform the required tests.

3.3 Sampling shall be performed as the shotcrete material is delivered to the shotcrete machine. The procedures used in sampling shall include the use of every precaution that will assist in obtaining samples that are truly representative of the nature and condition of the material sampled as follows:

3.3.1 *Sampling Dry Process Shotcrete Materials*—Sample the material by collecting two or more portions taken at regularly spaced intervals during discharge of the middle of the batch or two or more random portions from the discharge of continuous mixers. Combine the portions into one sample for testing purposes. Do not obtain portions of the composite sample from the first 15 % or the last 15 % of the discharge.

3.3.2 *Sampling Wet Process Shotcrete Material*—Sample as described in 3.3.1 within the following limits.

3.3.2.1 The elapsed time between obtaining the first and last portions of the composite sample shall be as short as possible but in no instance shall exceed 15 min.

3.3.2.2 Start test for slump or air content, or both, within 5 min after obtaining last portion of the composite.

3.3.3 *Alternative Procedure for Truck and Stationary Mixers*—The mixer shall be stopped and material portions removed by any suitable means at approximately equal distances from the front and back of the drum. Composite the portions into one sample for testing. Do not obtain portions from the very front and back of the drum. Sample wet process shotcrete material within the time limits described in 3.3.2.1 and 3.3.2.2.

3.3.4 *Sampling Bagged Prepackaged Material*—Randomly select a single package, or more if required to perform the specified tests, from a lot. A lot is the quantity normally placed on a pallet. In general, this quantity will weigh from 2000 to 4000 lbs [900 to 1300 kg].

3.3.5 *Sampling Bulk Prepackaged Material*—Sample the material at the point of delivery to the shotcrete machine by collecting three or more portions at regular intervals during discharge of the container or transportation unit. Obtain portions from the first, middle, and last third of the unit. Do not sample the first 15 % or last 15 % of the discharge. Combine portions for testing.

4. Keywords

4.1 dry process; sampling; shotcrete; wet process

[1] This practice is under the jurisdiction of ASTM Committee C09 on Concrete and Concrete Aggregates and is the direct responsibility of Subcommittee C09.46 on Shotcrete.

Current edition approved June 1, 2004. Published June 2004. Originally approved in 1998. Last previous edition approved in 1998 as C 1385 – 98.

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Designation: C1396/C1396M – 09a

Standard Specification for Gypsum Board[1]

This standard is issued under the fixed designation C1396/C1396M; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope*

1.1 This specification covers the gypsum boards described in 1.1.1-1.1.9.

NOTE 1—Specifications C840, C841, C844 and C1280 contain application procedures for gypsum board.

1.1.1 *Gypsum wallboard*, designed for use on walls, ceilings, or partitions and that affords a surface suitable to receive decoration.

1.1.2 *Predecorated gypsum board*, designed for use as the finished surfacing for walls, ceilings, or partitions.

1.1.3 *Gypsum backing board, coreboard, and shaftliner board*, designed for use as a base in multilayer systems or as a gypsum stud or core in semisolid or solid gypsum board partitions, or in shaft wall assemblies.

NOTE 2—The terms backing board, coreboard, and shaftliner board refer to different end uses. The term gypsum backing board, as used in this specification, shall include gypsum coreboard and gypsum shaftliner board unless otherwise stated.

1.1.4 *Water-resistant gypsum backing board*, designed primarily to be used as a base for the application of ceramic or plastic tile on walls or ceilings. This product is also suitable for decoration.

1.1.5 *Exterior gypsum soffit board*, designed for use on exterior soffits and carport ceilings that are completely protected from contact with liquid water.

1.1.6 *Gypsum sheathing board*, designed for use as sheathing on buildings.

1.1.7 *Gypsum base for veneer plaster*, designed for use as a base for the application of gypsum veneer plaster.

1.1.8 *Gypsum lath*, designed for use as a base for the application of gypsum plaster.

1.1.9 *Gypsum ceiling board*, designed for use on interior ceilings with framing spaced not more than 24 in. [610 mm] on center and that affords a surface suitable to receive water-based texture and other decoration. This product is also suitable for use on interior walls.

1.2 Specifications applicable to all gypsum boards are located in Section 1-4 and 13-15. Specifications applicable to specific gypsum boards are located in the following sections:

	Section
Gypsum wallboard, predecorated gypsum board	5
Gypsum backing board, gypsum coreboard, gypsum shaftliner board	6
Water-resistant gypsum backing board	7
Exterior gypsum soffit board	8
Gypsum sheathing board	9
Gypsum base for veneer plaster	10
Gypsum lath	11
Gypsum Ceiling Board	12

1.3 The values stated in either SI units or inch-pound units are to be regarded separately as standard. Within the text, the SI units are shown in brackets. The values stated in each system may not be exact equivalents; therefore, each system shall be used independently of the other. Combining values from the two systems may result in non-conformance with the standard

2. Referenced Documents

2.1 *ASTM Standards:*[2]

C11 Terminology Relating to Gypsum and Related Building Materials and Systems

C22/C22M Specification for Gypsum

C473 Test Methods for Physical Testing of Gypsum Panel Products

C645 Specification for Nonstructural Steel Framing Members

C840 Specification for Application and Finishing of Gypsum Board

C841 Specification for Installation of Interior Lathing and Furring

C844 Specification for Application of Gypsum Base to Receive Gypsum Veneer Plaster

C1264 Specification for Sampling, Inspection, Rejection, Certification, Packaging, Marking, Shipping, Handling, and Storage of Gypsum Panel Products

C1280 Specification for Application of Gypsum Sheathing

[1] This specification is under the jurisdiction of ASTM Committee C11 on Gypsum and Related Building Materials and Systems and is the direct responsibility of Subcommittee C11.01 on Specifications and Test Methods for Gypsum Products.

Current edition approved Nov. 15, 2009. Published December 2009. Originally approved in 1998. Last previous edition approved in 2009 as C1396/C1396M – 09. DOI: 10.1520/C1396_C1396M-09a.

[2] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

***A Summary of Changes section appears at the end of this standard.**

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E84 Test Method for Surface Burning Characteristics of Building Materials
E96/E96M Test Methods for Water Vapor Transmission of Materials
E119 Test Methods for Fire Tests of Building Construction and Materials

3. Terminology

3.1 Definitions used in this specification shall be in accordance with Terminology C11.

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *decorative coating*, *n*—a paint or other liquid material with or without aggregate.

3.2.2 *decorative sheet or film*, *n*—a plastic film, either backed or unbacked; plastic sheet; or combination of these.

3.2.3 *edge*, *n*—the bound edge as manufactured.

3.2.4 *gypsum backing board*, *n*—a ¼ to ⅝-in. [6.4 to 15.9-mm] gypsum board used as a backing for gypsum wallboard, acoustical tile, or other dry cladding.

3.2.5 *gypsum coreboard*, *n*—a ¾ to 1-in. [19.0 to 25.4-mm] gypsum board used as a gypsum stud or core in semisolid or solid gypsum board partitions.

3.2.6 *nominal thickness*, *n*—the manufacturer-stated fractional value of thickness of the gypsum panel product expressed in decimal value to the nearest one-thousandth (1/1000) of an inch.

4. Materials and Manufacture

4.1 Gypsum board shall consist of a noncombustible core of gypsum complying with Specification C22/C22M, surfaced with paper bonded to the core.

4.1.1 Gypsum sheathing board shall consist of a noncombustible water-resistant core of gypsum complying with Specification C22/C22M, surfaced on both the face and back with water-repellant paper bonded to the core.

4.1.2 Gypsum coreboard shall be either a single board or composed of two factory-laminated gypsum boards to provide up to 1 in. [25.4 mm] total nominal thickness.

4.1.3 Water-resistant gypsum backing board shall consist of a noncombustible water-resistant core of gypsum complying with Specification C22/C22M, surfaced on both the back and face with water-repellant paper bonded to the core.

4.1.4 Predecorated gypsum board shall consist of a noncombustible core of gypsum complying with Specification C22/C22M, surfaced with paper bonded to the core with the face covered with a decorative sheet, film, or coating.

4.1.4.1 Class I predecorated gypsum board shall have a decorative sheet or film laminated to the face.

4.1.4.2 Class II predecorated gypsum board shall have a decorative coating applied to the face.

4.2 The back surface of foil-backed gypsum board shall in addition be covered with aluminum foil.

4.3 *Gypsum Board, type X* (Special Fire-Resistant):

4.3.1 *Gypsum Board*, type X, designates gypsum board, except gypsum lath, gypsum coreboard, and gypsum shaftliner board, complying with this specification that provides not less than 1 h fire-resistance rating for boards ⅝ in. [15.9 mm] thick or ¾ h fire-resistance rating for boards ½ in. [12.7 mm] thick, applied parallel with and on each side of load bearing 2 by 4 wood studs spaced 16 in. [406 mm] on centers with 6d coated nails, 1⅞ in. [48 mm] long, 0.0915-in. [2.3-mm] diameter shank, ¼-in. [6.4-mm] diameter heads, spaced 7 in. [178 mm] on centers with gypsum board joints staggered 16 in. [406 mm] on each side of the partition and tested in accordance with Test Methods E119.

4.3.2 *Gypsum Lath*, type X designates gypsum lath complying with this specification that provides not less than a 1-h fire-resistance rating for gypsum lath ⅜ in. [9.5 mm] thick, when applied at right angles to and on each side of loadbearing 2 × 4 wood studs spaced 16 in. [406 mm] on centers with blue lath nails spaced 5 in. [127 mm] on centers over which is applied ½ in. [12.7 mm] 1:2 gypsum sand plaster and tested in accordance with the requirements of Test Method E119.

NOTE 3—Consult producers for independent test data on assembly details and fire-resistance ratings for other types of construction. See fire test reports or listings from recognized fire testing laboratories for assembly particulars, materials, and ratings.

4.3.3 Gypsum shaftliner board, type X, designates gypsum shaftliner board complying with this specification that meets the acceptance criteria for temperature rise for not less than 1-½ h for boards ¾-in. [19.0 mm] thick or 2 h for boards 1-in. [25.4 mm] thick, when applied in a double layer solid nonload bearing partition as described in 4.3.3.1 and tested in accordance with Test Methods E119 with thermocouple locations as specified in 4.3.3.2.

4.3.3.1 Two layers of gypsum shaftliner board applied vertically and friction fit into vertical 25-gage steel "H" members, 1-½-in. [38.1 mm] deep for boards ¾-in. [19.0 mm] thick or 2-in. [50.8 mm] deep for boards 1-in. [25.4 mm] thick, spaced 24-in. [610 mm] on centers and 25-gage steel track at the perimeter of the partition. "H" members shall be formed with a single web or shall be two pieces of perimeter track fastened together along the web with screws spaced 24-in. [610 mm] on centers.

4.3.3.2 Temperature rise on the unexposed surface shall be measured using not less than five thermocouples; one shall be located at the center of the assembly and one shall be located at the center of each quadrant. Thermocouples shall be located not less than 3-in. [76 mm] from an "H" member.

4.4 Gypsum wallboard, gypsum backing board, exterior gypsum soffit board, and gypsum ceiling board shall have a flame spread index of not more than 25 when tested in accordance with Test Method E84.

4.5 *Physical Properties, Dimensions, and Tolerances of Gypsum Board*:

4.5.1 Specimens shall be taken from the samples obtained in accordance with Specification C1264.

4.5.1.1 Specimens shall be tested in accordance with Test Methods C473.

4.5.2 *Core, End, and Edge Hardness*—The specimens shall have an average hardness of not less than 15 lbf [67 N] when tested by Method A and 11 lbf [49 N] when tested by Method B.

4.5.3 *Edges and Ends*—The edges and ends shall be straight.

4.5.4 *Length*—The tolerance in length shall be ±¼ in. [±6 mm].

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4.5.5 *Tapered Edge Depth*—The average thickness of the edge of recessed or tapered edge gypsum board shall be not less than 0.020 in. [0.51 mm] but not more than 0.090 in. [2.29 mm] less than the average thickness of the gypsum board.

5. Gypsum Wallboard and Predecorated Gypsum Board

5.1 *Physical Properties of Gypsum Wallboard and Predecorated Gypsum Board*:

5.1.1 *Flexural Strength*—The specimens shall be tested face up and face down. The average breaking load shall be not less than the following:

Thickness, in. [mm]	Method A Bearing Edges Perpendicular to Panel Length, lbf [N]	Method A Bearing Edges Parallel to Panel Length, lbf [N]	Method B Bearing Edges Perpendicular to Panel Length, lbf [N]	Method B Bearing Edges Parallel to Panel Length, lbf [N]
¼ [6.4]	50 [222]	20 [89]	46 [205]	16 [71]
5⁄16 [7.9]	65 [289]	25 [111]	62 [276]	21 [93]
⅜ [9.5]	80 [356]	30 [133]	77 [343]	26 [116]
½ [12.7]	110 [489]	40 [178]	107 [476]	36 [160]
⅝ [15.9]	150 [667]	50 [222]	147 [654]	46 [205]
¾ [19.0]	170 [756]	60 [267]	167 [743]	56 [249]

5.1.2 *Humidified Deflection*—The specimens shall have an average deflection of not more than the following:

Thickness, in. [mm]	Deflection, eighths of an inch [mm]
¼ [6.4]	not required
5⁄16 [7.9]	not required
⅜ [9.5]	15 [48]
½ [12.7]	10 [32]
⅝ [15.9]	5 [16]
¾ [19.0]	5 [16]

5.1.3 *Nail Pull Resistance*—The specimens shall have an average nail-pull resistance of not less than the following:

Thickness, in. [mm]	Method A, lbf [N]	Method B, lbf [N]
¼ [6.4]	40 [178]	36 [160]
5⁄16 [7.9]	50 [222]	46 [205]
⅜ [9.5]	60 [267]	56 [249]
½ [12.7]	80 [356]	77 [343]
⅝ [15.9]	90 [400]	87 [387]
¾ [19.0]	100 [445]	97 [432]

5.1.4 *Foil-Backed Gypsum Wallboard and Foil-Backed Predecorated Gypsum Board*:

5.1.4.1 Foil-backed gypsum wallboard and foil-backed predecorated gypsum board shall meet all of the requirements for gypsum wallboard and predecorated gypsum board.

5.1.4.2 When tested in accordance with Test Methods E96/E96M, the permeance of foil-backed gypsum wallboard and foil-backed predecorated gypsum board shall be not more than 0.30 perm [17 ng/Pa·s·m^2] (Desiccant Method) for the condition of 50 % relative humidity on the face of the board, and 0 % relative humidity on the back (foil-covered) side of the board.

5.2 *Dimensions and Tolerances of Gypsum Wallboard and Predecorated Gypsum Board*:

5.2.1 *Thickness*—The thickness shall be from ¼ to ¾ in. [6.4 to 19.0 mm] with tolerances of ± 0.015 in. [± 0.40 mm], and with local variations of ± 0.030 in. [± 0.80 mm].

5.2.2 *Width*—The width shall be up to 48 in. [1220 mm], or up to 54 in. [1370 mm], with a tolerance of 3⁄32 in. [3 mm] under the specified width.

5.2.3 *End Squareness*—Corners shall be square with a tolerance of ± ⅛ in. [±3 mm] in the full width of the board.

5.3 *Edges*:

5.3.1 The edges of gypsum wallboard shall be either square, beveled, featured, tapered, or featured and tapered.

5.3.2 The edges of predecorated gypsum board shall be either square, beveled, or featured.

6. Gypsum Backing Board, Gypsum Coreboard, and Gypsum Shaftliner Board

6.1 *Physical Properties of Gypsum Backing Board, Gypsum Coreboard, and Gypsum Shaftliner Board*:

6.1.1 *Flexural Strength*—The specimens shall be tested face up and face down. The average breaking load shall be not less than the following:

Thickness, in. [mm]	Method A Bearing Edges Perpendicular to Panel Length, lbf [N]	Method A Bearing Edges Parallel to Panel Length, lbf [N]	Method B Bearing Edges Perpendicular to Panel Length, lbf [N]	Method B Bearing Edges Parallel to Panel Length, lbf [N]
¼ [6.4]	50 [222]	20 [89]	46 [205]	16 [71]
⅜ [9.5]	80 [356]	30 [133]	77 [343]	26 [116]
½ [12.7]	110 [489]	40 [178]	107 [476]	36 [160]
⅝ [15.9]	140 [622]	50 [222]	137 [609]	46 [205]
¾ [19.0]	170 [756]	60 [267]	167 [743]	56 [249]
1 [25.4]	230 [1023]	80 [356]	228 [1014]	77 [343]

6.1.2 *Humidified Deflection*—The specimens shall have an average deflection of not more than the following:

Thickness, in. [mm]	Deflection, eighths of an inch [mm]
¼ [6.4]	not required
⅜ [9.5]	15 [48]
½ [12.7]	10 [32]
⅝ [15.9]	5 [16]
¾ [19.0]	not required
1 [25.4]	not required

6.1.3 *Nail Pull Resistance*—The specimens shall have an average nail-pull resistance of not less than the following:

Thickness, in. [mm]	Method A, lbf [N]	Method B, lbf [N]
¼ [6.4]	40 [178]	36 [160]
⅜ [9.5]	60 [267]	56 [249]
½ [12.7]	80 [356]	77 [343]
⅝ [15.9]	90 [400]	87 [387]
¾ [19.0]	not required	not required
1 [25.4]	not required	not required

6.1.4 *Foil-Backed Gypsum Backing Board, Foil-Backed Gypsum Coreboard, and Foil-Backed Gypsum Shaftliner Board*:

6.1.4.1 Foil-backed gypsum backing board, foil-backed gypsum coreboard, and foil-backed gypsum shaftliner board shall meet all of the requirements for gypsum backing board, gypsum coreboard, and gypsum shaftliner board.

6.1.4.2 When tested in accordance with Test Methods E96/E96M, the permeance of foil-backed gypsum backing board and foil-backed gypsum coreboard shall be not more than 0.30 perm [17 ng/Pa·s·m^2] (Desiccant Method) for the condition of 50 % relative humidity on the face of the board, and 0 % relative humidity on the back (foil-covered) side of the board.

6.2 *Dimensions and Tolerances of Gypsum Backing Board, Gypsum Coreboard, and Gypsum Shaftliner Board*:

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6.2.1 *Thickness*—The thickness shall be from ¼ to 1 in. [6.4 to 25.4 mm] with tolerances of ± 0.030 in. [± 0.80 mm], and with local variations of ± 0.060 in. [± 1.6 mm].

6.2.2 *Width*—The width shall be from 16 to 48 in. [406 to 1220 mm] with a tolerance of ⅛ in. [3.2 mm] under the specified width.

6.2.3 *End Squareness*—Corners shall be square with a tolerance of ±⅛ in. [±3 mm] in the full width of the board.

6.3 *Edges*—The edges shall be either square, beveled, round, V-tongue and groove, or featured.

7. Water-Resistant Gypsum Backing Board

7.1 *Physical Properties of Water-Resistant Gypsum Backing Board*:

7.1.1 *Flexural Strength*—The specimens shall be tested face up and face down. The average breaking load shall be not less than the following:

Thickness, in. [mm]	Method A Bearing Edges Perpendicular to Panel Length, lbf [N]	Method A Bearing Edges Parallel to Panel Length, lbf [N]	Method B Bearing Edges Perpendicular to Panel Length, lbf [N]	Method B Bearing Edges Parallel to Panel Length, lbf [N]
½ [12.7]	110 [489]	40 [178]	107 [476]	36 [160]
⅝ [15.9]	150 [667]	50 [222]	147 [654]	46 [205]

7.1.2 *Humidified Deflection*—The specimens shall have an average deflection of not more than the following:

Thickness, in. [mm]	Deflection, eighths of an inch [mm]
½ [12.7]	10 [32]
⅝ [15.9]	5 [16]

7.1.3 *Nail Pull Resistance*—The specimens shall have an average nail-pull resistance of not less than the following:

Thickness, in. [mm]	Method A, lbf [N]	Method B, lbf [N]
½ [12.7]	80 [356]	77 [343]
⅝ [15.9]	90 [400]	87 [387]

7.1.4 *Water Resistance*—The specimens shall have an average water absorption of not more than 5 weight % after 2-h immersion.

7.2 *Dimensions and Tolerances of Water-Resistant Gypsum Backing Board*:

7.2.1 *Thickness*—The thickness shall be ½ or ⅝ in. [12.7 or 15.9 mm] with tolerances of ± 0.015 in. [± 0.40 mm], and with local variations of ± 0.030 in. [± 0.80 mm].

7.2.2 *Width*—The width shall be up to 48 in. [1220 mm], or up to 54 in. [1370 mm], with a tolerance of 3/32 in. [3 mm] under the specified width.

7.2.3 *End Squareness*—Corners shall be square with a tolerance of ±⅛ in. [±3 mm] in the full width of the board.

7.3 *Edges*—The edges shall be either square, beveled, featured, tapered, or featured and tapered.

8. Exterior Gypsum Soffit Board

8.1 *Physical Properties of Exterior Gypsum Soffit Board*:

8.1.1 *Flexural Strength*—The specimens shall be tested face up and face down. The average breaking load shall be not less than the following:

Thickness, in. [mm]	Method A Bearing Edges Perpendicular to Panel Length, lbf [N]	Method A Bearing Edges Parallel to Panel Length, lbf [N]	Method B Bearing Edges Perpendicular to Panel Length, lbf [N]	Method B Bearing Edges Parallel to Panel Length, lbf [N]
½ [12.7]	110 [489]	40 [178]	107 [476]	36 [160]
⅝ [15.9]	150 [667]	50 [222]	147 [654]	46 [205]

8.1.2 *Humidified Deflection*—The specimens shall have an average deflection of not more than the following:

Thickness, in. [mm]	Deflection, eighths of an inch [mm]
½ [12.7]	7 [22]
⅝ [15.9]	4 [13]

8.1.3 *Nail Pull Resistance*—The specimens shall have an average nail-pull resistance of not less than the following:

Thickness, in. [mm]	Method A, lbf [N]	Method B, lbf [N]
½ [12.7]	80 [356]	77 [343]
⅝ [15.9]	90 [400]	87 [387]

8.2 *Dimensions and Tolerances of Exterior Gypsum Soffit Board*:

8.2.1 *Thickness*—The thickness shall be ½ or ⅝ in. [12.7 or 15.9 mm] with tolerances of ± 0.015 in. [± 0.40 mm], and with local variations of ± 0.030 in. [± 0.80 mm].

8.2.2 *Width*—The width shall be up to 48 in. [1220 mm] with a tolerance of 3/32 in. [3 mm] under the specified width.

8.2.3 *End Squareness*—Corners shall be square with a tolerance of ±⅛ in. [±3 mm] in the full width of the board.

8.3 *Edges*—The edges shall be either square, beveled, featured, tapered, or featured and tapered.

9. Gypsum Sheathing Board

9.1 *Physical Properties of Gypsum Sheathing Board:*

9.1.1 *Flexural Strength*—The specimens shall be tested face up and face down. The average breaking load shall be not less than the following:

Thickness, in. [mm]	Method A Bearing Edges Perpendicular to Panel Length, lbf [N]	Method A Bearing Edges Parallel to Panel Length, lbf [N]	Method B Bearing Edges Perpendicular to Panel Length, lbf [N]	Method B Bearing Edges Parallel to Panel Length, lbf [N]
⅜ [9.5]	80 [356]	30 [133]	77 [343]	26 [116]
4/10 [10.2]	88 [391]	32 [142]	85 [378]	28 [125]
½ [12.7]	110 [489]	40 [178]	107 [476]	36 [160]
⅝ [15.9]	150 [667]	50 [222]	147 [654]	46 [205]

9.1.2 *Humidified Deflection*—The specimens shall have an average deflection of not more than the following:

Thickness, in. [mm]	Deflection, eighths of an inch [mm]
⅜ [9.5]	15 [48]
4/10 [10.2]	12 [38]
½ [12.7]	10 [32]
⅝ [15.9]	5 [16]

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9.1.3 *Nail-Pull Resistance*—The specimens shall have an average nail-pull resistance of not less than the following:

Thickness, in. [mm]	Method A, lbf [N]	Method B, lbf [N]
⅜ [9.5]	60 [267]	56 [249]
4/10 [10.2]	70 [312]	67 [298]
½ [12.7]	80 [356]	77 [343]
⅝ [15.9]	90 [400]	87 [387]

9.1.4 *Water Resistance of Gypsum Sheathing Board*—The specimens shall have an average water absorption of not more than 10 weight % after 2-h immersion.

9.2 *Dimensions and Tolerances of Gypsum Sheathing Board:*

9.2.1 *Thickness*—The thickness shall be from ⅜ to ⅝ in. [9.5 to 15.9 mm] with tolerances of ± 0.030 in. [± 0.80 mm], and with local variations of ± 0.060 in. [± 1.6 mm].

9.2.2 *Width*—The nominal width shall be 24 or 48 in. [610 or 1220 mm] with a tolerance of ⅛ in. [3.2 mm] under the specified width.

9.2.3 *End Squareness*—Corners shall be square with a tolerance of ±⅛ in. [±3 mm] in the full width of the board.

9.3 *Edges*—The edges shall be either square or V-tongue and groove.

10. Gypsum Base for Veneer Plaster

10.1 *Physical Properties of Gypsum Base for Veneer Plaster*:

10.1.1 *Flexural Strength*—The specimens shall be tested face up and face down. The average breaking load shall be not less than the following:

Thickness, in. [mm]	Method A Bearing Edges Perpendicular to Panel Length, lbf [N]	Method A Bearing Edges Parallel to Panel Length, lbf [N]	Method B Bearing Edges Perpendicular to Panel Length, lbf [N]	Method B Bearing Edges Parallel to Panel Length, lbf [N]
⅜ [9.5]	80 [356]	30 [133]	77 [343]	26 [116]
½ [12.7]	110 [489]	40 [178]	107 [476]	36 [160]
⅝ [15.9]	150 [667]	50 [222]	147 [654]	46 [205]

10.1.2 *Humidified Deflection*—The specimens shall have an average deflection of not more than the following:

Thickness, in. [mm]	Deflection, eighths of an inch [m]
⅜ [9.5]	15 [48]
½ [12.7]	10 [32]
⅝ [15.9]	5 [16]

10.1.3 *Nail Pull Resistance*—The specimens shall have an average nail-pull resistance of not less than the following:

Thickness, in. [mm]	Method A, lbf [N]	Method B, lbf [N]
⅜ [9.5]	60 [267]	56 [249]
½ [12.7]	80 [356]	77 [343]
⅝ [15.9]	90 [400]	87 [387]

10.1.4 *Foil-Backed Gypsum Base for Veneer Plaster*:

10.1.4.1 Foil-backed gypsum base for veneer plaster shall meet all of the requirements for gypsum base for veneer plaster.

10.1.4.2 When tested in accordance with Test Methods E96/E96M, the permeance of foil-backed gypsum base for veneer plaster shall be not more than 0.30 perm [17 ng/Pa·s·m^2] (Desiccant Method) for the condition of 50 % relative humidity on the face of the board, and 0 % relative humidity on the back (foil-covered) side of the board.

10.2 *Dimensions and Tolerances of Gypsum Base for Veneer Plaster*:

10.2.1 *Thickness*—The thickness shall be from ⅜ to ⅝ in. [9.5 to 15.9 mm] with tolerances ± 0.015 in. [± 0.40 mm], and with local variations of ± 0.030 in. [± 0.80 mm].

10.2.2 *Width*—The width shall be 48 in. [1220 mm] with a tolerance of 3/32 in. [3 mm] under the specified width.

10.2.3 *End Squareness*—Corners shall be square with a tolerance of ±⅛ in. [±3 mm] in the full width of the board.

10.3 *Edges*—The edges shall be either square, beveled, featured, tapered, or featured and tapered.

11. Gypsum Lath

11.1 *Physical Properties of Gypsum Lath*:

11.1.1 *Flexural Strength*—The specimens shall be tested face up and face down. The average breaking load shall be not less than the following:

Thickness, in. [mm]	Method A Bearing Edges Perpendicular to Panel Length, lbf [N]	Method A Bearing Edges Parallel to Panel Length, lbf [N]	Method B Bearing Edges Perpendicular to Panel Length, lbf [N]	Method B Bearing Edges Parallel to Panel Length, lbf [N]
⅜ [9.5]	60 [267]	25 [111]	56 [249]	21 [93]
½ [12.7]	100 [445]	35 [156]	97 [431]	31 [138]

11.1.2 *Humidified Deflection*—The specimens shall have an average deflection of not more than the following:

Thickness, in. [mm]	Deflection, eighths of an inch [m]
⅜ [9.5]	15 [48]
½ [12.7]	10 [32]

11.1.3 *Nail Pull Resistance*—The specimens shall have an average nail-pull resistance of not less than the following:

Thickness, in. [mm]	Method A, lbf [N]	Method B, lbf [N]
⅜ [9.5]	50 [222]	46 [205]
½ [12.7]	70 [312]	66 [294]

11.1.4 *Foil-Backed Gypsum Lath*:

11.1.4.1 Foil-backed gypsum lath shall meet all of the requirements for gypsum lath.

11.1.4.2 When tested in accordance with Test Methods E96/E96M, the permeance of foil-backed gypsum lath shall be not more than 0.30 perm [17 ng/Pa·s·m^2] (Desiccant Method) for the condition of 50 % relative humidity on the face of the board, and 0 % relative humidity on the back (foil-covered) side of the board.

11.2 *Dimensions and Tolerances of Gypsum Lath*:

11.2.1 *Thickness*—The thickness shall be ⅜ or ½ in. [9.5 or 12.7 mm] with tolerances of ± 0.030 in. [± 0.80 mm], and with local variations of ± 0.060 in. [± 1.6 mm].

11.2.2 *Width*—The nominal width shall be up to 48 in. [1220 mm] with a tolerance of 3/16 in. [4.8 mm] under and ⅛ in. [3.2 mm] over the specified width.

11.2.3 *End Squareness*—Corners shall be square with a tolerance of ±¼ in. [±6.4 mm] in the full width of the board.

11.3 *Edges*—The edges shall be either round or square.

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12. Gypsum Ceiling Board

12.1 *Physical Properties of Gypsum Ceiling Board*:

12.1.1 *Flexural Strength*—The specimens shall be tested face up and face down. The average breaking load shall not be less than the following:

	METHOD A		METHOD B	
Thickness in. [mm]	Load, lbf [N] Bearing Edges Across Fiber of Surfacing	Load, lbf [N] Bearing Edges Parallel to Fiber of Surfacing	Load, lbf [N] Bearing Edges Across Fiber of Surfacing	Load, lbf [N] Bearing Edges Parallel to Fiber of Surfacing
½ [12.7]	110 [489]	40 [178]	107 [476]	36 [160]

12.1.2 *Humidified Deflection*—The specimens shall have an average humidified deflection of not more than 5⁄16 in. [8 mm].

12.1.3 *Nail Pull Resistance*—The specimens shall have an average nail-pull resistance of not less than 80 lbf [356 N] when tested by Method A and 77 lbf [343 N] when tested by Method B.

12.2 *Dimensions and Tolerances of Gypsum Ceiling Board*:

12.2.1 *Thickness*—The thickness shall be ½ in. [12.7 mm] with tolerances of ± 0.015 in. [± 0.40 mm] with local variations of ± 0.030 in. [± 0.80 mm].

12.2.2 *Width*—The width shall be up to 48 in. [1220 mm] with a tolerance of 3⁄32 in. [3 mm] under the specified width.

12.2.3 *End Squareness*—Corners shall be square with a tolerance of ±⅛ in. [3 mm] in the full width of the board.

12.3 *Edges*—The edges shall be either square, beveled, featured, tapered, or featured and tapered.

13. Finish and Appearance

13.1 The surfaces of gypsum board shall be true and free from imperfections that would render it unfit for use with or without decoration.

14. Sampling, Inspection, Rejection, Certification, Packaging, Marking, Shipping, Handling, and Storage

14.1 Sampling, inspection, rejection, certification, packaging, marking, shipping, handling, and storage of gypsum board shall be in accordance with Specification C1264.

15. Keywords

15.1 ceiling; coreboard; drywall; exterior gypsum soffit board; foil-backed; gypsum; gypsum backing board; gypsum base; gypsum board; gypsum ceiling board; gypsum coreboard; gypsum lath; gypsum sheathing; gypsum sheathing board; gypsum wallboard; partitions; plaster; predecorated gypsum board; shaftliner; sheathing; type X; veneer base; veneer plaster; wall; wallboard; water-resistant gypsum board

APPENDIXES

(Nonmandatory Information)

This appendix gives general information and also suggestions for inclusions to be made elsewhere by the specifier. They are not part of this specification.

The definition of type X as given in 4.3.1-4.3.3 and the alternate definition given in this appendix, are intended only as a test to define the gypsum board as meeting the requirements of type X products. These tests do not indicate a preferred application nor do they limit the use of the product in other fire rated assemblies.

All gypsum panel products for which type X is defined, except gypsum lath and gypsum shaftliner board, use the same test for type X products, therefore the type X definition indicates a consistent level of fire resistance.

X1. ALTERNATE DEFINITION FOR TYPE X

X1.1 Gypsum board, type X (special fire-resistant) designates gypsum board, except gypsum lath, providing a greater fire-resistance than regular gypsum board of the same thickness. Type X (special fire-resistant) gypsum board, when tested in accordance with Test Methods E119, shall provide the following minimum fire resistance ratings for the assemblies described:

X1.1.1 One hour for a 5⁄8-in. [15.9-mm] thickness applied to a partition in a single-layer application on each side of 3 5⁄8-in. [92-mm] deep non-loadbearing galvanized steel studs complying with Specification C645, spaced 24 in. [610 mm] on center. The 5⁄8-in. [15.9-mm] thick gypsum board 48 in. [1220 mm] wide shall be attached using 1-in. [25-mm] long drywall screws spaced 8 in. [203 mm] on center along the edges and ends, and 12 in. [305 mm] along intermediate studs. All joints shall be oriented parallel to and located over studs and staggered on opposite sides of the assembly, and

X1.1.2 Two hours for a ½-in. [12.7-mm] thickness applied to a partition in a double-layer application on each side of 2½-in. [64-mm] deep non-loadbearing galvanized steel studs complying with Specification C645, spaced 24 in. [610 mm] on center. The 48-in. [1220-mm] wide base layer shall be attached using 1-in. [25-mm] long drywall screws spaced 12 in. [305 mm] on center along board edges, ends, and along intermediate studs. Joints shall be oriented parallel to and located over studs and staggered on opposite sides of the assembly. The 48-in. [1220-m] wide face layer shall be attached using 1 5⁄8-in. [41-mm] long drywall screws spaced 12 in. [305 mm] along board edges, ends, and along intermediate studs. Joints shall be

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oriented parallel to and located over studs, offset 24 in. [610 mm] from the base layer joints, and staggered on opposite sides of the assembly.

X2. TABLE OF WITHDRAWN ASTM STANDARDS REPLACED BY SPECIFICATION C1396/C1396M

X2.1 As of December 1, 2004, a single ASTM International reference, Specification C1396/C1396M, has replaced nine standards previously used to designate specific gypsum boards employed in commercial and residential construction. The chart below identifies the withdrawn standard and its corresponding section within Specification C1396/C1396M.

	Withdrawn ASTM Standard	C1396/C1396M Section
C36/C 36/M	Specification for Gypsum Wallboard	5
C37/C37M	Specification for Gypsum Lath	11
C79/C79M	Specification for Gypsum Sheathing Board	9
C442/C442M	Specification for Gypsum Backing Board, Gypsum Coreboard, and Gypsum Shaftliner Board	6
C588/C588M	Specification for Gypsum Base for Veneer Plasters	10
C630/C630M	Specification for Water-Resistant Gypsum Backing Board	7
C931/C931M	Specification for Exterior Gypsum Soffit Board	8
C960/C960M	Specification for Predecorated Gypsum Board	5
C1395/C1395M	Specification for Gypsum Ceiling Board	12

SUMMARY OF CHANGES

Committee C11 has identified the location of selected changes to this specification since the last issue, C1396/C1396M – 09, that may impact the use of this specification. (Approved November 15, 2009)

(*1*) Deleted 7.1.5 and 9.1.5 on water absorption.

Committee C11 has identified the location of selected changes to this specification since the last issue, C1396/C1396M – 06a, that may impact the use of this specification. (Approved September 1, 2009)

(*1*) Revised 4.1.

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Designation: C1396/C1396M – 09a

Standard Specification for Gypsum Board[1]

This standard is issued under the fixed designation C1396/C1396M; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope*

1.1 This specification covers the gypsum boards described in 1.1.1-1.1.9.

NOTE 1—Specifications C840, C841, C844 and C1280 contain application procedures for gypsum board.

1.1.1 *Gypsum wallboard*, designed for use on walls, ceilings, or partitions and that affords a surface suitable to receive decoration.

1.1.2 *Predecorated gypsum board*, designed for use as the finished surfacing for walls, ceilings, or partitions.

1.1.3 *Gypsum backing board, coreboard, and shaftliner board*, designed for use as a base in multilayer systems or as a gypsum stud or core in semisolid or solid gypsum board partitions, or in shaft wall assemblies.

NOTE 2—The terms backing board, coreboard, and shaftliner board refer to different end uses. The term gypsum backing board, as used in this specification, shall include gypsum coreboard and gypsum shaftliner board unless otherwise stated.

1.1.4 *Water-resistant gypsum backing board*, designed primarily to be used as a base for the application of ceramic or plastic tile on walls or ceilings. This product is also suitable for decoration.

1.1.5 *Exterior gypsum soffit board*, designed for use on exterior soffits and carport ceilings that are completely protected from contact with liquid water.

1.1.6 *Gypsum sheathing board*, designed for use as sheathing on buildings.

1.1.7 *Gypsum base for veneer plaster*, designed for use as a base for the application of gypsum veneer plaster.

1.1.8 *Gypsum lath*, designed for use as a base for the application of gypsum plaster.

1.1.9 *Gypsum ceiling board*, designed for use on interior ceilings with framing spaced not more than 24 in. [610 mm] on center and that affords a surface suitable to receive water-based texture and other decoration. This product is also suitable for use on interior walls.

1.2 Specifications applicable to all gypsum boards are located in Section 1-4 and 13-15. Specifications applicable to specific gypsum boards are located in the following sections:

	Section
Gypsum wallboard, predecorated gypsum board	5
Gypsum backing board, gypsum coreboard, gypsum shaftliner board	6
Water-resistant gypsum backing board	7
Exterior gypsum soffit board	8
Gypsum sheathing board	9
Gypsum base for veneer plaster	10
Gypsum lath	11
Gypsum Ceiling Board	12

1.3 The values stated in either SI units or inch-pound units are to be regarded separately as standard. Within the text, the SI units are shown in brackets. The values stated in each system may not be exact equivalents; therefore, each system shall be used independently of the other. Combining values from the two systems may result in non-conformance with the standard

2. Referenced Documents

2.1 *ASTM Standards:*[2]

C11 Terminology Relating to Gypsum and Related Building Materials and Systems

C22/C22M Specification for Gypsum

C473 Test Methods for Physical Testing of Gypsum Panel Products

C645 Specification for Nonstructural Steel Framing Members

C840 Specification for Application and Finishing of Gypsum Board

C841 Specification for Installation of Interior Lathing and Furring

C844 Specification for Application of Gypsum Base to Receive Gypsum Veneer Plaster

C1264 Specification for Sampling, Inspection, Rejection, Certification, Packaging, Marking, Shipping, Handling, and Storage of Gypsum Panel Products

C1280 Specification for Application of Gypsum Sheathing

[1] This specification is under the jurisdiction of ASTM Committee C11 on Gypsum and Related Building Materials and Systems and is the direct responsibility of Subcommittee C11.01 on Specifications and Test Methods for Gypsum Products.

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[2] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

***A Summary of Changes section appears at the end of this standard.**

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E84 Test Method for Surface Burning Characteristics of Building Materials
E96/E96M Test Methods for Water Vapor Transmission of Materials
E119 Test Methods for Fire Tests of Building Construction and Materials

3. Terminology

3.1 Definitions used in this specification shall be in accordance with Terminology C11.

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *decorative coating*, *n*—a paint or other liquid material with or without aggregate.

3.2.2 *decorative sheet or film*, *n*—a plastic film, either backed or unbacked; plastic sheet; or combination of these.

3.2.3 *edge*, *n*—the bound edge as manufactured.

3.2.4 *gypsum backing board*, *n*—a ¼ to ⅝-in. [6.4 to 15.9-mm] gypsum board used as a backing for gypsum wallboard, acoustical tile, or other dry cladding.

3.2.5 *gypsum coreboard*, *n*—a ¾ to 1-in. [19.0 to 25.4-mm] gypsum board used as a gypsum stud or core in semisolid or solid gypsum board partitions.

3.2.6 *nominal thickness*, *n*—the manufacturer-stated fractional value of thickness of the gypsum panel product expressed in decimal value to the nearest one-thousandth (1/1000) of an inch.

4. Materials and Manufacture

4.1 Gypsum board shall consist of a noncombustible core of gypsum complying with Specification C22/C22M, surfaced with paper bonded to the core.

4.1.1 Gypsum sheathing board shall consist of a noncombustible water-resistant core of gypsum complying with Specification C22/C22M, surfaced on both the face and back with water-repellant paper bonded to the core.

4.1.2 Gypsum coreboard shall be either a single board or composed of two factory-laminated gypsum boards to provide up to 1 in. [25.4 mm] total nominal thickness.

4.1.3 Water-resistant gypsum backing board shall consist of a noncombustible water-resistant core of gypsum complying with Specification C22/C22M, surfaced on both the back and face with water-repellant paper bonded to the core.

4.1.4 Predecorated gypsum board shall consist of a noncombustible core of gypsum complying with Specification C22/C22M, surfaced with paper bonded to the core with the face covered with a decorative sheet, film, or coating.

4.1.4.1 Class I predecorated gypsum board shall have a decorative sheet or film laminated to the face.

4.1.4.2 Class II predecorated gypsum board shall have a decorative coating applied to the face.

4.2 The back surface of foil-backed gypsum board shall in addition be covered with aluminum foil.

4.3 *Gypsum Board, type X* (Special Fire-Resistant):

4.3.1 *Gypsum Board*, type X, designates gypsum board, except gypsum lath, gypsum coreboard, and gypsum shaftliner board, complying with this specification that provides not less than 1 h fire-resistance rating for boards ⅝ in. [15.9 mm] thick or ¾ h fire-resistance rating for boards ½ in. [12.7 mm] thick, applied parallel with and on each side of load bearing 2 by 4 wood studs spaced 16 in. [406 mm] on centers with 6d coated nails, 1⅞ in. [48 mm] long, 0.0915-in. [2.3-mm] diameter shank, ¼-in. [6.4-mm] diameter heads, spaced 7 in. [178 mm] on centers with gypsum board joints staggered 16 in. [406 mm] on each side of the partition and tested in accordance with Test Methods E119.

4.3.2 *Gypsum Lath*, type X designates gypsum lath complying with this specification that provides not less than a 1-h fire-resistance rating for gypsum lath ⅜ in. [9.5 mm] thick, when applied at right angles to and on each side of loadbearing 2 × 4 wood studs spaced 16 in. [406 mm] on centers with blue lath nails spaced 5 in. [127 mm] on centers over which is applied ½ in. [12.7 mm] 1:2 gypsum sand plaster and tested in accordance with the requirements of Test Method E119.

NOTE 3—Consult producers for independent test data on assembly details and fire-resistance ratings for other types of construction. See fire test reports or listings from recognized fire testing laboratories for assembly particulars, materials, and ratings.

4.3.3 Gypsum shaftliner board, type X, designates gypsum shaftliner board complying with this specification that meets the acceptance criteria for temperature rise for not less than 1-½ h for boards ¾-in. [19.0 mm] thick or 2 h for boards 1-in. [25.4 mm] thick, when applied in a double layer solid nonload bearing partition as described in 4.3.3.1 and tested in accordance with Test Methods E119 with thermocouple locations as specified in 4.3.3.2.

4.3.3.1 Two layers of gypsum shaftliner board applied vertically and friction fit into vertical 25-gage steel "H" members, 1-½-in. [38.1 mm] deep for boards ¾-in. [19.0 mm] thick or 2-in. [50.8 mm] deep for boards 1-in. [25.4 mm] thick, spaced 24-in. [610 mm] on centers and 25-gage steel track at the perimeter of the partition. "H" members shall be formed with a single web or shall be two pieces of perimeter track fastened together along the web with screws spaced 24-in. [610 mm] on centers.

4.3.3.2 Temperature rise on the unexposed surface shall be measured using not less than five thermocouples; one shall be located at the center of the assembly and one shall be located at the center of each quadrant. Thermocouples shall be located not less than 3-in. [76 mm] from an "H" member.

4.4 Gypsum wallboard, gypsum backing board, exterior gypsum soffit board, and gypsum ceiling board shall have a flame spread index of not more than 25 when tested in accordance with Test Method E84.

4.5 *Physical Properties, Dimensions, and Tolerances of Gypsum Board*:

4.5.1 Specimens shall be taken from the samples obtained in accordance with Specification C1264.

4.5.1.1 Specimens shall be tested in accordance with Test Methods C473.

4.5.2 *Core, End, and Edge Hardness*—The specimens shall have an average hardness of not less than 15 lbf [67 N] when tested by Method A and 11 lbf [49 N] when tested by Method B.

4.5.3 *Edges and Ends*—The edges and ends shall be straight.

4.5.4 *Length*—The tolerance in length shall be ±¼ in. [±6 mm].

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4.5.5 *Tapered Edge Depth*—The average thickness of the edge of recessed or tapered edge gypsum board shall be not less than 0.020 in. [0.51 mm] but not more than 0.090 in. [2.29 mm] less than the average thickness of the gypsum board.

5. Gypsum Wallboard and Predecorated Gypsum Board

5.1 *Physical Properties of Gypsum Wallboard and Predecorated Gypsum Board*:

5.1.1 *Flexural Strength*—The specimens shall be tested face up and face down. The average breaking load shall be not less than the following:

Thickness, in. [mm]	Method A Bearing Edges Perpendicular to Panel Length, lbf [N]	Method A Bearing Edges Parallel to Panel Length, lbf [N]	Method B Bearing Edges Perpendicular to Panel Length, lbf [N]	Method B Bearing Edges Parallel to Panel Length, lbf [N]
¼ [6.4]	50 [222]	20 [89]	46 [205]	16 [71]
5⁄16 [7.9]	65 [289]	25 [111]	62 [276]	21 [93]
⅜ [9.5]	80 [356]	30 [133]	77 [343]	26 [116]
½ [12.7]	110 [489]	40 [178]	107 [476]	36 [160]
⅝ [15.9]	150 [667]	50 [222]	147 [654]	46 [205]
¾ [19.0]	170 [756]	60 [267]	167 [743]	56 [249]

5.1.2 *Humidified Deflection*—The specimens shall have an average deflection of not more than the following:

Thickness, in. [mm]	Deflection, eighths of an inch [mm]
¼ [6.4]	not required
5⁄16 [7.9]	not required
⅜ [9.5]	15 [48]
½ [12.7]	10 [32]
⅝ [15.9]	5 [16]
¾ [19.0]	5 [16]

5.1.3 *Nail Pull Resistance*—The specimens shall have an average nail-pull resistance of not less than the following:

Thickness, in. [mm]	Method A, lbf [N]	Method B, lbf [N]
¼ [6.4]	40 [178]	36 [160]
5⁄16 [7.9]	50 [222]	46 [205]
⅜ [9.5]	60 [267]	56 [249]
½ [12.7]	80 [356]	77 [343]
⅝ [15.9]	90 [400]	87 [387]
¾ [19.0]	100 [445]	97 [432]

5.1.4 *Foil-Backed Gypsum Wallboard and Foil-Backed Predecorated Gypsum Board*:

5.1.4.1 Foil-backed gypsum wallboard and foil-backed predecorated gypsum board shall meet all of the requirements for gypsum wallboard and predecorated gypsum board.

5.1.4.2 When tested in accordance with Test Methods E96/E96M, the permeance of foil-backed gypsum wallboard and foil-backed predecorated gypsum board shall be not more than 0.30 perm [17 ng/Pa·s·m^2] (Desiccant Method) for the condition of 50 % relative humidity on the face of the board, and 0 % relative humidity on the back (foil-covered) side of the board.

5.2 *Dimensions and Tolerances of Gypsum Wallboard and Predecorated Gypsum Board*:

5.2.1 *Thickness*—The thickness shall be from ¼ to ¾ in. [6.4 to 19.0 mm] with tolerances of ± 0.015 in. [± 0.40 mm], and with local variations of ± 0.030 in. [± 0.80 mm].

5.2.2 *Width*—The width shall be up to 48 in. [1220 mm], or up to 54 in. [1370 mm], with a tolerance of 3⁄32 in. [3 mm] under the specified width.

5.2.3 *End Squareness*—Corners shall be square with a tolerance of ± ⅛ in. [±3 mm] in the full width of the board.

5.3 *Edges*:

5.3.1 The edges of gypsum wallboard shall be either square, beveled, featured, tapered, or featured and tapered.

5.3.2 The edges of predecorated gypsum board shall be either square, beveled, or featured.

6. Gypsum Backing Board, Gypsum Coreboard, and Gypsum Shaftliner Board

6.1 *Physical Properties of Gypsum Backing Board, Gypsum Coreboard, and Gypsum Shaftliner Board*:

6.1.1 *Flexural Strength*—The specimens shall be tested face up and face down. The average breaking load shall be not less than the following:

Thickness, in. [mm]	Method A Bearing Edges Perpendicular to Panel Length, lbf [N]	Method A Bearing Edges Parallel to Panel Length, lbf [N]	Method B Bearing Edges Perpendicular to Panel Length, lbf [N]	Method B Bearing Edges Parallel to Panel Length, lbf [N]
¼ [6.4]	50 [222]	20 [89]	46 [205]	16 [71]
⅜ [9.5]	80 [356]	30 [133]	77 [343]	26 [116]
½ [12.7]	110 [489]	40 [178]	107 [476]	36 [160]
⅝ [15.9]	140 [622]	50 [222]	137 [609]	46 [205]
¾ [19.0]	170 [756]	60 [267]	167 [743]	56 [249]
1 [25.4]	230 [1023]	80 [356]	228 [1014]	77 [343]

6.1.2 *Humidified Deflection*—The specimens shall have an average deflection of not more than the following:

Thickness, in. [mm]	Deflection, eighths of an inch [mm]
¼ [6.4]	not required
⅜ [9.5]	15 [48]
½ [12.7]	10 [32]
⅝ [15.9]	5 [16]
¾ [19.0]	not required
1 [25.4]	not required

6.1.3 *Nail Pull Resistance*—The specimens shall have an average nail-pull resistance of not less than the following:

Thickness, in. [mm]	Method A, lbf [N]	Method B, lbf [N]
¼ [6.4]	40 [178]	36 [160]
⅜ [9.5]	60 [267]	56 [249]
½ [12.7]	80 [356]	77 [343]
⅝ [15.9]	90 [400]	87 [387]
¾ [19.0]	not required	not required
1 [25.4]	not required	not required

6.1.4 *Foil-Backed Gypsum Backing Board, Foil-Backed Gypsum Coreboard, and Foil-Backed Gypsum Shaftliner Board*:

6.1.4.1 Foil-backed gypsum backing board, foil-backed gypsum coreboard, and foil-backed gypsum shaftliner board shall meet all of the requirements for gypsum backing board, gypsum coreboard, and gypsum shaftliner board.

6.1.4.2 When tested in accordance with Test Methods E96/E96M, the permeance of foil-backed gypsum backing board and foil-backed gypsum coreboard shall be not more than 0.30 perm [17 ng/Pa·s·m^2] (Desiccant Method) for the condition of 50 % relative humidity on the face of the board, and 0 % relative humidity on the back (foil-covered) side of the board.

6.2 *Dimensions and Tolerances of Gypsum Backing Board, Gypsum Coreboard, and Gypsum Shaftliner Board*:

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6.2.1 *Thickness*—The thickness shall be from ¼ to 1 in. [6.4 to 25.4 mm] with tolerances of ± 0.030 in. [± 0.80 mm], and with local variations of ± 0.060 in. [± 1.6 mm].

6.2.2 *Width*—The width shall be from 16 to 48 in. [406 to 1220 mm] with a tolerance of ⅛ in. [3.2 mm] under the specified width.

6.2.3 *End Squareness*—Corners shall be square with a tolerance of ±⅛ in. [±3 mm] in the full width of the board.

6.3 *Edges*—The edges shall be either square, beveled, round, V-tongue and groove, or featured.

7. Water-Resistant Gypsum Backing Board

7.1 *Physical Properties of Water-Resistant Gypsum Backing Board*:

7.1.1 *Flexural Strength*—The specimens shall be tested face up and face down. The average breaking load shall be not less than the following:

Thickness, in. [mm]	Method A Bearing Edges Perpendicular to Panel Length, lbf [N]	Method A Bearing Edges Parallel to Panel Length, lbf [N]	Method B Bearing Edges Perpendicular to Panel Length, lbf [N]	Method B Bearing Edges Parallel to Panel Length, lbf [N]
½ [12.7]	110 [489]	40 [178]	107 [476]	36 [160]
⅝ [15.9]	150 [667]	50 [222]	147 [654]	46 [205]

7.1.2 *Humidified Deflection*—The specimens shall have an average deflection of not more than the following:

Thickness, in. [mm]	Deflection, eighths of an inch [mm]
½ [12.7]	10 [32]
⅝ [15.9]	5 [16]

7.1.3 *Nail Pull Resistance*—The specimens shall have an average nail-pull resistance of not less than the following:

Thickness, in. [mm]	Method A, lbf [N]	Method B, lbf [N]
½ [12.7]	80 [356]	77 [343]
⅝ [15.9]	90 [400]	87 [387]

7.1.4 *Water Resistance*—The specimens shall have an average water absorption of not more than 5 weight % after 2-h immersion.

7.2 *Dimensions and Tolerances of Water-Resistant Gypsum Backing Board*:

7.2.1 *Thickness*—The thickness shall be ½ or ⅝ in. [12.7 or 15.9 mm] with tolerances of ± 0.015 in. [± 0.40 mm], and with local variations of ± 0.030 in. [± 0.80 mm].

7.2.2 *Width*—The width shall be up to 48 in. [1220 mm], or up to 54 in. [1370 mm], with a tolerance of 3/32 in. [3 mm] under the specified width.

7.2.3 *End Squareness*—Corners shall be square with a tolerance of ±⅛ in. [±3 mm] in the full width of the board.

7.3 *Edges*—The edges shall be either square, beveled, featured, tapered, or featured and tapered.

8. Exterior Gypsum Soffit Board

8.1 *Physical Properties of Exterior Gypsum Soffit Board*:

8.1.1 *Flexural Strength*—The specimens shall be tested face up and face down. The average breaking load shall be not less than the following:

Thickness, in. [mm]	Method A Bearing Edges Perpendicular to Panel Length, lbf [N]	Method A Bearing Edges Parallel to Panel Length, lbf [N]	Method B Bearing Edges Perpendicular to Panel Length, lbf [N]	Method B Bearing Edges Parallel to Panel Length, lbf [N]
½ [12.7]	110 [489]	40 [178]	107 [476]	36 [160]
⅝ [15.9]	150 [667]	50 [222]	147 [654]	46 [205]

8.1.2 *Humidified Deflection*—The specimens shall have an average deflection of not more than the following:

Thickness, in. [mm]	Deflection, eighths of an inch [mm]
½ [12.7]	7 [22]
⅝ [15.9]	4 [13]

8.1.3 *Nail Pull Resistance*—The specimens shall have an average nail-pull resistance of not less than the following:

Thickness, in. [mm]	Method A, lbf [N]	Method B, lbf [N]
½ [12.7]	80 [356]	77 [343]
⅝ [15.9]	90 [400]	87 [387]

8.2 *Dimensions and Tolerances of Exterior Gypsum Soffit Board*:

8.2.1 *Thickness*—The thickness shall be ½ or ⅝ in. [12.7 or 15.9 mm] with tolerances of ± 0.015 in. [± 0.40 mm], and with local variations of ± 0.030 in. [± 0.80 mm].

8.2.2 *Width*—The width shall be up to 48 in. [1220 mm] with a tolerance of 3/32 in. [3 mm] under the specified width.

8.2.3 *End Squareness*—Corners shall be square with a tolerance of ±⅛ in. [±3 mm] in the full width of the board.

8.3 *Edges*—The edges shall be either square, beveled, featured, tapered, or featured and tapered.

9. Gypsum Sheathing Board

9.1 *Physical Properties of Gypsum Sheathing Board:*

9.1.1 *Flexural Strength*—The specimens shall be tested face up and face down. The average breaking load shall be not less than the following:

Thickness, in. [mm]	Method A Bearing Edges Perpendicular to Panel Length, lbf [N]	Method A Bearing Edges Parallel to Panel Length, lbf [N]	Method B Bearing Edges Perpendicular to Panel Length, lbf [N]	Method B Bearing Edges Parallel to Panel Length, lbf [N]
⅜ [9.5]	80 [356]	30 [133]	77 [343]	26 [116]
4/10 [10.2]	88 [391]	32 [142]	85 [378]	28 [125]
½ [12.7]	110 [489]	40 [178]	107 [476]	36 [160]
⅝ [15.9]	150 [667]	50 [222]	147 [654]	46 [205]

9.1.2 *Humidified Deflection*—The specimens shall have an average deflection of not more than the following:

Thickness, in. [mm]	Deflection, eighths of an inch [mm]
⅜ [9.5]	15 [48]
4/10 [10.2]	12 [38]
½ [12.7]	10 [32]
⅝ [15.9]	5 [16]

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9.1.3 *Nail-Pull Resistance*—The specimens shall have an average nail-pull resistance of not less than the following:

Thickness, in. [mm]	Method A, lbf [N]	Method B, lbf [N]
3/8 [9.5]	60 [267]	56 [249]
4/10 [10.2]	70 [312]	67 [298]
1/2 [12.7]	80 [356]	77 [343]
5/8 [15.9]	90 [400]	87 [387]

9.1.4 *Water Resistance of Gypsum Sheathing Board*—The specimens shall have an average water absorption of not more than 10 weight % after 2-h immersion.

9.2 *Dimensions and Tolerances of Gypsum Sheathing Board:*

9.2.1 *Thickness*—The thickness shall be from 3/8 to 5/8 in. [9.5 to 15.9 mm] with tolerances of ± 0.030 in. [± 0.80 mm], and with local variations of ± 0.060 in. [± 1.6 mm].

9.2.2 *Width*—The nominal width shall be 24 or 48 in. [610 or 1220 mm] with a tolerance of 1/8 in. [3.2 mm] under the specified width.

9.2.3 *End Squareness*—Corners shall be square with a tolerance of ±1/8 in. [±3 mm] in the full width of the board.

9.3 *Edges*—The edges shall be either square or V-tongue and groove.

10. Gypsum Base for Veneer Plaster

10.1 *Physical Properties of Gypsum Base for Veneer Plaster*:

10.1.1 *Flexural Strength*—The specimens shall be tested face up and face down. The average breaking load shall be not less than the following:

Thickness, in. [mm]	Method A Bearing Edges Perpendicular to Panel Length, lbf [N]	Method A Bearing Edges Parallel to Panel Length, lbf [N]	Method B Bearing Edges Perpendicular to Panel Length, lbf [N]	Method B Bearing Edges Parallel to Panel Length, lbf [N]
3/8 [9.5]	80 [356]	30 [133]	77 [343]	26 [116]
1/2 [12.7]	110 [489]	40 [178]	107 [476]	36 [160]
5/8 [15.9]	150 [667]	50 [222]	147 [654]	46 [205]

10.1.2 *Humidified Deflection*—The specimens shall have an average deflection of not more than the following:

Thickness, in. [mm]	Deflection, eighths of an inch [m]
3/8 [9.5]	15 [48]
1/2 [12.7]	10 [32]
5/8 [15.9]	5 [16]

10.1.3 *Nail Pull Resistance*—The specimens shall have an average nail-pull resistance of not less than the following:

Thickness, in. [mm]	Method A, lbf [N]	Method B, lbf [N]
3/8 [9.5]	60 [267]	56 [249]
1/2 [12.7]	80 [356]	77 [343]
5/8 [15.9]	90 [400]	87 [387]

10.1.4 *Foil-Backed Gypsum Base for Veneer Plaster*:

10.1.4.1 Foil-backed gypsum base for veneer plaster shall meet all of the requirements for gypsum base for veneer plaster.

10.1.4.2 When tested in accordance with Test Methods E96/E96M, the permeance of foil-backed gypsum base for veneer plaster shall be not more than 0.30 perm [17 ng/Pa·s·m^2] (Desiccant Method) for the condition of 50 % relative humidity on the face of the board, and 0 % relative humidity on the back (foil-covered) side of the board.

10.2 *Dimensions and Tolerances of Gypsum Base for Veneer Plaster*:

10.2.1 *Thickness*—The thickness shall be from 3/8 to 5/8 in. [9.5 to 15.9 mm] with tolerances ± 0.015 in. [± 0.40 mm], and with local variations of ± 0.030 in. [± 0.80 mm].

10.2.2 *Width*—The width shall be 48 in. [1220 mm] with a tolerance of 3/32 in. [3 mm] under the specified width.

10.2.3 *End Squareness*—Corners shall be square with a tolerance of ±1/8 in. [±3 mm] in the full width of the board.

10.3 *Edges*—The edges shall be either square, beveled, featured, tapered, or featured and tapered.

11. Gypsum Lath

11.1 *Physical Properties of Gypsum Lath*:

11.1.1 *Flexural Strength*—The specimens shall be tested face up and face down. The average breaking load shall be not less than the following:

Thickness, in. [mm]	Method A Bearing Edges Perpendicular to Panel Length, lbf [N]	Method A Bearing Edges Parallel to Panel Length, lbf [N]	Method B Bearing Edges Perpendicular to Panel Length, lbf [N]	Method B Bearing Edges Parallel to Panel Length, lbf [N]
3/8 [9.5]	60 [267]	25 [111]	56 [249]	21 [93]
1/2 [12.7]	100 [445]	35 [156]	97 [431]	31 [138]

11.1.2 *Humidified Deflection*—The specimens shall have an average deflection of not more than the following:

Thickness, in. [mm]	Deflection, eighths of an inch [m]
3/8 [9.5]	15 [48]
1/2 [12.7]	10 [32]

11.1.3 *Nail Pull Resistance*—The specimens shall have an average nail-pull resistance of not less than the following:

Thickness, in. [mm]	Method A, lbf [N]	Method B, lbf [N]
3/8 [9.5]	50 [222]	46 [205]
1/2 [12.7]	70 [312]	66 [294]

11.1.4 *Foil-Backed Gypsum Lath*:

11.1.4.1 Foil-backed gypsum lath shall meet all of the requirements for gypsum lath.

11.1.4.2 When tested in accordance with Test Methods E96/E96M, the permeance of foil-backed gypsum lath shall be not more than 0.30 perm [17 ng/Pa·s·m^2] (Desiccant Method) for the condition of 50 % relative humidity on the face of the board, and 0 % relative humidity on the back (foil-covered) side of the board.

11.2 *Dimensions and Tolerances of Gypsum Lath*:

11.2.1 *Thickness*—The thickness shall be 3/8 or 1/2 in. [9.5 or 12.7 mm] with tolerances of ± 0.030 in. [± 0.80 mm], and with local variations of ± 0.060 in. [± 1.6 mm].

11.2.2 *Width*—The nominal width shall be up to 48 in. [1220 mm] with a tolerance of 3/16 in. [4.8 mm] under and 1/8 in. [3.2 mm] over the specified width.

11.2.3 *End Squareness*—Corners shall be square with a tolerance of ±1/4 in. [±6.4 mm] in the full width of the board.

11.3 *Edges*—The edges shall be either round or square.

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12. Gypsum Ceiling Board

12.1 *Physical Properties of Gypsum Ceiling Board*:

12.1.1 *Flexural Strength*—The specimens shall be tested face up and face down. The average breaking load shall not be less than the following:

	METHOD A		METHOD B	
Thickness in. [mm]	Load, lbf [N] Bearing Edges Across Fiber of Surfacing	Load, lbf [N] Bearing Edges Parallel to Fiber of Surfacing	Load, lbf [N] Bearing Edges Across Fiber of Surfacing	Load, lbf [N] Bearing Edges Parallel to Fiber of Surfacing
½ [12.7]	110 [489]	40 [178]	107 [476]	36 [160]

12.1.2 *Humidified Deflection*—The specimens shall have an average humidified deflection of not more than 5⁄16 in. [8 mm].

12.1.3 *Nail Pull Resistance*—The specimens shall have an average nail-pull resistance of not less than 80 lbf [356 N] when tested by Method A and 77 lbf [343 N] when tested by Method B.

12.2 *Dimensions and Tolerances of Gypsum Ceiling Board*:

12.2.1 *Thickness*—The thickness shall be ½ in. [12.7 mm] with tolerances of ± 0.015 in. [± 0.40 mm] with local variations of ± 0.030 in. [± 0.80 mm].

12.2.2 *Width*—The width shall be up to 48 in. [1220 mm] with a tolerance of 3⁄32 in. [3 mm] under the specified width.

12.2.3 *End Squareness*—Corners shall be square with a tolerance of ±⅛ in. [3 mm] in the full width of the board.

12.3 *Edges*—The edges shall be either square, beveled, featured, tapered, or featured and tapered.

13. Finish and Appearance

13.1 The surfaces of gypsum board shall be true and free from imperfections that would render it unfit for use with or without decoration.

14. Sampling, Inspection, Rejection, Certification, Packaging, Marking, Shipping, Handling, and Storage

14.1 Sampling, inspection, rejection, certification, packaging, marking, shipping, handling, and storage of gypsum board shall be in accordance with Specification C1264.

15. Keywords

15.1 ceiling; coreboard; drywall; exterior gypsum soffit board; foil-backed; gypsum; gypsum backing board; gypsum base; gypsum board; gypsum ceiling board; gypsum coreboard; gypsum lath; gypsum sheathing; gypsum sheathing board; gypsum wallboard; partitions; plaster; predecorated gypsum board; shaftliner; sheathing; type X; veneer base; veneer plaster; wall; wallboard; water-resistant gypsum board

APPENDIXES

(Nonmandatory Information)

This appendix gives general information and also suggestions for inclusions to be made elsewhere by the specifier. They are not part of this specification.

The definition of type X as given in 4.3.1-4.3.3 and the alternate definition given in this appendix, are intended only as a test to define the gypsum board as meeting the requirements of type X products. These tests do not indicate a preferred application nor do they limit the use of the product in other fire rated assemblies.

All gypsum panel products for which type X is defined, except gypsum lath and gypsum shaftliner board, use the same test for type X products, therefore the type X definition indicates a consistent level of fire resistance.

X1. ALTERNATE DEFINITION FOR TYPE X

X1.1 Gypsum board, type X (special fire-resistant) designates gypsum board, except gypsum lath, providing a greater fire-resistance than regular gypsum board of the same thickness. Type X (special fire-resistant) gypsum board, when tested in accordance with Test Methods E119, shall provide the following minimum fire resistance ratings for the assemblies described:

X1.1.1 One hour for a 5⁄8-in. [15.9-mm] thickness applied to a partition in a single-layer application on each side of 3 5⁄8-in. [92-mm] deep non-loadbearing galvanized steel studs complying with Specification C645, spaced 24 in. [610 mm] on center. The 5⁄8-in. [15.9-mm] thick gypsum board 48 in. [1220 mm] wide shall be attached using 1-in. [25-mm] long drywall screws spaced 8 in. [203 mm] on center along the edges and ends, and 12 in. [305 mm] along intermediate studs. All joints shall be oriented parallel to and located over studs and staggered on opposite sides of the assembly, and

X1.1.2 Two hours for a ½-in. [12.7-mm] thickness applied to a partition in a double-layer application on each side of 2½-in. [64-mm] deep non-loadbearing galvanized steel studs complying with Specification C645, spaced 24 in. [610 mm] on center. The 48-in. [1220-mm] wide base layer shall be attached using 1-in. [25-mm] long drywall screws spaced 12 in. [305 mm] on center along board edges, ends, and along intermediate studs. Joints shall be oriented parallel to and located over studs and staggered on opposite sides of the assembly. The 48-in. [1220-m] wide face layer shall be attached using 1 5⁄8-in. [41-mm] long drywall screws spaced 12 in. [305 mm] along board edges, ends, and along intermediate studs. Joints shall be

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oriented parallel to and located over studs, offset 24 in. [610 mm] from the base layer joints, and staggered on opposite sides of the assembly.

X2. TABLE OF WITHDRAWN ASTM STANDARDS REPLACED BY SPECIFICATION C1396/C1396M

X2.1 As of December 1, 2004, a single ASTM International reference, Specification C1396/C1396M, has replaced nine standards previously used to designate specific gypsum boards employed in commercial and residential construction. The chart below identifies the withdrawn standard and its corresponding section within Specification C1396/C1396M.

	Withdrawn ASTM Standard	C1396/C1396M Section
C36/C 36/M	Specification for Gypsum Wallboard	5
C37/C37M	Specification for Gypsum Lath	11
C79/C79M	Specification for Gypsum Sheathing Board	9
C442/C442M	Specification for Gypsum Backing Board, Gypsum Coreboard, and Gypsum Shaftliner Board	6
C588/C588M	Specification for Gypsum Base for Veneer Plasters	10
C630/C630M	Specification for Water-Resistant Gypsum Backing Board	7
C931/C931M	Specification for Exterior Gypsum Soffit Board	8
C960/C960M	Specification for Predecorated Gypsum Board	5
C1395/C1395M	Specification for Gypsum Ceiling Board	12

SUMMARY OF CHANGES

Committee C11 has identified the location of selected changes to this specification since the last issue, C1396/C1396M – 09, that may impact the use of this specification. (Approved November 15, 2009)

(*1*) Deleted 7.1.5 and 9.1.5 on water absorption.

Committee C11 has identified the location of selected changes to this specification since the last issue, C1396/C1396M – 06a, that may impact the use of this specification. (Approved September 1, 2009)

(*1*) Revised 4.1.

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Designation: C 1397 – 09

Standard Practice for Application of Class PB Exterior Insulation and Finish Systems (EIFS) and EIFS with Drainage[1]

This standard is issued under the fixed designation C 1397; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope*

1.1 This practice covers the minimum requirements and procedures for field or prefabricated application of Class PB Exterior Insulation and Finish Systems (EIFS) and EIFS with Drainage. Class PB EIFS are systems applied over insulation board, in which the base coat ranges from not less than 1/16 in. (1.6 mm) to 1/4 in. (6.4 mm) in dry thickness, depending upon the number of nonmetallic reinforcing mesh layers encapsulated in the base coat (see Specification E 2568). The base coat is then covered with a finish coat of varying thickness in a variety of textures and colors. EIFS with Drainage provides a mechanism to drain incidental moisture

1.2 The values stated in inch-pound units are to be regarded as standard. The values given in parentheses are mathematical conversions to SI units that are provided for information only and are not considered standard.

1.3 The text of this practice references notes and footnotes which provide explanatory material. These notes and footnotes (excluding those in tables and figures) shall not be considered as a requirement of the standard.

1.4 *This standard may involve hazardous materials, operations, and equipment. This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

2. Referenced Documents

2.1 *ASTM Standards:*[2]

C 11 Terminology Relating to Gypsum and Related Building Materials and Systems
C 150 Specification for Portland Cement
C 1063 Specification for Installation of Lathing and Furring to Receive Interior and Exterior Portland Cement-Based Plaster
C 1177/C 1177M Specification for Glass Mat Gypsum Substrate for Use as Sheathing
C 1186 Specification for Flat Fiber-Cement Sheets
C 1278/C 1278M Specification for Fiber-Reinforced Gypsum Panel
C 1280 Specification for Application of Gypsum Sheathing
C 1325 Specification for Non-Asbestos Fiber-Mat Reinforced Cementitious Backer Units
C 1382 Test Method for Determining Tensile Adhesion Properties of Sealants When Used in Exterior Insulation and Finish Systems (EIFS) Joints
C 1396/C 1396M Specification for Gypsum Board
C 1472 Guide for Calculating Movement and Other Effects When Establishing Sealant Joint Width
C 1481 Guide for Use of Joint Sealants with Exterior Insulation and Finish Systems (EIFS)
E 1825 Guide for Evaluation of Exterior Building Wall Materials, Products, and Systems
E 2110 Terminology for Exterior Insulation and Finish Systems (EIFS)
E 2430 Specification For Expanded Polystyrene ("EPS") Thermal Insulation Boards For Use In Exterior Insulation and Finish Systems ("EIFS")
E 2568 Specification for PB Exterior Insulation and Finish Systems
E 2570 Test Methods for Evaluating Water-Resistive Barrier (WRB) Coatings Used under Exterior Insulation and Finish Systems (EIFS) or EIFS with Drainage

3. Terminology

3.1 Definitions used in this standard shall be in accordance with Terminologies C 11 and E 2110.

[1] This practice is under the jurisdiction of ASTM Committee C11 on Gypsum and Related Building Materials and Systems and is the direct responsibility of Subcommittee C11.05 on Application of Exterior Insulating and Finish Systems and Related Products.

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[2] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

***A Summary of Changes section appears at the end of this standard.**

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4. Significance and Use

4.1 This practice provides minimum requirements for the application of Class PB EIFS and EIFS with Drainage (see Specification E 2568). The requirements for materials, mixtures, and details shall be contained in the project plans and specifications. See Guide E 1825 for guidance.

5. Delivery of Materials

5.1 All materials shall be delivered in packages, containers, or bundles with the identification and markings intact.

6. Inspection

6.1 Inspection of the materials shall be agreed upon between the purchaser and the supplier as part of the purchase agreement.

6.2 Inspection shall verify that the EIFS materials supplied are as required for the Class PB EIF System or EIFS with Drainage System specified. Mixing of EIFS materials from different manufacturers is not allowed.

7. Rejection

7.1 Materials that are damaged, frozen or in any way defective shall not be used. Rejection of materials shall be promptly reported verbally to the manufacturer and immediately reported in writing. The notice of rejection shall contain a statement documenting the basis for material rejection.

8. Certification

8.1 When specified in the contract documents, the producer shall furnish a report certifying that the materials are in conformance with product and material standards and contract documents.

8.2 *Insulation Boards*:

8.2.1 Insulation boards shall comply with Specification E 2430.

8.2.2 The insulation boards shall have been subjected to a third party quality control inspection and shall be marked as approved for use within the EIFS.

8.2.3 Prior to installation, the insulation board shall be inspected for conformance with contract documents. Nonconforming insulation board shall not be used.

8.2.4 The insulation board manufacturer shall furnish, for each shipment, a written certificate of conformance with the EIFS manufacturer's specifications.

9. Storage of Materials

9.1 All materials shall be kept dry by storage under cover and protected from the weather. When outside storage is required, materials shall be stacked off the ground, supported on a level platform and protected from the weather, surface contamination or physical damage in accordance with the EIFS manufacturer's written instructions.

9.2 Materials shall be protected from exposure to direct sunlight and temperatures less than 40 °F (4 °C), unless otherwise specified by the manufacturer.

9.3 Portland Cement shall meet Specification C 150 and shall be kept dry until ready for use. It shall be kept off the ground, under cover and away from damp walls and surfaces.

9.4 Insulation board shall be stacked flat with care taken to avoid damage to edges, ends, or surfaces; or exposure to direct sunlight (ultraviolet radiation).

10. Environmental Conditions

10.1 *Cold Weather Conditions*:

10.1.1 Wet materials shall not be applied when the temperature is less than 40 °F (4 °C), unless otherwise specified by the manufacturer, unless temporary heat and enclosures are provided to maintain minimum 40 °F (4 °C) for a minimum period of not less than 24 h before, during, and after application (see Annex A1.9.3).

10.1.2 Materials shall not be applied to a base containing frost. Substrate surface temperature shall be not less than 40 °F (4 °C). Mixtures for application shall not contain any frozen ingredients.

11. Assessment of Condition of Substrates to Receive Water-Resistive Barrier Coating (if applicable) or Exterior Insulation and Finish Systems or Both

11.1 The substrate shall be as required by the project plans and specifications and as recommended by the EIFS manufacturer for the particular system specified.

11.1.1 Insulation boards shall be as required by the EIFS manufacturer's specification and in the thickness specified.

11.2 The substrate shall be inspected by the applicator and general contractor to ensure that it meets the project plans and specifications and the requirements of 11.3-11.8.

11.3 Sheathing materials shall be inspected to ensure that:

11.3.1 The specified sheathing thickness has been installed for the stud spacing used.

11.3.2 Fastener type and fastener spacing are as specified.

11.3.3 All Specification C 1396/C 1396M gypsum sheathing boards shall have a water-resistant core.

11.3.4 Tongue and groove water-resistant treated core gypsum sheathing boards conforming to Specification C 1396/C 1396M shall be installed with the tongue edge oriented to the top.

11.3.5 Gypsum sheathing shall be installed in accordance with Specification C 1280.

11.3.6 Gypsum sheathing shall be protected from moisture at all penetrations and terminations.

11.3.7 Glass mat gypsum sheathing complying with Specification C 1177/C 1177M shall be installed in accordance with the sheathing manufacturer's written installation instructions, which include details of framing type and spacing, fastener type and spacing, and sheathing orientation and spacing.

11.3.8 Plywood shall be not less than ½ in. (12.7 mm) nominal in thickness, exterior or exposure 1 wood-based panel sheathing. The plywood shall be installed with a ⅛ in. (3.2 mm) space between sheets.

11.3.9 Oriented Strand Board (OSB) shall be nominal 7⁄16 in. (11.1 mm) thick APA Exposure 1 rated.

11.3.10 Fiber-cement sheets complying with Specification C 1186, Type A, shall be installed in accordance with the sheet manufacturer's written installation instructions, which include details of stud type and spacing, fastener type and spacing, and sheet spacing recommendations.

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11.3.11 Water-resistant exterior fiber-reinforced gypsum sheathing complying with Specification C 1278/C 1278M shall be installed in accordance with the sheathing manufacturer's written installation instructions, which include details of stud type and spacing, fastener type and spacing, and sheathing orientation and spacing.

11.3.12 Fiber-mat reinforced cement sheets complying with Specification C 1325, type A, shall be installed in accordance with the sheet manufacturer's written installation instructions, which include details of framing type and spacing, fastener type and spacing, and sheet orientation and spacing.

11.3.13 Sheathing shall be continuous.

11.4 *Alignment*—All substrate surfaces shall be straight and true within ¼ in. (6.4 mm) in 10 ft (3048 mm). More stringent requirements by the EIFS manufacturer shall supersede the above stated requirements.

11.5 *Suitability for Use*—The substrate surface shall be firm, sound, and undamaged in order to receive the Water-Resistive Barrier Coating or EIFS.

11.5.1 Loose, spalling or crumbling concrete or masonry shall be removed by sandblasting or other appropriate means. If the surface condition of the substrate is at all in doubt, an alternative attachment surface or method shall be provided.

11.5.2 Broken, cracked or delaminated substrate boards shall be replaced or restored to a condition equal to adjacent undamaged boards.

11.5.3 All rotted, decayed, or delaminated wood and plywood sheathing shall be replaced.

11.5.4 Paper-faced gypsum sheathing that has been installed and exposed to the elements for more than 30 days shall be checked at not less than two locations, or every 5000 ft^2 (465 m^2), whichever is greater, for integrity of the surface. The procedures for evaluating the gypsum sheathing are found in Annex A2.

NOTE 1—Gypsum sheathing conforming to Specification C 1396/C 1396M is sometimes not recommended for adhesive attachment by the gypsum sheathing manufacturer. Consult with the gypsum board manufacturer before use.

11.6 *Cleanliness*—The surface of all substrates shall be clean and free from any foreign materials such as paint, form release agents, curing compounds, dust, dirt, frost, oil or grease, efflorescence and laitance that would affect the EIFS or EIFS with Drainage application.

11.6.1 All sheathing board substrates shall have all loose dirt and dust removed by cleaning methods appropriate for the job and job conditions.

11.6.2 Efflorescence and laitance on concrete, masonry, stucco or clay tile substrates shall be removed prior to EIFS application. Concrete masonry shall be cleaned by light sandblasting, pressure washing, or brushing. Heavy deposits shall be removed through use of hand or power impact tools followed by washing with an appropriate cleaner. Light deposits shall be removed by washing with an appropriate cleaner. All loose particles and cleaner residue shall be removed by washing with clean, potable water. The surface shall be allowed to dry.

11.6.3 Existing paint on concrete or masonry surfaces shall be removed by sandblasting or grit blasting. If removal of existing paint is not practical, an alternate attachment surface or method shall be provided.

11.7 *Dryness*:

11.7.1 Newly constructed concrete or masonry surfaces shall be allowed to cure for a minimum of 28 days prior to application of the EIFS or EIFS with Drainage. Repaired areas on existing (aged) walls shall meet the same 28-day curing time.

11.7.2 Sheathing must be dry prior to EIFS or EIFS with Drainage application.

11.7.3 Substrate surfaces shall be free of visible water.

11.8 *Metal Lath*—If metal lath is used, it shall be installed in conformance with Specification C 1063, except lath edges shall be butted, not lapped. Metal lath shall be 3.4 lb/yd^2 (1.3 kg/m^2) or 2.5 lb/yd^2 (1.0 kg/m^2), self furring or flat, G 60 galvanized.

11.8.1 Metal members shall be properly attached, straight, and true unless required by the system design.

11.8.2 Metal members shall be free of rust, oil, or other foreign matter or contaminants, which cause bond failure or unsightly discoloration.

12. Water-Resistive Barrier (WRB) Coating (When Specified) (See Test Methods E 2570)

12.1 Manufacturer's Recommended Joint Treatment (not required with concrete or masonry substrates)

NOTE 2—Joint treatment materials and methods differ among manufacturers. Some manufacturers use self-adhesive membrane tapes and others use fluid-applied flexible coatings with embedded reinforcing mesh or fabric.

12.1.1 For sheathing substrates, apply manufacturer's recommended treatment along all joints in sheathing, inside and outside corners, and exposed edges of sheathing at terminations in accordance with manufacturers recommended details .

12.1.2 Center the treatment on sheathing joints, edges, etc. For self-adhesive membrane tapes and self-adhesive mesh, apply with the pressure-sensitive adhesive backing in contact with the sheathing surface.

12.1.3 When applicable, use a stainless steel trowel or spatula to apply water-resistive barrier coating over tape and spot all fastener heads. (Spotting of fasteners is not required when applying water-resistive barrier with a trowel.)

12.1.4 After the first pass has dried, check joints and spot any voids that may be present with additional coating to achieve a continuous film.

12.2 Water-Resistive Barrier Coating

12.2.1 Roller Application

12.2.1.1 Use a roller recommended by manufacturer.

12.2.1.2 Apply a uniform, continuous film of the water-resistive barrier coating over the entire surface of the sheathing, concrete, or masonry, including previously treated areas.

NOTE 3—For concrete and masonry ensure that a continuous film of uniform thickness is applied across the entire surface including mortar joints. Substrates with a surface texture or high porosity will require additional material.

12.2.2 Trowel Application

12.2.2.1 Using a stainless steel trowel, apply a continuous film of the water-resistive barrier coating onto the entire wall

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surface. The material shall be applied at a smooth, uniform, continuous film at the coverage rate specified by the manufacturer.

12.2.3 Spray Application

12.2.3.1 Using a handheld hopper gun or other suitable spray equipment, spray a layer of water-resistive barrier coating onto the wall surface.

12.2.3.2 In order to create a smooth continuous film, use a roller as described in 12.2.1 when specified by the manufacturer.

13. Drainage Means (If Applicable)

13.1 EIFS with Drainage require a means of drainage. This can be accomplished by one of the following methods; vertical notch trowel adhesive application, grooved insulation board, drainage mat, sheet type water-resistive barriers designed for drainage, metallic lath or non-metallic lath.

13.2 The EIFS shall be installed such that EIFS components, including sealants and flashings, do not hinder the drainage capability of the EIFS.

14. Insulation Board Installation

14.1 Method of attachment shall be approved by the system manufacturer.

14.2 *Adhesive Attachment Method*—The adhesive shall be applied to the back of the insulation board by one of the following methods:

14.2.1 *Notched Trowel (Required when Installing EIFS over Sheathing Substrates)*:

14.2.1.1 For EIFS with Drainage the notches shall be oriented vertically when using adhesive as the means to create the drainage plane. Refer to EIFS manufacturer for proper size of notch trowel and applications over lath.

14.2.2 *Ribbon and Dab (Acceptable over Concrete and Masonry)*:

14.2.2.1 The adhesive shall be applied to the entire perimeter of the insulation board in a ribbon fashion that is not less than 2 in. (50.8 mm) wide by not less than ⅜ in. (9.5 mm) thick. Dabs not less than 4 in. (101.6 mm) in diameter by not less than ⅜ in. (9.5 mm) thick shall be applied not more than 8 in. (203.2 mm) on center over the remainder of the board. Refer to EIFS manufacturer for applications over lath.

15. Adhesive and Mechanical Attachment Method

15.1 Adhesive shall be applied using the ribbon and dab method, the notched trowel method, or in accordance with system manufacturer's current published instructions.

15.2 Mechanical fasteners shall be installed into the framing or nailable substrate.

15.3 Fasteners shall penetrate not less than 5⁄16 in. (8.0 mm) into steel framing members, 1 in. (25 mm) into wood framing members, and 1 in. (25.4 mm) into masonry substrates.

15.4 Mechanical fasteners shall be corrosion resistant. Fastener type and spacing shall be in accordance with system manufacturer's current published instructions.

15.5 Selection and frequency of fasteners and fastener type will vary depending on substrate type, insulation board thickness and design wind load and whether used in combination with an adhesive attachment. Therefore fastener type, patterns, and use shall be in accordance with the EIFS manufacturer's written instructions and shall be included in the project plans and specifications.

16. Mechanical Attachment Method

16.1 Mechanical fasteners shall be installed into the framing or nailable substrate.

16.2 Mechanical fasteners shall be corrosion resistant. Fastener type and spacing shall be in accordance with the EIFS manufacturer's current published instructions.

NOTE 4—Wind-load requirements shall be considered for mechanically fastened systems.

17. General Requirements

17.1 Insulation boards shall be placed from a level base line with vertical joints staggered in a running bond pattern and butted tightly.

17.2 Insulation board joints at all inside and outside corners shall be staggered and interlocked.

17.3 Insulation boards must abut without gaps, eliminating space for adhesive or base coat intrusion between the board edges and ends.

17.4 Fenestration openings and other wall openings shall be cut out of a single insulation board. Board joints shall not be aligned at corners with head, sill or jambs of windows, doors, similar openings, and aesthetic reveals.

17.5 *Adhesively Attached*:

17.5.1 The final insulation board thickness shall be not less than ¾ in. (19.1 mm).

17.5.2 Insulation board joints shall be offset not less than 6 in. (152.4 mm) from horizontal sheathing board joints.

17.6 *Mechanically Fastened*:

17.6.1 The insulation board thickness shall be not less than ½ in. (38.1 mm).

17.6.2 Insulation board joints shall be offset from horizontal sheathing board joints.

17.7 When attachment is by adhesive or adhesive and mechanical fasteners, each insulation board shall be installed by sliding it into place until it abuts the adjoining insulation board tightly. Pressure shall be applied over the entire surface of the insulation board to achieve uniform contact and an overall level surface. The insulation board shall be occasionally checked for proper contact with the substrate by removing a piece of insulation board. Proper contact has been achieved when approximately equal portions of the adhesive remain on both the substrate and the insulation board when the board is removed from the wall. The insulation board shall remain undisturbed for no less than 24 h prior to proceeding with the installation of mechanical fasteners or the base coat. Cool, damp weather conditions extend minimum curing or drying time.

17.8 When the boards are attached only with mechanical fasteners, they shall be affixed to a nailable substrate or structural members with the proper fasteners, ensuring that all insulation boards abut tightly. Fastening patterns shall be in accordance with the EIFS manufacturer's recommendation.

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When installed, the portion of the fastener left flush with the face of the insulation board shall not fracture the insulation board.

18. Aesthetic Reveals

18.1 Aesthetic reveals shall be cut into the insulation board prior to applying the reinforcing mesh.

18.2 The insulation board thickness in the bottom of a reveal shall be not less than ¾ in. (19.1 mm).

18.3 Aesthetic reveals shall be cut true and straight.

18.4 Horizontal aesthetic reveal configuration shall provide for outward positive drainage.

18.5 Aesthetic reveals shall not occur at the abutment of two pieces of insulation board.

18.6 The reveal shall be reinforced with base coat and reinforcing mesh prior to application of the full base coat and reinforcing mesh.

19. Reinforced Base Coat Application

19.1 Inspect the insulation board surface to ensure that it is clean, dry, free of all foreign materials, and damage of any type. Insulation board planar irregularities of more than 1/16 in. (1.6 mm) shall be corrected. All board joints shall be tightly abutted or shall be filled with an insulating material. The entire wall area shall be sanded or rasped to minimize any irregularities.

19.2 *Base Coat Preparation*—All materials requiring field preparation shall be mixed in accordance with the EIFS manufacturer's specifications.

19.3 *Base Coat Application*—The prepared base coat shall be uniformly spread over the entire surface of the insulation board.

19.4 *Nonmetallic Reinforcing Mesh*—The single layer reinforcing mesh shall be fully embedded in wet base coat in the field of the wall, at corners, edges, and joints. While the base coat is wet, trowel from the center to the edge of the reinforcing mesh to avoid wrinkles. Mesh shall not be installed before base coat. The single layer of reinforcing mesh shall be continuous at all corners.

19.4.1 The surface shall be free of voids, projections, trowel marks and other surface irregularities. The base coat thickness shall be sufficient to totally embed the reinforcing mesh.

19.5 *Reinforcing Mesh Overlap*—All reinforcing mesh edges shall be overlapped not less than 2½ in. (63.5 mm).

19.6 *Impact Layers*—When required, higher impact performance shall be achieved with multiple layers of reinforcing mesh or by incorporating heavier weight reinforcing mesh. All areas requiring higher impact performance shall be detailed on the project plans and specifications. When overlapping of high impact mesh is not required, a complete second layer of reinforcing mesh shall be applied over the layer of high impact mesh.

19.7 *Corners*—Reinforcing mesh shall not be lapped within 8 in. (203.2 mm) of any corner. Double wrap the mesh 8 in. (203.2 mm) onto each side of the building's interior and exterior corners, not including small openings such as doors and windows.

19.8 *Wall Penetrations*—All edges of the insulation board at penetrations of the EIFS, such as at windows, doors, HVAC, pipes, ducts, electrical boxes, and at the base of the wall shall be wrapped with either the base coat and reinforcing mesh or trim, or as specified by the EIFS manufacturer. Wall openings such as doors, windows, and HVAC sleeves shall be diagonally reinforced at corners with mesh not less than 9 in. (228.6 mm) by 12 in. (304.8 mm).

19.8.1 The corners of returns to windows, doors, and similar wall openings shall have reinforcing mesh the full width of the return and extending not less than 2½ in. (63.5 mm) on both sides of the corner.

19.9 *Expansion Joints*—All edges of the insulation board at expansion joints shall be wrapped with either the base coat and reinforcing mesh or trim as specified by the EIFS manufacturer for the particular EIFS or EIFS with Drainage. The reinforcing mesh shall be fully embedded in the base coat material.

19.10 *Aesthetic Reveal*—The reinforcing mesh shall be continuous and care shall be taken to ensure that the reinforcing mesh is fully embedded in the base coat material at the base of the reveal and that the reinforcing mesh shall not be cut during application of the base coat.

19.11 *Reinforced Base Coat*—The reinforcing mesh shall be fully embedded in the base coat material throughout the field of the wall, at corners, edges, and joints. The surface shall be free of voids, projections, trowel marks and other surface irregularities.

19.12 *Special Insulation Shapes*—Nonmetallic reinforcing mesh embedded in the base coat material shall be used over specially shaped insulation board.

NOTE 5—Materials other than specified by EIFS manufacturer are not acceptable.

20. Finish Coat Application

20.1 The reinforced base coat shall be allowed to dry and harden for not less than 24 h prior to finish coat application, unless specifically allowed by the EIFS manufacturer.

20.2 *Material Preparation*—The finish coat shall be mixed in accordance with the EIFS manufacturer's specifications. Only clean potable water shall be added to adjust workability. Always add the same amount of water to each container within a given lot of finish.

20.3 *Execution*—Finish shall be applied with a stainless steel trowel or appropriate equipment as specified by the EIFS manufacturer. Tools and equipment shall be kept clean at all times. Finish shall be applied continuously to a natural break such as corners, joints or tape line. Apply finish to the base coat maintaining a wet edge. Sufficient manpower and scaffolding shall be provided to continuously finish a distinct wall area. Scaffolding shall be spaced a distance from the wall, consistent with safety standards, that will allow uniform texturing of the finish without staging marks. On hot windy days, misting is permitted with clean, potable water to cool the wall. Work shall precede the sun whenever possible. Water shall not be added to the finish once it is applied to the wall. Use the same tool and hand motion and match the texture of the surrounding area. The finish coat thickness shall be as specified by the EIFS manufacturer. Protect all finish work from damage until fully dried.

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20.4 *Joints*—The application of finish into the joints shall be consistent with the EIFS manufacturer's recommendations and job conditions.

20.5 *Sealant Joints*—The application of finish into the sealant joint is not allowed.

21. Curing Time Between Application Steps

21.1 Manufacturer's recommendations for climatic conditions, mixing, and application practices shall be followed to allow respective coats sufficient time to cure or dry before any subsequent coats are applied. Each application step shall be permitted to cure or dry to prevent degradation to the system integrity with subsequent steps.

21.2 Auxiliary protection (tenting, supplemental heat, shading) from adverse environmental conditions shall be utilized to minimize deviations from standard, expected cure or dry times. (See Annex A1.9.3.)

21.3 All substrates shall be sound and cured or dry before continuing on to the next application step.

22. Cleanup

22.1 Adjacent materials, surfaces, and the work area shall be cleaned of foreign materials resulting from the work.

22.2 All excess EIFS materials shall be removed from the job site.

23. Keywords

23.1 Class PB; coating; drainage; EIFS; exterior insulation and finish system; water-resistive barrier; WRB

ANNEXES

(Mandatory Information)

A1. GENERAL INFORMATION

A1.1 *General:*

A1.1.1 The work includes all labor, materials, services, equipment and scaffolding required to complete the EIFS or EIFS with Drainage installation on the project in accordance with the project drawings and specifications, except electrical power and potable water.

A1.1.2 Where a specific fire resistance rating is required for the EIFS or EIFS with Drainage assemblies and construction, details of construction shall be in accordance with official reports of tests conducted by recognized testing laboratories and a part of approved plans and specifications.

A1.1.3 The installation of the EIFS or EIFS with Drainage is to be coordinated by the owner's authorized agent with work of other trades.

A1.1.4 Surfaces and accessories to receive EIFS or EIFS with Drainage components shall be examined and accepted as provided in 11.2 before the EIFS or EIFS with Drainage components are installed thereto. The proper authorities shall be notified about unacceptable conditions. The unsatisfactory conditions shall be corrected prior to the application of the EIFS or EIFS with Drainage components. Unsatisfactory conditions shall be corrected by the party or parties responsible for such conditions.

A1.1.5 The construction specifier shall describe, in the proper section of the project specifications, the physical characteristics of the surfaces to receive the EIFS or EIFS with Drainage.

A1.2 *Design Considerations:*

A1.2.1 EIFS or EIFS with Drainage are attached to outside surfaces of all types of structures to provide weather resistant, energy efficient, and durable claddings. The claddings will be subjected to various exposures such as abrasion, vibration, moisture, freezing, thawing, negative and positive wind loading, ultraviolet light, acid rain, thermally induced expansion and contraction, and impact.

A1.2.2 Provide sufficient slope on faces of EIFS or EIFS with Drainage surfaces to prevent water, snow or ice from accumulating or standing. A minimum 6 in. (152.4 mm) in 12 in. (304.8 mm) (1:2) pitch is recommended. Length of sloped surfaces shall not be more than 12 in. (304.8 mm).

A1.2.3 Provide parapet cap made only from corrosion resistant materials. The parapet cap shall extend not less than 2½ in. (63.5 mm) over the faces of the EIFS or EIFS with Drainage, not including wood blocking and shall include a drip edge detail. Detailed requirements for furnishing and installing the parapet cap shall be in the appropriate section of the project specifications. Parapet caps shall be clearly shown in large scale details. Parapet caps shall be installed as soon as practical after the installation of the EIFS or EIFS with Drainage.

A1.2.4 Provide for sealing of expansion joints, panel joints, system terminations and all interfaces of the EIFS or EIFS with Drainage with other building components.

A1.2.5 At soffits, window and door heads provide for a drip edge.

A1.2.6 Windows installed in EIFS or EIFS with Drainage walls shall have metal sill flashing.

A1.2.7 The specifier shall evaluate the potential of the EIFS or EIFS with Drainage surface being subjected to abnormal stresses or impacts.

A1.2.8 Wall assemblies have properties that in certain applications make a dew point analysis critical to ensure successful performance of the wall system. The specifier shall evaluate these conditions.

A1.2.9 Sheathing must be continuous over floor slabs, intersecting walls, columns, beams and similar constructions.

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The EIFS or EIFS with Drainage shall not be installed over areas without sheathing. If the sheathing cannot be continuous, the installation of expansion joints shall be considered.

A1.2.10 Where the sheathing is interrupted or out of plane, corrections must be made prior to EIFS or EIFS with Drainage application.

A1.2.11 A water-resistive barrier and flashing may be required as specified in moist and water sensitive applications. The EIFS manufacturer, design professional, and specifier shall evaluate the conditions and the need.

A1.2.12 Refer to EIFS manufacturer for appropriate drainage means and method of installation.

A1.3 *Relief from Stress:*

A1.3.1 Where the EIFS or EIFS with Drainage and dissimilar types of substrates, materials and building components interface, provide for appropriate size and location of expansion joints.

A1.3.2 Where roof elevations change, provide for appropriate size and location of expansion joints.

A1.4 *Bonding Agents:*

A1.4.1 Bonding compounds or agents are sometimes applied to a substrate surface to receive the adhesive. Follow the EIFS manufacturer's instructions and specifications for their use.

A1.5 *Adhesives:*

A1.5.1 The types of adhesives and the methods of installation used will vary depending on the substrate to which the insulation boards will be attached. Therefore, the adhesive type and application method used shall be in accordance with the EIFS manufacturer's written instructions.

A1.6 *Mechanical Fasteners:*

A1.6.1 The types of mechanical fasteners used and the methods of installation will vary depending on the substrate to which the insulation boards are to be fastened.

A1.6.2 Fastener washers shall be installed flush with the insulation board surface.

A1.6.3 Fastener spacing shall be specified by the design professional consistent with wind load requirements on the specific project.

A1.7 *Reinforced Base Coats:*

A1.7.1 Base coat thickness is a function of various conditioins including the thickness of the reinforcing mesh, application techniques, and base coat properties.

A1.7.2 A small amount of base coat shrinkage is normal. Due to color variations, it shall not be unusual to see a very slight telegraphing of the reinforcing mesh pattern after the base coat cures. Bare mesh shall not be visible and the mesh pattern shall not be tactile.

A1.7.3 The EIFS manufacturer's instructions shall be followed to ensure that the base coat and cement is properly proportioned. The proper portioning of cement based material is important. Excess cement may cause the base coat to become hard and stiff as the cement hydrates over time.

A1.7.4 The minimum amount of water to form a workable mix shall be used. Excess water will cause the base coat to be porous and less weather resistant. Never add more water than recommended by the EIFS manufacturer. Measure water in containers of known volume.

A1.7.5 Mix materials only at low speed with paddles designed to reduce air entrapment.

A1.7.6 EIFS manufacturer's recommendations for climatic conditions, mixing and application practices to allow respective coats sufficient time to cure or dry before any subsequent coats are applied shall be followed. Each application step shall be cured or dried to prevent degradation to the system integrity with subsequent steps.

A1.7.7 Trowel aesthetic reveals and corners with a trowel shaped to fit the profiles.

A1.8 *Finish Textures:*

A1.8.1 Textures, as a description of surface appearance, generally are identified with the method and tools used to achieve the finish appearance. Texture is sometimes varied by the size and shape of the aggregate contained in the finish, equipment or tools employed, the consistency of the finish mix, the condition of the base to which it is applied and by decorative and protective treatments.

A1.8.2 With almost limitless variations possible for finish appearance or texture, the same term sometimes does not have the same meaning to the specifier, contractor or applicator. Sample panels of sufficient size including components and features specified shall be constructed using the methods, tools and techniques to be used in the actual construction. It is recommended that in the case of prefabrication, two panels be constructed. One panel remains at the jobsite. One panel remains at the fabrication site. The samples shall be approved by the architect and owner in writing.

A1.8.3 To provide some guidance, the following categories are generally understood and recognized to imply a particular method of application or finished appearance.

A1.8.3.1 *Sand Finish*—A finish material devoid of coarse aggregate applied in a thin coat completely covering the base coat and floated to a true plane, yielding a relatively fine-textured finish.

A1.8.3.2 *Trowel Texture*—A freshly applied finish is given various textures, designs or stippled effects by hand motion and trowel used. The effects achieved are individualized and it is sometimes difficult for different applicators to duplicate.

A1.8.3.3 *Standard Finish*—A finish with various size aggregates, applied in a thin coat completely covering the base coat and floated in a random pattern. The applicators are cautioned to use the same type texturing tools to help ensure a consistent texture.

A1.8.3.4 *Exposed Aggregate*—Varying sizes of natural or manufactured stone, gravel, shell or ceramic aggregates are embedded by hand or by machine propulsion into a freshly applied "bed coat." The size of the aggregate shall not be more than ½ in. (12.7 mm) in diameter. The size of the aggregate determines the thickness of the bedding coat. The bedding coat shall be no less than one-half the thickness of the aggregate to be embedded.

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A1.8.3.5 *Spray Texture*—A machine applied finish material. The texture achieved depends on many factors some of which are the consistency of the sprayed mixture, the angle and distance of the spray nozzle to the surface, the pressure of the machine, orifice size used, operator expertise, climatic conditions (wind specifically), and base coat conditions.

A1.8.3.6 *Miscellaneous Types*—Similar to trowel textures except that the freshly applied finish is textured with instruments other than a trowel, such as swept with a broom or brush, or corrugated by raking or combing. A variation of texturing a finish involves waiting until the applied finish has partially dried and then lightly troweling the unevenly applied finish. The effects achieved are sometimes difficult for different applicators to duplicate.

A1.9 *Conditions for EIFS Application:*

A1.9.1 The amount of water used to mix materials is to be within the allowable range published by the EIFS manufacturer. Factors such as the drying conditions and finishing operations must be considered in determining water usage. The applicator is cautioned that the use of excessive water results in fall off or slide off, excessive shrinkage, higher porosity, lower strength, and inconsistent color.

A1.9.2 Timing between coats will vary with climatic conditions and types of materials used. Temperature and relative humidity extend or reduce the curing and drying time. Cold or wet weather lengthens, and hot or dry weather shortens the drying period. Moderate changes in temperature and relative humidity are overcome by providing additional heating during cold weather and by pre-wetting the base during hot, dry weather.

A1.9.3 Heated enclosures require adequate air circulation to prevent hot or cold spots that allow too rapid drying or freezing. When using heated enclosures it is important to control the relative humidity as well as the temperature. Maintain relative humidity at not more than 90 %.

A1.9.4 Staining and discoloration of finishes or other building components that are caused by free water draining from one plane to another, dissimilar materials, or other building components, are minimized by providing sufficient depth and angle for drip caps and drip edges.

A2. EVALUATION OF PAPER-FACED GYPSUM SHEATHING FOR SURFACE ACCEPTABILITY

A2.1 The following procedure is valid only if, at the time of the test, the gypsum sheathing has not been wetted or exposed to high humidity in the previous 24 h.

A2.2 Using a sharp knife or razor blade, cut a 3-in. (76.2-mm) long diagonal in the middle of the gypsum sheathing. The cut must be sufficient to cut through the paper face and just into the underlying gypsum. Make a 3-in. (76.2-mm) cut at a right angle to the first, forming an “X”.

A2.3 Using the sharp edge of the cutting tool, peel the paper face (in one quadrant) back approximately ¼ in. (6.4 mm) from the intersection of the two lines.

A2.4 Firmly holding this peeled edge between the thumb and forefinger, lift the paper face and continue removing the facing material.

A2.5 If the paper splits cohesively so that part is still adhering to the underlying gypsum, the gypsum sheathing has not been overly exposed to the weather or moisture. If the paper lifts and directly exposes the gypsum, the gypsum sheathing has been exposed to the weather beyond the required limit and shall be replaced.

A3. SEALANT SYSTEMS

A3.1 The size and location of joints and selection of the sealant to be used is the responsibility of the design professional and shall be consistent with project conditions and guidelines of the EIFS manufacturer. See Guide C 1472 for guidance.

A3.2 The sealant system must be tested for compatibility with the specified EIFS or EIFS with Drainage by an independent laboratory and found to be compatible with the EIFS or EIFS with Dranage. See Test Method C 1382 for guidance.

A3.3 The sealant system is recommended by the EIFS and sealant manufacturer. Non-recommended sealant systems must be jointly approved by the design professional and the sealant manufacturer.

A3.4 Base the joint design and surface preparation on the sealant manufacturer’s recommendations and project conditions. See Guide C 1481 for guidance.

A3.5 Allow the EIFS material to cure prior to sealant system installation.

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SUMMARY OF CHANGES

Committee C11 has identified the location of selected changes to this practice since the last issue, C 1397 – 05, that may impact the use of this practice. (Approved July 15, 2009)

(*1*) Revised the standard throughout, including the title, to include EIFS with Drainage.

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Designation: C 1398 – 07

Standard Test Method for The Laboratory Determination of the Time of Setting of Hydraulic-Cement Mortars Containing Additives for Shotcrete by the Use of Gillmore Needles[1]

This standard is issued under the fixed designation C 1398; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope*

1.1 This is a laboratory test method that covers the determination of the time of setting of hydraulic–cement mortars containing additives for shotcrete for comparison with control mixes containing no additives or to compare the performance of shotcrete mixtures which contain additives that produce rapid setting or rapid stiffening of shotcrete.

1.2 The values stated in SI units (see IEEE/ASTM SI 10) are the standard.

1.3 *This standard may involve hazardous materials, operations, and equipment. This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

2. Referenced Documents

2.1 *ASTM Standards:* [2]

C 125 Terminology Relating to Concrete and Concrete Aggregates
C 150 Specification for Portland Cement
C 185 Test Method for Air Content of Hydraulic Cement Mortar
C 266 Test Method for Time of Setting of Hydraulic-Cement Paste by Gillmore Needles
C 305 Practice for Mechanical Mixing of Hydraulic Cement Pastes and Mortars of Plastic Consistency
C 490 Practice for Use of Apparatus for the Determination of Length Change of Hardened Cement Paste, Mortar, and Concrete
C 778 Specification for Standard Sand
C 1005 Specification for Reference Masses and Devices for Determining Mass and Volume for Use in the Physical Testing of Hydraulic Cements
C 1141 Specification for Admixtures for Shotcrete
D 1193 Specification for Reagent Water
IEEE/ASTM SI 10 Standard for Use of the International System of Units (SI): The Modern Metric System

3. Terminology

3.1 *Definitions*:

3.1.1 For definitions of terms used in this test method, refer to Terminology C 125.

4. Summary of Test Method

4.1 A mortar consisting of the sand, hydraulic cement, and water to be tested is proportioned by mass. The appropriate admixture or admixtures are added and a specimen is prepared from the mortar and tested for time of setting by means of Gillmore initial and final needles. A time of setting determination is then made for initial and final time of setting for each specimen. The time of setting shall be compared to a treated control mixture to demonstrate the effect of the admixture if such a comparison is the purpose of the study.

5. Significance and Use

5.1 The performance of an admixture for shotcrete in the field varies with the composition of the hydraulic cement and sand combination. Since this test method involves the determination of time of setting of a particular combination of hydraulic cement, sand and an admixture, it therefore provides information on the suitability for use of that particular combination in the field.

5.2 The time of setting of the combination established in the laboratory does not necessarily indicate the time of setting this combination will produce in actual shotcreting in the field.

5.3 This method is used to determine the effect on time of setting of mortars containing admixtures as compared to a control mortar.

5.4 The test method is used for comparison in laboratory pre–evaluation studies to demonstrate the effect of shotcrete admixtures in mortar compared with plain mortar and can be

[1] This practice is under the jurisdiction of ASTM Committee C09 on Concrete and Concrete Aggregates and is the direct responsibility of Subcommittee C09.46 on Shotcrete.

Current edition approved July 15, 2007. Published August 2007. Originally approved in 1998. Last previous edition approved in 1998 as C 1398-98ε1.

[2] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

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used to demonstrate or compare the performance of shotcrete admixtures which produce rapid setting or rapid rheological stiffening of shotcrete.

5.5 The test method is used to evaluate the relative performance of more than one shotcrete admixture for comparison of performance.

5.6 The test method is used to determine or verify that no adverse effects on setting time may be experienced with the use of admixtures that are not intended to accelerate or are used to produce stiffening of shotcrete mixtures.

5.7 Although specific environmental conditions are indicated, the testing environment can be varied to simulate the performance of admixtures in mortars at different temperatures. Such variations are reported as indicated in Section 11.

6. Apparatus

6.1 *Trowel*, having a steel blade 100 to 150 mm in length with a straight edge.

6.2 *Mixer, Bowl, Paddle with Scraper*, shall conform to the requirements of Practice C 305.

6.3 *Glass Graduates*, shall conform to the requirements of Practice C 490.

6.4 *Scales and Weights*, shall conform to the requirements of Specification C 1005.

6.5 *Disposable, Round, Plastic Petri Dishes*, 15 mm by 100 mm.

6.6 *Gillmore Needles*, shall conform to the requirements of Test Method C 266.

6.7 *Spoon*—a metal restaurant spoon as described in Test Method C 185.

6.8 *Stopwatch*.

7. Materials

7.1 *Mixing Water*— Potable water is satisfactory for routine tests. For referee and cooperative tests, use reagent water conforming to the requirements for Type II or Type IV of Specification D 1193.

7.2 *Fine Aggregate*. Use 20-30 sand in conformance with the requirements of Specification C 778.

7.3 *Portland cement* conforming to the requirements of Specification C 150.

7.4 *Accelerating shotcrete*, admixtures conforming to the requirements of Specification C 1141.

8. Conditioning

8.1 The temperature of the room, dry materials, paddle, bowl, and disposable plastic petri dishes shall be maintained between 20 and 28 °C . The temperature of the mixing water shall not vary from 23 ± 2 °C.

8.2 The relative humidity of the laboratory shall be 50 % ± 5 %.

8.3 The test area shall be free of airflow and drafts.

9. Mixing Procedure – Dry-Mix Shotcrete

9.1 *Preparation of the control mortar*—Proportion 200 g of cement, 400 g of standard 20–30 sand, with 70 mL (w/c = 0.35) water following the mixing procedure for cement mortars described in 9.2 except without the addition of admixture.

9.2 *Preparation of Mortar Containing Admixtures*:

9.2.1 *Mortar with non–liquid*—Proportion the sand and cement as in 9.1. Add the prescribed amount of non-liquid admixture to the mixing bowl with the dry sand and cement.

9.2.2 *Mortar with liquid admixtures*—Proportion the sand and cement as in 9.1 adding the mixture to the mixing bowl. Add mixing water to the prescribed amount of admixture to obtain a volume of 70 mL. This solution is added to the mortar as described in 9.3.3.

9.3 *Mixing of Mortar*— The mixing shall be done in the mechanical mixer as follows:

9.3.1 Place the appropriate dry materials in the mixing bowls, as in 9.2.1 or 9.2.2 and hand mix them with a spoon until a homogeneous mixture is achieved.

9.3.2 Position the bowl in the mixer and set the paddle in place.

9.3.3 With the mixer operating at medium speed, add 70 mL of mixing water to the non-liquid admixture as in 9.2.1 or 70 mL of mixing water and liquid admixture as in 9.2.2, start the stopwatch when the water contacts the dry mixture in the bowl. Mix for 10s.

9.4 *Preparation of Test Specimens*:

9.4.1 Stop the mixer and immediately remove the bowl from the mixer. With a spoon, quickly fill the plastic petri dish, and with the trowel, using the flat surface, cover three quarters of the dish surface and press straight down forcing the excess out of the remaining uncovered quarter. Draw the straight edge of the trowel across the surface in one motion.

10. Mixing Procedure – Wet–Mix Shotcrete

10.1 *Preparation of control mortar*—mix 200 g of cement and 400 g of standard 20–30 sand, with 70 mL of water (w/c = 0.35) following the mixing procedure for cement mortars described in 10.2 except without the addition of admixture.

10.2 *Preparation of Mortar Containing Admixtures*—Use a mechanical mixer as follows,

10.2.1 Place the sand and cement in the dry bowl, and hand mix the material with a spoon for a few seconds or until a homogeneous mixture is produced.

10.2.2 Position the bowl in the mixer, and set the paddle in place.

10.2.3 With the mixer operating at a slow speed add the entire quantity of mixing water within 15 s and continue mixing for 1 min, starting the stopwatch and timing from the first addition of water.

10.2.4 Stop the mixer, quickly scrape down the sides of the mixing bowl with the rubber scraper. Restart the mixer and mix for 15 s.

10.2.5 Stop the mixer, change to a medium speed. Start the mixer and quickly add the specified amount of admixture, continue mixing the mortar for 10 s.

10.3 Preparation of Test Specimens

10.3.1 Stop the mixer and immediately remove the bowl from the mixer. With a spoon, quickly fill the plastic petri dish, and with a trowel using the flat surface, cover three quarters of the dish surface and press straight down forcing the excess out of the remaining uncovered quarter. Draw the straight edge of the trowel across the surface in one motion.

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11. Time of Setting Determination

11.1 After filling the plastic petri dish, immediately place the initial Gillmore needle in contact with surface of the mortar near the center of the dish. Release the needle. The mortar has reached time of setting when the surface will bear, without appreciable indentation, the initial Gillmore needle. The difference in hours, minutes, and seconds between the time of contact of the mortar with the liquid admixture, and the time at which the initial Gillmore needle makes no appreciable indentation is the initial time of setting.

11.2 Use the final Gillmore needle to determine the final time of setting, following the same procedure. For dry-mix shotcrete, the difference in hours, minutes, and seconds between the time of contact of the mortar and mixing water, and the time at which the final Gillmore needle makes no appreciable indentation is the final time of setting. For wet–mix shotcrete, the difference, in hours, minutes, and seconds between the time of contact of the mortar with the added liquid admixture, and the time at which the final Gillmore needle makes no appreciable indentation is the final time of setting

NOTE 1—When using admixtures that cause rapid rheological stiffening, prolonging the time of mixing or, not starting the Gillmore needle testing immediately may result in erroneous results in the determination of initial time of setting.

12. Report

12.1 Report the following information:

12.1.1 The times of initial and final setting in hours, minutes, and seconds for both the control specimen and specimen that was treated with admixtures if desired,

12.1.2 Brand and type of cement,

12.1.3 Brand and type of admixture,

12.1.4 Admixture dose,

12.1.5 Mix Temperature,

12.1.6 Room Temperature, and

12.1.7 Room Humidity.

13. Precision and Bias

13.1 It is not practical to specify the precision of this test method for measuring time of setting because test data are unavailable. A statement will be included at such time that sufficient test data have been obtained and analyzed.

13.2 The procedure in this test method has no bias because the value of time of setting of mortars is defined in terms of this test method.

14. Keywords

14.1 admixture; dry–mix shotcrete; mortar; quick—setting accelerating admixture; shotcrete; time of setting; wet-mix shotcrete

SUMMARY OF CHANGES

Committee C09 has identified the location of selected changes to this test method since the last issue, C 1398 – 98$^{\epsilon 1}$, that may impact the use of this test method. (Approved July 15, 2007)

(*1*) Added terminology section and renumbered subsequent sections.

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Designation: C1399/C1399M – 10

Standard Test Method for Obtaining Average Residual-Strength of Fiber-Reinforced Concrete[1]

This standard is issued under the fixed designation C1399/C1399M; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope*

1.1 This test method covers the determination of residual strength of a fiber–reinforced concrete test beam. The average residual strength is computed using specified beam deflections that are obtained from a beam that has been cracked in a standard manner. The test provides data needed to obtain that portion of the load–deflection curve beyond which a significant amount of cracking damage has occurred and it provides a measure of post–cracking strength, as such strength is affected by the use of fiber–reinforcement.

1.2 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

1.3 The values stated in either SI units or inch-pound units are to be regarded separately as standard. The values stated in each system may not be exact equivalents; therefore, each system shall be used independently of the other. Combining values from the two systems may result in non-conformance with the standard.

2. Referenced Documents

2.1 *ASTM Standards:*[2]

C31/C31M Practice for Making and Curing Concrete Test Specimens in the Field

C42/C42M Test Method for Obtaining and Testing Drilled Cores and Sawed Beams of Concrete

C78 Test Method for Flexural Strength of Concrete (Using Simple Beam with Third-Point Loading)

C172 Practice for Sampling Freshly Mixed Concrete

C192/C192M Practice for Making and Curing Concrete Test Specimens in the Laboratory

C823 Practice for Examination and Sampling of Hardened Concrete in Constructions

C1609/C1609M Test Method for Flexural Performance of Fiber-Reinforced Concrete (Using Beam With Third-Point Loading)

3. Terminology

3.1 *Definitions of Terms Specific to This Standard:*

3.1.1 *deflection*—mid–span deflection of the test beam obtained in a manner that excludes deflection caused by the following: (*1*) the flexural test apparatus, (*2*) crushing and seating of the beam at support contact points, and (*3*) torsion of the beam; sometimes termed net deflection.

3.1.2 *initial loading curve*—the load–deflection curve obtained by testing an assembly that includes both the test beam and a specified steel plate (Fig. 1); plotted to a deflection of at least 0.20 mm [0.008 in.] (Fig. 2).

3.1.3 *reloading curve*—the load–deflection curve obtained by reloading and retesting the pre-cracked beam, that is, after the initial loading but without the steel plate. (Fig. 2)

3.1.4 *reloading deflection*—deflection measured during the reloading of the cracked beam and with zero deflection referenced to the start of the reloading.

3.1.5 *residual strength*—the flexural stress on the cracked beam section obtained by calculation using loads obtained from the reloading curve at specified deflection values (See Note 1).

NOTE 1—Residual strength is not a true stress but an engineering stress computed using the flexure formula for linear elastic materials and gross (uncracked) section properties.

3.1.6 *average residual strength*—the average stress–carrying ability of the cracked beam that is obtained by calculation using the residual strength at four specified deflections.

4. Summary of Test Method

4.1 Cast or sawed beams of fiber–reinforced concrete are cracked using the third–point loading apparatus specified in Test Method C78 modified by a steel plate used to assist in support of the concrete beam during an initial loading cycle

[1] This test method is under the jurisdiction of ASTM Committee C09 on Concrete and Concrete Aggregates and is the direct responsibility of Subcommittee C09.42 on Fiber-Reinforced Concrete.

Current edition approved Jan. 1, 2010. Published February 2010. Originally approved in 1998. Last previous edition approved in 2007 as C1399–07a. DOI: 10.1520/C1399_C1399M-10.

[2] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

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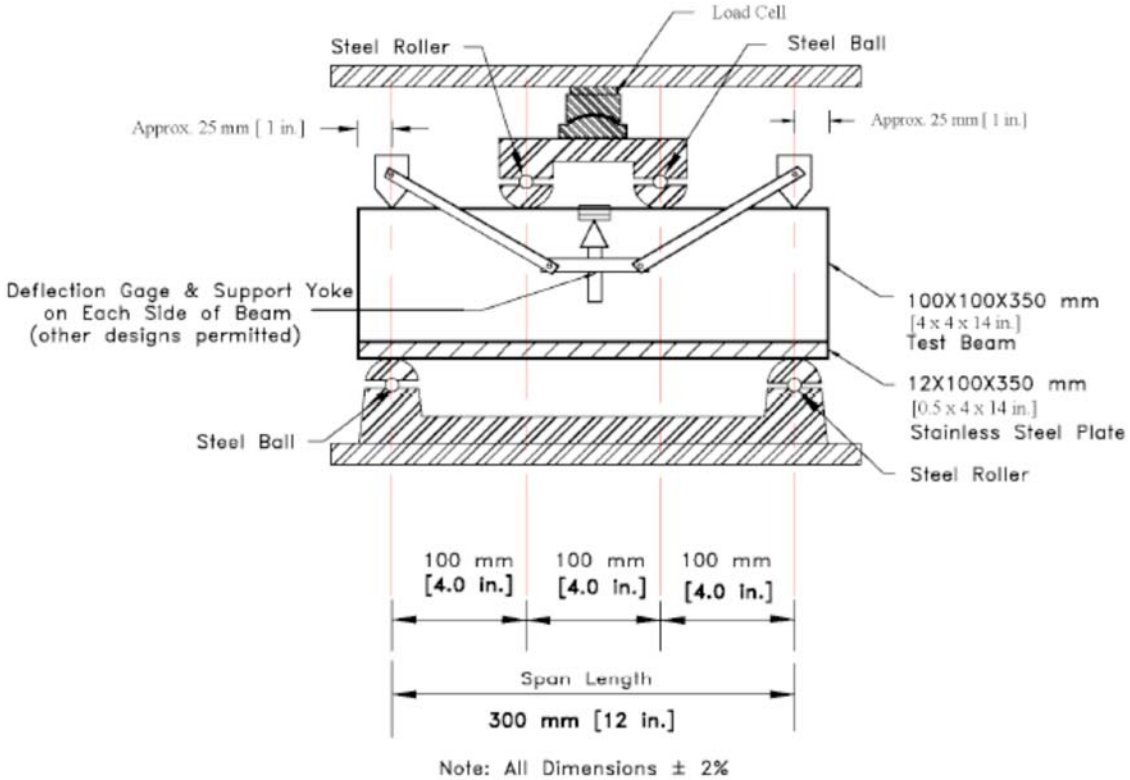

FIG. 1 Schematic of a Suitable Apparatus Where the Deflection Gauge Support Frame is Seated on the Beam

(Fig. 1). The steel plate is used to help control the rate of deflection when the beam cracks. After the beam has been cracked in the specified manner, the steel plate is removed and the cracked beam is reloaded to obtain data to plot a reloading load–deflection curve. Load values at specified deflection values on the reloading curve are averaged and used to calculate the average residual strength of the beam.

5. Significance and Use

5.1 This test method provides a quantitative measure useful in the evaluation of the performance of fiber–reinforced concrete. It allows for comparative analysis among beams containing different fiber types, including materials, dimension and shape, and different fiber contents. Results can be used to optimize the proportions of fiber–reinforced concrete mixtures, to determine compliance with construction specifications, to evaluate fiber–reinforced concrete which has been in service, and as a tool for research and development of fiber–reinforced concrete (See Note 2).

NOTE 2—Banthia and Dubey[3] compared results using this test method with residual strengths at the same net deflections using a test protocol that is similar to that described in Test Method C1609/C1609M on 45 beams with a single fiber configuration at proportions of 0.1, 0.3, and 0.5 % by volume. The results by this test method were on average 6.4 % lower than by the procedure of Test Method C1609/C1609M.

[3] Banthia, N. and Dubey, A., "Measurement of Flexural Toughness of Fiber Reinforced Concrete Using a Novel Technique, Part I: Assessment and Calibration," In Press, *Materials Journal*, American Concrete Institute.

5.2 Test results are intended to reflect either consistency or differences among variables used in proportioning the fiber–reinforced concrete to be tested, including fiber type (material), fiber size and shape, fiber amount, beam preparation (sawed or molded), and beam conditioning.

5.3 In molded beams fiber orientation near molded surfaces will be affected by the process of molding. For tests of fiber-reinforced concrete containing relatively rigid or stiff fibers of length greater than 35 mm [1.4 in.], the use of sawed beams cut from samples with an initial width and depth of at least 3 times the length of the fiber is required to minimize effects of fiber orientation. When sawed beams are employed, and to avoid the effects of fiber orientation, care shall be applied to ensure that the flexural tensile surface of the beam is a sawed surface.

6. Apparatus

6.1 *Either Screw Gear or Hydraulic Testing Apparatus*, with the ability to control the rate of motion of the loading head and meeting the requirements of Test Method C78. A load cell with a 44.5 kN capacity [10,000 lbf] will generally be required. Closed-loop feed-back controlled deflection apparatus is not required.

6.2 *Flexural-Loading Beam-Support Apparatus*, conforming to the requirements of Test Method C78.

6.3 *Load and Deflection–Measuring Devices*, such as load cells and electronic transducers, capable of producing electronic analog signals and having support apparatus located and arranged in a manner that provides determination of applied load and mid-span deflection (See 3.1.5) of the beam. Measure

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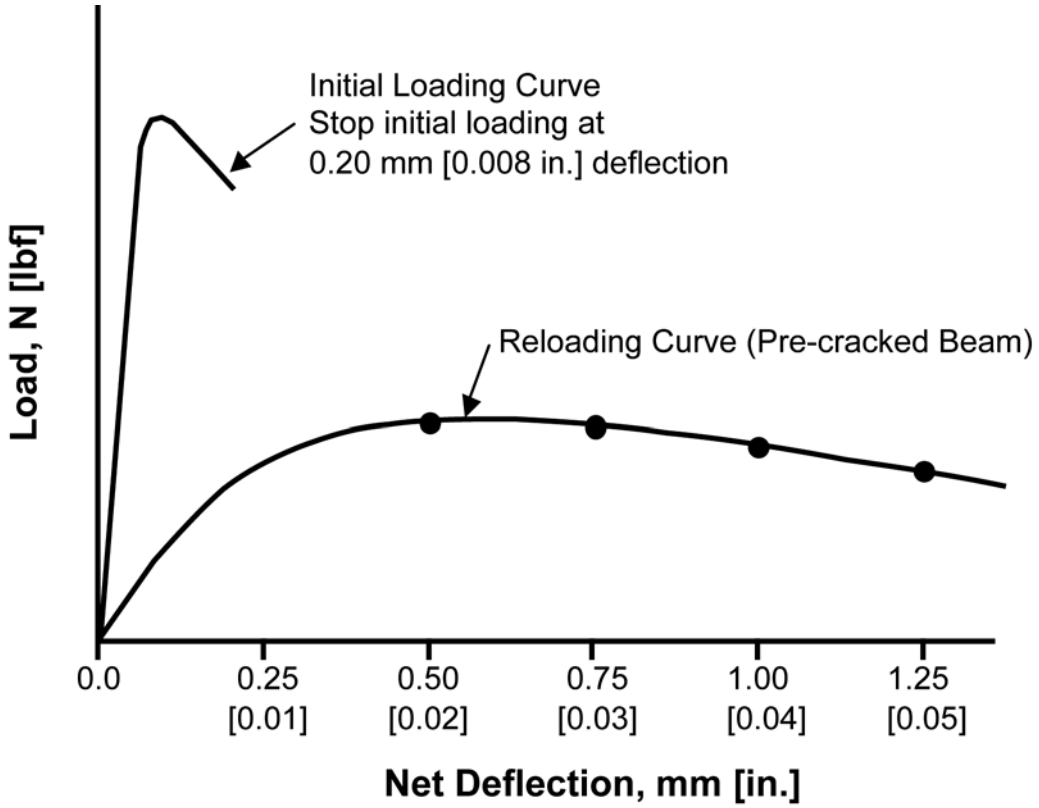

FIG. 2 Load-Deflection Curves

deflection using a device capable of measuring net deflection at the beam mid–span with a minimum resolution of 0.025 mm [0.001 in.] by one of the following alternative methods.

NOTE 3—The deflection measurement requires care in the arrangement of displacement transducers in order to minimize extraneous contributions such as might be caused by seating or twisting of the specimen. Experience has shown that apparatus designed to support deflection measuring devices that eliminate extraneous deflections is acceptable. Methods to accomplish this measurement use spring-loaded electronic displacement transducers mounted on suspension frames or support frames as shown in Fig. 1.

6.3.1 *Three Electronic Transducers*, mounted on a support frame. The support frame positions the transducers along the centerline of the top surface of the test beam at locations so as to contact the beam at mid-span and each support location. Average the measured support deflections and subtract this value from the recorded mid-span deflection to obtain the net deflection.

6.3.2 *Two Electronic Transducers*, mounted on a support frame. The support frame either (*1*) surrounds the test beam and is clamped to the sides of the beam at points on a line passing vertically through the beam support locations, or (*2*) is seated on top of the beam and is itself supported at points directly over the beam supports. In each case one transducer is located on each side of the test beam at mid-span, recording deflection between the mounted transducers and contact points that are rigid attachments located on the beam at the center of the span. The average of the transducer measurements are the net deflection.

6.4 *Data Acquisition Equipment*, capable of simultaneously recording data from the load and deflection transducers by either of the following alternative methods.

6.4.1 *X-Y Plotter*, driven by analog signals from load and deflection transducers to record the load–deflection curve.

6.4.2 *Analog Signal Sampling and Digital Conversion Using Automatic Data Acquisition Equipment With a Minimum Sampling Frequency of 2.5 Hz*, to record load and corresponding deflection values from which load–deflection curves can be produced.

6.5 *Stainless Steel Plate*, nominally 100 by 12 by 350 mm [4 by ½ by 14 in.].

6.6 *Mechanical Dial Gauge*, with 0.025 mm [0.001 in.] resolution.

6.7 *Magnetic–Mount Dial Gauge Holder*.

6.8 *Beam Molds*, conforming to the requirements of Practice C192/C192M that will produce 100 mm by 100 mm by 350 mm [4 in. by 4 in. by 14 in.] beams.

7. Sampling, Test Beams, and Test Units

7.1 Prepare a set of at least five beams from each sample of fresh or hardened concrete.

7.2 *Freshly Mixed Concrete*:

7.2.1 Obtain samples of freshly mixed fiber–reinforced concrete in accordance with Practice C172.

7.2.2 Mold beams in accordance with Practice C31/C31M or Practice C192/C192M and cast in one layer using a vibrating table for consolidation. Internal vibration or rodding may produce non–uniform fiber distribution.

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7.2.3 Cure samples for a minimum of 7 days in accordance with the standard curing procedure in Practice C31/C31M or the procedure in Practice C192/C192M. Use the same curing time when comparison between or among laboratories is desired.

7.3 *Hardened Concrete*:

7.3.1 Select samples of hardened fiber-reinforced concrete from structures in accordance with Practice C823.

7.3.2 Prepare and condition sawed beams in accordance with Test Method C42/C42M. The sawed beams shall have dimensions 100 mm by 100 mm by 350 mm [4 in. by 4 in. by 14 in.].

8. Procedure

8.1 Set the rate of platen or cross-head movement at 0.65 ± 0.15 mm/min [0.025 ± 0.005 in/min.] before the beam is loaded.

NOTE 4—When necessary use the mechanical dial gauge to establish the setting for the rate of platen or cross–head movement.

8.2 Place the specimen on the top of the steel plate to be loaded with the specimen (see Note 5). Molded specimens or specimens sawed from molded specimens shall be turned on their side from the position as cast before placing on the support system (see Fig. 3(a)). Specimens sawed from in-place

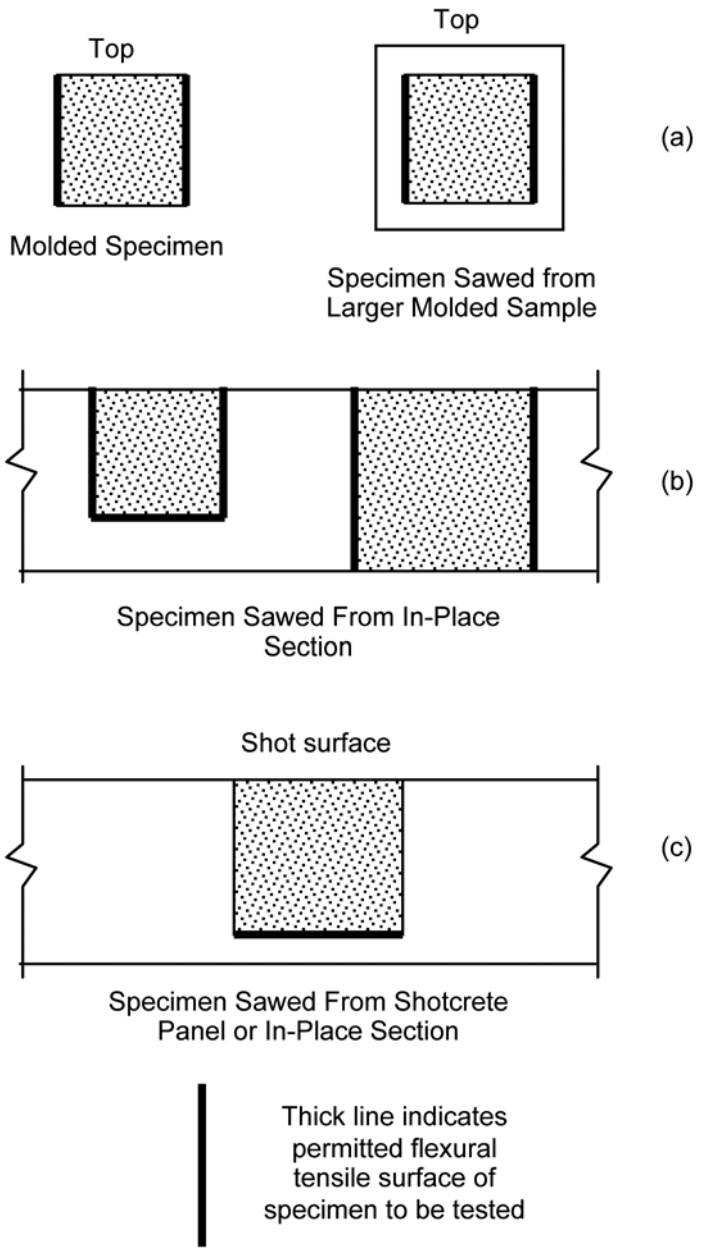

FIG. 3 Schematic of Specimen Cross Sections to Indicate Permitted Flexural Tensile Surfaces During Testing

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concrete shall be loaded so that a sawed surface is the flexural tensile surface (see Fig. 3(b)). Specimens representing shotcrete shall be loaded in the same direction as the specimen was shot (see Fig. 3(c)).

NOTE 5—The purpose of the stainless steel plate is to support the test beam during the initial loading cycle to help control the expected high rate of deflection of the beam upon cracking.

8.3 Place the plate and beam on the support apparatus so that the steel plate is centered on the lower bearing blocks and the concrete beam is centered on the steel plate. Adjust the displacement transducer(s) according to the chosen apparatus for obtaining net deflection.

8.4 Ensure that the X–Y plotter or alternate data acquisition system is activated and responding to signals from all load and displacement transducers.

8.5 Begin loading the beam and steel plate combination at the set rate and continue loading until reaching a deflection of 0.20 mm [0.008 in.]. If cracking has not occurred after reaching a deflection of 0.20 mm [0.008 in.] the test is invalid. The maximum load is not to be used to calculate modulus of rupture in accordance with Test Method C78 as this load includes load carried by the steel plate as well as by the concrete beam.

8.6 In anticipation of reloading the cracked beam only, remove the steel plate and center the cracked beam on the lower bearing blocks retaining the same orientation as during the initial loading test cycle. Adjust the displacement transducer(s) to lightly contact the beam in accordance with the chosen method for obtaining net deflection so that readings will immediately be obtained upon beam reloading. Zero the deflection recording device.

8.7 Begin reloading at the specified rate used for the initial loading. Terminate the test at a deflection of 1.25 mm [0.050 in.] as measured from the beginning of reloading.

8.8 Measure the beam and crack location as in Test Method C78.

9. Calculation

9.1 Calculate the average residual strength (ARS) for each beam to the nearest 0.01 MPa [2 psi] using the loads determined at reloading curve deflections of 0.50, 0.75, 1.00, and 1.25 mm [0.020, 0.030, 0.040, and 0.050 in.] as follows:

$$ARS = ((P_A + P_B + P_C + P_D)/4) \times k \quad (1)$$

where:

k = L/bd^2, mm^{-2} [in^{-2}]
ARS = average residual strength, MPa [psi],
$P_A+P_B+P_C+P_D$ = sum of recorded loads at specified deflections, N [lbf],
L = span length, mm [in.],
b = average width of beam, mm [in.], and
d = average depth of beam, mm [in.].

9.2 Calculate the mean ARS for each set of beams to the nearest 0.05 MPa [5 psi].

10. Report

10.1 The test report shall include the following information. If specific information is unknown at the time of the test then the word "UNKNOWN" shall be used.

10.1.1 Concrete mixture proportions.
10.1.2 Type and amount of fiber reinforcement.
10.1.3 Test beam information including:
10.1.3.1 beam identification labels,
10.1.3.2 type of beam (molded or sawed),
10.1.3.3 average width of beam to the nearest 1.0 mm [0.05 in.],
10.1.3.4 average depth of beam to the nearest 1.0 mm [0.05 in.],
10.1.3.5 beam age at time of test,
10.1.3.6 curing history and moisture condition at time of test,
10.1.3.7 defects in beam or abnormalities during testing,
10.1.3.8 loads obtained at reloading deflections of 0.50, 0.75, 1.00, and 1.25 mm [0.020, 0.030, 0.040, and 0.050 in.],
10.1.3.9 Average Residual Strength (ARS) for each beam to the nearest 0.01 MPa [2 psi],
10.1.3.10 plots of the reloading curves from which the average residual strengths (ARS) were determined, and
10.1.3.11 mean value of the ARS found for each set of beams to the nearest 0.05 MPa [5 psi].

11. Precision and Bias

11.1 *Precision*—Criteria for judging the acceptability of test results obtained for this test method are given in Table 1 (See Note 6).

NOTE 6—The precision statements are based on tests conducted in ten laboratories on sets of three duplicate samples of four different mixtures.[4]

11.2 *Bias*—The test method has no bias because the values determined can be defined only in terms of this test method.

12. Keywords

12.1 fiber–reinforced concrete; residual strength; flexure testing; post cracking strength

[4] Supporting data have been filed at ASTM International Headquarters and may be obtained by requesting Research Report RR:C09-1018.

TABLE 1 Precision Data for Test Samples[4]

ARS (MPa)	Standard Deviation (MPa)	Acceptable Range of Two Results (MPa)	Acceptable Range Difference Between High and Low, Three Results (MPa)
Single Operator Precision:			
0.50	0.10	0.28	0.33
1.00	0.12	0.34	0.40
2.00	0.28	0.78	0.92
3.50	0.45	1.26	1.49
Multilaboratory Precision:			
0.50	0.22	0.62	0.73
1.00	0.21	0.59	0.69
2.00	0.41	1.15	1.35
3.50	0.55	1.54	1.82

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SUMMARY OF CHANGES

Committee C09 has identified the location of selected changes to this test method since the last issue, C1399 – 07a, that may impact the use of this test method. (Approved January 1, 2010)

(*1*) Revised the standard as a dual units test method.
(*2*) Reduced the fiber length in 5.3 to 35 mm [1.4 in.].
(*3*) Deleted old Figure 2 and Note 4 because that method of measuring deflection is no longer permitted.
(*4*) Revised Figs. 1 and 2 to be consistent with the format of a dual units standard.
(*5*) Revised the description for orienting the specimen in the loading apparatus in 8.2 and added a new Fig. 3 for clarity.

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Designation: C 1404/C 1404M – 98 (Reapproved 2003)

Standard Test Method for Bond Strength of Adhesive Systems Used With Concrete as Measured by Direct Tension[1]

This standard is issued under the fixed designation C 1404/C 1404M; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope

1.1 This test method covers the laboratory determination of the bond strength of adhesive systems used to adhere freshly mixed mortar to hardened portland-cement concrete.

1.2 The values stated, in either SI units or other units shall be regarded separately as standard. The values stated in each system may not be exact equivalents; therefore each system must be used independently of the other, without combining values in any way.

1.3 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

2. Referenced Documents

2.1 *ASTM Standards:* [2]

A 333/A 333M Specification for Seamless and Welded Steel Pipe for Low-Temperature Service

C 33 Specification for Concrete Aggregates

C 39 Test Method for Compressive Strength of Cylindrical Concrete Specimens

C 42 Test Method for Obtaining and Testing Drilled Cores and Sawed Beams of Concrete

C 109 Test Method for Compressive Strength of Hydraulic Cement Mortars using 2-in. [50 mm] Cube Specimens

C 150 Specification for Portland Cement

C 171 Specification for Sheet Materials for Curing Concrete

C 192 Practice for Making and Curing Concrete Specimens in the Laboratory

C 305 Practice for Mechanical Mixing of Hydraulic Cement Pastes and Mortars of Plastic Consistency

C 494 Specification for Chemical Admixtures for Concrete

C 881 Specification for Epoxy-Resin-Base Bonding Systems for Concrete

C 670 Practice for Preparing Precision Statements for Test Methods for Construction Materials

3. Summary of Test Method

3.1 Each specimen consists of a base and overlay, bonded together with the adhesive being tested. The base is half of a 3-in. [75-mm] by 6-in. [150-mm] hardened-concrete cylinder mounted inside of a steel-pipe nipple. The overlay consists of freshly mixed mortar placed in a steel-pipe nipple positioned on top of the base.

3.2 The prepared surface of the base is coated with the adhesive, onto which freshly mixed mortar is applied. After curing, the assembly is pulled in tension to measure the bond strength of the adhesive. The tensile strength is calculated, and the location of failure is determined visually.

4. Significance and Use

4.1 The bonding properties of adhesives are important for concrete repair applications. This test method provides a means to measure the adhesive characteristics of materials used to bond freshly mixed mortar to hardened concrete.

4.2 In addition to providing information on bond strength, the location of failure is determined visually and is thus instructive regarding the weakest element in the composite tested.

4.3 The bond strength that is measured is limited by the tensile strength of the base concrete and mortar. While an attempt has been made to choose materials that are strong enough to force a bond failure, there may be cases where failure occurs in concrete or mortar. In these situations, the actual bond strength exceeds the measured result.

5. Apparatus

5.1 *Testing Machine*—The testing machine shall be of the hydraulic or screw-type and capable of measuring tensile loads up to 5000 lbf [22 kN] in increments of 45 lbf [200 N] at rates described in 9.3.

5.2 *Steel-Pipe Nipples*—The steel-pipe nipples shall conform to Specification A 333/A 333M, be nominally 3 in. [75 mm] in diameter by 3 in. [75 mm] long Schedule 40, threaded;

[1] This test method is under the jurisdiction of ASTM Committee C09 on Concrete and Concrete Aggregates , and is the direct responsibility of Subcommittee C09.25 on Organic Materials for Bonding.

Current edition approved Sept. 10, 1998. Published April 1999. Originally approved in 1998. Last previous edition approved in 1998 as C 1404/C 1404M – 98.

[2] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

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two per specimen. The inside surface of the steel-pipe nipples shall be clean and free of oil or other contaminants that could inhibit bond. The inside surface shall be sandblasted to gray metal condition.

5.3 *Steel-Pipe Cap*—Two steel-pipe caps nominally 3 in. [75 mm] in diameter, and threaded to fit the steel-pipe nipple molds. Each cap shall be fitted with a steel rod or eye bolt with at least one universal joint for connection to the testing machine. The assembly shall have a tensile capacity of at least 5000 lbf [22 kN]. See Fig. 1 for details of preparation.

5.4 *Base Assembly*—Concrete cylinder and steel pipe nipple, prepared according to Section 7; one for each specimen.

5.5 *O-rings*—Rubber, 2-⅞ in. [73 mm] inside diameter× 3-¼ in. [83 mm] outside diameter; 3⁄16 in. [5 mm] thick; one for each specimen.

5.6 *Concrete Mixer*—As described in Practice C 192.

5.7 *Mixer, Bowl, and Paddle*—A mechanical mortar mixer, as described in Practice C 305.

5.8 *Small Tools*—Tools and items such as a straightedge, scoops, rubber gloves, and metal mixing bowls.

5.9 *Tamping Rod*—The tamping rod shall be a round steel rod, ⅜ in. [10 mm] in diameter, conforming to Practice C 192.

5.10 *Saw*, as described in Test Method C 42, with diamond saw blade and plain water as the only cutting fluid.

5.11 *Cylinder Molds*—The cylinder molds shall be 3-in. [75-mm] diameter by 6-in. [150-mm] long, as described in Practice C 192.

6. Materials

6.1 *Cement*—The cement shall be portland cement meeting the requirements of Specification C 150.

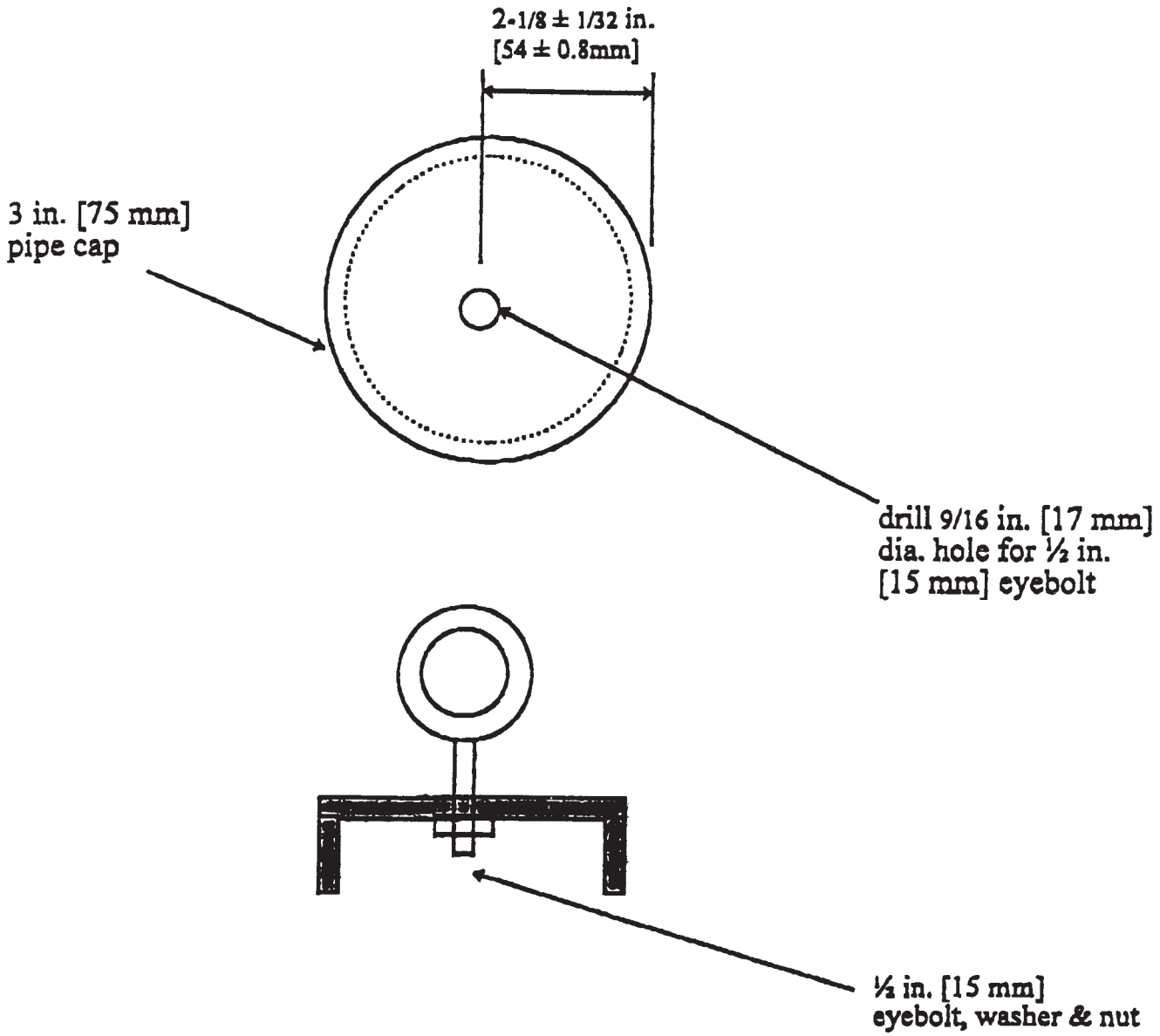

FIG. 1 Pipe Cap Detail

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6.2 *Aggregate*—The aggregate shall conform to Specification C 33; the coarse aggregate shall conform to Size No. 7.

6.3 *Mortar*—Prepare and test the mortar in accordance with Test Method C 109, and each specimen tested shall have a compressive strength of at least 4500 psi [31 MPa] at seven days age.

6.4 *Concrete*—The concrete shall be non air-entrained, prepared and cured in accordance with Practice C 192, tested according to Test Method C 39, and each specimen tested shall have a compressive strength of at least 6000 psi [41 MPa] at 28 days. Water-reducing admixtures, meeting Specification C 494, may be used.

6.5 For the purpose of qualifying the reference mortar and concrete, compressive strengths of all specimens tested shall exceed the minimum stated.

6.6 *Abrasive Paper*—Sandpaper, emery cloth, or other abrasive paper of grit No. 100.

6.7 *Tape*—Plastic tape, minimum 2 in. [50 mm] wide.

6.8 *Epoxy*—Type V, Grade 1 epoxy resin, Specification C 881, shall have low enough viscosity to flow into the annular space between the concrete base cylinder and steel-pipe nipple.

NOTE 1—A hot-air blower to heat the pipe nipple has been found useful to increase flow of the epoxy adhesive between the pipe and the concrete cylinder.

6.9 *Sealant*—Capable of sealing the rubber to the concrete to prevent the flow of the epoxy adhesive; an example is RTV silicone rubber.

6.10 *Polyethylene Film*—Meeting Specification C 171 and having a minimum thickness of 4 mil [0.1 mm].

7. Base Assembly Preparation

7.1 Prepare concrete as described in 6.4 and place in the cylinder molds, 3-in. [75-mm] diameter by 6-in [150-mm] long.

7.2 Cure in accordance with Practice C 192 except that moist curing shall be continuous for 28 days. After this time, and until the cylinders are cut, they shall be stored at 73.4 ± 3.0°F [23 ± 2°C] and 50 ± 10 % R.H.

7.3 Not more than seven days after completing the curing cycle, cut the cast cylinders so that two cylinders, 3 in. [75 mm] diameter by nominally 3 in. [75 mm] long, are produced. Take care that the edges are not chipped during the cutting operation. Discard any half-cylinders with chips or defects estimated to be greater than 5 % of the cross-sectional area. Store the acceptable half-cylinders with the cut surface down, on a clean, dry surface, at 73.4 ± 3.0°F [23 ± 2°C] and 50 ± 10 % R.H. until used.

7.4 Place a half-cylinder, cut end down, on a clean, nonporous surface and position the O-ring so that it rests snugly against the clean surface. Seal the O-ring to the side of the concrete half-cylinder with sealant. Before the sealant cures, place a 3 in. [75 mm] long steel pipe nipple onto the cylinder so that it rests against the O-ring and the sealant. After the sealant cures, pour epoxy into the annular space between the nipple and cylinder until the space is full. See Fig. 2 for details.

8. Preparation and Curing of Composite Specimens

8.1 After the epoxy has cured, invert the base assembly so that the cut surface of the concrete is up. Rub this surface with the abrasive paper to remove any extraneous material that could inhibit bond. Wipe this prepared surface with a damp cloth to remove any dust or powder that may have accumulated.

8.2 Place a 3 in. [75 mm] long nipple on this assembly and secure it to the bottom nipple with tape around the outside of both nipples.

8.3 Apply the adhesive being tested to the prepared surface of the concrete base using the manufacturer's recommendations for thickness and procedure, including moisture condition of substrate.

8.4 Mix mortar as described in Test Method C 109. Fill the nipple in two equal layers, and rod the mortar with 25 strokes per layer. Strike off the surface with a trowel and cover with polyethylene film.

8.5 Prepare a minimum of three specimens per test age.

8.6 Moist cure the specimens according to Practice C 192.

9. Procedure

9.1 Remove the tape from the specimens.

9.2 Screw the pipe caps (Fig. 1) onto the ends of the specimen (Fig. 2) and connect to the testing machine (see Fig. 3).

9.3 Set the testing machine so the specimen can be loaded into tension, at least 5000 lbf [22 kN] maximum load capability. For screw type, set cross-head speed at 0.04 in/min [1.0 mm/min]; for hydraulic type, load at 5 ± 2 psi/s [35 ± 15 kPa/s].

9.4 Load the specimen at constant rate until failure.

10. Calculation

10.1 Calculate the tensile strength to the nearest 10 psi [0.1 MPa] as follows:

$$T = P/A \quad (1)$$

where:

T = tensile strength at failure, psi [MPa],
P = maximum applied load, lbf [N], and
A = cross sectional area of concrete base.

10.2 Estimate the location of failure in percent of cross sectional area for each element of the specimen, that is, in concrete base, at bond line, in mortar overlay. The sum of the three values must equal 100.

11. Report

11.1 Report the following information:

11.1.1 Identification of specimen,

11.1.2 Identification of type of cement used to make the test mortar,

11.1.3 Identification of bonding agent tested,

11.1.4 Moisture condition of substrate,

11.1.5 Length of cure of overlay for each set of specimens,

11.1.6 Number of specimens, Mean and Coefficient of Variation of T for each set, and

11.1.7 Results of test in the following manner:

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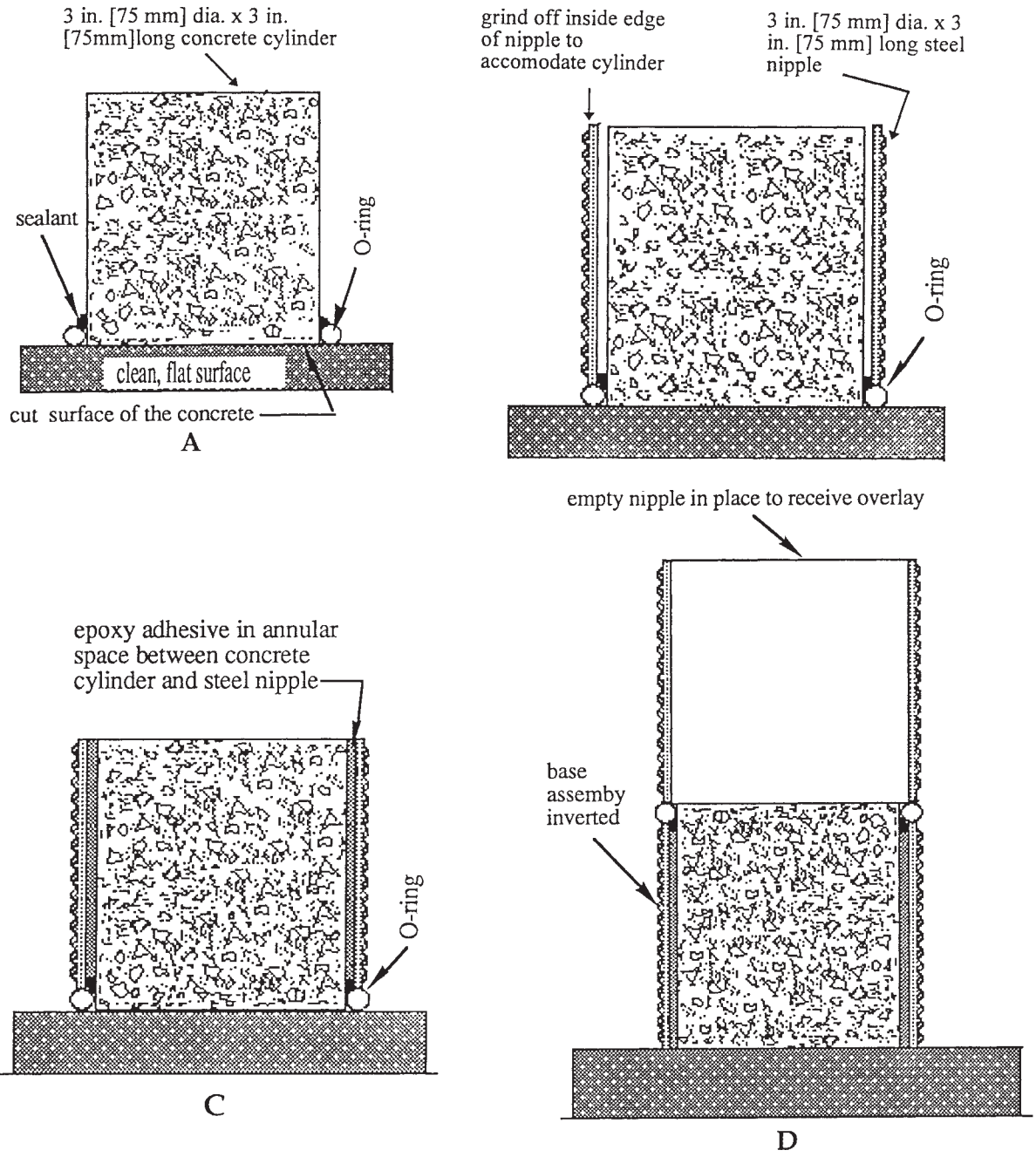

NOTE 1—(A) Place the concrete cylinder on a clean, flat surface; seal the O-ring to the cylinder with the sealant; (B) Place a pipe nipple over the concrete cylinder; (C) Pour epoxy adhesive into the space between the cylinder and nipple; (D) after the epoxy adhesive cures, invert the base assembly and place the second pipe nipple on top.

NOTE 2—Tape is wrapped around the outside of this final assembly to keep the pieces aligned as well as protect the threads from being covered with the overlay.

FIG. 2 Specimen Preparation

Specimen No.	*T*, Tensile Strength at Failure, psi [MPa]	Location of Failure, % Area		
		In Mortar Overlay	At Bond Line	In Concrete Base

12. Precision and Bias

12.1 *Single Operator Precision*—The single operator within laboratory and multilaboratory standard deviations, as shown below, have been found to be the same:

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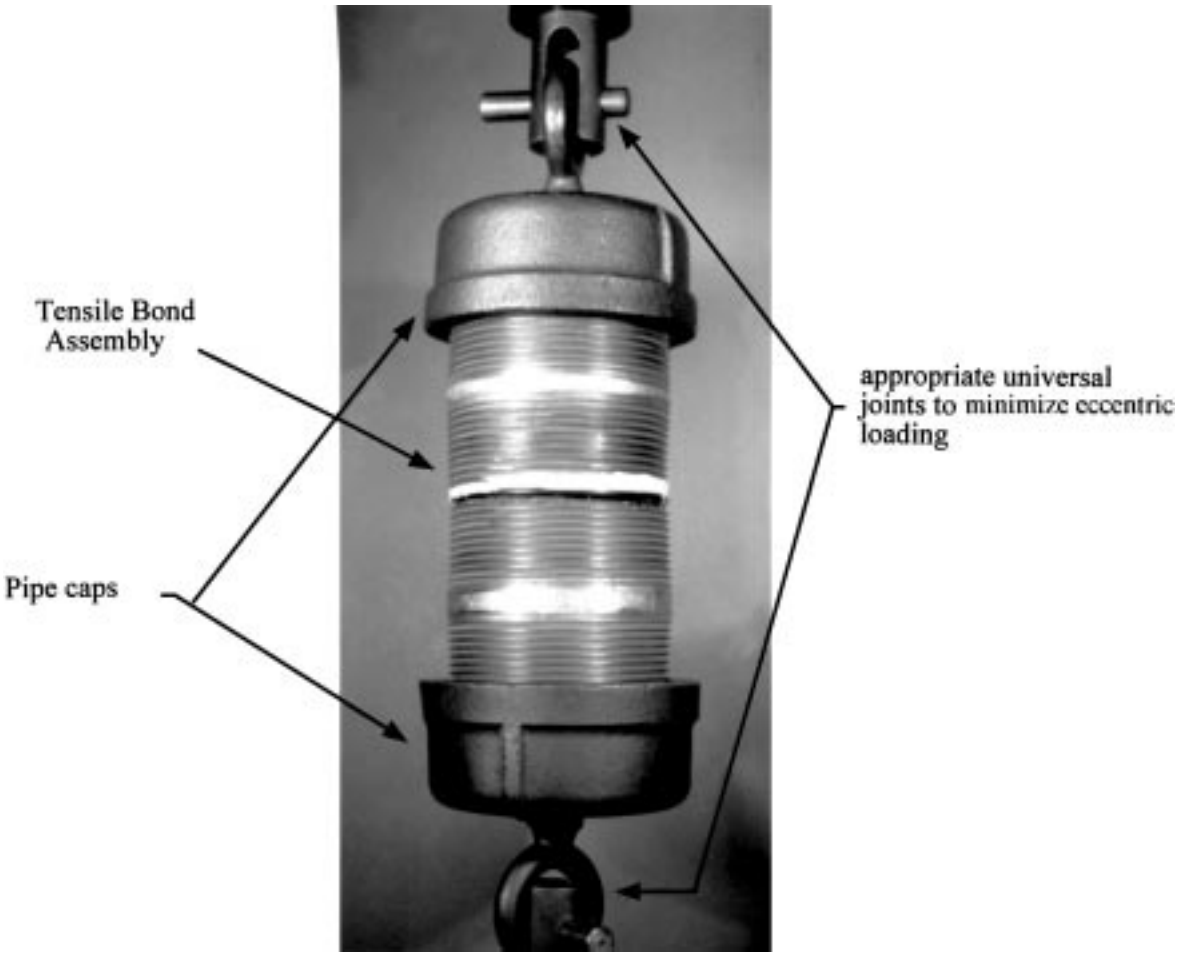

FIG. 3 Tensile Bond Assembly in Testing Machine

44 psi [0.30 MPa] for 3-day cure
52 psi [0.36 MPa] for 7-day cure
41 psi [0.28 MPa] for 28-day cure

Therefore, the results of two properly conducted tests from the same operator or from two different laboratories on similar batches should not differ from each other by more than shown below:

124 psi [0.84 MPa] for 3-day cure
145 psi [1.01 MPa] for 7-day cure
114 psi [0.78 MPa] for 28-day cure

NOTE 2—These numbers represent the (d2s) limit as described in Practice C 670. Data are from test of specimens that had strengths in the range of 246 to 522 psi [1.7 to 3.6 MPa].

12.2 *Bias*—The test method has no bias because the values determined can be defined only in terms of the test method.

13. Keywords

13.1 adhesives; bond strength; bonding agents; concrete-bonding; overlays; tensile bond

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Designation: C 1435/C 1435M – 08

Standard Practice for Molding Roller-Compacted Concrete in Cylinder Molds Using a Vibrating Hammer[1]

This standard is issued under the fixed designation C 1435/C 1435M; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope*

1.1 This practice covers molding cylindrical test specimens from concrete when the standard procedures of rodding and internal vibration, as described in Practice C 31/C 31M and Practice C 1176, are not practicable. This practice is applicable to freshly-mixed concrete, prepared in the laboratory and the field.

1.2 Freshly-mixed concrete is molded in cylindrical molds using an electric vibrating hammer equipped with a shaft and circular plate.

1.3 The values stated in either SI units or inch-pound units are to be regarded separately as standard. Within the text, the inch-pound units are shown in brackets. The values stated in each system may not be exact equivalents; therefore, each system shall be used independently of the other. Combining values from the two systems may result in non-conformance with the standard.

1.4 The text of this practice references notes and footnotes, which provide explanatory material. These notes and footnotes (excluding those in tables and figures) shall not be considered as requirements of this practice.

1.5 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

2. Referenced Documents

2.1 *ASTM Standards:* [2]

C 31/C 31M Practice for Making and Curing Concrete Test Specimens in the Field

C 39/C 39M Test Method for Compressive Strength of Cylindrical Concrete Specimens

C 172 Practice for Sampling Freshly Mixed Concrete

C 470/C 470M Specification for Molds for Forming Concrete Test Cylinders Vertically

C 496/C 496M Test Method for Splitting Tensile Strength of Cylindrical Concrete Specimens

C 1170 Test Method for Determining Consistency and Density of Roller-Compacted Concrete Using a Vibrating Table

C 1176 Practice for Making Roller-Compacted Concrete in Cylinder Molds Using a Vibrating Table

2.2 *ACI Documents:*

207.5R Report on Roller-Compacted Concrete[3]

211.3 Practice for Selecting Proportions for No-Slump Concrete[3]

3. Summary of Practice

3.1 This practice describes molding cylindrical concrete test specimens using a vibrating hammer. Test specimens are molded vertically in cylindrical molds by compacting the stiff to very dry concrete mixture in four lifts using a vibrating hammer.

4. Significance and Use

4.1 This practice, intended for use in testing roller-compacted concrete, may be applicable to testing other types of cementitious material such as coarse-grained, soil-cement. This practice provides standardized requirements for molding stiff to very dry consistency concrete mixtures commonly used in roller compacted concrete construction. This practice is used instead of rodding or internal vibration, which cannot properly consolidate concrete of this consistency (Note 1).

NOTE 1—Further description of roller compacted concrete consistency is given in ACI 207.5R and 211.3. The consistency of concrete using a vibrating table may be determined in accordance with Test Methods C 1170.

4.2 This practice is used to mold cylindrical test specimens commonly used for testing compressive or tensile strength of concrete. Specimens tested for compressive strength and splitting tensile strength shall be in accordance with Test Methods C 39/C 39M and C 496/C 496M, respectively. Test specimens also may be used to determine density of fresh concrete.

[1] This practice is under the jurisdiction of Committee C09 on Concrete and Concrete Aggregates and are the direct responsibility of Subcommittee C09.45 on Roller-Compacted Concrete.

Current edition approved June 1, 2008. Published July 2008. Originally approved in 1999. Last previous edition approved in 2007 as C 1435/C 1435M – 07.

[2] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

[3] *ACI Manual of Concrete Practice, Part 1, Materials and General Properties of Concrete*, American Concrete Institute, Farmington Hills, MI.

***A Summary of Changes section appears at the end of this standard.**

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Specimens tested for density of fresh concrete shall be in accordance with Test Methods C 1170.

NOTE 2—For some extremely dry mixtures; (those with a consistency greater than 45 s when tested in accordance with Test Methods C 1170)[4] the density of specimens made in accordance with this practice may be greater than the in-place density of roller-compacted concrete due to the greater potential for voids at the bottom of the lifts in the field.

5. Apparatus

5.1 *Molds*:

5.1.1 *Type A Reusable Mold*—A cylindrical mold conforming to the requirements of Specification C 470/C 470M for 150-mm [6-in.] diameter by 300-mm [12-in.] high reusable molds.

5.1.2 *Type B Single-Use Mold*—A single-use plastic, cylindrical mold 150-mm [6-in.] diameter and 300-mm [12-in.] in height. The mold specifications shall conform to Specification C 470/C 470M for single-use, plastic molds.

5.1.2.1 *Mold Sleeve*—A Type B cylindrical mold shall be inserted into a rigid cylindrical sleeve. The cylindrical sleeve shall be made of steel or other hard metal resistant to cement paste corrosion. The sleeve shall be capable of firmly holding the plastic mold upright without deformation of the mold. The sleeve shall be split and hinged on one side so that it can be opened to remove the plastic mold; adjustable clamps shall be provided on the other side for tightening the sleeve around the mold. A metal base plate with brackets shall be provided in which to insert the bottom portion of the sleeve to hold the sleeve during compaction. The sleeve shall have a minimum wall thickness of 3 mm [⅛ in.], and a minimum base plate thickness of 6 mm [¼ in.]. The inside diameter of the mold sleeve shall be 3 ± 1 mm [⅛ ± 1/16 in.] larger than the outside diameter of the Type B mold and have a height 13 ± 6 mm [½ ± ¼ in.] less than the height of the Type B mold.

5.2 *Vibrating Hammer*—A vibrating compaction hammer having a mass (without tamping plate and shaft) of 10 ± 1.5 kg [22 ± 3.3 lb]. It also shall have a minimum power input of 900 W and be capable of providing 2000 ± 200 impacts/min.

NOTE 3—The vibrating hammer used to compact the specimens, such as shown in Fig. 1, is of the type used typically for breaking up concrete and masonry. It provides oscillatory motion in the axial direction that makes the hammer an effective vibratory compactor.

5.3 *Tamping Plate*—A circular steel plate attached to a steel shaft, which is inserted into the vibrating hammer chuck. The plate diameter shall be 140 ± 3 mm [5 ½ ± ⅛ in.] and the mass of the plate and shaft assembly shall be 3 ± 1 kg [6.6 ± 2.2 lb] (See Fig. 2).

5.4 *Small Tools*—A square-ended shovel, a hand scoop, a tamping rod, and a stopwatch.

6. Sampling

6.1 Samples of freshly-mixed concrete shall be obtained in accordance with Practice C 172.

6.2 Concrete samples shall have a maximum size aggregate of 50 mm [2 in.] or less. If the concrete has aggregate larger than 50 mm [2 in.] samples shall be obtained by wet sieving over a 50-mm [2-in.] sieve in accordance with Practice C 172.

6.3 Concrete test specimens shall be molded within 45 min after the completion of mixing unless otherwise specified.

6.4 *Technical Precautions*:

6.4.1 When obtaining samples, ensure that the samples are representative of the bulk production.

6.4.2 Concrete with stiff to very dry consistency is highly susceptible to segregation during handling. To minimize segregation, use care in obtaining samples and during transporting, remixing, and preparation of the specimens.

7. Calibration

7.1 Calibrate the vibrating hammer after any event, including repairs, that might affect its operation, after 300 h of service, or at least one time per year.

8. Molding Specimens

8.1 *Method A, Type A Molds*:

8.1.1 Coat Type A molds with a suitable lubricant or bond breaker prior to casting the test specimens to facilitate removal from the mold.

8.1.2 Hold the mold stationary either by clamping to a rigid, flat base or standing on the foot brackets and center the vibrating hammer so that the edges of the tamping plate do not touch the walls of the mold. Lower the vibrating hammer into the mold to check for proper clearance.

8.1.3 Place enough concrete in the mold so that the mold will be filled to one-fourth of its volume after consolidation, approximately 3.4 kg [7.5 lb]. Use a tamping rod to distribute the loose concrete as it is added. During filling, use square-ended shovels and scoops to obtain representative samples and handle the concrete in such a manner that larger sized coarse aggregates do not separate from the mortar.

8.1.4 Place the vibrating hammer with tamping plate onto the concrete (Fig. 1).

8.1.5 Start the vibrating hammer and allow the concrete to consolidate under the tamping plate. Observe the concrete in the annular space between the edge of the tamping plate and the inside wall of the mold. As the concrete consolidates, mortar should fill in the annular space between the outer edge of the tamping plate and the inside mold wall. Observe the mortar until it forms a ring around the total perimeter of the tamping plate. When the mortar ring forms completely around the tamping plate, stop the vibrating hammer.

8.1.6 If a rock pocket prevents the mortar ring from forming at one small location, even though it has formed in all other locations, the vibrating hammer can be stopped and the next layer of concrete added.

8.1.7 If a significant portion of the mortar ring does not form after 20 s, the vibrating hammer shall be stopped and the next layer of concrete added. This situation may be a result of insufficient mortar due to either improper sampling, segregation, or improper mixture proportioning. In these instances, the concrete should be inspected visually after stripping from the mold to determine if there is adequate mortar distribution and a decision made whether to accept or reject the specimen.

8.1.8 Repeat the procedure in 8.1.3-8.1.7 for the second and third lifts of concrete, filling the mold to approximately

[4] Hansen, K. and Kahler, C., "RCC Tests, Testing, and Test Sections – Lessons Learned," *The Journal of Dam Safety*, Volume 2, Issue 1 (Winter 2004), p.14

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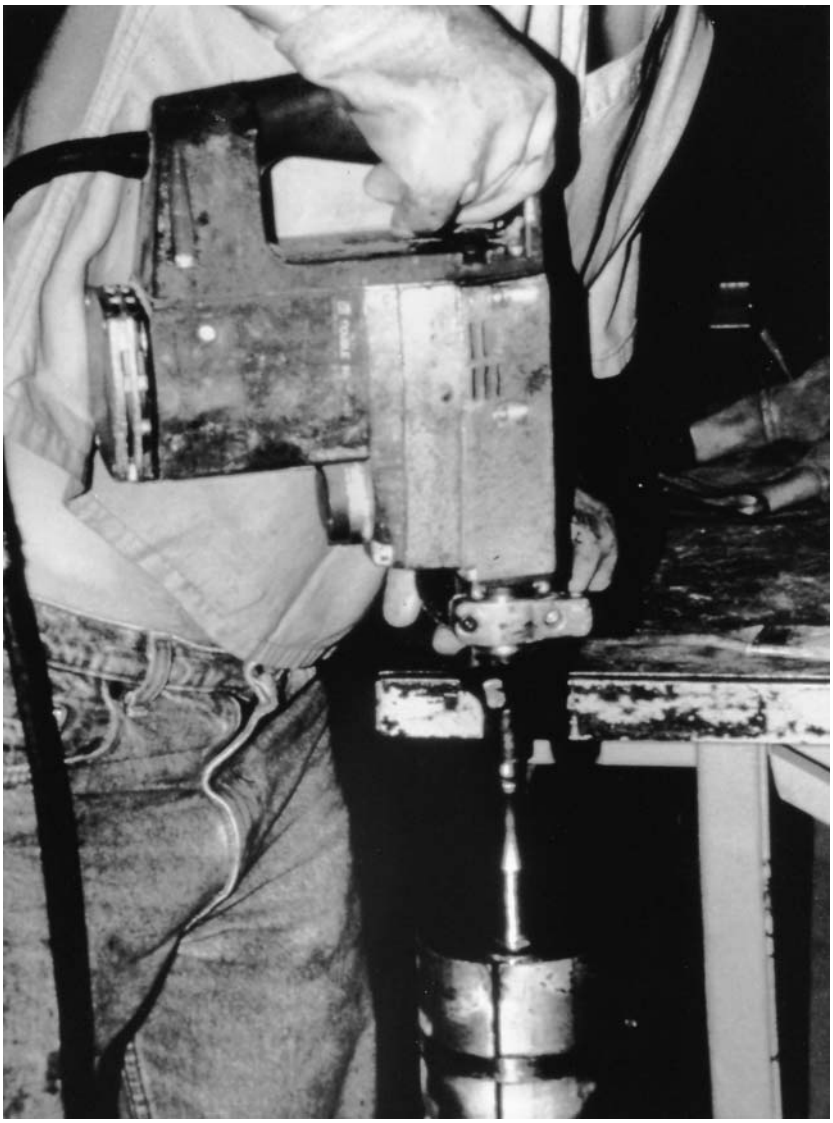

FIG. 1 Vibrating Hammer for Molding RCC Specimens

one-half and three-fourths of its volume, respectively. For the fourth lift, overfill the mold by mounding the concrete above the top of the mold. Again, place the tamping plate on the loose concrete and consolidate. If the tamping plate consolidates concrete below the top level of the mold, turn off the vibrating hammer. Place additional concrete in the mold so that, when consolidated, the concrete can be finished smooth and level with the top of the mold.

8.1.9 Finally, strike off the top of the concrete with the vibrating hammer and tamping plate. With the hammer in operation and the plate in contact with the rim of the cylinder mold, move the plate back and forth across the top of the cylinder to force excess material beyond the rim. Continue working the surface until it is smooth and level with the top of the cylinder mold. Avoid tearing the surface of the concrete.

9. Keywords

9.1 compressive; consolidate; cylinder; molds; roller compacted concrete; soil cement; specimen; strength; tensile; vibrating hammer

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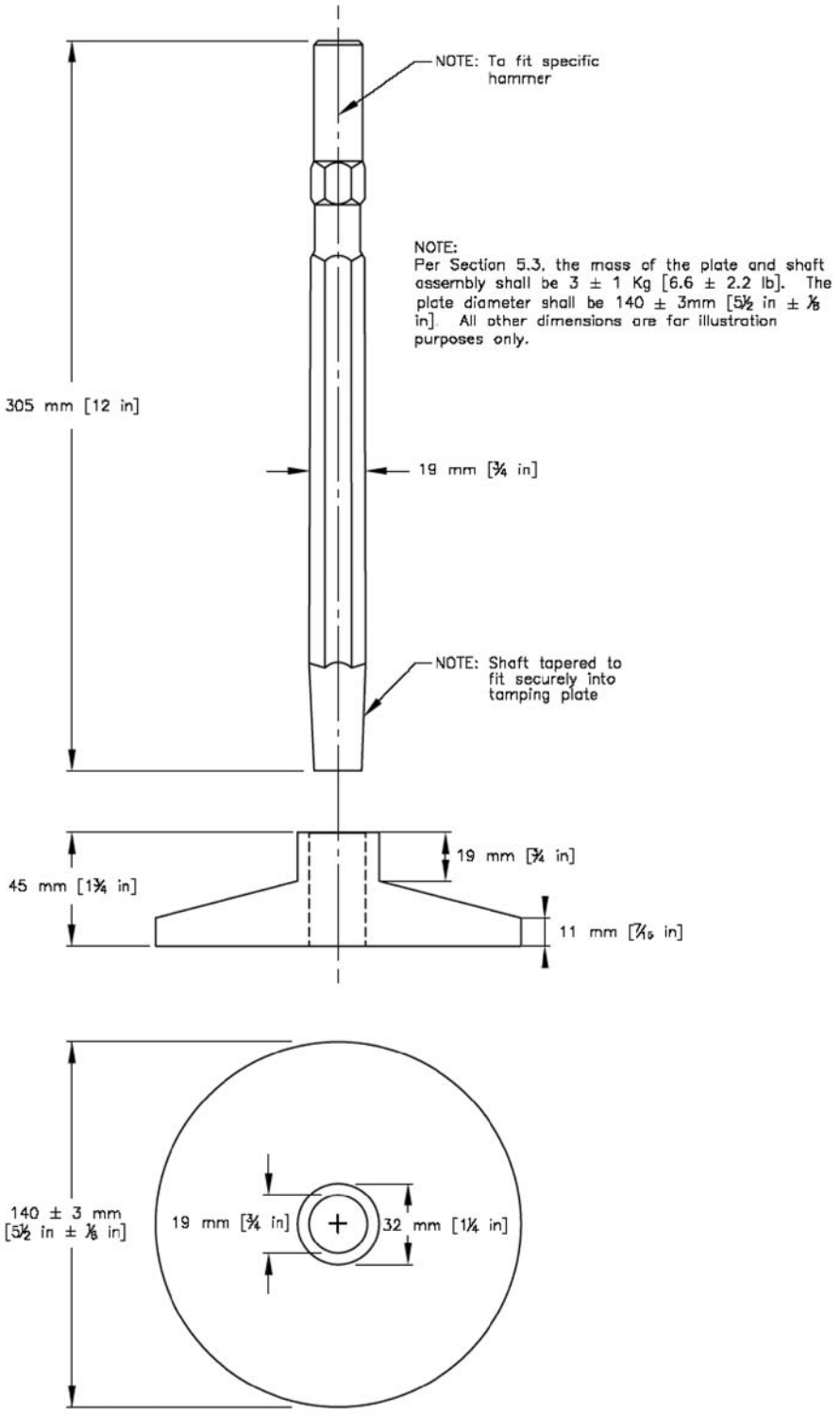

FIG. 2 Circular Steel Tamping Plate and Metal Shaft

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SUMMARY OF CHANGES

Committee C09 has identified the location of selected changes to this practice since the last issue, C 1435/C 1435M – 07, that may impact the use of this practice. (Approved June 1, 2008)

(*1*) Revised Fig. 2.

Committee C09 has identified the location of selected changes to this practice since the last issue, C 1435/C 1435M – 06, that may impact the use of this practice. (Approved November 1, 2007)

(*1*) Revised Fig. 2.

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Designation: C 1436 – 08

Standard Specification for Materials for Shotcrete[1]

This standard is issued under the fixed designation C 1436; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope*

1.1 This specification covers materials for use in hydraulic-cement concrete mixtures to be placed by shotcreting. It does not cover mixing, placement, curing, or protection of the concrete placed by shotcreting.

1.2 This specification covers materials for both wet-mix and dry-mix shotcreting.

1.3 The values stated in SI units are to be regarded as standard. No other units of measurement are included in this standard.

1.4 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of the standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

2. Referenced Documents

2.1 *ASTM Standards:*[2]

C 33 Specification for Concrete Aggregates

C 125 Terminology Relating to Concrete and Concrete Aggregates

C 150 Specification for Portland Cement

C 330 Specification for Lightweight Aggregates for Structural Concrete

C 595 Specification for Blended Hydraulic Cements

C 1116/C 1116M Specification for Fiber-Reinforced Concrete

C 1141/C 1141M Specification for Admixtures for Shotcrete

C 1157 Performance Specification for Hydraulic Cement

C 1385/C 1385M Practice for Sampling Materials for Shotcrete

C 1602/C 1602M Specification for Mixing Water Used in the Production of Hydraulic Cement Concrete

E 11 Specification for Wire Cloth and Sieves for Testing Purposes

3. Terminology

3.1 For definitions of terms used in this specification, refer to Terminology C 125.

4. Ordering Information

4.1 In the absence of designated applicable general specifications, the purchaser shall include the following information in the purchase contract or order, if applicable:

4.1.1 The specification designation and date of issue,

4.1.2 Specification for cement and type (see 5.1.1),

4.1.3 Grading number for total combined aggregates required (see 5.1.2),

4.1.4 Specification, type, and grade(s) for admixtures required (see 5.1.4), and

4.1.5 Specification, type, length, and, if appropriate, the diameter (or equivalent cross-sectional dimensions) of fiber required (see 5.1.5).

5. Material Requirements

5.1 In the absence of designated applicable specifications covering requirements for quality of materials, the following requirements shall govern:

5.1.1 *Cement*—Cement shall be in accordance with Specification C 150, Specification C 595, or Performance Specification C 1157. If special properties are required, the purchaser shall limit the choice of cements to those suitable for the special use.

5.1.2 *Aggregates*—Aggregates shall be in accordance with Specification C 33 or Specification C 330 if lightweight shotcrete is specified by the purchaser except that the grading of the total aggregate constituent of the shotcrete shall be in accordance with the requirements prescribed in Table 1 for the grading number specified.

NOTE 1—The ranges shown in Table 1 are by necessity wide in order to accommodate nationwide conditions. For quality control of any specific operation, a producer should develop an average grading for the particular source and production facilities, and control the grading within reasonable tolerances from this average.

5.1.3 *Water*—The mixing water shall be in accordance with Specification C 1602/C 1602M.

[1] This specification is under the jurisdiction of Committee C09 on Concrete and Concrete Aggregates and is the direct responsibility of Subcommittee C09.46 on Shotcrete.

Current edition approved Dec. 15, 2008. Published January 2009. Originally approved in 1999. Last previous edition approved in 2004 as C 1436 – 99(2004).

[2] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

***A Summary of Changes section appears at the end of this standard.**

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TABLE 1 Grading Limits for Combined Aggregate for Shotcrete

Percent by Mass Passing Individual Sieve		
Sieve Size, U.S. Standard[A]	Grading, No. 1	Grading, No. 2
12.5 mm (½ in.)	-	100
9.5 mm (⅜ in.)	100	90 - 100
4.75 mm (No. 4)	95 - 100	70 - 85
2.36 mm (No. 8)	80 - 98	50 - 70
1.18 mm (No. 16)	50 - 85	35 - 55
600 µm (No. 30)	25 - 60	20 - 35
300 µm (No. 50)	10 - 30	8 - 20
150 µm (No. 100)	2 - 10	2 - 10

[A]The sieve designations in parentheses are provided for information only; the only standard sieve sizes are those stated in Specification E 11 in SI units.

5.1.4 *Admixtures*—Mineral and chemical admixtures shall be in accordance with Specification C 1141/C 1141M.

5.1.5 *Fibers*—Fibers shall be in accordance with the requirements for fibers prescribed in Specification C 1116/C 1116M.

6. Sampling

6.1 Access shall be provided to the purchaser for sampling, either at the point of manufacture or at the site of the work, as specified by the purchaser. Sampling of materials shall be in accordance with Practice C 1385/C 1385M.

7. Number of Tests and Retests

7.1 Testing, number of tests, and retests to be performed on specified materials shall be in accordance with the referenced ASTM standard.

8. Inspection

8.1 Inspection of the materials shall be agreed upon between the purchaser and the supplier as part of the purchase contract.

9. Rejection, Certification, and Product Marking

9.1 Rejection, certifications, and product markings on specified materials shall be in accordance with the referenced ASTM specification.

10. Keywords

10.1 dry-mix shotcrete, materials for; ordering; shotcrete; specification; testing; wet-mix shotcrete

SUMMARY OF CHANGES

Committee C09 has identified the location of selected changes to this specification since the last issue, C 1436 – 99(2004), that may impact the use of this specification. (Approved December 15, 2008)

(*1*) Updated Referenced Documents.

(*2*) Revised Table 1.

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Designation: C 1437 – 07

Standard Test Method for Flow of Hydraulic Cement Mortar[1]

This standard is issued under the fixed designation C 1437; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope*

1.1 This test method covers the determination of flow of hydraulic cement mortars.

1.2 The values stated in SI units are to be regarded as the standard. Values in parentheses are for information only.

1.3 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

2. Referenced Documents

2.1 *ASTM Standards:* [2]

C 109/C 109M Test Method for Compressive Strength of Hydraulic Cement Mortars (Using 2-in. or [50-mm] Cube Specimens)

C 185 Test Method for Air Content of Hydraulic Cement Mortar

C 230/C 230M Specification for Flow Table for Use in Tests of Hydraulic Cement

C 511 Specification for Mixing Rooms, Moist Cabinets, Moist Rooms, and Water Storage Tanks Used in the Testing of Hydraulic Cements and Concretes

3. Significance and Use

3.1 This test method is intended to be used to determine the flow of hydraulic cement mortars, and of mortars containing cementitious materials other than hydraulic cements.

3.2 While flow is not usually included in hydraulic cement specifications, it is commonly used in standard tests that require the mortar to have a water content that provides a specified flow level.

4. Apparatus

4.1 *Flow Table, Flow Mold*, Conforming to the requirements of Specification C 230.

4.2 *Caliper*, Conforming to the requirements of Specification C 230. Alternatively, any outside-measuring caliper constructed of corrosion-resistant material may be used, provided that it is incremented in millimetres and its maximum extent of measuring is at least 260 mm (10¼ in.).

4.3 *Tamper*, conforming to the requirements of Test Method C 109.

4.4 *Trowel*, having a steel blade 100 to 150 mm (4 to 6 in.) in length, with straight edges. The edges when placed on a plane surface shall not depart from straightness by more than 1 mm (0.04 in.) (Note 1).

4.5 *Straightedge*, made of steel, shall be at least 200 mm (8 in.) long and not less than 1.5 mm (0.06 in.) nor more than 3.5 mm (0.14 in.) in thickness. Its edge shall not depart from a plane surface by more than 1 mm (0.04-in.) (Note 1).

NOTE 1—The trowel specified in Test Method C 109 and the straightedge specified in Test Method C 185 may be used for this purpose, providing they comply with the planeness indicated.

5. Temperature and Humidity

5.1 The temperature and relative humidity of the air in the mixing room shall be as prescribed in Specification C 511.

6. Materials

6.1 *Hydraulic Cement Mortar*—A mortar for which the determination of flow is specified or desired.

7. Procedure

7.1 *Determination of Flow*:

7.1.1 Carefully wipe the flow table clean and dry, and place the flow mold at the center. Place a layer of mortar about 25 mm (1 in.) in thickness in the mold and tamp 20 times with the tamper. The tamping pressure shall be just sufficient to ensure uniform filling of the mold. Then fill the mold with mortar and tamp as specified for the first layer. Cut off the mortar to a plane surface flush with the top of the mold by drawing the straightedge or the edge of the trowel with a sawing motion across the top of the mold. Wipe the table top clean and dry, being especially careful to remove any water from around the edge of the flow mold. Lift the mold away from the mortar 1 min after completing the mixing operation. Immediately drop the table 25 times in 15 s, unless otherwise specified.

[1] This test method is under the jurisdiction of ASTM Committee C01 on Cement and is the direct responsibility of Subcommittee C01.22 on Workability.

Current edition Nov. 1, 2007. Published December 2007. Originally approved in 1999. Last previous edition approved in 2001 as C 1437 - 01.

[2] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

***A Summary of Changes section appears at the end of this standard.**

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7.1.2 If using the caliper specified in Specification C 230, measure the diameter of the mortar along the four lines scribed in the table top, recording each diameter as the number of caliper divisions, estimated to one tenth of a division. If some other caliper is being used, measure the diameter of the mortar along the four lines scribed in the table top, recording each diameter to the nearest millimetre.

8. Calculation

8.1 The flow is the resulting increase in average base diameter of the mortar mass, expressed as a percentage of the original base diameter.

8.2 If using the caliper specified in Specification C 230, add the four readings, and record the total. This gives the flow in percent. If using some other caliper, compute the flow in percent by dividing *"A"* by the original inside base diameter in millimetres and multiplying by 100.

where:

A = average of four readings in millimetres, minus the original inside base diameter in millimetres.

Report the flow to the nearest 1 %.

9. Precision and Bias

9.1 *Precision*—The single-operator, within-laboratory standard deviation has been found to be 4 % flow. Therefore, results of two properly conducted tests by the same operator on similar batches should not differ by more than 11 % (Note 2).

9.1.1 The multilaboratory standard deviation has been found to be 11 %. Therefore, results of two different laboratories on similar batches should not differ by more than 31 % flow (Note 2).

NOTE 2—Data produced when water content is being varied to obtain a given flow is not applicable for this purpose. Only data where flow has been determined using a given cement and fixed water content is applicable. Consequently, the only data currently available is that extracted from the CCRL Proficiency Sample Program for CS Flow on C 109 mortars (dropping the flow table 25 times in 15 s). The data for Sample Nos. 109, 110, 111, and 112 have been used to develop the precision statements given.

9.2 *Bias*—Since there is no accepted reference material suitable for determining flow available, no statement on bias is made.

10. Keywords

10.1 flow; hydraulic cement; mortar

SUMMARY OF CHANGES

Committee C01 has identified the location of selected changes to this test method since the last issue, C 1437 – 01, that may impact the use of this test method. (Approved November 1, 2007)

(*1*) Revised 5.1.

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Designation: C1438 – 99 (Reapproved 2005)ε1

Standard Specification for Latex and Powder Polymer Modifiers for Hydraulic Cement Concrete and Mortar[1]

This standard is issued under the fixed designation C1438; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

ε[1] NOTE—Paragraphs 1.2 and 1.3 were revised editorially November 2005.

1. Scope

1.1 This specification covers performance criteria for latexes and redispersible powders when used as modifiers in hydraulic cement concretes and mortars to improve adhesion and reduce permeability (see Note 1).

NOTE 1—For further information concerning theory, benefits, limitations, and applications of polymer-modified hydraulic cementitious mixtures, refer to ACI 548.3R-95.

1.2 The performance criteria are based on certain property changes that are achieved by use of the polymer modifier when compared to reference concrete or mortar (Test Methods C 1439).

1.3 Prepackaged, proprietary mortar products are not included in this specification. Also, this specification covers only those materials contained in the reference or test mixtures listed in Test Methods C 1439.

1.4 The values stated in SI units are to be regarded as standard.

1.5 The following precautionary statement pertains only to the test method portion, Section 10, of this specification: *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

2. Referenced Documents

2.1 *ASTM Standards:* [2]

C 125 Terminology Relating to Concrete and Concrete Aggregates

C 494/C 494M Specification for Chemical Admixtures for Concrete

C 1439 Test Methods for Polymer-Modified Mortar and Concrete

2.2 *ACI Standard:*

ACI 548.3R-95 State-of-the-Art Report on Polymer-Modified Concrete[3]

3. Terminology

3.1 *Definitions of Terms Specific to This Standard*—Terms used in this specification are defined in Terminology C 125 or in this section.

3.1.1 *latex*, *n*—a dispersion of organic polymer particles in water.

3.1.2 *polymer-modified concrete or mortar*, *n*—a hydraulic cement concrete or mortar containing a polymer modifier.

3.1.3 *polymer modifier*, *n*—latex or redispersible powder formulated for use with hydraulic cements.

3.1.4 *redispersible powder*, *n*—powder that redisperses in water to form a latex.

3.1.5 *reference concrete or mortar*, *n*—concrete or mortar having the amounts of cement and aggregates given in Test Methods C 1439 and having an amount of water to achieve the specified slump or flow.

3.1.6 *test concrete or mortar*, *n*—concrete or mortar containing a polymer modifier and having the same composition (except for water content) and slump or flow as the reference concrete or mortar.

4. Classification

4.1 Polymer modifiers are classified into two product types:

4.1.1 *Type I*—For use in areas not exposed to moisture.

4.1.2 *Type II*—For general use.

[1] This specification is under the jurisdiction of ASTM Committee C09 on Concrete and Concrete Aggregates and is the direct responsibility of Subcommittee C09.44 on Polymer-Modified Concrete.

Current edition approved Nov. 1, 2005. Published January 2006. Originally approved in 1999. Last previous edition approved in 1999 as C 1438 – 99ε1.

[2] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

[3] Available from American Concrete Institute (ACI), P.O. Box 9094, Farmington Hills, MI 48333.

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5. Ordering Information

5.1 The purchaser shall specify the type of polymer modifier desired and the size and type of containers in which the material is to be supplied.

6. Physical and Mechanical Properties

6.1 The polymer modifier shall produce test mortar or test concrete which conforms to the requirements listed in Table 1 for the type specified.

7. Lot Uniformity and Equivalence

7.1 When specified by the purchaser, the uniformity of a lot, or the equivalence of different lots from the same source shall be established by evaluation following Specification C 494, with the following exception:

7.1.1 *Residue by Oven Drying*—Within a range not greater than 2 percentage points of the initial sample.

TABLE 1 Requirements for Test Mortar and Concrete Made With Polymer Modifier

	MORTAR		CONCRETE
	Type I	Type II	Type II
Air Content, % maximum	12.0	12.0	7.0
Time of Setting, allowable deviation from reference mixture, h:min:			
Initial:			
not more than, earlier	1:00	1:00	1:00
nor, later	3:30	3:30	3:30
Final:			
not more than, earlier	1:00	1:00	1:00
nor, later	3:30	3:30	3:30
Compressive Strength, minimum % of reference mixture			
at each age	70	70	80
Bond Strength, minimum % of reference mixture			
at each age	140	140	140
Indication of Chloride Ion penetration, maximum % of reference mixture			
at each age	na[A]	25	25

[A] na = not applicable.

8. Storage

8.1 The supplier shall store the polymer modifier in such a manner as to permit easy access for proper inspection and identification of each shipment, in a suitable building that will protect the polymer modifier from dampness and freezing, and in accordance with manufacturer's recommendations.

9. Sampling and Inspection

9.1 The supplier shall provide facilities for proper sampling of the product as specified by the purchaser.

9.2 Sampling shall conform to the requirements of Specification C 494.

10. Test Methods

10.1 Test the polymer modifier in accordance with the requirements of Test Methods C 1439.

11. Rejection

11.1 The purchaser has the right to reject the polymer modifier if it fails to meet any of the applicable requirements of this specification.

11.2 It is permitted to reject packages that are more than 2 % below the mass or volume marked on them, and it is permitted to reject the entire shipment if the average mass of packages in any shipment, as shown by weighing 50 packages taken at random, is less than that marked on the packages.

12. Packaging and Package Marking

12.1 When the polymer modifier is delivered in packages and containers, the proprietary name of the polymer modifier, the type under this specification, and the net mass or volume shall be plainly marked thereon. Similar information shall be provided in the shipping papers accompanying bulk shipments of the polymer modifier.

13. Keywords

13.1 latex; polymer modifier; polymer-modified concrete or mortar

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Designation: C 1439 – 08a

Standard Test Methods for Evaluating Polymer Modifiers in Mortar and Concrete[1]

This standard is issued under the fixed designation C 1439; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope*

1.1 These test methods provide a means of determining the effect of adding polymer modifiers to reference concrete or mortar.

1.2 Most sections of ASTM test methods and practices for hydraulic cement mortar and concrete apply to the preparation and testing of specimens made with polymer-modifiers. However, there are some exceptions, most notably curing, that need special procedures in order to develop the properties inherent with polymer-modification. These test methods cover these exceptions.

1.3 For testing polymer-modified mortar and concrete specimens, the procedures in this standard supersede those in the referenced ASTM test methods and practices. These test methods are not applicable to dry, packaged mortar and concrete.

1.4 The values stated in SI units are to be regarded as standard. No other units of measurement are included in this standard.

1.5 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.* (**Warning**—Fresh hydraulic cementitious mixtures are caustic and may cause chemical burns to skin and tissue upon prolonged exposure.[2])

2. Referenced Documents

2.1 *ASTM Standards:* [3]

C 33 Specification for Concrete Aggregates

C 39/C 39M Test Method for Compressive Strength of Cylindrical Concrete Specimens

C 109/C 109M Test Method for Compressive Strength of Hydraulic Cement Mortars (Using 2-in. or [50-mm] Cube Specimens)

C 127 Test Method for Density, Relative Density (Specific Gravity), and Absorption of Coarse Aggregate

C 128 Test Method for Density, Relative Density (Specific Gravity), and Absorption of Fine Aggregate

C 138/C 138M Test Method for Density (Unit Weight), Yield, and Air Content (Gravimetric) of Concrete

C 143/C 143M Test Method for Slump of Hydraulic-Cement Concrete

C 150 Specification for Portland Cement

C 173/C 173M Test Method for Air Content of Freshly Mixed Concrete by the Volumetric Method

C 185 Test Method for Air Content of Hydraulic Cement Mortar

C 192/C 192M Practice for Making and Curing Concrete Test Specimens in the Laboratory

C 231 Test Method for Air Content of Freshly Mixed Concrete by the Pressure Method

C 260 Specification for Air-Entraining Admixtures for Concrete

C 305 Practice for Mechanical Mixing of Hydraulic Cement Pastes and Mortars of Plastic Consistency

C 403/C 403M Test Method for Time of Setting of Concrete Mixtures by Penetration Resistance

C 494/C 494M Specification for Chemical Admixtures for Concrete

C 778 Specification for Standard Sand

C 1202 Test Method for Electrical Indication of Concrete's Ability to Resist Chloride Ion Penetration

C 1404/C 1404M Test Method for Bond Strength of Adhesive Systems Used With Concrete as Measured by Direct Tension

C 1437 Test Method for Flow of Hydraulic Cement Mortar

C 1438 Specification for Latex and Powder Polymer Modifiers for Hydraulic Cement Concrete and Mortar

3. Significance and Use

3.1 These test methods are used to develop data for comparison with the requirements of Specification C 1438. Standardized procedures are used to compare the properties of

[1] These test methods are under the jurisdiction of ASTM Committee C09 on Concrete and Concrete Aggregates and are the direct responsibility of Subcommittee C09.44 on Polymer-Modified Concrete and Mortars

Current edition approved Sept. 1, 2008. Published October 2008. Originally approved in 1999. Last previous edition approved in 2008 as C 1439 – 08.

[2] Section on Safety Precautions, Manual of Aggregate and Concrete Testing, *Annual Book of ASTM Standards*, Vol. 04.02.

[3] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

***A Summary of Changes section appears at the end of this standard.**

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specimens made from test mixtures of polymer-modified concrete or mortar with the properties of specimens made from reference mixtures. These test methods are not intended to simulate job conditions.

4. Materials

4.1 *polymer modifier*—the polymer modifier of the required type as furnished by the supplier.

4.2 *antifoam agent*—antifoam agent of the type recommended by the manufacturer, if one is not incorporated in the polymer modifier.

4.3 *cement*—portland cement conforming to Specification C 150; if necessary, blend into a single lot prior to test. Use same lot for both test and reference mixtures.

4.4 *aggregates*—fine and coarse aggregates for concrete conforming to Specification C 33; if necessary, blend each into a single lot prior to test. Use same lot for both test and reference mixtures.

4.5 *graded sand*—sand for mortar mixtures conforming to Specification C 778; if necessary, blend into a single lot prior to test. Use same lot for both test and reference mixtures.

5. Proportioning of Concrete and Mortar Mixtures

5.1 *Concrete Mixture Proportioning*—Make the test and reference concrete with proportions similar to those shown for a nominal cubic-meter batch.

5.1.1 *Test Concrete*—Make the test concrete conforming to the following requirements:

	Parts by Mass, kg
Portland cement	390 ± 3
Fine aggregate[A]	975 ± 6
Coarse aggregate #8[A]	780 ± 6
Polymer Modifier	[B]
Antifoam agent	[C]
Potable water	[D]

[A] Saturated-surface-dry basis as described in Test Methods C 127 and C 128.

[B] The level recommended by the manufacturer.

[C] If the polymer modifier does not contain an antifoam agent, add the type and dosage recommended by the manufacturer, to the polymer modifier prior to mixing the concrete.

[D] The amount of water to give a slump of 90 ± 15 mm.

5.1.2 *Reference Concrete*—Make the reference concrete conforming to the following requirements:

	Parts by Mass, kg
Portland cement	390 ± 3
Fine aggregate[A]	975 ± 6
Coarse aggregate #8[A]	780 ± 6
Air-entraining admixture	[B]
Potable water	[C]

[A] Saturated-surface-dry basis as described in Test Methods C 127 and C 128.

[B] The amount of air-entraining admixture, meeting Specification C 260, to give an air content within 2 % of the test concrete and not exceeding 7.0 %.

[C] The amount of water to give a slump of 90 ± 15 mm.

5.2 *Mortar Mixture Proportioning*:

5.2.1 *Test Mortar*—Make the test mortar conforming to the following proportions:

	Parts by Mass, kg
Portland cement	100 ± 2
Graded sand[A]	275 ± 10
Polymer modifier	[B]
Antifoam agent	[C]
Potable water	[D]

[A] Saturated-surface-dry basis as described in Test Methods C 128.

[B] The level recommended by the manufacturer.

[C] If the polymer modifier does not contain an antifoam agent, add the type and dosage recommended by the manufacturer, to the polymer modifier prior to mixing the mortar.

[D] The amount of water that produces a flow of 105 to 115 % when tested according to Test Method C 1437.

5.2.2 *Reference Mortar*—Make the reference mortar conforming to the following proportions:

	Parts by Mass, kg
Portland cement	100 ± 2
Graded sand[A]	275 ± 10
Air-entraining admixture	[B]
Potable water	[C]

[A] Saturated-surface-dry basis as described in Test Methods C 128.

[B] The amount of air-entraining admixture, meeting Specification C 260, to give an air content that is within 2 % of the test mortar and not exceeding 12.0 %.

[C] Amount of water that produces a flow of 105 to 115 % when tested according to Test Method C 1437.

6. Procedure

6.1 *General*—Mix concretes and mortars in mechanical mixers in batches of such size as to leave about 10 % excess after molding test specimens and testing the unhardened mixtures.

6.2 *Temperature*—Before mixing the concrete or mortar, bring the materials to a uniform temperature, as described in Practice C 192/C 192M for concrete and Test Method C 109/C 109M for mortar.

6.3 *Polymer Modifier*—Store the polymer modifier in a dry place, in moisture-proof containers. Mix the polymer modifier thoroughly before use to ensure uniformity.

6.4 *Reference Concrete and Mortar*—Prepare reference concrete or mortar in compliance with Practice C 192/C 192M or Test Method C 109/C 109M, respectively.

NOTE 1—For trial batches to establish the amounts of water and air-entraining admixture to achieve the specified fresh properties, it is permissible to add these ingredients in increments and remix the batches. With the first increment of water and air-entraining admixture, if applicable, follow the mixing procedures specified in the previous section. If the slump, or flow, or air content is less than required, add additional water or air-entraining admixture and remix the batch. For mortar mixtures, remix at slow speed for 30 s. For concrete, remix the batch for 1 min. Remixing is permitted as often as necessary, provided the elapsed time from the start of initial mixing to the completion of mixing does not exceed 30 min. Cover the mixer to minimize evaporation when tests of fresh properties are being performed. These are trial batches only and are not to be used for testing.

6.5 *Test Mortar*—For mixing test mortar, follow Practice C 305, with the following changes:

6.5.1 *For Latex Polymer Modifiers*:

6.5.1.1 Place all the polymer modifier (with antifoam agent, as required) and mixing water in the bowl.

6.5.1.2 Add the cement to the bowl; start the mixer and mix at the slow speed (140 ± 5 r/min) for 30 s.

6.5.2 *For Powder Polymer Modifiers*:

6.5.2.1 Blend all the polymer modifier (with antifoam agent, as required) and cement, within 1 h of mixing the mortar.

6.5.2.2 Place the water in the bowl.

6.5.2.3 Add the cement/polymer modifier blend to the water; start the mixer and mix at the slow speed (140 ± 5 r/min) for 30 s

6.6 *Test Concrete*—For mixing test concrete, follow Practice C 192/C 192M, with the following changes:

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6.6.1 *For Latex Polymer Modifiers*—Prior to starting rotation of the mixer, add the coarse aggregate, polymer modifier, and approximately half of the water. Rotate the mixer a few revolutions, then add the fine aggregate, cement and remaining water. Mix the concrete for 3 min, followed by a 1 minute rest, followed by 1 min final mixing. Cover the open end of the mixer during the rest period to prevent evaporation. Take precautions to compensate for mortar retained by the mixer so that the discharged batch, as used, will be correctly proportioned (see Note 2).

6.6.2 *For Powder Polymer Modifiers*—Blend all the polymer modifier (with antifoam agent, as required) and cement, within 1 h of mixing the concrete. Prior to starting rotation of the mixer, add the coarse aggregate and approximately half of the water. Rotate the mixer a few revolutions, then add the fine aggregate, cement/polymer modifier blend, and remaining water. Mix the concrete for 3 min, followed by a 1 min rest, followed by 1 min final mixing. Cover the open end of the mixer during the rest period to prevent evaporation. Take precautions to compensate for mortar retained by the mixer so that the discharged batch, as used, will be correctly proportioned (see Note 2).

NOTE 2—It is difficult to recover all of the mortar from mixers. To compensate for this difficulty one of the following procedures may be used to ensure the correct final proportions in the batch:

(1) "Buttering the Mixer"—Just prior to mixing the test batch, the mixer is "buttered" by mixing a batch proportioned to simulate closely the test batch. The mortar adhering to the mixer after discharging is intended to compensate for loss of mortar from the test batch.

(2) "Over-Mortaring" the Mixture—The test mixture is proportioned by the use of an excess mortar, the amount established in advance, to compensate for that which, on the average, adheres to the mixer. In this case the mixer is cleaned before mixing the test batch.

7. Tests of Freshly Mixed Concrete and Mortar

7.1 *Concretes*—Test samples of the freshly mixed concrete in accordance with the following methods:

7.1.1 *Slump*—Test Method C 143/C 143M.

7.1.2 *Air Content*—Test Method C 173/C 173M or C 231.

7.1.3 *Unit Weight*—Test Method C 138/C 138M.

7.1.4 *Time of Setting*—Test Method C 403/C 403M.

7.2 *Mortars*—Test samples of the freshly mixed mortar in accordance with the following methods:

7.2.1 *Flow*—Test Method C 1437.

7.2.2 *Unit Weight*—Test Method C 185.

7.2.3 *Time of Setting*—Test Method C 403/C 403M.

7.2.4 *Air Content*.

7.2.5 *Test Mortar*:

7.2.5.1 *Mass per 400 mL of Test Mortar*—When the quantity of mixing water has been found that produces a flow of 105 to 115 %, immediately determine the mass per 400 mL of mortar, following the procedures in Test Method C 185.

7.2.5.2 *Air Content Calculation*—Calculate the air content of the test mortar using the following formulas, which are based on the assumption that the specific gravities of the portland cement and sand are 3.15 and 2.65, respectively:

$$\text{air content, volume \%} = 100\,(1 - W_a / W_c) \quad (1)$$

where

W_a = measured density of test mortar, g/mL,
= W_t/400, where W_t is the mass in grams of 400 mL of the test mortar,

W_c = theoretical mass per unit volume, calculated on an air-free basis as follows:

$$= \frac{100 + 275 + L + A + D}{\frac{100}{3.15} + \frac{275}{2.65} + \frac{L}{S_L} + \frac{A}{S_A} + \frac{D}{1.0}} \quad (2)$$

where:

L = mass of polymer modifier (includes water), g/100 g cement,
S_L = specific gravity of polymer modifier,
A = mass of antifoam agent, g/100 g cement,
S_A = specific gravity of antifoam agent, and
D = mass of water added, g/100 g cement.

7.2.6 *Reference Mortar*:

7.2.6.1 *Mass per 400 mL of Reference Mortar*—When the quantity of mixing water has been found that produces a flow of 105 to 115 %, immediately determine the mass per 400 mL of mortar, following the procedures in Test Method C 185.

7.2.6.2 *Air Content Calculation*—Calculate the air content of the reference mortar using the following formulas, which are based on the assumption that the specific gravities of the portland cement and sand are 3.15 and 2.65, respectively:

$$\text{Air content, volume \%} = 100\,(1 - W_a / W_c) \quad (3)$$

where:

W_a = measured density of reference mortar, g/mL,
= W_r/400, where W_r is the mass in grams of 400 mL of the reference mortar,

W_c = theoretical mass per unit volume, calculated on an air-free basis as follows:

$$\frac{100 + 275 + AE + D}{\frac{100}{3.15} + \frac{275}{2.65} + \frac{AE}{S_{AE}} + \frac{D}{1.0}} \quad (4)$$

where:

AE = mass of air-entraining admixture, g/100 g cement,
S_{AE} = specific gravity of air-entraining admixture, and
D = mass of water added, g/100 g cement.

8. Preparation of Test Specimens

8.1 Prepare test specimens, from at least three separate batches of the mixtures being tested, according to the procedures in the test methods prescribed in Section 9. Three replicates shall be required for each test, except for Test Method C 1202, for which two replicates are acceptable. Complete the preparation of all specimens within three days.

8.2 *Manifestly Faulty Specimens*—Visually examine each specimen before testing. Do not test any specimen found to be manifestly faulty by such examination. Visually examine all specimens after testing, and discard the test result of any specimen found to be manifestly faulty. Should more than one specimen for a given test at a given age be found manifestly faulty either before or after testing, disregard the entire test and repeat. The test results reported shall be the average of the individual test results of the three specimens tested or, in the event that one specimen or one result has been disregarded, the average of the test results of the two remaining specimens.

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8.3 *Curing*:

8.3.1 *Reference Concrete and Mortar*—Cure reference concrete and mortar specimens in conformance with Practice C 192/C 192M and Test Method C 109/C 109M, respectively.

8.3.2 *Test Concrete and Mortar*—Unless otherwise specified, immediately cover the polymer-modified concrete and mortar specimens with polyethylene film (0.1 mm minimum thickness) and store at 23 ± 2°C for 24 ± 1 h. Remove the polyethylene cover and store the specimens at 23 ± 2°C and 50 ± 10 % R. H. until time of test.

9. Tests on Hardened Concretes and Mortars

9.1 *Concretes*—Test specimens of hardened concrete in accordance with the following methods:

9.1.1 *Compressive Strength*—Test Method C 39/C 39M.

9.1.2 *Bond Strength*—Use the procedure in Test Method C 1404/C 1404M to prepare the base assembly. After the top nipple has been taped to the bottom nipple, use the following procedure to complete the composite specimen.

9.1.2.1 Dampen the cut surface with water. A properly prepared surface will be damp but have no water sheen.

NOTE 3—Paper and cloth towels have been used to remove standing water.

9.1.2.2 Place approximately 50 mL of the test mixture onto the damp, cut surface and, using the brush, apply a uniform coating of paste to the concrete surface and the inside surface of the nipple.

9.1.2.3 Fill the top nipple in two equal layers, and rod each layer using 25 strokes. Strike off the surface with a trowel and cover with polyethylene film.

9.1.2.4 At the specified age, test the composite specimen, calculate the tensile strength at failure, and estimate the percentage of each mode of failure (base, bond line, or overlay), in accordance with Test Method C 1404/C 1404M.

9.1.3 *Indication of Chloride Ion Penetration*—Test Method C 1202. Use cylinders.

9.2 *Mortars*—test specimens of hardened mortar in accordance with the following methods:

9.2.1 *Compressive Strength*—Test Method C 109/C 109M.

9.2.2 *Bond Strength*—Test Method C 1404/C 1404M. Use the same procedure as described above for concrete.

9.2.3 *Indication of Chloride Ion Penetration*—Test Method C 1202.

10. Calculation

10.1 Calculate the water content, exclusive of water absorbed by the aggregates, of the test mixtures and the reference mixtures. Include the water in the polymer modifier, if applicable.

10.2 Calculate the water content of test concrete as a percentage of the reference concrete, and the test mortar as a percentage of the reference mortar, as follows:

$$WC_P = WC_t / WC_r \times 100 \quad (5)$$

where:

WC_P = water content of test concrete or mortar as a percentage of the reference concrete or mortar,

WC_t = water content of test concrete or mortar corrected to saturated-surface-dry condition of the aggregates, kg, and

WC_r = water content of reference concrete or mortar corrected to saturated-surface-dry condition of the aggregates, kg.

WC_t is calculated as follows:

$$WC_t = (WL + AW) \quad (6)$$

where:

WL = mass of water contributed by latex, and

AW = mass of water added to the mixer corrected to saturated-surface-dry condition of the aggregates.

WL is calculated as follows:

$$WL = [(100-P)/100]\,(ML) \quad (7)$$

where:

P = polymer content of latex (percent), measured by oven drying in accordance with Specification C 494/C 494M, and

ML = mass of latex added to batch.

11. Report

11.1 Report the following information:

11.1.1 Brand name, manufacturer's name, lot number, chemical composition, polymer content, type and dosage of polymer-modifier; brand name and dosage of any post-added antifoam agent.

11.1.2 Type of portland cement used.

11.1.3 Water content of the test mixture as a percent of the reference mixture.

11.1.4 Curing conditions and age of each specimen tested.

11.1.5 *For the Test Concretes*—Slump, air content, unit weight, time of setting, compressive strength, size of compressive strength cylinders, bond strength, indication of chloride penetration; as actual values, and percent of reference concrete.

11.1.6 *For the Test Mortars*—Flow, air content, unit weight, time of setting, compressive strength, bond strength, indication of chloride penetration; as actual values, and percent of reference mortar.

12. Precision and Bias

12.1 *Precision*—The precision of each of the procedures in this test method is being determined.

12.2 *Bias*—The procedures in this test method have no bias because the values are defined only in terms of this test method.

13. Keywords

13.1 latex; latex polymer; polymer-modified concrete; polymer-modified mortar; powder polymer

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SUMMARY OF CHANGES

Committee C09 has identified the location of selected changes to these test methods since the last issue, C 1439 – 08, that may impact the use of these test methods. (Approved September 1, 2008)

(*1*) Added a warning statement about fresh hydraulic cementitious mixtures in 1.5.

Committee C09 has identified the location of selected changes to these test methods since the last issue, C 1439 – 99(2008), that may impact the use of these test methods. (Approved August 1, 2008)

(*1*) Revised the title.
(*2*) Added new 1.1 and renumbered subsequent sections.
(*3*) Replaced references to Test Method C 109/C 109M with Test Method C 1437 in 5.2.1, 5.2.2, and 7.2.1.

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Designation: C 1451 – 05

Standard Practice for Determining Uniformity of Ingredients of Concrete From a Single Source[1]

This standard is issued under the fixed designation C 1451; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope

1.1 This practice covers a procedure for determining the uniformity of properties of concrete materials from a single source. It includes recommendations on sampling, testing, analysis of data, and reporting.

1.2 The values stated in SI units are to be regarded as the standard.

1.3 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

2. Referenced Documents

2.1 *ASTM Standards:* [2]

C 109/C 109M Test Method for Compressive Strength of Hydraulic Cement Mortars (Using 2-in. or [50-mm] Cube Specimens)

C 125 Terminology Relating to Concrete and Concrete Aggregates

C 219 Terminology Relating to Hydraulic Cement

C 294 Descriptive Nomenclature for Constituents of Concrete Aggregates

C 494/C 494M Specification for Chemical Admixtures for Concrete

C 638 Descriptive Nomenclature of Constituents of Aggregates for Radiation Shielding Concrete

C 917 Test Method for Evaluation of Cement Strength Uniformity from a Single Source

D 75 Practice for Sampling Aggregates

D 3665 Practice for Random Sampling of Construction Materials

2.2 *Other Document*

MNL 7 (STP 150) Manual on Presentation of Data and Control Chart Analysis, 6th edition

3. Terminology

3.1 *Definitions*—For definitions of terms relating to this practice refer to Terminology C 125, Terminology C 219, Descriptive Nomenclature C 294, and Descriptive Nomenclature C 638.

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *lot*, *n*—a user-defined quantity, typically representing any amount of material for which uniformity information is to be calculated.

3.2.1.1 *Discussion*—The minimum lot size is generally the amount of material in a single conveyance, such as a truck load, a rail-car load, or a barge load. At the other extreme, a lot might be defined by a user as the total amount of material used in a single construction or by a supplier as the amount of material produced over a given interval of time.

3.2.2 *sampling unit*, *n*—amount of material from which a grab sample is taken.

3.2.2.1 *Discussion*—Generally a lot is subdivided into sampling units, and then sampling units are chosen at random for taking of grab samples. The size of the sampling unit is user-defined, depending on the purposes of the evaluation. The term *sub lot* is sometimes used to define this concept.

4. Significance and Use

4.1 This practice provides a systematic procedure for sampling and determining the uniformity of user-selected properties of ingredients of concrete. Results derived from application of the practice are generally intended for information only and are not requirements of any existing ASTM specification on concrete or concrete materials. A concrete materials specification may make reference to this practice as a means of obtaining uniformity information, but needs to define the properties to be measured and the lot size and sample unit to be used. The practice is applicable to both producers of concrete materials and to consumers of concrete materials, although details of application of the practice may vary, depending on the intended purpose of the user of the practice.

4.2 The procedure is applicable to any property of any concrete ingredient that can be described quantitatively, and for which conventional parametric statistics are applicable. The

[1] This practice is under the jurisdiction of ASTM Committee C09 on Concrete and Concrete Aggregates and is the direct responsibility of Subcommittee C09.94 on Evaluation of Data.

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[2] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

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procedure is based on grab samples, which will tend to show the maximum amount of variation in the selected material property. The procedure was developed for application to materials from a single source, but it can be applied to a materials delivery stream from more than one source, depending on the purposes of the user of the practice. Calculations are corrected for testing error, therefore giving an estimate of the uniformity of the selected material property. The uniformity of the selected material property provides the user with one indicator of the source variation of the concrete ingredient.

4.3 Although variability in properties of concrete materials can be a significant cause of variability in concrete properties, this practice does not purport to give information on this relationship. This practice does give information on uniformity of ingredients from which the user can, along with supplementary information or correlative testing of concrete properties, develop quantitative estimates of the effects.

5. Sampling

5.1 The sampling plan underlying the analysis of uniformity is critical to the interpretation of results. The sampling plan will vary, depending on the details of concrete materials supply and user-defined purpose of the evaluation. The sampling plan should, at a minimum, address the lot size and sampling frequency, location and procedure of sampling from sampling unit, and handling of samples. All sampling is to be performed by personnel specifically trained for this purpose.

5.2 The first step in determining the sampling plan is to define the objective and scope of the evaluation. This requires considerable experience and knowledge of details involved with the particular production under evaluation. The objective and scope of the evaluation may vary between users and producers of materials. It may also range from determining the uniformity of materials during a relatively small production period to covering a very long production period. If there is no prior knowledge of the uniformity of a material property, or if it is suspected that the material might show considerable variation, a relatively intense sampling plan might be designed initially. If the prior knowledge indicates that the material property is relatively stable, then a less intense sampling plan might be designed.

5.3 The second step is to define the size of the *lot* and the size of the *sampling unit* (see 3.2). Typically a lot is divided into a number of sampling units; then sampling units are selected at random for the taking of grab samples. Typically, the number of sampling units is larger than the number actually sampled, although for small lot sizes, the number of sampling units may equal the number of samples being taken.

5.4 Take random grab samples from a point in the storage and handling process of the material that will accurately reflect the uniformity of the material as it will be used in concrete. Practice D 3665 provides general guidance. Additional guidance for specific materials is listed in 5.4.1-5.4.4. Identify samples by the date on which the material was shipped or received, its source, and designated type and applicable specifications.

5.4.1 Sample cement in accordance with Test Method C 917.

5.4.2 Sample fine and coarse aggregates in accordance with Practice D 75.

5.4.3 Sample chemical admixtures in accordance with Specification C 494/C 494M.

5.4.4 Sample pozzolan or ground granulated blast-furnace slag in accordance with Test Method C 917.

5.5 The required sampling frequency depends on how the data are being used and the nature of the material being evaluated. The sampling plan used should be described in the report (Section 8).

6. Procedure

6.1 *General*—Test all samples in accordance with the appropriate ASTM Test Method for the particular property being measured. Choose a property and method that has good precision so that the material uniformity is not masked by the testing error. It is also advisable to select a method that does not incur significant cost and is conducted frequently so the operators are proficient with the procedure. Variation within a single source is estimated by first calculating total variation from test data on grab samples, and then correcting this by subtracting variation inherent in the test method (testing error). Best results are obtained if all tests are conducted in the same laboratory, but guidance is provided if it is necessary to use data from more than one laboratory.

6.2 *Total Variation*—Test all samples in accordance with the appropriate ASTM Standard Test Method for the particular test property being measured. Choose a property and method that has good precision so that the material uniformity is not masked by the testing error. It is also advisable to select a method that does not incur significant cost and is conducted frequently so the operators are proficient with the procedure. Calculate the total variation among the samples, as directed in 7.1.2.

6.3 *Testing Error*—Testing error is composed of components due to within-laboratory variation and between-laboratory variation. If results are obtained from only one laboratory, then between-laboratory variation makes no contribution. If data are obtained from more than one laboratory, it is preferable to keep data from each one separate during data analysis, pooling estimates of variation at the end of the analysis.

6.3.1 To estimate within-laboratory testing error, duplicate tests made from a single sample are required. Samples must be tested in duplicate on different days until at least ten samples have been tested in duplicate. The rate of duplicate tests initially should be at least once in five samples and not less frequently than once per month. Calculate the testing error standard deviation and the coefficient of variation, as outlined in 7.1.3. If the testing error exceeds the single laboratory precision (1s or 1s%) reported in the precision statement for the applicable test method, but is less than 1.5 times this value, continue duplicate tests at this same rate. When the testing error is equal to or less than the testing error reported in the precision statement, reduce the frequency of duplicate testing. If the testing error exceeds 1.5 times the testing error reported in the precision statement, the data are of unacceptable precision, and the laboratory procedure and equipment should be thoroughly examined. Use the results of duplicate tests,

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indicating acceptable precision to estimate the within-laboratory testing error for all other types of similar materials tested in that laboratory during the same period of time.

6.3.2 When two or more laboratories are used to evaluate the uniformity of a source, then additional tests of a standard sample or exchanged portions of the same sample may be necessary to determine differences in testing that are likely to be obtained in the different laboratories. When two laboratories exchange portions of the sample and run single tests, results from the laboratories shall not differ by more than the multi-laboratory precision (D2S value) of the average of the two laboratories. If a larger number of samples are exchanged, then the difference between laboratories exceed the D2S no more than 5 % of the time.

6.3.3 Calculate the testing error from duplicate tests conducted in each laboratory as outlined in 7.1.3.

6.4 *Single-Source Variation*—Calculate single-source variation according to 7.1.4.

7. Calculation

7.1 The calculations shall include the following (Note 1):

NOTE 1—Values for averages and standard deviations can be calculated by other methods that are available in MNL 7 (STP 150). Electronic calculators and spreadsheets are available for obtaining these statistics directly.

7.1.1 *Average Measurement*:

$$\bar{x} = \frac{x_1 + x_2 + \ldots + x_n}{n} \quad (1)$$

where:

$\bar{x}$ = average measurement,
$x_1, x_2, \ldots x_n$ = individual measurements, and
n = number of individual tests.

7.1.2 *Standard Deviation*:

$$s_t = \sqrt{\frac{(x_1 - \bar{x})^2 + (x_2 - \bar{x})^2 + \ldots + (x_n - \bar{x})^2}{(n-1)}} \quad (2)$$

where:

s_t = standard deviation in units of measurement.

7.1.3 *Testing Error:*

7.1.3.1 The standard deviation for testing error is calculated as follows (See Table 1):

$$s_e = \sqrt{\frac{\sum d^2}{2k}} \quad (3)$$

where:

s_e = standard deviation for testing error estimated from tests of duplicate measurements made in a single laboratory from the sample,
d = difference between duplicate determinations, and
k = number of sets of duplicate determinations.

7.1.3.2 The coefficient of variation for testing error is calculated as follows,

$$v_e = \frac{s_e}{\bar{x}_d} \quad (4)$$

where:

v_e = coefficient of variation for testing error estimated from tests of duplicate measurements made in a single laboratory from the sample, and
$\bar{x}_d$ = average measurement from duplicate tests.

7.1.4 *Single-Source Variation*:

7.1.4.1 Variation of material from a single source expressed in terms of standard deviation, corrected for testing error, is calculated as follows:

$$s_c = \sqrt{s_t^2 - s_e^2} \quad (5)$$

where:

s_c = standard deviation corrected for testing error,
s_t = standard deviation for all tests included in the calculation, and
s_e = standard deviation for testing error estimated from tests of duplicate measurements made in a single laboratory from the sample.

7.1.4.2 When data are collected from two laboratories, calculate the pooled single-source standard deviation as follows:

$$\bar{s}_c = \sqrt{\frac{(n_1 - 1){s_{c1}}^2 + (n_2 - 1){s_{c2}}^2}{n_1 + n_2 - 2}} \quad (6)$$

where:

$\bar{s}_c$ = pooled estimate of single-source standard deviation
s_{c1} *and* s_{c2} = standard deviation corrected for testing error from lab 1 and lab 2, respectively, and
n_1 *and* n_2 = number of tests in lab 1 and lab 2, respectively.

7.1.4.3 Single-source variation expressed as coefficient of variation, corrected for testing error, is calculated as follows:

$$v_c = \frac{s_c}{\bar{x}} \quad (7)$$

TABLE 1 Example Illustrating Calculation of Testing Error

Date	Samp. No.	Test "a," MPa	Test "b," MPa	Average, MPa	d^2
01/06	3	43.9	45.7	44.8	2.97
01/16	6	43.1	41.5	42.3	2.52
01/30	9	41.7	42.2	42.0	0.23
02/05	12	41.5	43.0	42.2	2.10
02/13	15	38.6	37.4	38.0	1.54
02/21	18	37.9	38.1	38.0	0.04
03/04	21	43.6	43.3	43.4	0.08
03/14	24	40.8	41.4	41.1	0.39
03/19	27	43.4	41.7	42.6	2.97
03/27	30	43.8	44.2	44.0	0.17
k = 10			Average, $\bar{x}_d$ = 41.9		
				Σd^2	13.0
			Testing Standard Deviation, s_e		0.81
			Testing Coefficient of Variation, v_e		1.9 %

8. Report

8.1 Sufficient information shall be provided to identify the material sampled including the following:

8.1.1 Name of manufacturer and location,

8.1.2 Classification or type of material,

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8.1.3 Location of sampling,
8.1.4 Laboratory designation,
8.1.5 Period of time represented by the report, and
8.1.6 Description of sampling frequency.

8.2 For ongoing programs, the minimum period covered by the report shall include all tests made in the preceding three months, but in no instances less than that period of time necessary to include 20 consecutive samples.

8.2.1 The report shall not cover a period of time greater than one year or tests of more than 120 samples.

8.3 The report of results shall be either in tabular form as shown in Table 2, or in graphical form as shown in Fig. 1, at the option of the reporting organization (Note 2).

NOTE 2—For purposes of analyzing trends, the graphical presentation is to be preferred. The average and standard deviation, as calculated in Section 7, shall be shown.

8.4 Report the results of duplicate tests on the same sample within the period covered by the report. When duplicate tests are made from samples other than that being tested during the same period of time, by the same laboratory, these test results will not normally be reported on a regular basis, but results of such tests will be made available upon request. However, report the testing standard deviation.

8.5 The report shall include the following values calculated from the reported data. Each sample shall be represented only by a single result in these calculations. The second of a pair of duplicate test results shall not be included in the overall calculation, but shall be used only to establish testing error. (See Footnote A of Table 2.)

8.5.1 Calculate from the reported data:
8.5.1.1 $\bar{x}$ = the average,
8.5.1.2 s_t = the standard deviation,
8.5.1.3 s_e = testing standard deviation,
8.5.1.4 n = the number of samples tested,
8.5.1.5 s_c = the single source variation expressed in terms of standard deviation corrected for testing, and
8.5.1.6 x_5 = the moving averages of the five most recent results.

8.5.2 The calculations shall not be made and reported until five results are available. The moving average of the five most recent results should be updated with each successive result by adding the new value in the calculation and deleting the oldest previous value (see Table 2).

8.5.3 Whenever the reporting agency concludes that a consistent change in properties has occurred, at its option, it may discontinue calculation until results from five additional samples have been obtained. In this instance, the values calculated from samples prior to the change shall also be reported.

8.5.4 When there is a break in the calculation, the sampling dates included in each set of calculated values shall be clearly identified.

9. Keywords

9.1 concrete materials; uniformity

TABLE 2 Sample Uniformity Test Report

ABC Cement Inc., Qualitytown, NJ

Material Tested	Type I Portland Cement
Sampling Location	Truck loading, Qualitytown
Tested at	ABC Qualitytown Laboratory
Dates Represented	January – March, 2004
Property measured	28-day strength, Test Method C 109/C 109M
Sampling Frequency	10 per month
Duplicate test frequency	1 in 3

Average Strength, MPa	41.1
Total Standard Deviation, MPa, s_t	2.25
Number of Tests (n)	30
Testing Standard Deviation, MPa, s_e	0.81
Number of Duplicate tests (k)	10
Single Source Standard Deviation, MPa, s_c	2.10
Single Source Coefficient of Variation, v_c	5.1 %

Date Shipped	Samp. No.[A]	Test "a," MPa	Avg. 5, MPa	Date Shipped	Samp. No.	Test "a," MPa	Avg. 5, MPa
01/02	1	42.3		02/17	16	43.6	40.5
01/03	2	37.2		02/19	17	39.0	40.2
01/06	3a	43.9		02/21	18a	37.9	38.2
01/08	4	40.8		02/25	19	40.0	38.6
01/14	5	39.5	40.8	02/27	20	39.2	39.9
01/16	6a	43.1	40.9	03/04	21a	43.6	39.9
01/21	7	41.5	41.8	03/07	22	40.8	40.3
01/24	8	43.6	41.7	03/12	23	42.9	41.3
01/30	9a	41.7	41.9	03/14	24a	40.8	41.5
01/31	10	41.9	42.4	03/15	25	39.1	41.4
02/03	11	38.5	41.4	03/18	26	41.0	40.9
02/05	12a	41.5	41.4	03/19	27a	43.4	41.5
02/06	13	44.1	41.5	03/22	28	42.1	41.3
02/07	14	37.9	40.8	03/25	29	43.2	41.8
02/13	15a	38.6	40.1	03/27	30a	43.8	42.7

[A] "a" represents samples in which duplicate tests were conducted.

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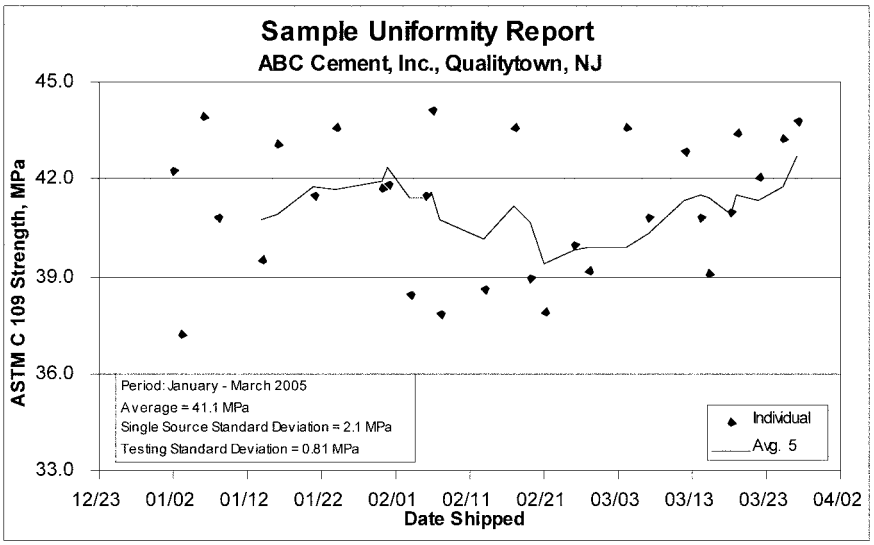

FIG. 1 Data Plots, Uniformity Test Report

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Designation: C 1467/C 1467M – 00 (Reapproved 2006)

Standard Specification for the Installation of Molded Glass Fiber Reinforced Gypsum Parts[1]

This standard is issued under the fixed designation C 1467/C 1467M; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope

1.1 This specification covers the installation of molded glass fiber reinforced gypsum (GRG) parts.

1.2 The values stated in either inch-pound units or SI (metric) are to be regarded separately as the standard. Within the text, SI units are shown in brackets. The values stated in each shall be used independent of the other. Values from the two systems shall not be combined.

1.3 All references to finishes, dimensions and tolerances shall refer to the finished surface of the part.

1.4 The text of this standard references notes and footnotes that provide explanatory material. These notes and footnotes (excluding those in tables and figures) shall not be considered as requirements of the standard.

2. Referenced Documents

2.1 *ASTM Standards:* [2]

C 11 Terminology Relating to Gypsum and Related Building Materials and Systems

C 754 Specification for Installation of Steel Framing Members to Receive Screw-Attached Gypsum Panel Products

C 840 Specification for Application and Finishing of Gypsum Board

C 1007 Specification for Installation of Load Bearing (Transverse and Axial) Steel Studs and Related Accessories

C 1381 Specification for Molded Glass Fiber Reinforced Gypsum Parts

3. Terminology

3.1 *Definitions*— Definitions of terms shall be in accordance with Terminology C 11.

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *critical lighting*, *n*—strong side lighting from natural or artificial light sources.

3.2.2 *primer*, *n*—paint material formulated to fill the pores and equalize the suction difference between the GRG part and finishing compounds used.

4. Materials

4.1 Molded GRG parts shall meet the requirements of Specification C 1381.

5. Environmental Conditions

5.1 Room temperature shall be maintained at not less than 40 °F [4 °C] during the installation of GRG parts except when adhesive is used for the bonding or attachment of parts to each other or to a substrate. For the bonding of adhesive and joint treatment the room temperature shall be maintained at not less than 50 °F [10 °C] for 48 hours prior to application and continuously thereafter until completely dry.

5.2 When a temporary heat source is used, the temperature shall not exceed 95 °F [35 °C] in any given room or area.

5.3 Installed GRG shall be protected from direct exposure to rain, snow, sunlight and other excessive weather conditions.

NOTE 1—Installation in conditions of excessive humidity is not recommended. The ideal conditions to install molded GRG parts is 70 °F [21 °C] and 50 % RH.

6. Substrate Preparation

6.1 Substrates to accept GRG parts shall be installed straight and true within ⅛ in. in 8 ft [3 mm in 2500 mm] and shall be free of obstructions and interference that prohibits correct attachment of GRG parts.

6.2 Metal framing members shall be of the proper size and design for the intended use and shall be sufficient to properly support the installed GRG parts. Metal framing members shall be installed in accordance with Specification C 754 or C 1007 as required.

7. Tolerances of Installed GRG Parts

7.1 Parts shall be installed plumb and not be out of line more than ± ⅛ in. in 8 ft [3 mm in 2500 mm] in any direction.

[1] This specification is under the jurisdiction of ASTM Committee C11 on Gypsum and Related Building Materials and Systems and is the direct responsibility of Subcommittee C11.03 on Specifications for the Application of Gypsum and Other Products in Assemblies.

Current edition approved May 1, 2006. Published May 2006. Originally approved in 2000. Last previous edition approved in 2000 as C 1467/C 1467M – 00.

[2] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

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7.2 The planar surface of any part shall not vary by more than ⅛ in. [3 mm] from the planar surface of any adjacent part.

7.3 GRG parts shall be installed so that the joints between parts are not more than ¼ in. [6 mm] in width.

8. Installation of GRG Parts

8.1 GRG parts shall be installed to the tolerances stated in Section 7.

8.2 GRG parts shall be installed according to manufacturers' directions onto substrates and with fastening devices as specified by the GRG manufacturer.

9. Finishing of GRG Parts

9.1 GRG parts shall be finished in accordance with the manufacturers' directions.

9.2 GRG parts subject to critical lighting or scheduled to receive gloss or semi-gloss decoration shall be prepared as a Level 5 finish in accordance with Specification C 840.

NOTE 2—GRG parts are furnished with a primer-ready surface.

10. Handling and Storage

10.1 GRG parts shall be stored in accordance with the manufacturers' recommendations.

10.2 GRG parts shall be protected from rain, snow, sunlight, excessive weather conditions and jobsite damage during storage.

10.3 GRG parts shall be stored on a clean and dry surface.

10.4 GRG parts shall not be stacked or placed on other GRG parts unless approved by the manufacturer in writing.

NOTE 3—Parts improperly stored could be subject to warping, bowing and dimensional variations.

11. Keywords

11.1 GRG parts; installation

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Designation: C 1480/C 1480M – 07

Standard Specification for Packaged, Pre-Blended, Dry, Combined Materials for Use in Wet or Dry Shotcrete Application[1]

This standard is issued under the fixed designation C 1480/C 1480M; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope*

1.1 This specification covers laboratory performance standards for pre-blended, dry, packaged, combined materials for use in wet or dry shotcrete applications that are delivered to a purchaser with the ingredients uniformly mixed. The use of supplemental materials, placement, curing, or protection of the shotcrete after delivery to the purchaser is not addressed by this specification.

1.2 The values stated in either SI units or inch-pound units shall be regarded separately as standard. The values stated in each system are not exact equivalents; therefore, each system shall be used independently of the other. Combining values from the two systems may result in nonconformance with the standard.

1.3 The following safety hazards caveat pertains only to the test method portion of this specification: *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

2. Referenced Documents

2.1 *ASTM Standards:* [2]

C 78 Test Method for Flexural Strength of Concrete (Using Simple Beam with Third-Point Loading)

C 150 Specification for Portland Cement

C 387/C 387M Specification for Packaged, Dry, Combined Materials for Mortar and Concrete

C 595 Specification for Blended Hydraulic Cements

C 1012 Test Method for Length Change of Hydraulic-Cement Mortars Exposed to a Sulfate Solution

C 1140 Practice for Preparing and Testing Specimens from Shotcrete Test Panels

C 1157 Performance Specification for Hydraulic Cement

C 1202 Test Method for Electrical Indication of Concrete's Ability to Resist Chloride Ion Penetration

C 1385/C 1385M Practice for Sampling Materials for Shotcrete

C 1399 Test Method for Obtaining Average Residual-Strength of Fiber-Reinforced Concrete

C 1436 Specification for Materials for Shotcrete

2.2 *National Institute of Standards and Technology:*

Handbook 44 Specifications, Tolerances, and Other Technical Requirements for Commercial Weighing Devices[3]

3. Terminology

3.1 *Definitions of Terms Specific to This Standard:*

3.1.1 *Packaged, pre-blended, dry, combined materials*—for use in wet or dry shotcrete applications consist primarily of hydraulic cement and concrete aggregates blended, in a dry state, with other ingredients to enhance one or more properties of the mixture.

4. Classification

4.1 Dry packaged shotcrete materials are categorized as to type and grade.

4.1.1 Shotcrete type is based on aggregate size.

4.1.2 Type FA shotcrete shall contain aggregate in accordance with the requirements of Specification C 1436 Grading #1. Aggregates failing to comply with Grading #1 can be used only if preconstruction testing proves that they give satisfactory results or if acceptable service records are available.

4.1.3 Type CA shotcrete shall contain coarse and fine aggregates in accordance with the requirements of Specification C 1436, Grading No. 2. Aggregates failing to comply with Grading #2 can be used only if preconstruction testing proves that they give satisfactory results or if acceptable service records are available.

[1] This specification is under the jurisdiction of ASTM committee C09 on Concrete and Concrete Aggregates and is the direct responsibility of Subcommittee C09.46 on Shotcrete.

Current edition approved Feb. 1, 2007. Published February 2007. Originally approved in 2000. Last previous edition approved in 2005 as C 1480 – 00(2005).

[2] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

[3] Available from National Institute of Standards and Technology (NIST), Superintendent of Documents, U.S. Government Printing Office, Washington, DC 20402

***A Summary of Changes section appears at the end of this standard.**

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4.2 Shotcrete grade is based on the desired physical properties of the material.

4.2.1 Grade GU shotcrete is a general use product.

4.2.2 Grade SR shotcrete has sulfate resistance in accordance with the requirements of 7.4

4.2.3 Grade LP shotcrete has permeability values in accordance with the requirements of 7.5

4.2.4 Grade FR shotcrete has average residual strength values in accordance with the requirements of 7.6, Type I or II.

4.2.4.1 Class I shotcrete has average residual strength values in accordance with the requirements of 7.6.1.

4.2.4.2 Class II shotcrete has flexural strength and average residual strength values in accordance with the requirements of 7.6.2.

NOTE 1—Grade FR Class I shotcrete is intended to minimize plastic shrinkage cracking. Grade FR Class 2 shotcrete is intended to provide a minimum level of post-crack flexural load capacity for hardened shotcrete.

5. Ordering Information

5.1 The purchaser shall specify the type, grade, and class (if applicable) of shotcrete required.

NOTE 2—A single material may meet more than one grade. Other properties may be specified by the purchaser, but are beyond the scope of this specification.

5.2 At the request of the purchaser, the producer shall, prior to delivery, furnish laboratory performance data satisfactory to the purchaser that the product meets the specified type and grades.

6. Materials and Manufacture

6.1 Basic materials shall meet the requirements of Specification C 1436.

6.2 Additional materials shall be permitted only if adequate test data are available to insure that the ingredient has no deleterious effects on the specified properties.

6.3 Aggregates shall be dried, without disintegration, to a moisture content of less than 0.2 mass percent, computed on material dried substantially to constant mass at 105 to 110 °C [210 to 230 °F].

6.4 *Measurement of Materials*—Measure materials in accordance with 6.4.1-6.4.4.

6.4.1 Cementitious materials and aggregates shall be measured by mass (or by volume). Volumetric measurement shall be calibrated by mass.

6.4.2 Scales for batching ingredients shall conform to the applicable section of the current edition of the National Institute of Standards and Technology Handbook 44 Specifications, Tolerance, and Other Technical Requirements for Commercial Weighing Devices.

6.4.3 Measure fibers by mass.

6.4.4 Measure admixtures by mass or volume.

6.5 Shotcrete ingredients shall be thoroughly blended at a central location. Mixer performance tests shall be performed to establish the mixing time suitable for uniformity of mixing. Representative samples shall be obtained in accordance with Practice C 1385/C 1385M.

6.6 *Delivery*—Unless otherwise specified, delivery of the shotcrete materials shall conform to 6.6.1-6.6.3.

6.6.1 Thoroughly mix and deliver to the construction site materials without segregation or lumps of ingredients.

6.6.2 Temperature of pre-blended, dry, combined materials for shotcrete at time of delivery shall not exceed 65 °C [150 °F].

6.6.3 Delivery shall be in any size package as agreed between the purchaser and producer.

7. Physical Requirements

7.1 Type FA shotcrete shall meet the requirements of Table 1 when mixed and tested in accordance with the procedure for mixing and testing high strength mortar in accordance with Specification C 387/C 387M.

7.2 Type CA shotcrete shall meet the requirements of Table 1 when mixed and tested in accordance with the procedures for mixing and testing normal strength concrete in accordance with Specification C 387/C 387M.

7.3 Grade GU shotcrete shall meet the general requirements for type FA or type CA shotcrete.

7.4 Grade SR shotcrete shall have sulfate resistance as determined in one of the following ways:

7.4.1 Product shall be prepared with a cement meeting Specification C 150 types II or V, Specification C 595 cements with an MS designation or Performance Specification C 1157 types MS or HS

7.4.2 Product shall exhibit an expansion of less than 0.1 % at 180 days when tested in accordance with applicable portions of Test Method C 1012. Samples for testing shall be mixed and placed in accordance with this specification.

7.4.3 In Test Method C 1012 the samples are normally prepared at a fixed water content using standard sand. Those portions of the method will not apply in this case

7.5 Grade LP shotcrete shall have a chloride penetrability rating of "very low" (< 1000 coulombs) when tested at an age of 28 days in accordance with Test Method C 1202. Specimens for the test shall be either from laboratory prepared samples mixed and placed in accordance with this specification or from field samples obtained in accordance with Practice C 1140 and Test Method C 1202.

NOTE 3—Due to the potential differences between laboratory and field conditions it may be necessary to test field samples in order to verify performance with the applied material specifications. See appendix for a discussion of expected field performance vs. laboratory performance for wet mix vs. dry mix shotcrete.

7.6 Grade FR shotcrete shall have fiber reinforcement with the following minimum requirements:

7.6.1 Grade FR Class I shotcrete shall have a minimum 28-day average residual strength of 275 kPa [40 psi] when tested in accordance with Test Method C 1399.

TABLE 1 Physical Requirements

Property	Requirement for Type FA	Requirement for Type CA
Flow	105 to 115	- - -
Slump	- - -	50 to 75 mm [2 to 3 in.]
7 day Compressive strength (min)	21.0 MPa [3000 psi]	21.0 MPa [3000 psi]
28 day Compressive Strength (min)	35.0 MPa [5000 psi]	35.0 MPa [5000 psi]

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7.6.2 Grade FR Class II shotcrete shall have a minimum 28-day flexural strength of 4MPa [600 psi] when 100 by 100 by 350 mm specimens are tested in accordance with Test Method C 78 and a minimum 28-day average residual strength of 2 MPa [300 psi] when tested in accordance with Test Method C 1399.

8. Sampling and Specimen Preparation

8.1 Samples of the finished product for testing shall be provided by the manufacturer or obtained in the field prior to the addition of water in accordance with Practice C 1385/C 1385M.

8.2 Specimens for testing for compliance with this specification shall be cast and tested in accordance with the applicable portions of Specification C 387/C 387M unless otherwise specified within this specification.

NOTE 4—Specimens for testing mixtures for compliance with this specification are laboratory mixtures cast in accordance to applicable portions of Specification C 387/C 387M, not mixtures that have been shotcreted. The values of test results may be higher or lower than the values of test results from nominally similar mixtures that have been shotcreted.

9. Rejection

9.1 The purchaser has the right to reject material that fails to conform to the requirements of this specification. Rejection shall be reported to the producer of supplier promptly and in writing.

9.2 The seller has no control over the application of the shotcrete material; therefore unsatisfactory field performance of the material shall not be used as a basis for rejection of the product.

NOTE 5—For instructions on the proper application of shotcrete refer to ACI 506.2[4].

10. Packaging and Package Marking

10.1 All packages shall be identified as conforming to Specification C 1480, and as to type, grade(s), and class (if applicable) of shotcrete material and the net mass in each package printed thereon.

10.2 The yield in cubic metres [cubic feet] and the approximate amount of water recommended for mixing shall be marked on the package.

NOTE 6—The amount of water recommended shall be the amount required to produce a 50 to 75-mm [2 to 3-in.] slump for Type CA or a flow of 105-115 for Type FA.

11. Keywords

11.1 average residual strength; compressive strength; dry mix shotcrete; flexural strength; packaged shotcrete materials; pre-blended shotcrete materials; shotcrete; wet mix shotcrete

[4] ACI 506.2, "Specification for Shotcrete," American Concrete Institute (ACI), P.O. Box 9094, Farmington Hills, MI 48333.

APPENDIXES

(Nonmandatory Information)

X1. DIFFERENCE BETWEEN DRY-MIX AND WET-MIX SHOTCRETE

X1.1 Dry mix shotcrete (also known as gunite) is typically placed in the field at a water content that is 10 to 15 % lower than that required for laboratory testing. Therefore field performance of dry mix shotcrete under ideal conditions will provide substantially higher strengths than in the laboratory.

X1.2 Wet mix shotcrete will be more likely to be placed with a water content similar to that used in the laboratory. Wet mix shotcrete is sometimes modified at the nozzle by the addition of a shotcrete accelerator. This can affect the in-place results.

X2. FIELD TESTING

X2.1 It is recommended that job mock-ups be prepared by the contractor and tested prior to beginning a project to establish the expected in-place performance that will be achieved with the specified product. ACI Committee 506 provides extensive recommendations as to proper surface preparation and equipment as well as nozzlemen certification and proper shotcrete placement and curing procedures. See reference ACI 506R[5], 506.2[4], and CP-60[6], as well as Practice C 1140.

[5] ACI 506R-05, "Guide to Shotcrete," American Concrete Institute (ACI), P.O. Box 9094, Farmington Hills, MI 48333.

[6] ACI CP-60, "Craftmans Workbook," ACI Certification Program for Shotcrete Nozzlemen, American Concrete Institute (ACI), P.O. Box 9094, Farmington Hills, MI 48333.

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SUMMARY OF CHANGES

Committee C09 has identified the location of selected changes to this specification since the last issue, C 1480 – 00(2005), that may impact the use of this specification. (Approved February 1, 2007)

(*1*) Converted the standard into a combined units standard. (*2*) Deleted paragraph 10.3.

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Designation: C 1489 – 01 (Reapproved 2008)$^{\varepsilon 1}$

Standard Specification for Lime Putty for Structural Purposes[1]

This standard is issued under the fixed designation C 1489; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

ε^1 NOTE—A units statement was added editorially as new subsection 1.2 in September 2008.

1. Scope

1.1 This specification covers lime putty products made from hydrated lime or quicklime products. Lime putty is suitable for use in masonry, plaster and stucco applications.

1.2 The values stated in SI units are to be regarded as standard. No other units of measurement are included in this standard.

1.3 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

2. Referenced Documents

2.1 *ASTM Standards:* [2]

C 5 Specification for Quicklime for Structural Purposes

C 25 Test Methods for Chemical Analysis of Limestone, Quicklime, and Hydrated Lime

C 50 Practice for Sampling, Sample Preparation, Packaging, and Marking of Lime and Limestone Products

C 51 Terminology Relating to Lime and Limestone (as used by the Industry)

C 110 Test Methods for Physical Testing of Quicklime, Hydrated Lime, and Limestone

C 185 Test Method for Air Content of Hydraulic Cement Mortar

C 206 Specification for Finishing Hydrated Lime

C 207 Specification for Hydrated Lime for Masonry Purposes

3. Terminology

3.1 *Definitions:*

3.1.1 *lime putty*—the product obtained by either slaking quicklime with water according to the direction of the manufacturer or by mixing hydrated lime and water to the desired consistency.

3.1.2 Unless otherwise specified, for definitions of terms used in this standard, refer to Terminology C 51.

4. Chemical Composition

4.1 The hydrated lime or quicklime products used to make lime putty shall conform to the following chemical composition requirements:

Calcium and magnesium oxides (non volatile basis)	92 % min.
Carbon dioxide (presoaked basis)	
If sample is taken at place of manufacture	5 % max.
If sample is taken at other place	7 % max.

4.2 Chemical composition of putty product of unknown composition must be determined by drying the sample in a CO_2 free atmosphere by a method such as Test Methods C 25, Section 21, (Free Moisture in Hydrated Lime).

5. Plasticity

5.1 Lime putty shall have a plasticity of not less than 200 Emley units when tested by the Emley method prescribed in Test Methods C 110. Vicat consistency of the putty should be adjusted to a penetration of 20 ± 5 mm prior to running the Emley test. If penetration results are above 25 mm, the consistency of the putty can be increased by allowing the putty to settle and decanting off the excess water or by the use of a suction pad such as the one used for the water retention test in Test Methods C 110. If the penetration is below 15 mm, water should be added to the lime putty to increase the penetration. When water is added to the putty, the putty should be mixed for a minimum of 15 s prior to testing the penetration.

6. Residue

6.1 Residue of lime putty shall not be more than 0.5 % on a 30 mesh sieve on a total putty weight basis. The residue of lime putty should be determined by the method in Test Methods C 110, Section 5, using an amount of lime putty equivalent to approximately 100 g of solids.

[1] This specification is under the jurisdiction of ASTM Committee C07 on Lime and is the direct responsibility of Subcommittee C07.02 on Specifications and Guidelines.

Current edition approved June 1, 2008. Published September 2008. Originally approved in 2001. Last previous edition approved in 2001 as C 1489 – 01.

[2] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

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7. Soaking Period

7.1 Lime putty made from quicklime or hydrated lime must be soaked for a period of time prior to use of the product. The actual time required to ensure complete hydration of the lime putty is dependent on the reactivity of the unhydrated oxides used to make the putty.

7.1.1 Lime putty made from quicklime must be soaked for a minimum of two weeks prior to use in construction applications.

7.1.2 Lime putty made with Type N hydrated lime must be soaked for at least 16 h prior to use.

7.1.3 Lime putty made with Type S hydrated lime requires enough soaking to wet the lime particles (minimum of 20 min.).

8. Popping and Pitting

8.1 Lime putty shall show no pops or pits when tested in accordance with the method prescribed in Test Methods C 110. Vicat consistency of the lime putty should be adjusted to a penetration of 20 ± 5 mm prior to running the popping and pitting test. If penetration results are above 25 mm, the consistency of the putty can be increased by allowing the putty to settle and decanting off the excess water or by the use of a suction pad such as the one used for the water retention test in Test Methods C 110. If the penetration is below 15 mm, water should be added to the lime putty to increase the penetration. When water is added to the putty, the putty should be mixed for a minimum of 15 s prior to testing the penetration.

9. Density

9.1 The wet density of the lime putty shall be no less than 80 lbs/ft^3 and not more than 90 lbs/ft^3. The density of lime putty can be measured in the 400 ml cylindrical cup described in the Apparatus Section of Test Method C 185. Care should be taken when placing putty in the cup to minimize the entrapment of air. The cup should be filled in three lifts, tamping after each lift to remove entrapped air. The top surface of the putty should be struck and leveled with a metal spatula prior to weighing. The calculations used for the density determination can be found in Test Methods C 110, Section 16.

10. Sampling and Inspection

10.1 The sampling, inspection, rejection, retesting, packaging, and marking shall be conducted in accordance with Practice C 50.

11. Test Methods

11.1 Determine the properties enumerated in this specification in accordance with the following methods:

11.1.1 *Chemical Analysis*—Test Methods C 25.

11.1.2 *Physical Analysis*—Test Methods C 110.

12. Keywords

12.1 finish lime; lime putty; masonry; plaster; plasticity; popping and pitting; residue; stucco; unhydrated oxides

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Designation: C1506 – 09

Standard Test Method for Water Retention of Hydraulic Cement-Based Mortars and Plasters[1]

This standard is issued under the fixed designation C1506; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope*

1.1 This test method provides for the determination of water retention of hydraulic cement-based mortars and plasters.

1.2 The values stated in SI units are to be regarded as standard. No other units of measurement are included in this standard.

1.3 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.* (**Warning**—Fresh hydraulic cementitious mixtures are caustic and may cause chemical burns to skin and tissue upon prolonged exposure.)[2]

2. Referenced Documents

2.1 *ASTM Standards:*[3]

C109/C109M Test Method for Compressive Strength of Hydraulic Cement Mortars (Using 2-in. or [50-mm] Cube Specimens)

C185 Test Method for Air Content of Hydraulic Cement Mortar

C230/C230M Specification for Flow Table for Use in Tests of Hydraulic Cement

C305 Practice for Mechanical Mixing of Hydraulic Cement Pastes and Mortars of Plastic Consistency

C511 Specification for Mixing Rooms, Moist Cabinets, Moist Rooms, and Water Storage Tanks Used in the Testing of Hydraulic Cements and Concretes

C670 Practice for Preparing Precision and Bias Statements for Test Methods for Construction Materials

C1437 Test Method for Flow of Hydraulic Cement Mortar

3. Summary of Test Method

3.1 The flow of the mortar or plaster is determined. The mortar or plaster is then subjected to a controlled vacuum suction for 60 s, after which the flow is again determined. The water retention is the final flow divided by the initial flow expressed as a percentage.

4. Significance and Use

4.1 This test method provides a means for determining the ability of mortars and plasters to retain water under suction. Test results may be used to determine compliance with specifications.

4.2 The results obtained using this test method can be used to compare the relative ability of mortars and plasters to retain water under suction.

4.3 The results obtained using this test method for masonry mortars do not necessarily indicate the degree of water retention when used with masonry units, since the amount of water absorbed by the unit depends on the rate of absorption of the masonry unit.

4.4 The results obtained using this test method for plasters (stucco) do not necessarily indicate the degree of water retention when the plaster is applied as a second coat on the surface of a previously applied plaster base coat, since the amount of water absorbed from the second coat of plaster depends on the rate of absorption of the base coat. This is also true when a plaster is applied as a coating on masonry units.

5. Apparatus

5.1 *Tamper*, conforming to Test Method C109/C109M.

5.2 *Straightedge*, conforming to Test Method C185.

5.3 *Flow Table*, conforming to Specification C230/C230M.

5.4 *Mixing Apparatus*, conforming to the requirements prescribed in Practice C305.

5.5 *Filtration Assembly*, an apparatus essentially as shown in Fig. 1 shall be used. This apparatus consists of a perforated dish resting on a funnel, which is connected by a three-way stopcock to a vacuum flask, to which a controlled vacuum is applied. The perforated dish shall be made of metal not attacked by masonry mortar or plaster (Note 1). The metal base of the dish shall have a thickness of 2.0 ± 0.3 mm and shall conform to the requirements given in Fig. 1. The stopcock bore

[1] This test method is under the jurisdiction of ASTM Committee C01 on Cement and is the direct responsibility of Subcommittee C01.22 on Workability.

Current edition approved Dec. 1, 2009. Published January 2010. Originally approved in 2001. Last previous edition approved in 2008 as C1506–08. DOI: 10.1520/C1506-09.

[2] Section on Safety, Manual of Cement Testing, *Annual Book of ASTM Standards*, Vol 04.01.

[3] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

***A Summary of Changes section appears at the end of this standard.**

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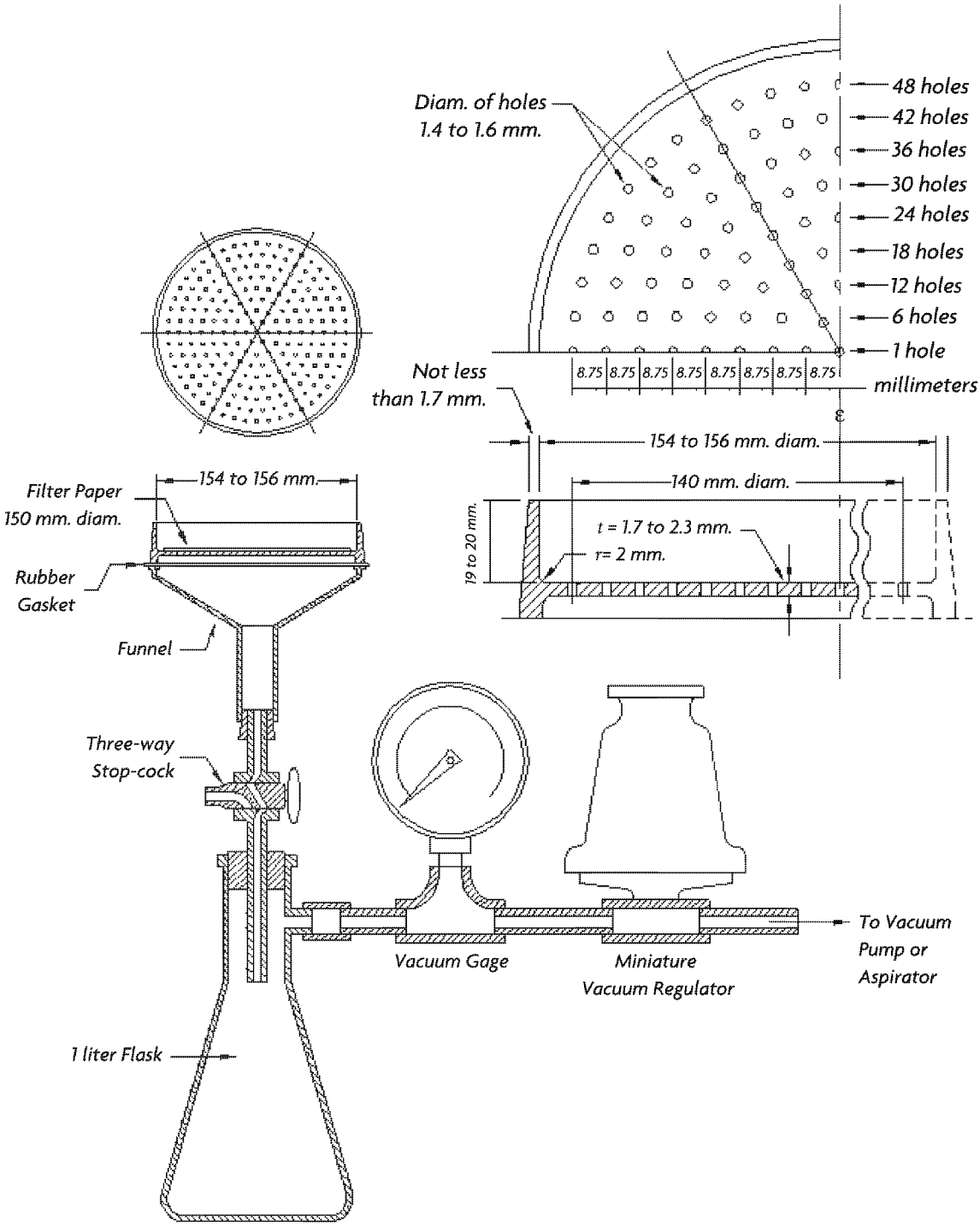

NOTE—The gasket is to be synthetic rubber. The stopcock and the bore of the tubing shall be at least 4-mm. A check valve or water trap, or both, is suggested for the connection to the vacuum source.

FIG. 1 Apparatus Assembly for the Water-Retention Test

shall have a 4.0 ± 0.5-mm diameter, and the connecting glass tubing shall have a minimum inside diameter of 4 mm. The length of the tubing projecting into the 1-L flask from the stopcock shall extend at least 25 mm below the center line of the vacuum connection. The contact surfaces of the funnel and perforated dish shall be plane and may need to be lapped to ensure intimate contact. An airtight seal shall be maintained between the funnel and the dish during the test. This shall be accomplished by either of the following procedures. (*1*) A synthetic (grease-resistant) rubber gasket may be permanently sealed to the top of the funnel using petrolatum or light grease to ensure a seal between the gasket and dish. (*2*) The top of the

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funnel may be lightly coated with petroleum or light grease to ensure a seal between the funnel and dish. Care should be taken to ensure that none of the holes in the perforated dish become clogged. Hardened, smooth, not rapid filter paper shall be used. It shall be 150 mm in diameter and be placed so as to completely cover the perforations in the dish.

NOTE 1—Stainless steel, brass, and bronze are suitable metals for this purpose.

5.6 *Controlled Vacuum Source*:

5.6.1 A vacuum gage capable of reading at least 9-kPa pressure in 0.1-kPa increments (Note 2 and Note 3), connected to a miniature vacuum regulator having a maximum 55-kPa capacity, which is then connected to a vacuum pump or water aspirator as shown in Fig. 1. Connection is made between the vacuum flask and the vacuum gage.

NOTE 2—Vacuum values are all given as pressure relative to atmospheric pressure.

NOTE 3—Gages reading pressure in other units are acceptable as long as their capacity and scale increments comply with the levels specified here. (For example, a vacuum gage with a minimum capacity of 70 mm of Hg in 1-mm increments is acceptable. To convert mm of Hg to kPa, multiply by 0.1333. Thus the 7.0-kPa starting pressure is equivalent to 53-mm Hg.)

6. Temperature and Humidity

6.1 The temperature of the mixing room and the room containing the water retention apparatus shall conform to the requirements of Specification C511.

7. Materials

7.1 The composition of the mortar or plaster to be tested for water retention shall be that described in the specification of the material being considered, or that desired.

8. Mixing of Mortar and Plaster

8.1 The mortar or plaster to be tested for water retention shall be mixed as specified in the section on Procedure for Mixing Mortars of Practice C305, or as described in the specification for the material being considered.

9. Procedure

9.1 *Preparation of Apparatus*—Seat the perforated dish on the greased gasket or greased rim of the funnel. Place a wetted filter paper in the bottom of the dish. Turn the stopcock to apply the vacuum to the funnel and check the apparatus for leaks. Adjust the vacuum to 7.0 ± 0.4 kPa (Note 2). Turn the stopcock to shut off the vacuum from the funnel. Do not remove the dish from the funnel until instructed to do so in 9.5.

9.2 *Determination of Flow*—Determine the flow in accordance with Test Method C1437.

9.3 *Preparation of Mortar or Plaster Bed*—Immediately after making the flow test, return the mortar or plaster on the flow table to the mixing bowl and remix the entire batch for 15 s at medium speed. Immediately after remixing, fill the perforated dish with the material to slightly above the rim. Tamp 15 times with the tamper. Apply ten of the tamping strokes at approximately uniform spacing adjacent to the rim of the dish, and with the long axis of the tamping face held at right angles to the radius of the dish. Apply the remaining five tamping strokes at random points distributed over the central area of the dish. Use just enough tamping pressure to fill the dish with the top of the material extending slightly above the rim. Smooth off the material by drawing the flat side of the straightedge (with the leading edge slightly raised) across the top of the dish. Strike-off the material to a plane surface flush with the rim of the dish with the straightedge held in a perpendicular position; using a sawing motion, draw the straightedge across half of the surface of the dish; repeat the procedure on the other half of the unfinished surface. If the material is pulled away from the side of the dish during the process of drawing the straightedge across the dish, gently press the material back into contact with the side of the dish using the tamper. Complete the entire filling and strike-off operation in not more than 2 min.

9.4 *Application of Vacuum to Mortar or Plaster*—Turn the stopcock to apply the vacuum to the funnel. After suction for 60 s, quickly turn the stopcock to expose the funnel to atmospheric pressure.

9.5 *Determination of Flow After Suction*—Immediately slide the perforated dish off the funnel, touch the bottom of the dish momentarily on a damp cloth to remove droplets of water. Set the dish on a work table, plow and mix the mortar or plaster for 15 s, with the rubber scraper prescribed in Practice C305. Determine the flow in accordance with Test Method C1437. Remove the vacuum and complete the flow test in less than 2 min.

10. Calculation

10.1 Calculate the water retention value for the mortar or plaster as follows:

$$\text{Water retention, \%} = (A/B) \times 100$$

where:

A = flow after suction, and

B = flow immediately after initial mixing.

Report to the nearest 1 %.

11. Precision and Bias

11.1 *Precision*—The following precision values were calculated from results of tests reported to Cement and Concrete Reference Laboratory (CCRL) for masonry cement proficiency samples Number 3 through 42 (Note 4). Within- and among-laboratory standard deviations were calculated by CCRL for each sample pair. Values were pooled over all 40 samples for purposes of this analysis. Water retention test results (excluding outliers) ranged from 72 to 88 %. The average number of laboratories reporting was 69.

NOTE 4—These tests utilized a slightly different test pressure, 6.7 ± 0.4 kPa (50 ± 0.3 mm Hg).

11.1.1 *Single-laboratory Precision*—The single-laboratory standard deviation has been found to be 3.5 % (Note 5). Therefore, the results of two properly conducted tests in the same laboratory on the same material should not differ by more than 9.8 % (Note 5) in 95 % of such pairwise comparisons.

11.1.2 *Multilaboratory Precision*—The multilaboratory standard deviation has been found to be 5.1 % (Note 5).

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Therefore, the results of two properly conducted tests in different laboratories on the same material should not differ by more than 14.3 % (Note 5) in 95 % of such pairwise comparisons.

NOTE 5—These numbers represent, respectively, the 1s and d2s limits as described in Practice C670.

11.2 *Bias*—Since there is no accepted reference material suitable for determining bias in this test method, no statement on bias is being made.

12. Keywords

12.1 hydraulic cement; mortar; plaster; water retention

SUMMARY OF CHANGES

Committee C01 has identified the location of selected changes to this test method since the last issue, C1506 – 08, that may impact the use of this test method. (Approved December 1, 2009)

(*1*) Revised 9.1.

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Designation: C 1513 – 04 (Reapproved 2009)ε1

Standard Specification for Steel Tapping Screws for Cold-Formed Steel Framing Connections[1]

This standard is issued under the fixed designation C 1513; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

ε[1] NOTE—The units statement in 1.2 was revised editorially in May 2009.

1. Scope

1.1 This specification covers steel self-drilling and self-piercing tapping screws for the connection of cold-formed steel members manufactured in accordance with Specifications C 645 and C 955. This specification also covers test methods for determining performance requirements and physical properties.

1.2 The values stated in inch-pound units are to be regarded as standard. The values given in parentheses are mathematical conversions to SI units that are provided for information only and are not considered standard.

1.3 The following safety hazards caveat pertains only to the test methods described in this specification. *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory requirements prior to use.*

2. Referenced Documents

2.1 *ASTM Standards:*[2]

A 370 Test Methods and Definitions for Mechanical Testing of Steel Products

A 510 Specification for General Requirements for Wire Rods and Coarse Round Wire, Carbon Steel

B 117 Practice for Operating Salt Spray (Fog) Apparatus

C 11 Terminology Relating to Gypsum and Related Building Materials and Systems

C 645 Specification for Nonstructural Steel Framing Members

C 955 Specification for Load-Bearing (Transverse and Axial) Steel Studs, Runners (Tracks), and Bracing or Bridging for Screw Application of Gypsum Panel Products and Metal Plaster Bases

F 1941 Specification for Electrodeposited Coatings on Threaded Fasteners (Unified Inch Screw Threads (UN/UNR))

2.2 *ANSI/ASME Documents:*

B18.18.1M Inspection and Quality Assurance for General Purpose Fasteners[3]

B18.6.4 Standard Specification for Thread Forming and Thread-Cutting Screws[3]

2.3 *SAE Standards:*

SAE J78-1998 Steel Self-Drilling Tapping Screws[4]

SAE J933 Mechanical and Quality Requirements for Tapping Screws[4]

3. Terminology

3.1 *Definitions*—For definitions relating to gypsum and related building materials and systems, use Terminology C 11.

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *bearing surface (of the screw)*, *n*—the supporting or locating surface of a fastener with respect to the part which it fastens (mates). The loading of the fastener is usually through the bearing surface, (that is, the bearing surface of the hex washer head style is under the head, the part that touches the top material being fastened).

3.2.2 *case depth (of the screw)*, *n*—the thickness of the hardened surface of the screw.

3.2.3 *countersunk head style (for a screw)*, *n*—all screw head designs that sink into the top material being fastened and that have the bearing surface (see 3.2.1), at the top of the head (that is, flat and bugle).

3.2.4 *crest (of the screw thread)*, *n*—the highest point of the screw thread.

3.2.5 *drill capacity (of the self-drilling screw)*, *n*—the total thickness of material the fastener is designed to drill through, including any space between the layers.

[1] This specification is under the jurisdiction of ASTM Committee C11 on Gypsum and Related Building Materials and Systems and is the direct responsibility of Subcommittee C11.02 on Specifications and Test Methods for Accessories and Related Products.

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[2] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

[3] Available from American Society of Mechanical Engineers (ASME), ASME International Headquarters, Three Park Ave., New York, NY 10016-5990, http://www.asme.org.

[4] Available from Society of Automotive Engineers (SAE), 400 Commonwealth Dr., Warrendale, PA 15096-0001, http://www.sae.org.

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3.2.6 *head styles (of the screw)*, *n*—refer to Fig. 1 drawings.

3.2.6.1 *bugle head, n*—bugle shape countersinking head typically used for fastening gypsum panel products to wood and steel.

3.2.6.2 *hex washer head, n*—has an indented top surface and six flat sides formed integrally with a flat washer which projects beyond the sides and provides a flat bearing surface.

3.2.6.3 *lath head, n*—see *modified truss*.

3.2.6.4 *modified truss, n*—low profile round washer head.

3.2.6.5 *pan framing head, n*—flat top surface rounding into cylindrical sides and a flat bearing surface.

3.2.6.6 *pan head, n*—a slightly rounded top surface rounding into cylindrical sides and a flat bearing surface.

3.2.6.7 *pancake head, n*—lower profile head style than the hex washer and pan head with a larger flat bearing surface.

3.2.6.8 *wafer head, n*—a countersinking head style with a large lip at the top of the countersinking contour that will "flush" with the substrate creating a greater bearing surface, therefore a greater pull-over/pull-through value.

3.2.7 *point style*, *n*—of the self-drilling tapping screw is designated by a number (that is, 1, 2, 3, 4, or 5). The higher the number, the higher the drill capacity (see 3.2.5) of the screw.

3.2.8 *root (of the screw thread)*, *n*—the lowest point of the screw thread.

3.2.9 *self-drilling tapping screw*, *n*—externally threaded fasteners with the ability to drill their own hole and form or cut their own internal mating threads without breaking.

3.2.10 *self-piercing tapping screw*, *n*—externally threaded fasteners with the ability to pierce metallic material 33 mils (0.84 mm), or less, form a sleeve by extruding metallic material and "tap" their own mating threads when driven. Self-piercing screws have a sharp point with the point angle not more than 30 degrees.

3.2.11 *spin-out (for a screw)*, *n*—for a screw, the continued rotation of a screw without further penetration into the substrate.

3.2.12 *tapping screw*, *n*—externally threaded fasteners with the ability to "tap" their own internal mating threads when installed.

4. Classification

4.1 Steel tapping screws covered by this specification are two types:

4.1.1 Self-drilling.

4.1.2 Self-piercing.

5. Materials

5.1 Steel wire, Specification A 510–minimum grade 1018.

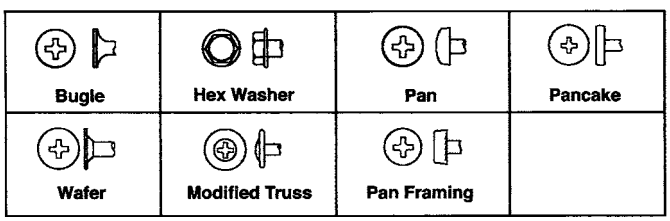

FIG. 1 Head Styles

6. Physical Properties

6.1 *Dimensions*:

6.1.1 Self-drilling tapping screws shall be in accordance with SAE J78.

6.1.2 Self-piercing tapping screws shall be in accordance with head dimensions as shown in ANSI/ASME B18.6.4.

6.2 *Total Case Depth*—Screws shall have a total case depth conforming to the tabulation in Table 1.

6.2.1 Case depth shall be measured at the mid-point between crest and root on the thread shank.

7. Packaging and Head Marking

7.1 Screws shall be marked with manufacturer's/supplier's head marking for traceability.

7.2 Screws shall be packaged in substantial commercial shipping containers, constructed so as to preserve the contents in good condition and to ensure acceptance and safe delivery by common or other carriers.

7.2.1 Individual packages shall be so constructed that the contents shall be able to be partially removed without destroying the container's ability to serve as a receptacle for the remainder of the contents.

7.2.2 Individual packages and shipping containers shall be marked with the type, size, use, and quantity of the screws contained therein, the name brand headmarking example and trademark of the producer or supplier, the ASTM designation, and any or all appropriate evaluation reports . Boxes shall be marked with the drill capacity of the self-drilling tapping screws.

8. Performance Requirements

8.1 *Hardness*:

8.1.1 The self-drilling tapping screws shall have a surface hardness of not less than Rockwell C 50 and core hardness of not less than Rockwell C 32 as tested in accordance with SAE J78.

8.1.2 The self-piercing screws shall have a surface hardness of not less than Rockwell C 45 and core hardness of not less than Rockwell C 28 as tested in accordance with SAE J933.

8.2 *Ductility*:

8.2.1 The self-drilling tapping screws shall have sufficient ductility to be able to withstand a 5° bend without visible signs of fracture as tested in accordance with SAE J78.

8.2.2 The self-piercing tapping screws shall have sufficient ductility to be able to withstand a 10° bend without visible signs of fracture as tested in accordance with SAE J933.

8.3 *Torsional Strength*:

8.3.1 Self-drilling tapping screws shall not fail the application of torque less than or equal to the torsional strength specified in Table 2, when tested in accordance with SAE J78.

8.3.2 Self-piercing tapping screws shall not fail with the application of torque less than the torsional strength specified

TABLE 1 Total Case Depth

Nominal Screw Size	Total Case Depth, Maximum, in. (mm)	Total Case Depth, Minimum, in. (mm)
8 through 12	0.009 (.2286 mm)	0.004 (.1016 mm)
¼ in.	0.011 (.2794 mm)	0.005 (.1270 mm)

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TABLE 2 Torsional Strength–Self-Drilling Tapping Screws

Nominal Screw Size	Minimum lb-in. Type BSD[A]	Minimum lb-in. Type CSD[B]
6	24	24
8	42	48
10	61	65
12	92	100
¼ in.	150	156

[A] Type BSD–spaced threads referred to as coarse thread.
[B] Type CSD–machine screw threads referred to as fine thread.

in Table 3, as tested in accordance with ANSI/ASME B18.6.4, Section 2.9.1.2, for tapping screws.

8.4 *Drill Drive Performance Requirement*:

8.4.1 Self-drilling tapping screws shall not fail the drill-drive test requirements as noted in SAE J78 and shown in Table 4.

8.4.2 Self-drilling tapping screws shall be tested in accordance with SAE J78 as shown in Fig. 2.

8.5 *Self-Drilling Tapping Screw Drill Capacity*:

8.5.1 Screws shall be able to self-drill and thread into cold-formed steel thicknesses without breaking or stripping as specified by each specific manufacturer's published recommendations. Manufacturers shall provide a min-max recommendation with the drill capacity of each self-drilling point style screw.

9. Finish and Appearance

9.1 The threads shall be clean, smooth, and neatly formed.

9.2 Each fastener shall have manufacturer's/supplier's head marking for traceability.

9.3 Screws shall have a corrosion-resistant treatment. The finish shall not inhibit adhesion to finishing materials nor bleed through field-applied decoration. The screws shall meet a minimum requirement as listed in Specification F 1941 as tested in accordance with Practice B 117.

10. Sampling

10.1 Obtain not less than one randomly selected specimen of each type of screw to be tested from each of five containers, with not less than five screws per 250 000 screws, to constitute a lot for testing.

11. Test Methods

11.1 Screws shall be tested per SAE J78 Table number 4, Section 8.4, to determine the ability of the screws to self-drill through cold-formed steel without spinout, thread deformation, or breaking.

11.2 *Significance and Use*:

11.2.1 The test methods provide procedures for evaluating the physical properties and performance requirements of steel drill screws.

TABLE 3 Torsional Strength–Self-Piercing Tapping Screws

Nominal Screw Size	Minimum lb-in.
6	24
7	30
8	39
10	56

TABLE 4 Drill-Drive Test Requirements

Nominal Screw Size	Test Plate Thickness,[A] in., Max	Test Plate Thickness,[A] in., Min	Axial Loading,[B] lb, A, max	Axial Loading,[B] lb, B, Max	Axial Loading,[B] lb, C, Max	Time to Drill and Form Thread,[C] s, Max
4	0.068	0.062	25	30	40	2.0
6	0.068	0.062	30	35	45	2.5
8	0.068	0.062	30	35	45	3.0
10	0.068	0.062	35	40	50	3.5
12	0.068	0.062	45	50	60	4.0
¼	0.068	0.062	45	50	60	5.0

[A] Test plates shall be low carbon, cold rolled steel having a hardness of Rockwell B 80-85.
[B] Axial loads are varied to offset the detrimental effects on drilling capability created by finishes applied to screws in accordance with the following:
Column A—Axial loads tabulated shall apply to plain, oiled, and commercial phosphate coating and cadmium and zinc platings up to 0.0003 in. in thickness.
Column B—Axial loads tabulated shall apply to special electroplated finishes exceeding 0.0003 in. in thickness and to special coatings, such as thread sealing hot melts, and so forth.
Column C—Axial loads tabulated shall apply to chromium finish.
[C] Tool speed shall be 2500 rpm for screw sizes No. 4 through No. 10. Tool speed of 1800 rpm is recommended for screw sizes No. 12 and ¼; however, 2500 rpm may be used provided care is exercised to minimize influence of high heat buildup due to surface speed.

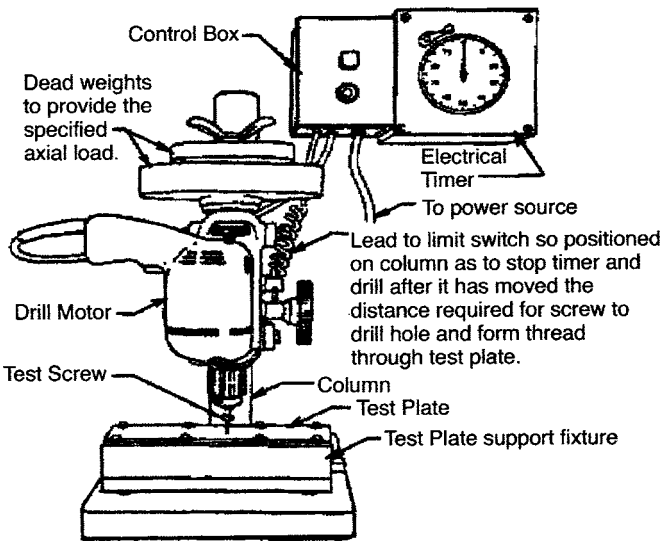

FIG. 2 Drill-Drive Test Apparatus

12. Test Materials

12.1 *Materials*:

12.1.1 Screw fasteners used in the tests shall be of standard manufacturer and representative of the product for which recognition is sought. Where tested fasteners are prototype, the fasteners shall be representative of later production. Fasteners shall meet the minimum and quality requirements for tapping screws in accordance with ANSI/ASME B18.6.4 and ANSI/ASME B18.18.1M, 1987 or the pertinent standard, whichever is more restrictive. Compliance is determined by test reports submitted by a qualified testing laboratory.

12.1.2 *Sheet Steel*—Steel description, including material specification, yield strength, and minimum uncoated steel thickness noted.

12.2 Sharp point screws shall be tested using 33 mil (0.84 mm) steel.

12.3 Drill point screws shall be tested using 54 mil (1.37 mm) steel.

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13. Specimen Preparation

13.1 Where the number of steel coupon specimens is not noted in the specific standard, a minimum of three steel coupon specimens shall be tested to show compliance with the appropriate standard and to determine the minimum uncoated steel thickness and strengths. Steel tension test shall be performed in accordance with Test Methods and Definitions A 370.

13.2 *Screw Fasteners*—A minimum of three test specimens are to be tested for tension (pull-out) and for the lap shear connection. If the result from any one test is more than 15 % higher or lower than the other two, the lowest test value is used, unless an additional three tests are performed. Then use the average results of all six tests, regardless of the variation.

14. Procedure

14.1 If any of the first lot on the drill-drive testing fails, test another lot. If two of that lot fail, the entire lot fails.

15. Dimensional Measurement

15.1 *Self-Piercing Screws*—ANSI/ASME B18.6.4.
15.2 *Self-Drilling Tapping Screws*—SAE J78.

16. Ductility Test

16.1 *Self-Piercing Screws*—ANSI/ASME B18.6.4.
16.2 *Self-Drilling Tapping Screws*—SAE J78.

17. Torsional Strength

17.1 *Self-Piercing Screws*—ANSI/ASME B18.6.4.
17.2 *Self-Drilling Tapping Screws*—SAE J78.

18. Inspection

18.1 Inspection of the steel screws shall be agreed upon between the purchaser and producer or supplier as part of the purchase agreement.

19. Rejection and Rehearing

19.1 Rejection of steel screws that fail to conform to the requirements of the specification shall be reported to the producer or supplier promptly and in writing within 10 working days from receipt of shipment. Notice of rejection shall contain a specific statement as to the respects in which the screws have failed to conform to the requirements of the specification. In case of dissatisfaction with the test results, and at the request of the producer or supplier, such notice of rehearing shall be supported by results of a test conducted by a mutually agreeable independent laboratory.

20. Certification

20.1 When specified in the purchase agreement, the producer or supplier shall furnish a report certifying that, at the time of shipment, the screws were in compliance with the requirements of this specification.

21. Keywords

21.1 bugle head; crest; hex washer head; modified truss; pancake head; pan head; root; screws; self-drilling; self-piercing; spin-out; wafer head drill capacity

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Designation: C 1516 – 05

Standard Practice for Application of Direct-Applied Exterior Finish Systems[1]

This standard is issued under the fixed designation C 1516; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope*

1.1 This practice covers the minimum requirements and procedures for field application of Direct-applied Exterior Finish Systems (DEFS). Direct-applied exterior finish systems are coating systems applied over various substrates with non-metallic reinforcing mesh, in which the base coat ranges from not less than 1/16 in. (1.6 mm) to 3/32 in. (2.4 mm) in dry thickness, depending on the mass of the reinforcing mesh. This base coat is subsequently covered with a finish coat that is available in a variety of textures and colors.

1.2 The values stated in inch-pound units are to be regarded as the standard. The metric values given in parentheses are approximate and are provided for information purposes only.

1.3 *This standard may involve hazardous materials, operations and equipment. This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

2. Referenced Documents

2.1 *ASTM Standards:* [2]

C 11 Terminology Relating to Gypsum and Related Building Materials and Systems

C 1063 Specification for Installation of Lathing and Furring to Receive Interior and Exterior Portland Cement-Based Plaster

C 1177/C 1177M Specification for Glass Mat Gypsum Substrate for Use as Sheathing

C 1186 Specification for Flat Non-Asbestos Fiber-Cement Sheets

C 1278/C 1278M Specification for Fiber-Reinforced Gypsum Panel

C 1325 Specification for Non-Asbestos Fiber-Mat Reinforced Cement Substrate Sheets

E 1825 Guide for Evaluation of Exterior Building Wall Materials, Products, and Systems

3. Terminology

3.1 Definitions used in this standard shall be in accordance with Terminology C 11.

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *accessories*, *n*—preformed metal, fiberglass or plastic members used to form corners, edges, control joints, or decorative effects.

3.2.2 *back wrapping*, *n*—a deprecated term. See *wrap*.

3.2.3 *base coat*, *n*—a material, either factory or field-mixed, used to cover the substrate and to encapsulate the reinforcing mesh.

3.2.4 *cold joint*, *n*—the visible junction in an exterior finish.

3.2.5 *cure*, *v*—to develop the ultimate properties of a wet state material by a chemical process.

3.2.6 *dry*, *v*—to develop the ultimate properties of a wet state material solely by evaporation of volatile ingredients.

3.2.7 *durability*, *n*—the capability of a building, assembly, component, product, or construction to maintain serviceability over not less than a specified time.

3.2.8 *embed*, *v*—to encapsulate a non-metallic reinforcing mesh in either the joint compound or exterior finish.

3.2.9 *expansion joint*, *n*—a structural separation between building elements that allows independent movement without damage to the assembly.

3.2.10 *factory mixed*, *n*—a material that is prepared at the point of manufacture and is ready to use without the addition of other materials, except possibly water to adjust consistency.

3.2.11 *field mix*, *n*—a material that is mixed in the field with other components and/or water.

3.2.12 *finish coat*, *n*—the final wet state material, that provides color or additional texture, applied over the reinforced base coat.

3.2.13 *flash set (quick set)*, *n*—the early hardening or stiffness in the working characteristics of a Portland-cement paste, mortar, or concrete, usually with the evolution of considerable heat; stiffness cannot be dispelled nor the plasticity regained by further mixing without addition of water; also known as "quick set."

[1] This practice is under the jurisdiction of ASTM Committee C11 on Gypsum and Related Building Materials and Systems and is the direct responsibility of Subcommittee C11.05 on Application of Exterior Insulating and Finish Systems and Related Products.

Current edition approved October 1, 2005. Published October 2005. Originally approved in 2002. Last previous edition approved in 2002 as C 1516 – 02.

[2] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

***A Summary of Changes section appears at the end of this standard.**

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3.2.14 *framing member*, *n*—studs, joist, runners (tracks), bridging, bracing, and related accessories manufactured or supplied in wood or hot or cold formed steel.

3.2.15 *initial grab*, *n*—the ability of a wet state material to remain in place initially after it has been applied.

3.2.16 *initial set*, *n*—a time related set caused by the hydration process.

3.2.17 *lamina*, *n*—composite of base coat, reinforcement, and finish coat.

3.2.18 *mechanical fastener*, *n*—corrosion resistant component used to attach the substrate to the framing member.

3.2.19 *reinforcing mesh*, *n*—a non-metallic component of the DEFS encapsulated in the base coat to strengthen the system.

3.2.19.1 *Discussion*—Non-metallic reinforcing mesh is available in various weights to achieve different levels of impact and stress resistance.

3.2.20 *pot life*, *n*—the duration of time that the wet state material remains workable after it has been mixed.

3.2.21 *primers*, *n*—liquid coatings applied to improve the adhesion of the DEFS to the substrate.

3.2.21.1 *Discussion*—Primers are sometimes applied to improve the water resistance of cementitious base coats.

3.2.22 *reinforced base coat*, *n*—base coat that has been reinforced with a non-metallic reinforcing mesh.

3.2.23 *substrate*, *n*—surface to which the DEFS is applied.

3.2.24 *surface sealer*, *n*—material used to enhance weather resistance.

3.2.25 *temper*, *v*—to bring to a workable state by adding water.

3.2.26 *texture*, *n*—any surface appearance as contrasted to a smooth surface.

3.2.27 *wet edge*, *n*—the leading edge of a continuously applied wet state material.

3.2.28 *wet state materials*, *n*—the adhesive, base coat and finish coat components applied in liquid or semi-liquid state.

4. Significance and Use

4.1 This practice provides minimum requirements for the application of Direct-applied Exterior Finish Systems. The requirements for materials, mixtures, and details shall be contained in the project plans and specifications.

5. Delivery of Materials

5.1 All materials shall be delivered in packages, containers, or bundles with the identification and markings intact.

6. Inspection

6.1 Inspection of the materials shall be agreed upon between the purchaser and the supplier as part of the purchase agreement.

7. Rejection

7.1 Materials that are damaged, frozen or in any way defective shall not be used. Rejection of materials shall be promptly reported verbally to the producer and immediately reported in writing. The notice of rejection shall contain a statement documenting the basis for material rejection.

8. Certification

8.1 When specified in the contract documents, the exterior finish producer shall furnish a report certifying that the materials are in conformance with product and material standards and contract documents.

8.2 The substrate panels shall be marked as complying with the applicable product specification.

9. Storage of Materials

9.1 All materials shall be kept dry by storage under cover and protected from the weather.

9.1.1 When outside storage is required, substrate panels shall be stacked flat with care taken to avoid damage to edges, ends, or surfaces.

9.1.2 All other DEFS components shall be stacked off the ground, supported on a level platform and protected from the direct sunlight, weather, surface contamination or physical damage in accordance with the DEFS producer's written instructions.

9.2 Materials shall be protected from exposure to temperatures less than 40 °F (4 °C), unless otherwise specified by the manufacturer.

9.3 Portland Cement shall be kept dry until ready for use. It shall be kept off the ground, under cover and away from damp walls and surfaces.

10. Environmental Conditions

10.1 *Cold Weather Conditions*:

10.1.1 Wet materials shall not be applied when the temperature is less than 40 °F (4 °C) unless temporary heat and enclosures are provided to maintain a minimum temperature of 40 °F (4 °C) for a minimum period of not less than 24 h before, during and after application or unless otherwise specified by the manufacturer.

10.1.2 Materials shall not be applied to a base containing frost. Substrate surface temperature shall be not less than 40 °F (4 °C) unless otherwise specified by the manufacturer. Mixtures for application shall not contain any frozen ingredients.

11. Assessment of Condition of Substrates to Receive Direct Exterior and Finish Systems

11.1 The substrate shall be as required by the project plans and specifications and as specified by the DEFS producer for the particular system.

11.2 The substrate shall be inspected by the applicator and general contractor to ensure that it meets the project plans and specifications and the requirements of 11.3-11.8.2.

11.3 Sheathing materials shall be inspected to ensure that:

11.3.1 The specified sheathing thickness has been installed for the stud spacing used.

11.3.2 Fastener type and fastener spacing are as specified.

11.3.3 Water-resistant exterior fiber-reinforced gypsum sheathing panels complying with Specification C 1278/C 1278M, shall be installed in accordance with the sheet producer's written installation instructions, which include details of framing type and spacing, fastener type and spacing, and sheet orientation and spacing.

11.3.4 Glass mat gypsum sheathing complying with Specification C 1177/C 1177M, shall be installed in accordance with

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the sheet producer's written installation instructions, which include details of framing type and spacing, fastener type and spacing, and sheet orientation and spacing.

11.3.5 Fiber-cement sheets complying with Specification C 1186, Type A, shall be installed in accordance with the sheet producer's written installation instructions, which include details of framing type and spacing, fastener type and spacing, and sheet orientation and spacing.

11.3.6 Fiber-mat reinforced cement sheets complying with Specification C 1325, type A, shall be installed in accordance with the sheet producer's written installation instructions, which include details of framing type and spacing, fastener type and spacing, and sheet orientation and spacing.

11.4 *Alignment*—All substrate surfaces shall be straight and true within ¼ in. in 10 ft. (2 mm/m). More stringent requirements by the DEFS producer shall supersede the above stated requirements.

11.5 *Suitability for Use*—The substrate surface shall be firm, sound, and undamaged in order to receive the exterior finish.

11.5.1 Broken, cracked or delaminated substrate boards shall be replaced or restored to a condition equal to adjacent undamaged boards.

11.6 *Cleanliness*—The surface of all substrates shall be clean and free from any foreign materials such as form release agents, curing compounds, dust, dirt, frost, oil or grease, efflorescence and laitance.

11.6.1 All substrate panels shall have all loose dirt and dust removed by cleaning methods appropriate for the job and job conditions.

11.6.2 Efflorescence and laitance on substrate panels shall be removed prior to exterior finish application. Heavy deposits shall be removed using hand or power impact tools followed by washing with an appropriate cleaner. Light deposits shall be removed by washing with an appropriate cleaner. All loose particles and cleaner residue shall be removed by washing with clean, potable water. The surface shall be allowed to dry.

11.7 *Substrate Condition*—There shall be no visible water.

11.8 If furring or accessories are used, they shall be installed in conformance with Specification C 1063.

11.8.1 These members shall be properly attached, straight, and true unless required by the system design.

11.8.2 All accessories shall be free of rust, oil, or other foreign matter or contaminants, which cause bond failure or unsightly discoloration.

12. Reinforced Base Coat Application

12.1 Inspect the substrate panel surface to ensure that it is clean, dry, free of all foreign materials, and damage of any type. Substrate panel planar irregularities of more than 1/16 in. (1.6 mm) shall be corrected. All panel joints shall be tightly abutted or shall be filled with recommended joint bedding material.

12.2 *Base Coat Preparation*—All materials requiring field preparation shall be mixed in accordance with the DEFS producer's specifications.

12.3 *Base Coat Application*—The prepared base coat shall be uniformly spread over the entire surface of the substrate panel.

12.4 *Reinforcing Mesh*—The single layer reinforcing mesh, when specified, shall be fully encapsulated in the field of the wall, at corners, edges, and joints. Trowel from the center to the edge of the reinforcing mesh to avoid wrinkles. The single layer reinforcing mesh shall be continuous at all corners.

12.4.1 *Discussion*—The recommended method is to apply the base coat in two applications.

12.4.2 The surface shall be free of voids, projections, trowel marks and other surface irregularities. The base coat thickness shall be not less than 1/16 in. (1.6 mm) dry as measured from the surface of the substrate panel.

12.5 *Reinforcing Mesh Overlap*—-- All reinforcing mesh edges shall be overlapped not less than 2½ in. (64 mm).

12.6 *Impact Layers*—When required, higher impact performance shall be achieved with multiple layers of reinforcing mesh or by incorporating heavier weight reinforcing mesh. All areas requiring higher impact performance shall be detailed on the project plans and specifications. When overlapping of high impact mesh is not required, a complete second layer of reinforcing mesh shall be applied over the layer of high impact mesh.

12.7 *Corners*—Reinforcing mesh shall not be lapped within 8 in. (204 mm) of any corner.

12.8 *Wall Penetrations*—All edges of the substrate panel board at penetrations of the DEFS, such as at windows, doors, Heating, Ventilation and Air Conditioning (HVAC) sleeves, pipes, duct, electrical boxes, and at the base of the wall shall be wrapped with either the base coat and reinforcing mesh or trim, or as specified by the project plans and specifications. Wall openings such as doors, windows, HVAC sleeves, shall be diagonally reinforced at corners with mesh not less than 9 in. (230 mm) by 12 in. (305 mm).

12.8.1 The corners of returns to windows, doors, and similar wall openings shall have reinforcing mesh the full width of the return and extending not less than 2½ in. (64 mm) on both sides of the corner.

12.9 *Expansion Joints*—All edges of the substrate panels at expansion joints shall be wrapped with either the base coat and reinforcing mesh or trim as specified by the DEFS producer for the particular system. The reinforcing mesh shall be fully encapsulated.

12.10 *Reinforcing Mesh*—The reinforcing mesh shall be fully encapsulated in the base coat throughout the field of the wall, at corners, edges, and joints. The surface shall be free of voids, projections, trowel marks and other surface irregularities.

12.11 *Special Architectural Shapes*—When special EPS (expanded polystyrene) architectural shapes are installed, glass fiber reinforcing mesh encapsulated in the base coat shall be used.

13. Finish Coat Application

13.1 The reinforced base coat shall be allowed to dry and harden for not less than 24 h prior to finish coat application.

13.2 *Material Preparation*—The finish coat shall be mixed in accordance with the DEFS producer's specifications. Only clean potable water shall be added to adjust workability. Always add the same amount of water to each container within a given lot of finish.

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13.3 *Execution*—Reinforcing base coat and finish coats shall be applied with a stainless steel trowel or appropriate equipment as specified by the DEFS producer. Tools and equipment shall be kept clean. Finish coat shall be applied continuously to a natural break such as corners, joints or tape line. Apply supplementary finishes to the exterior finish maintaining a wet edge. Sufficient manpower and scaffolding shall be provided to continuously finish a distinct wall area. Scaffolding shall be spaced a distance from the wall, consistent with safety standards, that allows uniform texturing of the finish without staging marks. On hot windy days, it shall be permitted to fog the wall with clean, potable water to cool the wall. Work shall precede the sun whenever possible. Water shall not be added to the finish once it is applied to the wall. Use the same tool and hand motion and match the texture of the surrounding area. The finish coat thickness shall be as specified by the DEFS producer. Protect all finish work from damage until fully dried.

13.4 *Joints*—The application of finish coat into the joints shall be as required by the project plans and specifications.

14. Curing Time Between Application Steps

14.1 Manufacturer's recommendations for climatic conditions, mixing and application practices to allow respective coats sufficient time to cure or dry before any subsequent coats are applied shall be followed. Each application step shall be permitted to cure or dry to prevent degradation to the system integrity with subsequent steps.

14.2 Auxiliary protection (tenting, supplemental heat, shading) from adverse environmental conditions shall be utilized to provide expected curing or drying conditions as recommended by the DEFS manufacturer.

14.3 All substrates shall be sound and cured or dry before continuing on to the next application step.

15. Clean Up

15.1 Adjacent materials, surfaces and the work area shall be cleaned of foreign materials resulting from the work.

15.2 All excess DEFS materials shall be removed from the job site.

16. Keywords

16.1 DEFS; direct-applied; exterior finish

APPENDIXES

(Nonmandatory Information)

X1. GENERAL INFORMATION

INTRODUCTION

These Appendixes give general information and also suggestions for inclusions to be made elsewhere by the specifier. They are not part of this practice.

X1.1 General

X1.1.1 The work includes all labor, materials, services, equipment and scaffolding required to complete the DEFS installation on the project in accordance with the project drawings and specifications, except electrical power and potable water.

X1.1.2 Where a specific fire resistance rating is required for the DEFS assemblies and construction, details of construction shall be in accordance with official reports of tests conducted by recognized testing laboratories and a part of approved plans and specifications.

X1.1.3 The installation of the DEFS is to be coordinated by the owner's authorized agent with work of other trades.

X1.1.4 Surfaces and accessories to receive DEFS components shall be examined and accepted as provided in 11.1 before the DEFS components are installed thereto. The proper authorities shall be notified about unacceptable conditions. The unsatisfactory conditions shall be corrected prior to the application of the DEFS components. Unsatisfactory conditions shall be corrected by the party(ies) responsible for such conditions.

X1.1.5 The construction specifier shall describe, in the proper section of the project specifications, the physical characteristics of the surfaces to receive the DEFS.

X1.2 Design Considerations

X1.2.1 Guidance, for design professionals, for determining the suitability and use of direct-applied exterior finish systems, as an exterior building wall, is contained in Guide E 1825. DEFS are attached to outside substrates of all types of structures to provide weather resistant and durable surfaces. The surfaces will be subjected to various exposures such as abrasion, vibration, moisture, freezing, thawing, negative and positive wind loading , ultraviolet light, acid rain, thermally induced expansion and contraction, and impact.

X1.2.2 Provide sufficient slope on faces of DEFS surfaces to prevent water, snow or ice from accumulating or standing. A minimum 6 in. (152 mm) in 12 in. (305 mm) (1:2) pitch is recommended. Length of sloped surfaces shall not be more than 12 in. (305 mm).

X1.2.3 Provide parapet cap made only from corrosion resistant materials. The parapet cap shall extend not less than

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2½ in. (64 mm) over the faces of the DEFS, not including wood blocking and include a drip edge detail. Detailed requirements for furnishing and installing the parapet cap shall be in the appropriate section of the project specifications. Parapet caps shall be clearly shown in large scale details. Parapet caps shall be installed as soon as practical after the installation of the DEFS.

X1.2.4 Provide for sealing of expansion joints, panel joints, system terminations and all interfaces of the DEFS with other building components.

X1.2.5 At soffits, window and door heads provide for a drip edge.

X1.2.6 Sills and headers shall be flashed.

X1.2.7 Windows installed in DEFS walls shall have sill pan flashing of corrosion-resistant material.

X1.2.8 The specifier shall evaluate the potential of the DEFS surface being subjected to abnormal stresses or impacts.

X1.2.9 Wall assemblies have properties that in certain applications make a dew point analysis critical to ensure successful performance of the wall system. The specifier shall evaluate these conditions.

X1.2.10 Substrate panels must be continuous over floor slabs, intersecting walls, columns, beams and similar constructions. The DEFS shall not be installed over areas without substrate panels.

X1.2.11 Where the substrate panel is interrupted or out of plane, corrections must be made prior to DEFS application. If the substrate panel cannot be continuous, the installation of expansion joints shall be considered.

X1.3 Relief From Stress

X1.3.1 Where the DEFS and dissimilar types of substrates, materials and building components interface, provide for appropriate size and location of expansion joints.

X1.3.2 Where roof elevations change, provide for appropriate size and location of expansion joints.

X1.4 Bonding Agents

X1.4.1 Bonding compounds or agents are sometimes applied to a substrate panel surface to receive exterior finish. Follow the DEFS producer's instructions and specifications for their use.

X1.5 Mechanical Fasteners

X1.5.1 The types of mechanical fasteners used and the methods of installation will vary depending on the framing to which the substrate panels are to be fastened.

X1.6 Reinforced Exterior Finish

X1.6.1 The basecoat thickness is permitted to exceed 3⁄32 in. (2.4 mm) dry depending on the type of reinforcing mesh and number of layers.

X1.6.2 A small amount of basecoat shrinkage is normal. Bare mesh shall not be visible.

X1.6.3 The proper portioning of hydraulic cement-based material is important. The producer's instructions shall be followed to ensure that the base coat cement is properly proportioned.

X1.6.4 The minimum amount of mix water to form a workable mix shall be used. Excess mix water causes the base coat to be porous and less weather resistant. Never add more water than recommended by the producer. Measure water in containers of known volume.

X1.6.5 Mix materials only at low speed with paddles designed to reduce air entrapment.

X1.6.6 Generally, the finish coat is applied after the base coat has sufficiently cured.

X1.7 Finish Textures

X1.7.1 Textures, as a description of surface appearance, generally are identified with the method and tools used to achieve the finish appearance. Texture is sometimes varied by the size and shape of the aggregate contained in the finish, equipment or tools employed, the consistency of the finish mix, the condition of the base to which it is applied and by decorative and protective treatments.

X1.7.2 With almost limitless variations possible for finish appearance or texture, the same term sometimes does not have the same meaning to the specifier, contractor or applicator. Sample panels of sufficient size including components and features specified shall be constructed using the methods, tools and techniques to be used in the actual construction.

X1.7.3 To provide some guidance, the following categories are generally understood and recognized to imply a particular method of application or finished appearance.

X1.7.3.1 *Sand Finish*—A finish material devoid of coarse aggregate applied in a thin coat completely covering the base coat and floated to a true plane, yielding a relatively fine-textured finish.

X1.7.3.2 *Trowel Texture*—A freshly applied finish is given various textures, designs or stippled effects by hand motion and trowel used. The effects achieved are individualized and it is sometimes difficult for different applicators to duplicate.

X1.7.3.3 *Standard Finish*—A finish with various size aggregates, applied in a thin coat completely covering the base coat and floated in a random pattern. The applicators are cautioned to use the same type texturing tools to help ensure a consistent texture.

X1.7.3.4 *Exposed Aggregate*—Varying sizes of natural or manufactured stone, gravel, shell or ceramic aggregates are embedded by hand or by machine propulsion into a freshly applied "bed coat." The size of the aggregate shall not be more than ½ in. (12.7 mm) diameter. The size of the aggregate determines the thickness of the bedding coat. The bedding coat shall be no less than one-half the thickness of the aggregate to be embedded.

X1.7.3.5 *Spray Texture*—A machine applied finish material. The texture achieved depends on many factors some of which are the consistency of the sprayed mixture, the angle and distance of the spray nozzle to the surface, the pressure of the machine, orifice size used, operator expertise, climatic conditions (wind specifically), and base coat conditions.

X1.7.3.6 *Miscellaneous Types*—Similar to trowel textures except that the freshly applied finish is textured with instruments other than a trowel, such as swept with a broom or brush, or corrugated by raking or combing. A variation of texturing a finish involves waiting until the applied finish has partially

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dried and then lightly troweling the unevenly applied finish. The effects achieved are sometimes difficult for different applicators to duplicate.

X1.8 Conditions for DEFS Application

X1.8.1 The amount of water used to mix materials is to be within the allowable range published by the DEFS producer. Factors such as the drying conditions and finishing operations must be considered in determining water usage. The applicator is cautioned that the use of excessive water results in fall off or slide off, excessive shrinkage, higher porosity, lower strength, and inconsistent color.

X1.8.2 Timing between coats varies with climatic conditions and types of materials used. Temperature and relative humidity extend or reduce the curing and drying times. Cold or wet weather lengthens and hot or dry weather shortens these periods. Moderate changes in temperature and relative humidity are overcome by providing additional heating during cold weather and by pre-wetting the base during hot, dry weather.

X1.8.3 Heated enclosures require adequate air circulation to prevent hot or cold spots that allow too rapid drying or freezing. When using heated enclosures it is important to control the relative humidity as well as the temperature. Maintain relative humidity at not more than 90 percent.

X1.8.4 Staining and discoloration of finishes or other building components that are caused by free water draining from one plane to another, dissimilar materials, or other building components, are minimized by providing sufficient depth and angle for drip caps and drip edges.

X2. SEALANT SYSTEMS

X2.1 The size and location of joints and selection of the sealant to be used is responsibility of the Design Professional and shall be consistent with project conditions and guidelines of the DEFS producer.

X2.2 The sealant system must be tested for compatibility with the specified DEFS by an independent laboratory and found to be compatible with the DEFS.

X2.3 The sealant system is recommended by the DEFS and Sealant producer. Non recommended sealant systems must be jointly approved by the Architect and the sealant producer.

X2.4 Base the joint design and surface preparation on the sealant producer's recommendations and project conditions.

X2.5 Allow the DEFS material to cure prior to sealant system installation.

SUMMARY OF CHANGES

Committee C11 has identified the location of selected changes to this practice since the last issue, C 1516 – 02, that may impact the use of this practice. (Approved October 1, 2005)

(*1*) Added Specification C 1325 to Referenced Documents.

(*2*) Added new paragraph 11.3.6.

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Designation: C 1524 – 02a

Standard Test Method for Water-Extractable Chloride in Aggregate (Soxhlet Method)[1]

This standard is issued under the fixed designation C 1524; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope

1.1 This test method provides procedures for sampling and analysis of aggregate for water-extractable chloride using a Soxhlet extractor.

NOTE 1—This test method is to be used when significantly high chloride content has been found in aggregates, concretes, or mortars.

1.2 The values stated in SI units are to be regarded as standard.

1.3 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

2. Referenced Documents

2.1 *ASTM Standards:*

C 114 Test Methods for Chemical Analysis of Hydraulic Cement[2]

C 670 Practice for Preparing Precision and Bias Statements for Test Methods for Construction Materials[3]

C 1152/C 1152M Test Method for Acid-Soluble Chloride in Mortar and Concrete[3]

C 1218/C 1218M Test Method for Water-Soluble Chloride in Mortar and Concrete[3]

D 75 Practice for Sampling Aggregates[4]

D 1193 Specification for Reagent Water[5]

E 11 Specification for Wire Cloth and Sieves for Testing Purposes[6]

2.2 *American Concrete Institute Standard:*

ACI 222.1–96 Provisional Standard Test Method for Water-Soluble Chloride Available for Corrosion of Embedded Steel in Mortar and Concrete Using the Soxhlet Extractor[7]

3. Significance and Use

3.1 Water-extractable chloride, when present in sufficient amount, has a potential to initiate or accelerate corrosion of metals, such as steel, embedded in or contacting a cementitious system, such as mortar, grout, or concrete. This test method is applicable when aggregates contain a high background of naturally occurring chloride (see ACI 222.1–96). Test Method C 1152/C 1152M determines acid-soluble chloride and Test Method C 1218/C 1218M determines water-soluble chloride. Both Test Methods C 1152/C 1152M and C 1218/C 1218M pulverize the sample to a fine powder or fine granular material. The Soxhlet method is intended to use nonpulverized material. Results with some aggregates have shown that the Soxhlet procedure extracts an extremely low amount of chloride, with most of it remaining in the rock, and therefore, it is not available for corrosion.

3.2 The Soxhlet extraction apparatus consists of three sections: the boiling flask, which contains reagent water at the beginning of the test; the extractor, which contains the sample inside a thimble; and, the condenser. The extractor functions by boiling the water, which condenses and drips on to the sample. When the water attains a fixed height above the sample, the extractor siphons the water from the thimble back to the boiling flask. The process repeats itself until the test is terminated. (Refer to Fig. 1.)

4. Apparatus

4.1 *Sampling Equipment*:

4.1.1 The apparatus required for obtaining aggregate samples is described in Practice D 75.

4.2 *Sampling Processing Apparatus*, the same as in Test Method C 1218/C 1218M without pulverization.

4.3 *Soxhlet Extractor Apparatus*, shall have the following minimum size and consist of the following (see Fig. 1).

4.3.1 *Reflux-Type Condenser*, with a 34/45-mm ground-glass fitting to the extractor, and having a 27-mm inside diameter by a 192-mm body length.

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[1] This test method is under the jurisdiction of ASTM Committee C09 on Concrete and Concrete Aggregates and is the direct responsibility of Subcommittee C09.69 on Miscellaneous Tests.

Current edition approved Dec. 10, 2002. Published January 2003. Originally approved in 2002. Last previous edition approved in 2002 as C 1524–02.

[2] *Annual Book of ASTM Standards*, Vol 04.01.

[3] *Annual Book of ASTM Standards*, Vol 04.02.

[4] *Annual Book of ASTM Standards*, Vol 04.03.

[5] *Annual Book of ASTM Standards*, Vol 11.01.

[6] *Annual Book of ASTM Standards*, Vol 14.02.

[7] Available from American Concrete Institute (ACI), P.O. Box 9094, Farmington Hills, MI 48333.

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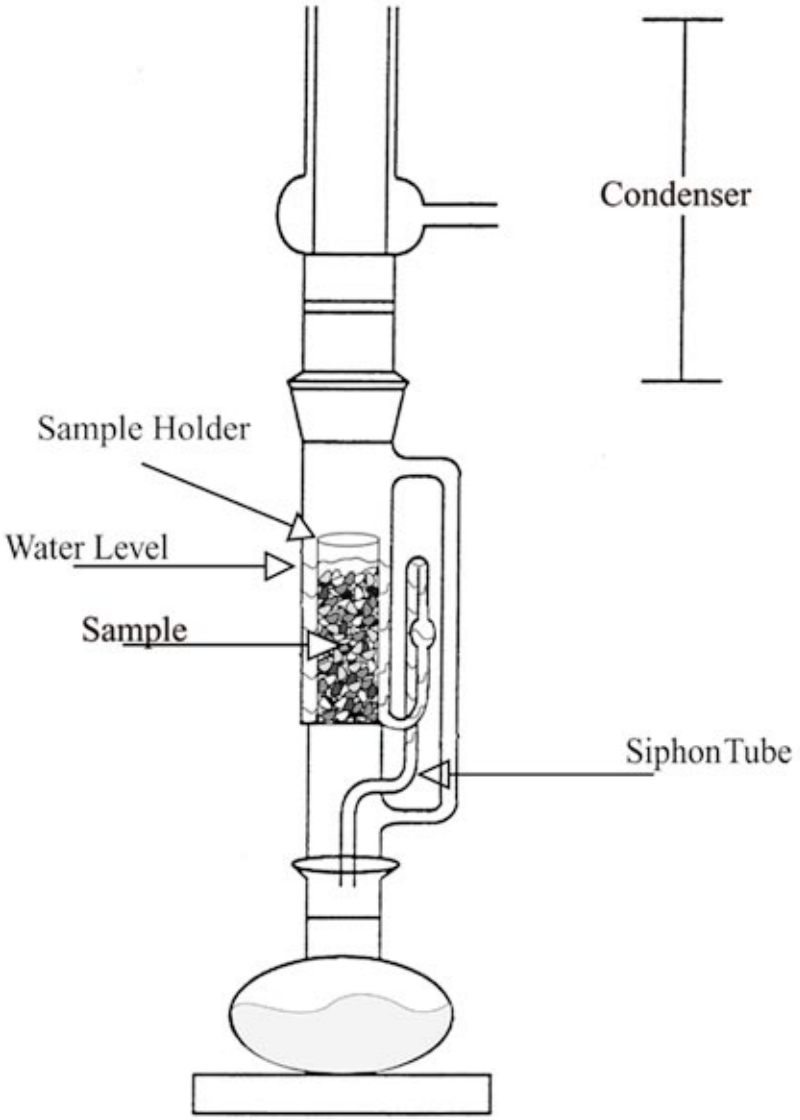

FIG. 1 Soxhlet Extraction Apparatus

4.3.2 *Soxhlet Extraction Tube*, with a 34/45-mm ground-glass fitting to the condenser and a 24/40-mm ground-glass fitting to the boiling flask, for holding sample thimbles 25 mm by 80 mm (diameter by height).

4.3.3 A 250-mL boiling flask with a 24/40-mm ground-glass fitting.

4.3.4 A heating mantel, burner, or hot plate configured for the flask capable of attaining 200°C.

4.3.5 *Suitable Sample Holder*, such as a porous extraction thimble having a 25-mm inside diameter and 80-mm external length.

4.4 The apparatus required for the chloride determination step is given in the test method for chloride in Test Methods C 114.

4.5 *pH Paper*, short-range 0.0-3.0.

4.6 *Drying Oven*, of sufficient size, capable of continuously heating at 110 ± 5°C.

4.7 *Sieve*, 25.0 mm, complying with Specification E 11.

5. Reagents

5.1 The reagents required for the chloride determination are given in the test method for chloride of Test Methods C 114, and the Procedure section of Test Method C 1218/C 1218M.

5.2 Reagent water is either deionized or distilled, conforming to the requirements of Specification D 1193 for Type III reagent water.

6. Sample Preparation

6.1 *Preparation*:

6.1.1 *For Nominal Maximum Aggregate Sizes 25.0 mm or Greater*:

Use a jaw crusher or hammer, and reduce the sample so that the particles pass a 25.0-mm sieve and are representative of the sample. Use a sample splitter or use coning and quartering to reduce the sample to between 200 and 500 g. Do not crush the sample to a powder. Oven dry the reduced sample at 110 ± 5°C for 2 h.

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6.1.2 *For Nominal Maximum Aggregate Sizes Less Than 25.0 mm* :

Use a sample splitter or use coning and quartering to reduce the sample to between 200 and 500 g. Do not crush the sample to a powder. Oven dry the reduced sample at 110 ± 5°C for 2 h.

7. Procedure

7.1 Mix and cone the reduced sample three times before sampling each replicate. Obtain a minimum mass of 30.0 g of the sample by sampling from at least four points, record the mass to the nearest 0.01 g, and transfer it to the porous sample holder of the Soxhlet extractor. Place at least 200 mL of reagent water in the lower flask. Conduct this procedure in triplicate. Make a blank determination by using the Soxhlet apparatus, with thimble but containing no sample.

NOTE 2—Replicate sample size can be larger than 30 g; however, the top of the sample in the thimble needs to be kept below the top of the siphon to properly extract the sample with solution. The sample will include aggregate particles and the fines produced by crushing.

7.1.1 Place the top of the thimble above the top of the glass tube regulating the level at which the water siphons off. Do not completely fill the thimble with the sample. Assemble the condenser complete with cooling water supply tubing to the extractor and place on the heater. Turn on both the heater and condenser cooling water and allow extraction to continue for 24 h; the heating rate shall be adjusted to give a cycle every 20 ± 5 min. The number of cycles shall be not less than 70. One cycle consists of the thimble filling with solution and discharging.

NOTE 3—Larger-sized Soxhlet apparatus are available; however, the cycle times will be longer and the total extraction time for 70 cycles will be about 1.5 to 3 days.

7.1.2 At the conclusion of the extraction stage, quantitatively transfer the solution to a 400-mL beaker by rinsing the boiling flask three times with 10 mL of reagent water, and transferring the washings to the beaker. Add 3 ± 0.1 mL of nitric acid that has been diluted one-on-one with water, and add 3 ± 0.1 mL 30 % solution hydrogen peroxide, to the extract. Using pH paper, determine the pH of the solution. If the pH of the solution is more than 2, add additional 1:1 nitric acid until the pH is less than 2. Cover the beaker with a watch glass. Add a stirring bar composed of polytetrafluoroethylene (PTFE) and allow to stand for 1 to 2 min. While stirring, heat the covered beaker rapidly to boiling. Do not boil for more than a few seconds. Remove from the hot plate.

NOTE 4—It is important to keep the beaker covered during heating and digestion to prevent the loss of volatile chloride.

7.1.3 Proceed in accordance with the reference test method for chloride in Test Methods C 114, starting with the procedure that follows removal of the sample from the hot plate.

8. Calculation and Reporting

8.1 Calculate percent chloride by mass of oven-dry aggregate by the reference test method for chloride in Test Methods C 114.

8.2 Report both the individual and average values of Soxhlet extracted chloride content.

8.3 The report shall state whether the sample was fractured or not fractured during preparation for testing.

9. Precision and Bias

9.1 *Precision*:

9.1.1 The single-laboratory standard deviation has been found to be 0.0004 % [8] chloride by mass of aggregate. Therefore, two acceptable test results are not expected to differ by more than 0.0015 %.

9.1.2 The multilaboratory standard deviation has been found to be 0.0006 % [8] chloride by mass of aggregate. Therefore, acceptable results obtained in two different laboratories are not expected to differ by more than 0.0020 %.

9.2 *Bias*—The procedure in this test method has no bias because the value of Soxhlet-extracted chloride is defined by the procedure (see Practice C 670).

10. Keywords

10.1 aggregate; chloride content

[8] These numbers represent, respectively, the (1s) and (d2s) limits as described in Practice C 670.

APPENDIX

(Nonmandatory Information)

X1. Summary of Soxhlet Round Robin Precision Testing

X1.1 Round robin testing to determine within-laboratory and between-laboratory precision of the Soxhlet method was performed by six laboratories. Each laboratory was provided with three aggregates to analyze, two containing integral chloride and one aggregate containing chloride absorbed from a marine environment. The aggregates were analyzed as received using the Soxhlet method. The results of the interlaboratory study are found in Tables X1.1-X1.3.

NOTE X1.1—Data from Aggregate C was not used to calculate within-laboratory and between-laboratory precision.

X1.2 The Soxhlet method is intended for the analyses of limestone aggregates that contain a large amount of chloride that is encapsulated or integral within the aggregate shell. These are primarily aggregates from the Niagara Escarpment extending from southern Ontario down through New York,

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TABLE X1.1 Aggregate A Containing Integral Chloride—Chloride, % by Mass of Sample

Laboratory	Data			Average	Standard Deviation
	a	b	c	X_n	S_n
1	0.0012	0.0021	0.0011	0.0015	0.00055
2	0.0004	0.0014	0.0009	0.0009	0.00050
3	0.0021	0.0023	0.0023	0.0022	0.00012
4	0.0010	0.0008	0.0025	0.0014	0.00093
5	0.0011	0.0012	0.0011	0.0011	0.00006
6[A]	0.0226	0.0226	0.0051	0.0168	0.01010

[A] Data from Laboratory 6 was not used to calculate the between-lab average.

TABLE X1.2 Aggregate B Containing Integral Chloride—Chloride, % by Mass of Sample

Laboratory	Data			Average	Standard Deviation
	a	b	c	X_n	S_n
1	0.0025	0.0028	0.0022	0.0025	0.00030
2	0.0021	0.0024	0.0017	0.0021	0.00035
3	0.0015	0.0018	0.0021	0.0018	0.00030
4	0.0023	0.0021	0.0016	0.0020	0.00036
5	0.0011	0.0010	0.0016	0.0012	0.00032
6[A]	0.0342	0.0301	0.0242	0.0295	0.00503

[A] Data from Laboratory 6 was not used to calculate the between-lab average.

TABLE X1.3 Aggregate C Containing Absorbed Chloride—Chloride, % by Mass of Sample

Laboratory	Data			Average	Standard Deviation
	a	b	c	X_n	S_n
1	0.2279	0.2780	0.2739	0.2766	0.00234
2	0.2301	0.2880	0.2954	0.2712	0.03576
3	0.3201	0.3172	0.3174	0.3182	0.00162
4	0.3065	0.2824	0.2971	0.2953	0.01215
5	0.2704	0.2984	0.2511	0.2733	0.02378
6	0.2088	0.2047	0.2673	0.2269	0.03502

northern Michigan and into the Chicago area. Aggregates of this type will produce a high chloride value when ground and analyzed according to Test Method C 1218/C 1218M and a substantially lower chloride value analyzed by the Soxhlet method.

X1.3 The Soxhlet method is not intended for marine aggregates or aggregates that contain absorbed chloride as indicated by an insignificant difference between water-soluble (Test Method C 1218/C 1218M) and water-extractable (Soxhlet) chloride.

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Designation: C 1529 – 06a

Standard Specification for Quicklime, Hydrated Lime, and Limestone for Environmental Uses[1]

This standard is issued under the fixed designation C 1529; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope*

1.1 This specification covers lime and limestone products and by-product alkaline materials suitable for environmental uses as shown in Table 1.

1.2 The buyer shall designate the use, as listed in Table 1, and may specify one or more of the type designations listed below Table 1.

1.3 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory requirements prior to use.*

2. Referenced Documents

2.1 *ASTM Standards:* [2]

C 25 Test Methods for Chemical Analysis of Limestone, Quicklime, and Hydrated Lime

C 50 Practice for Sampling, Sample Preparation, Packaging, and Marking of Lime and Limestone Products

C 110 Test Methods for Physical Testing of Quicklime, Hydrated Lime, and Limestone

C 400 Test Methods for Quicklime and Hydrated Lime for Neutralization of Waste Acid

D 6249 Guide for Alkaline Stabilization of Wastewater Treatment Plant Residuals

3. Terminology

3.1 *By-product alkaline materials*—By-product lime (such as lime kiln dust) or other secondary materials (such as high-lime fly ash) that contain adequate amounts and types of calcium and/or magnesium oxides or hydroxides to meet the physical and chemical requirements in this specification. It is advised that the specific compositions, physical properties, performance characteristics, and anticipated variabilities of such materials be evaluated for the service intended.

4. Chemical Composition and Physical Properties

4.1 The requirements for quicklime, hydrated lime, and limestone for the designated end uses are as shown in Table 1, and are on the basis of the weight of sample taken at the place of manufacture.

5. General Requirements

5.1 Quicklime shall be reasonably free of unslakable residues and shall be capable of disintegrating in water to form a suspension of finely divided material. The amount of residue shall not exceed that agreed upon between the manufacturer and the purchaser (the residue is the amount of material retained on a specified screen). The method for measuring quicklime residue appears in Test Methods C 110.

5.2 The slaking rate for the specified quicklime should be matched to the requirements of the slaking equipment. The method for measuring the slaking rate of quicklime appears in Test Methods C 110.

6. Sampling and Inspection

6.1 Conduct the sampling, inspection, rejection, retesting, packaging, and marking in accordance with Practice C 50.

7. Test Methods

7.1 The chemical analyses shall be made in accordance with Test Methods C 25.

7.2 The physical tests shall be made in accordance with Test Methods C 110.

7.3 The basicity-factor tests shall be made in accordance with Test Methods C 400.

8. Keywords

8.1 biosolids; by-product lime; calcium oxide; dolomitic lime; dolomitic limestone; drinking water; environmental; high calcium lime; high calcium limestone; hydrated lime; industrial waste; lime; limestone; magnesian lime; magnesian limestone; neutralization; quicklime; residuals; sewage sludge; stabilization; treatment; waste; wastewater; water; water softening

[1] This specification is under the jurisdiction of ASTM Committee C07 on Lime and is the direct responsibility of Subcommittee C07.02 on Specifications and Guidelines.

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[2] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

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TABLE 1 Lime and Limestone for Environmental Uses

Use	Notes Referenced	Approved Types of Lime	Chemical Requirements, %				Physical Requirements, % less than	
			CaO +MgO, min	CO_2, max	Available CaO, min	Basicity Factor, min	Dry Sieve, 3/8 in.	Wet Sieve, 100 mesh
Drinking water softening	[A]	CQ	. . .	. . .	90	. . .	. . .	. . .
		CH	. . .	. . .	68	. . .	. . .	. . .
Waste and wastewater neutralization	[B]	CH	95.0[C]	5.0	. . .	0.72	. . .	. . .
		DH	95.0[C]	5.0	. . .	0.81	. . .	. . .
		MH	95.0[C]	5.0	. . .	0.74	. . .	. . .
		CQ	90.0	. . .	. . .	0.93	. . .	. . .
		DQ	90.0	. . .	. . .	1.06	. . .	. . .
		MQ	90.0	. . .	. . .	0.93	. . .	. . .
		CL[D]	90.0[C]	. . .	. . .	0.45	. . .	. . .
		DL[D]	90.0[C]	. . .	. . .	0.56	. . .	. . .
		ML[D]	90.0[C]	. . .	. . .	0.48	. . .	. . .
Wastewater treatment plant residuals stabilization[E]	[F,G,H]	CQ, DQ, MQ	90.0	. . .	. . .	. . .	100	. . .
		CH, DH, MH	90.0[C]	. . .	. . .	. . .	. . .	95
		By-product alkaline materials	25.0[I,J]	. . .	. . .	. . .	100	. . .

CQ = Quicklime, high-calcium
DQ = Quicklime, dolomitic
MQ = Quicklime, magnesian
CH = Hydrated lime, high-calcium
DH = Hydrated lime, dolomitic
MH = Hydrated lime, magnesian
CL = Limestone, high-calcium
DL = Limestone, dolomitic
ML = Limestone, magnesian

[A] In the softening of drinking water, lime is used alone or with coagulant aids to produce a precipitate that assists in the clarification of water, removal of bacteria, and removal of hardness. Lime and soda ash may be used together for softening water. The lime serves as a chemical reagent in water softening. The only useful constituent of the lime is the calcium oxide content of the quicklime or hydrated lime capable of reacting with the other chemicals in the water or added to it. Inert material, besides reducing the value in proportion to its amount, also makes more sludge to be disposed of for a given amount of chemical action and thus reduces the capacity of the equipment in which it is used. In addition to water softening, lime is also used for color removal and clarification of water.

[B] When determining the quantity of liming material for the neutralization of liquid acidic wastes, use is made of an acid value-basicity factor relationship. Acid value and basicity factor test methods are in Test Methods C 400.

[C] On a nonvolatile basis.

[D] Limestone analyses are typically reported as carbonate (CO_3). The requirement that limestone contains a minimum of 90 % CaO + MgO on a non-volatile basis corresponds to approximately 95 % $CaCO_3$+ $MgCO_3$.

[E] Wastewater treatment plant residuals may be referred to as sewage sludge or biosolids.

[F] Also see “Standard Guide for Alkaline Stabilization of Wastewater Treatment Plant Residuals” (D 6249).

[G] Quicklime, hydrated lime, and alkaline by-product materials will raise the pH of biosolids.

[H] If quicklime or by-product alkaline materials containing calcium or magnesium oxide are used, the reaction with water will generate heat. High calcium quicklime will slake more quickly and achieve a higher total temperature rise than other alkaline materials, which generally facilitates treatment. Although slaking rate and total temperature rise are not part of this specification, they are critical site-specific factors that should be matched to the user’s treatment objective and technology. The methods for measuring the slaking rate of quicklime and total temperature rise appear in Test Methods C 110.

[I] Tested on an as received basis.

[J] The available lime index test in Test Methods C 25, which measures only calcium oxide and hydroxide, can be used.

SUMMARY OF CHANGES

Committee C07 has identified the location of selected changes to this specification since the last issue, C 1529 – 06, that may impact the use of this specification. (Approved November 15, 2006)

(*1*) Revised 1.1.

Committee C07 has identified the location of selected changes to this specification since the last issue, C 1529 – 02a, that may impact the use of this specification. (Approved September 1, 2006)

(*1*) Removed by-product hydrated lime from Table 1.

(*2*) Added a Terminology section.

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Designation: C 1535 – 05

Standard Practice for Application of Exterior Insulation and Finish Systems Class PI[1]

This standard is issued under the fixed designation C 1535; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope*

1.1 This practice covers the minimum requirements and procedures for field or prefabricated application of Class PI Exterior Insulation and Finish Systems (EIFS). Class PI EIFS are systems applied over polyisocyanurate insulation board, in which the base coat ranges from not less than 1/16 in. (1.6 mm) to 1/4 in. (6.4 mm) in dry thickness, depending upon the number of nonmetallic reinforcing mesh layers encapsulated in the base coat. The base coat is then covered with a finish coat of various thickness in a variety of textures and colors. The insulation board shall be applied over a substrate or over open framing.

1.2 This practice does not cover Class PI EIFS with drainage. Consult the EIFS producer for information.

1.3 The values stated in inch-pound units are to be regarded as the standard. The SI (metric) values given in parentheses are approximate and are provided for information purposes only.

1.4 The text of this standard references notes and footnotes that provide explanatory material. These notes and footnotes shall not be considered as requirements of the standard.

1.5 *This standard may involve hazardous materials, operations and equipment. This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

2. Referenced Documents

2.1 *ASTM Standards:* [2]

C 11 Terminology Relating to Gypsum and Related Building Materials and Systems

C 79/C 79M Specification for Treated Core and Nontreated Core Gypsum Sheathing Board

C 150 Specification for Portland Cement

C 1063 Specification for Installation of Lathing and Furring to Receive Interior and Exterior Portland Cement-Based Plaster

C 1177 Specification for Glass Mat Gypsum Substrate for Use as Sheathing

C 1186 Specification for Flat Non-Asbestos Fiber-Cement Sheets

C 1278/C 1278M Specification for Fiber-Reinforced Gypsum Panel

C 1280 Specification for Application of Gypsum Sheathing

C 1289 Specification for Faced Rigid Cellular Polyisocyanurate Thermal Insulation Board

C 1325 Specification for Non-Asbestos Fiber-Mat Reinforced Cement Substrate Sheets

C 1382 Test Method for Determining Tensile Adhesion Properties of Sealants When Used in Exterior Insulation and Finish Systems (EIFS) Joints

C 1472 Guide for Calculating Movement and Other Effects When Establishing Sealant Joint Width

C 1481 Guide for Use of Joint Sealants with Exterior Insulation and Finish Systems (EIFS)

E 1825 Guide for Evaluation of Exterior Building Wall Materials, Products, and Systems

E 2110 Terminology for Exterior Insulation and Finish Systems (EIFS)

3. Terminology

3.1 Definitions used in this standard shall be in accordance with Terminologies C 11 and E 2110.

4. Significance and Use

4.1 This practice provides minimum requirements for the application of Class PI EIFS. The requirements for materials, mixtures, and details shall be contained in the project plans and specifications. See Guide E 1825 for guidance.

[1] This practice is under the jurisdiction of ASTM Committee C11 on Gypsum and Related Building Materials and Systems and is the direct responsibility of Subcommittee C11.05 on Application of Exterior Insulating and Finish Systems and Related Products.

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5. Delivery of Materials

5.1 All materials shall be delivered in packages, containers, or bundles with the identification and markings intact.

6. Inspection

6.1 Inspection of the materials shall be agreed upon and be a part of the purchase agreement.

6.2 Inspection shall include the determination that the materials supplied are as required for the Class PI EIF System specified. Mixing of materials from different manufacturers is not allowed.

7. Rejection

7.1 Materials that are damaged, frozen or defective shall not be used. Rejection of materials shall be promptly reported verbally to the producer and immediately reported in writing. The notice of rejection shall contain a statement documenting the basis for material rejection.

8. Certification

8.1 When specified in the contract documents, the producer shall furnish a report certifying that the materials are in conformance with product and material standards and contract documents.

8.2 *Insulation Boards*:

8.2.1 Insulation boards shall be in compliance with Specification C 1289 , Type II, Class 2.

8.2.2 Insulation boards shall have been subjected to a third party quality control inspection and shall be marked as approved for use within the EIFS and in accordance with applicable building code.

8.2.3 Prior to installation, the insulation board shall be inspected for conformance with contract documents. Nonconforming insulation board shall not be used.

8.2.4 The insulation board producer shall furnish, for each shipment, a written certificate of conformance with the EIFS producer's specifications.

9. Storage of Materials

9.1 All materials shall be kept dry by storage under cover and protected from the weather. When outside storage is required, materials shall be stacked off the ground, supported on a level platform and protected from the weather, surface contamination or physical damage in accordance with the EIFS producer's written instructions.

9.2 Materials shall be protected from exposure to direct sunlight and temperatures less than 40 °F (4 °C) unless otherwise specified by the manufacturer.

9.3 Portland Cement shall meet Specification C 150 and shall be kept dry until ready for use. It shall be kept off the ground, under cover and away from damp walls and surfaces.

9.4 Insulation board shall be stacked flat with care taken to avoid damage to edges, ends, or surfaces; or exposure to direct sunlight (ultraviolet radiation).

10. Environmental Conditions

10.1 *Cold Weather Conditions*:

10.1.1 Wet materials shall not be applied when the temperature is less than 40 °F (4 °C) unless otherwise specified by the manufacturer or unless temporary heat and enclosures are provided to maintain minimum 40 °F (4 °C) for a minimum period of not less than 24 hours before, during and after application. (See X1.8.3)

10.1.2 Materials shall not be applied to a base containing frost. Substrate surface temperature shall be not less than 40 °F (4 °C). Mixtures for application shall not contain any frozen ingredients.

11. Assessment of Condition of Substrates to Receive Exterior Insulation and Finish Systems

11.1 The substrate shall be as required by the project plans and specifications and as recommended by the EIFS producer for the particular system specified.

11.1.1 Polyisocyanurate boards for use over open framing in conformance with the EIFS producer's specification shall not be less than 1.0 in. (25.4 mm) in thickness.

11.1.2 Polyisocyanurate boards for use over a substrate in conformance with the EIFS producer's specification shall not be less than ⅝ in. (15.9 mm) in thickness.

NOTE 1—Polyisocyanurate board thickness shall conform to building code requirements.

11.2 The substrate shall be inspected by the applicator and general contractor to assure that it meets the project plans and specifications and the requirements of 11.3-11.8.

11.3 Sheathing materials shall be inspected to ensure the following:

11.3.1 The specified sheathing thickness has been installed for the stud spacing used.

11.3.2 Fastener type and fastener spacing are as specified.

11.3.3 All Specification C 79/C 79M gypsum sheathing boards have a water-resistant treated core.

11.3.4 Tongue and groove water-resistant core gypsum sheathing boards conforming to Specification C 79/C 79M are installed with the tongue edge oriented to the top.

11.3.5 Gypsum sheathing shall be installed with the face paper exposed in accordance with Specification C 1280.

11.3.6 Gypsum sheathing shall be protected from moisture at all penetrations and terminations.

11.3.7 Glass mat gypsum sheathing complying with Specification C 1177 shall be installed in accordance with the sheathing producer's written installation instructions, which include details of framing type and spacing, fastener type and spacing, and sheathing orientation and spacing.

11.3.8 Plywood shall be not less than ½ in. (12.7 mm) nominal in thickness, exterior or exposure 1 panel sheathing. The plywood shall be installed with a ⅛ in. (3.2 mm) space between sheets at edges and ends.

11.3.9 Fiber-Cement sheets complying with Specification C 1186, Type A, shall be installed in accordance with the sheet producer's written installation instructions, which include details of stud type and spacing, fastener type and spacing, and sheet spacing recommendations.

11.3.10 Water-resistant exterior fiber-reinforced gypsum sheathing complying with Specification C 1278/C 1278M shall be installed in accordance with the sheathing producer's

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written installation instructions, which include details of framing type and spacing, fastener type and spacing, and sheathing orientation and spacing.

11.3.11 Fiber-mat reinforced cement sheets complying with Specification C 1325, type A, shall be installed in accordance with the sheet producer's written installation instructions, which include details of framing type and spacing, fastener type and spacing, and sheet orientation and spacing.

11.3.12 Sheathing shall be continuous.

11.4 *Alignment*—All substrate surfaces shall be straight and true within ¼ in./10 ft (2 mm/m). More stringent requirements by the EIFS producer shall supersede the above stated requirements.

11.5 *Suitability for Use*—The substrate shall be firm, sound, and undamaged in order to receive the EIFS.

11.6 *Cleanliness*—The surface of all substrates shall be clean and free from any foreign materials such as paint, form release agents, curing compounds, dust, dirt, frost, oil or grease, efflorescence and laitance that would affect the EIFS application.

11.7 *Dryness*:

11.7.1 Newly constructed concrete or masonry surfaces shall be allowed to cure not less than 28 days prior to application of the EIFS. Repaired areas on existing (aged) walls shall meet the same 28-day curing time.

11.7.2 Substrate surfaces shall be free of visible water.

11.8 *Metal Lath or Furring and Accessories*—If metal lath or furring and accessories are used, they shall be installed in conformance with Specification C 1063, except lath edges and ends shall be butted and not lapped. Metal lath shall be 3.4 lb/yd^2 (1.3 kg/m^2) self-furring, galvanized.

11.8.1 Metal members shall be properly attached, straight, and true unless otherwise required by the system design.

11.8.2 Metal members shall be free of rust, oil, or other foreign matter or contaminants, which cause bond failure or unsightly discoloration.

12. Insulation Board Installation

12.1 Method of Attachment shall be approved by the system producer and be in accordance with applicable building code.

12.2 *Mechanical Attachment Method*:

12.2.1 Mechanical fasteners shall be installed into the framing or nailable substrate.

12.2.2 Mechanical fasteners shall be corrosion resistant. Fastener type and spacing shall be in accordance with system producer's current published instructions.

NOTE 2—Specific consideration of building code wind load requirements shall be given for mechanically fastened systems.

12.3 Placement of a weather resistive barrier, if specified, shall be as required by the system producer.

13. General Requirements

13.1 Insulation boards shall be placed from a level base line with vertical joints staggered in a running bond pattern and butted tightly. Over open framing, joints shall occur over framing or horizontal blocking.

13.2 Insulation board joints at all inside and outside corners shall be staggered and interlocked.

13.3 Insulation boards must abut without gaps, eliminating space for base coat intrusion between the board edges and ends.

13.4 Fenestration opening corners and other wall penetrations shall be cut out of a single insulation board. Board joints shall not be aligned at corners with head, sill or jambs of windows, doors, similar openings, and aesthetic reveals.

13.5 *Mechanically Fastened*:

13.5.1 Insulation board joints shall be offset from sheathing board joints.

13.5.2 When the boards are attached only with mechanical fasteners, they shall be affixed to a nailable substrate or structural members with the proper fasteners, ensuring that all boards abut tightly. Fastening pattern shall be in accordance with the EIFS producer's recommendation and local building code requirements. When installed, the washer shall be left flush with the face of the insulation board and shall not fracture the face or core of insulation board.

14. Aesthetic Reveals

14.1 Aesthetic reveals shall be cut into the insulation board prior to applying the reinforcing mesh.

14.2 The insulation board thickness at the bottom of a reveal shall be not less than ¾ in. (19.0 mm). Over open framing, aesthetic reveals shall occur over framing or blocking.

14.3 Aesthetic reveals shall be cut true and straight.

14.4 Horizontal aesthetic reveal configuration shall provide for outward positive drainage.

14.5 Aesthetic reveals shall not occur at the abutment of two pieces of insulation board.

14.6 The reveal shall be reinforced with base coat and reinforcing mesh prior to application of the full base coat and reinforcing mesh.

15. Reinforced Base Coat Application

15.1 Inspect the insulation board surface to ensure that it is clean, dry, free of all foreign materials, and damage of any type. Insulation board planar irregularities of more than 1/16 in. (1.6 mm) shall be corrected. All board joints shall be tightly abutted or shall be filled with an insulating material.

15.2 *Base Coat Preparation*—All materials requiring field preparation shall be mixed in accordance with the EIFS producer's specifications.

15.3 *Base Coat Application*—The prepared base coat shall be uniformly spread over the entire surface of the insulation board.

15.4 *Non Metallic Reinforcing Mesh*—The single layer reinforcing mesh shall be fully encapsulated in the field of the wall, at corners, edges, and joints. Trowel from the center to the edge of the reinforcing mesh to avoid wrinkles. The single layer reinforcing mesh shall be continuous at all corners.

15.4.1 The surface shall be free of voids, projections, trowel marks and other surface irregularities. The base coat thickness shall be not less than 1/16 in. (1.6 mm) dry as measured from the surface of the insulation board. The base coat shall be applied in two applications unless otherwise recommended by the EIFS's producer.

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NOTE 3—The recommended method is to apply the base coat in two applications.

15.5 *Reinforcing Mesh Overlap*—All reinforcing mesh edges shall be overlapped not less than 2 ½ in. (64 mm).

15.6 *Impact Layers*—When required, higher impact performance shall be achieved with multiple layers of reinforcing mesh or by incorporating heavier weight reinforcing mesh. All areas requiring higher impact performance shall be detailed on the project plans and specifications. When overlapping of high impact mesh is not required, a complete second layer of reinforcing mesh shall be applied over the layer of high impact mesh.

15.7 *Corners*—Reinforcing mesh shall not be lapped within 8 in. (200 mm) of any corner.

15.8 *Wall Penetrations*—All edges of the insulation board at penetrations of the EIFS, such as at windows, doors, HVAC sleeves, pipes, ducts, electrical boxes, and at the base of the wall shall be wrapped with either the base coat and reinforcing mesh or trim, or as specified by the project plans and specifications. Wall openings such as doors, windows, HVAC sleeves, shall be diagonally reinforced at corners with mesh not less than 9 in. (230 mm) by 12 in. (305 mm).

15.8.1 The corners of returns to windows, doors, and similar wall openings shall have reinforcing mesh the full width of the return and extending not less than 2½ in. (64 mm) on both sides of the corner.

15.9 *Expansion Joints*—All edges of the insulation board at expansion joints shall be wrapped with either the base coat and reinforcing mesh or trim as specified by the EIFS producer for the particular EIFS. The reinforcing mesh shall be fully encapsulated.

15.10 *Aesthetic Reveal*—The reinforcing mesh shall be continuous and care shall be taken to ensure that the reinforcing mesh is fully encapsulated into the reveal and that the reinforcing mesh shall not be cut during application of the base coat.

15.11 *Reinforced Base Coat*—The reinforcing mesh shall be fully encapsulated in the base coat throughout the field of the wall, at corners, edges, and joints. The surface shall be free of voids, projections, trowel marks and other surface irregularities.

15.12 *Special Insulation Shapes*—When special insulation shapes are installed over EIFS, nonmetallic reinforcing mesh encapsulated in the base coat shall be used to cover the shape.

16. Finish Coat Application

16.1 The reinforced base coat shall be allowed to dry and harden for not less than 24 h prior to finish coat application unless specifically allowed by the EIFS producer.

16.2 *Material Preparation*—The finish coat shall be mixed in accordance with the EIFS producer's specifications. Only clean potable water shall be added to adjust workability. Always add the same amount of water to each container within a given lot of finish.

16.3 *Execution*—Finish shall be applied with a stainless steel trowel or appropriate equipment as specified by the EIFS producer. Tools and equipment shall be kept clean at all times. Finish shall be applied continuously to a natural break such as corners, joints or tape line. Apply finish to the base coat maintaining a wet edge. Sufficient manpower and scaffolding shall be provided to continuously finish a distinct wall area. Scaffolding shall be spaced a distance from the wall, consistent with safety standards, that will allow uniform texturing of the finish without staging marks. On hot windy days, misting is permitted with clean, potable water to cool the wall. Work shall precede the sun whenever possible. Water shall not be added to the finish once it is applied to the wall. Use the same tool and hand motion and match the texture of the surrounding area. The finish coat thickness shall be as specified by the EIFS producer. Protect all finish work from damage until fully dried.

16.4 *Sealant Joints*—The application of finish into the sealant joint is not allowed.

17. Curing Time Between Application Steps

17.1 Manufacturer's recommendations for climatic conditions, mixing and application practices to allow respective coats sufficient time to cure or dry before any subsequent coats are applied shall be followed. Each application step shall be cured or dried to prevent degradation to the system integrity with subsequent steps.

17.2 Auxiliary protection (tenting, supplemental heat, shading) from adverse environmental conditions shall be utilized to provide curing and drying conditions as recommended by the producer (see X1.8).

17.3 All substrates shall be sound and cured or dry before continuing on to the next application step.

18. Clean Up

18.1 Adjacent materials, surfaces and the work area shall be cleaned of foreign materials resulting from the work.

18.2 All excess EIFS materials shall be removed from the job site.

19. Keywords

19.1 Class PI; EIFS; exterior insulation and finish system

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APPENDIXES

(Nonmandatory Information)

X1. GENERAL INFORMATION

INTRODUCTION

These appendixes give general information and also suggestions for inclusions to be made elsewhere by the specifier. They are not part of this practice.

X1.1 General

X1.1.1 The work includes all labor, materials, services, equipment and scaffolding required to complete the EIFS installation on the project in accordance with the project drawings and specifications, except electrical power and potable water.

X1.1.2 Where a specific fire resistance rating is required for the EIFS assemblies and construction, details of construction shall be in accordance with official reports of tests conducted by recognized testing laboratories and a part of approved plans and specifications.

X1.1.3 The installation of the EIFS is to be coordinated by the owner's authorized agent with work of other trades.

X1.1.4 Surfaces and accessories to receive EIFS components shall be examined and accepted as provided in 11.2 before the EIFS components are installed thereto. The proper authorities shall be notified about unacceptable conditions. The unsatisfactory conditions shall be corrected prior to the application of the EIFS components. Unsatisfactory conditions shall be corrected by the party or parties responsible for such conditions.

X1.1.5 The construction specifier shall describe, in the proper section of the project specifications, the physical characteristics of the surfaces to receive the EIFS.

X1.2 Design Considerations

X1.2.1 EIFS are attached to outside surfaces of all types of structures to provide weather resistant, energy efficient, and durable claddings. The claddings will be subjected to various exposures such as abrasion, vibration, moisture, freezing, thawing, negative and positive wind loading , ultraviolet light, acid rain, thermally induced expansion and contraction, and impact.

X1.2.2 Provide sufficient slope on faces of EIFS surfaces to prevent water, snow or ice from accumulating or standing. A minimum 6 in. (152 mm) in 12 in. (305 mm) (1:2) pitch is recommended. Length of sloped surfaces shall not be more than 12 in. (305 mm).

X1.2.3 Provide parapet cap made only from corrosion resistant materials. The parapet cap shall extend not less than 2½ in. (64 mm) over the faces of the EIFS, not including wood blocking and include a drip edge detail. Detailed requirements for furnishing and installing the parapet cap shall be in the appropriate section of the project specifications. Parapet caps shall be clearly shown in large scale details. Parapet caps shall be installed as soon as practical after the installation of the EIFS.

X1.2.4 Provide for sealing of expansion joints, panel joints, system terminations and all interfaces of the EIFS with other building components.

X1.2.5 At soffits, window and door heads provide for a drip edge.

X1.2.6 Windows installed in EIFS walls shall have a sill pan flashing of corrosion-resistant material.

X1.2.7 The specifier shall evaluate the potential of the EIFS surface being subjected to abnormal stresses or impacts.

X1.2.8 Wall assemblies have properties that in certain applications make a dew point analysis critical to ensure successful performance of the wall system. The specifier shall evaluate these conditions.

X1.2.9 Sheathing must be continuous over floor slabs, intersecting walls, columns, beams and similar constructions. The EIFS shall not be installed over areas without sheathing. If the sheathing cannot be continuous, the installation of expansion joints shall be considered.

X1.2.10 Where the sheathing is interrupted or out of plane, corrections must be made prior to EIFS application.

X1.2.11 A weather resistive barrier and flashings may be required and specified in moisture and water sensitive construction. The EIFS producer, architect, and specifier shall evaluate the conditions and determine the need.

X1.3 Relief From Stress

X1.3.1 Where the EIFS and dissimilar types of substrates, materials and building components interface, provide for appropriate size and location of expansion joints.

X1.3.2 Where roof elevations change, provide for appropriate size and location of expansion joints.

X1.4 Bonding Agents

X1.4.1 Bonding compounds or agents are sometimes applied to the insulation board surface prior to base coat application. Follow the EIFS producer's instructions and specifications for their use.

X1.5 Mechanical Fasteners

X1.5.1 The types of mechanical fasteners used and the methods of installation will vary depending upon the substrate to which the insulation boards are to be fastened.

X1.5.2 Fastener washers shall be installed flush with the insulation board surface.

X1.5.3 Fastener spacing shall be specified by the design professional consistent with wind load requirements and the local building code on the specific project.

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X1.6 Reinforced Base Coats

X1.6.1 Base coat thickness is permitted to exceed 1/16 in. (1.6 mm) dry depending on the type of base coat used and the impact resistance specified.

X1.6.2 A small amount of base coat shrinkage is normal. Due to color variations, a very slight telegraphing of the reinforcing mesh pattern may appear after the base coat cures. Bare mesh shall not be visible and the mesh pattern shall not be tactile.

X1.6.3 The producer's instructions shall be followed to ensure that the base coat and cement are properly proportioned. The proper portioning of cement-based material is important. Excess cement may cause the base coat to become hard and stiff as the cement hydrates over time.

X1.6.4 The minimum amount of mix water to form a workable mix shall be used. Excess mix water causes the base coat to be porous, less weather resistant, and contribute to shrinkage. Never add more water than recommended by the producer. Measure water in containers of known volume.

X1.6.5 Mix materials only at low speed with paddles designed to reduce air entrapment.

X1.6.6 Generally, when applying 2 layers of mesh, the second base coat layer is applied as soon as the first layer has dried sufficiently to receive the second base coat application. Depending upon material composition and weather conditions, this sometimes occurs within the first 24 h after the completion of the application of the initial base coat, and, in some cases, it will require waiting until the following day.

X1.6.7 Trowel aesthetic reveals and corners with a trowel shaped to fit the profiles.

X1.7 Finish Textures

X1.7.1 Textures, as a description of surface appearance, generally are identified with the method and tools used to achieve the finish appearance. Texture is sometimes varied by the size and shape of the aggregate contained in the finish, equipment or tools employed, the consistency of the finish mix, the condition of the base to which it is applied and by decorative and protective treatments.

X1.7.2 With almost limitless variations possible for finish appearance or texture, the same term sometimes does not have the same meaning to the specifier, contractor or applicator. Sample panels of sufficient size including components and features specified shall be constructed using the methods, tools and techniques to be used in the actual construction. It is recommended that in the case of prefabrication, two panels be constructed. One panel remains at the jobsite. One panel remains at the fabrication site. The samples shall be approved by the architect and owner in writing.

X1.7.3 To provide some guidance, the following categories are generally understood and recognized to imply a particular method of application or finished appearance.

X1.7.3.1 *Sand Finish*—A finish material devoid of coarse aggregate applied in a thin coat completely covering the base coat and floated to a true plane, yielding a relatively fine-textured finish.

X1.7.3.2 *Trowel Texture*—A freshly applied finish is given various textures, designs or stippled effects by hand motion and trowel used. The effects achieved are individualized and it is sometimes difficult for different applicators to duplicate.

X1.7.3.3 *Standard Finish*—A finish with various size aggregates, applied in a thin coat completely covering the base coat and floated in a random pattern. The applicators are cautioned to use the same type texturing tools to help ensure a consistent texture.

X1.7.3.4 *Exposed Aggregate*—Varying sizes of natural or manufactured stone, gravel, shell or ceramic aggregates are embedded by hand or by machine propulsion into a freshly applied "bed coat." The size of the aggregate shall not be more than ½ in. (12.7 mm) diameter. The size of the aggregate determines the thickness of the bedding coat. The bedding coat shall be no less than one-half the thickness of the aggregate to be embedded.

X1.7.3.5 *Spray Texture*—A machine applied finish material. The texture achieved depends on many factors some of which are the consistency of the sprayed mixture, the angle and distance of the spray nozzle to the surface, the pressure of the machine, orifice size used, operator expertise, climatic conditions (wind specifically), and base coat conditions.

X1.7.3.6 *Miscellaneous Types*—Similar to trowel textures except that the freshly applied finish is textured with instruments other than a trowel, such as swept with a broom or brush, or corrugated by raking or combing. A variation of texturing a finish involves waiting until the applied finish has partially dried and then lightly troweling the unevenly applied finish. The effects achieved are sometimes difficult for different applicators to duplicate.

X1.8 Conditions for EIFS Application

X1.8.1 The amount of water used to mix materials is to be within the allowable range published by the EIFS producer. Factors such as the drying conditions and finishing operations must be considered in determining water usage. The applicator is cautioned that the use of excessive water results in fall off or slide off, excessive shrinkage, higher porosity, lower strength, and inconsistent color.

X1.8.2 Timing between coats will vary with climatic conditions and types of materials used. Temperature and relative humidity extend or reduce the curing and drying time. Cold or wet weather lengthens and hot or dry weather shortens the drying period. Moderate changes in temperature and relative humidity are overcome by providing additional heating during cold weather and by pre-wetting the base during hot, dry weather.

X1.8.3 Heated enclosures require adequate air circulation to prevent hot or cold spots that allow too rapid drying or freezing. When using heated enclosures it is important to control the relative humidity as well as the temperature. Maintain relative humidity at not more than 90 %.

X1.8.4 Staining and discoloration of finishes or other building components that are caused by free water draining from one plane to another, dissimilar materials, or other building components, are minimized by providing sufficient depth and angle for drip caps and drip edges.

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X2. SEALANT SYSTEMS

X2.1 The size and location of joints and selection of the sealant to be used is the responsibility of the design professional and shall be consistent with project conditions and guidelines of the EIFS producer. See Guide C 1472 for guidance.

X2.2 The sealant system must be tested for compatibility with the specified EIFS by an independent laboratory and found to be compatible with the EIFS. See Test Method C 1382 for guidance.

X2.3 The sealant system is recommended by the EIFS and sealant producer. Non-recommended sealant systems must be jointly approved by the architect and the sealant producer.

X2.4 Base the joint design and surface preparation on the sealant producer's recommendations and project conditions. See Guide C 1481 for guidance.

X2.5 Allow the EIFS material to cure prior to sealant system installation.

SUMMARY OF CHANGES

Committee C11 has identified the location of selected changes to this practice since the last issue, C 1535 – 04, that may impact the use of this practice. (Approved October 1, 2005)

(*1*) Added Specification C 1325 to Referenced Documents.

(*2*) Added new paragraph 11.3.11.

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Designation: C 1542/C 1542M – 02

Standard Test Method for Measuring Length of Concrete Cores[1]

This standard is issued under the fixed designation C 1542/C 1542M; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope

1.1 This test method covers the determination of the length of a core drilled from a concrete structure when the reason is other than measuring dimensional tolerances of concrete elements.

1.2 The values stated in either SI units or inch-pound units are to be regarded separately as standard. Within the text, the inch-pound units are shown in brackets. The values stated in each system are not exact equivalents; therefore, each system shall be used independently of the other.

1.3 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

2. Referenced Documents

2.1 *ASTM Standards:*

C 42/C 42M Test Method for Obtaining and Testing Drilled Cores and Sawed Beams of Concrete[2]

C 174 Test Method for Measuring Thickness of Concrete Elements Using Drilled Concrete Cores[2]

C 670 Practice for Preparing Precision and Bias Statements for Test Methods for Construction Materials[2]

3. Significance and Use

3.1 This test method provides two procedures for determining the length of a core as measured along its axis. This length is used in conjunction with length to diameter relationships, condition surveys, absorption, density and voids analysis, petrography, cement content analysis, and other applications. It does not meet requirements for determining the distance between two parallel surfaces, which represents the thickness of a structural element often used to establish compliance with design specifications as outlined by Test Method C 174.

4. Apparatus

4.1 *Jaw Caliper*, depth of jaw 65 mm [2.5 in.]. Measuring range 0 to 300 mm [0 to 12 in.]. Accuracy to 0.03 mm [0.001 in.].

4.2 *Ruler*, 300 to 380 mm [12 to 15 in.] divided into 1 mm [1⁄16 or 0.1 in.] graduations.

5. Procedure

5.1 *Jaw Caliper Procedure*:

5.1.1 Hold the specimen and place the open jaws of the caliper midpoint between the center and edge of the specimen. Measure and record the value to the nearest 0.25 mm [0.01 in.]. Rotate the specimen 90º, 180º, and 270º and repeat procedure. Obtain one measurement across the center of the specimen and record.

5.2 *Ruler Procedure*:

5.2.1 Position core with finished or formed face placed down against flat and level surface. Place ruler on flat surface against side of core and measure length to nearest 1 mm [1⁄16 or 0.1 in.] and record. Rotate core and repeat measurements at approximately 90º, 180º, and 270º.

NOTE 1—This procedure does not intend to include in the length measurement adhered pieces of material not part of the original concrete mixture.

6. Report

6.1 *Jaw Caliper*—Average five measurements and report to nearest 1 mm [0.1 in.].

6.2 *Ruler*—Average four measurements and report to nearest 1 mm [0.1 in.].

7. Precision and Bias

7.1 *Precision*:

7.1.1 With-and between-lab precision of the jaw caliper and ruler procedures was estimated from the results of an interlaboratory study that included 12 laboratories, each measuring three times a core from each of three concretes. The length of the cores ranged approximately from 64 to 117 mm [2.5 to 4.6 in.]. A report of the results of the interlaboratory study is available from ASTM International Headquarters.[3]

7.1.2 *Jaw Caliper Procedure*—The single-operator coefficient of variation (1S %)[4] has been found to be 1.02 %, therefore, two measures of the same core should not differ by

[1] This test method is under the jurisdiction of ASTM Committee C09 on Concrete and Concrete Aggregates and is the direct responsibility of Subcommittee C09.69 on Miscellaneous Tests.

Current edition approved Aug. 10, 2002. Published October 2002.

[2] *Annual Book of ASTM Standards*, Vol 04.02.

[3] Supporting data have been filed at ASTM International Headquarters and may be obtained by requesting Research Report RR: C09-1024.

[4] As described in Practice C 670.

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more than 2.89 % (D2S %)[4] of the mean length of the core. The between-laboratory coefficient of variation (1S %)[4] has been found to be 1.60 %, therefore, two measures of the same core by two different laboratories should not differ by more than 4.23 % (D2S %)[4] of the mean length of the core.

7.1.3 *Ruler Procedure*—The single-operator coefficient of variation (1S %)[4] has been found to be 1.94 %, therefore, two measures of the same core should not differ by more than 5.43 % (D2S %)[4] of the mean length of the core. The between-laboratory coefficient of variation (1S %)[4] has been found to be 4.35 %, therefore, two measures of the same core by two different laboratories should not differ by more than 12.18 % (D2S %)[4] of the mean length of the core.

7.2 *Bias*—Since there are not acceptable reference cores suitable for determining the bias of these procedures, no statement on bias is being made.

8. Keywords

8.1 concrete; core; jaw caliper; length; ruler

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Designation: C1543 – 09

Standard Test Method for Determining the Penetration of Chloride Ion into Concrete by Ponding[1]

This standard is issued under the fixed designation C1543; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope*

1.1 This test method determines the penetration of chloride ion into concrete from a sodium-chloride solution pond. This method is applicable to all types of concrete, as well as to concretes treated with systems such as sealants, penetrating sealers, or thin-bonded overlays.

1.2 The values stated in SI units are to be regarded as standard. No other units of measurement are included in this standard.

1.3 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

2. Referenced Documents

2.1 *ASTM Standards:*[2]

C125 Terminology Relating to Concrete and Concrete Aggregates

C192/C192M Practice for Making and Curing Concrete Test Specimens in the Laboratory

C672/C672M Test Method for Scaling Resistance of Concrete Surfaces Exposed to Deicing Chemicals

C1152/C1152M Test Method for Acid-Soluble Chloride in Mortar and Concrete

C1202 Test Method for Electrical Indication of Concrete's Ability to Resist Chloride Ion Penetration

2.2 *AASHTO Standard:*

T 259 Method of Test for Resistance of Concrete to Chloride Ion Penetration

3. Terminology

3.1 Terms used in this standard are defined in Terminology C125.

4. Summary of Test Method

4.1 A sodium-chloride solution is ponded on the surface of concrete specimens. Samples from specified depths are periodically extracted and chemically analyzed to determine the chloride content of the concrete at those depths. The curing and moisture conditioning to which a specimen is subjected prior to ponding affects the mechanisms involved in chloride-ion penetration. These factors must be considered carefully in interpreting the results. Information on the mechanisms of chloride penetration into concrete is given in the appendix.

5. Significance and Use

5.1 This test method is suitable for evaluation of materials and material proportions for construction purposes as well as for research and development.

5.2 This test method can be used to establish the correlation between indirect measures of the chloride-ion penetration of concrete (see Test Method C1202) and the actual chloride-ion penetration under controlled conditions.

5.3 This test method is not intended to provide a measure of the length of service that may be expected from use of a specific concrete mixture or sealing material.

6. Apparatus

6.1 *Glass Plates or Polyethylene Sheets*, of sufficient size to cover the ponded surface of the specimen.

6.2 *Molds*, of the proper size for the test specimens to be used, and conforming to the applicable requirements of Practice C192/C192M.

7. Reagents

7.1 *Ponding Solution*—3 % reagent grade sodium chloride (NaCl) by mass in distilled water (see Note 1).

NOTE 1—Other chloride-bearing solutions or different sodium-chloride concentrations may be used when there is a need to evaluate their specific effects. The concentration of the solution can be checked using a hydrometer calibrated to indicate the mass fraction of sodium chloride.

8. Specimens

8.1 Use as ponding specimens in this test method slabs having a surface area of at least 0.030 m^2 and a thickness of 90 ± 15 mm. At least two replicate specimens shall be made for each combination of variables to be tested.

[1] This test method is under the jurisdiction of ASTM Committee C09 on Concrete and Concrete Aggregates and is the direct responsibility of Subcommittee C09.66 on Concrete's Resistance to Fluid Penetration.

Current edition approved Dec. 15, 2009. Published February 2010. Originally approved in 2002. Last previous edition approved in 2002 as C1543–02. DOI: 10.1520/C1543-09.

[2] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

***A Summary of Changes section appears at the end of this standard.**

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8.2 Fabricate and cure molded ponding specimens in accordance with applicable sections of Test Method C672/C672M, unless otherwise specified.

8.3 Obtain a sample of concrete for use in determining the background chloride content. Cast a 100 by 200-mm cylinder from the concrete mixture for this purpose when fabricating ponding specimens.

8.4 Provide a dike approximately 20 mm high along the perimeter of the top surface of the specimen to retain the ponding solution. The dike shall be made of a material that adheres to the specimen or be integrally cast as a part of the specimen. It shall serve to keep the top of the specimen covered completely by ponding solution throughout the period of the ponding (see Note 2).

NOTE 2—Closed-cell polystyrene foam 12 to 25 mm thick and acrylic strips 6 mm thick, bonded to the specimen with an adhesive caulking compound or silicone sealant, have been used successfully.

8.5 Coat the sides of the specimens with a suitable material (see Note 3) to prevent lateral moisture migration. Do not coat the bottom of the specimen. Allow the coating to cure according to the manufacturer's instructions.

NOTE 3—A rapid setting epoxy sufficiently viscous to adhere to vertical surfaces without excessive running has been used successfully for this purpose.

9. Procedure

9.1 Following completion of curing, cover the surface of the specimen with the ponding solution to a depth of 15 ± 5 mm.

9.2 Place a glass plate or polyethylene sheet over the ponded specimen to retard evaporation of water from the solution.

9.3 Store the ponded specimens at 23.0 ± 2°C and 50 ± 5 % relative humidity. Provide for air circulation across the bottom of specimens.

9.4 Periodically monitor the depth of solution on the surface of the specimen and maintain at the specified depth by adding additional fresh solution. At 2-month intervals during the ponding, remove the solution and replace with fresh solution.

9.5 Select the duration of the ponding period and the sampling intervals to be appropriate for the purposes for which the tests are being made (see Note 4).

NOTE 4—It is recommended that the initial sampling be performed after 3 months ponding. Subsequent sampling can be performed after 6 and 12 months of ponding and at 12-month intervals thereafter.

9.6 *Sampling*:

9.6.1 Prior to sampling, remove the ponded solution and allow the specimen surface to dry. After drying is completed, remove the salt crystals from the surface by brushing with a wire brush.

9.6.2 Sample the specimen by coring. The diameter of the core shall be at least three times the nominal maximum aggregate size.

9.6.3 Alternatively, obtain powdered sample by rotary-impact hammer as described in Test Method C1152/C1152M.

9.6.4 Space the sampling point at least 25 mm away from the inside edge of the dike or the edge of any previous sampling point. Samples shall be obtained from at least the following depths to provide a profile of the chloride penetration:

Sampling Intervals, mm
10–20
25–35
40–50
55–65

9.6.5 If the purposes of the test require a precise profiling of the chloride penetration, the sampling shall be accomplished by removing a core from the specimen. The core shall be profiled by precision milling to obtain powdered concrete from horizons of the desired depth and thickness (see Note 5).

NOTE 5—Chloride penetration profiling on 1-mm thick horizons has been accomplished using this technique. An equation can then be fitted to the profile to calculate an effective diffusion coefficient using Fick's Second Law.[3] If a diffusion coefficient is to be calculated, at least 6 test points should be obtained.

9.6.6 If the specimen is to be re-ponded after sampling, patch the hole with a suitable low-permeability repair material (see Note 6). The location of the sampling point shall be clearly identifiable so it can be avoided during subsequent sampling.

NOTE 6—Epoxy mortar has been used successfully for this purpose.

9.7 Determine the chloride content of the sample from each depth of the ponded specimens and the background sample in accordance with Test Method C1152/C1152M. The background chloride content is subtracted from the value obtained for each depth of the ponded specimen to determine the penetrated chloride value.

10. Report

10.1 Report the following information:

10.1.1 Type and source of hydraulic cements,

10.1.2 Type and source of other cementitious materials,

10.1.3 Type and source of coarse and fine aggregates,

10.1.4 Type and source of chemical admixtures,

10.1.5 Concrete mixture proportions,

10.1.6 Type and manufacturer of any treatment system used,

10.1.7 Curing conditions and duration and other special specimen preparation procedures that were performed,

10.1.8 The moisture conditioning the specimen was subjected to prior to ponding,

10.1.9 The type and concentration of the ponding solution, if different from that specified in 7.1,

10.1.10 The chloride content of the specimen as a function of depth and the duration of ponding for each sample tested, and

10.1.11 The background chloride content of the concrete.

11. Precision and Bias

11.1 *Precision*—The precision of this test method has not been determined, but the subcommittee is planning to determine the precision in the future.

[3] Hearn, N., Hooton, R. D., and Mills, R. H., "Pore Structure and Permeability," *STP 169C, Significance of Tests and Properties of Concrete and Concrete Making Materials*, P. Klieger and J. F. Lamond, Eds., American Society for Testing and Materials, Philadelphia, PA, 1994, pp. 240–262.

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11.2 *Bias*—No information can be presented on the bias of the procedures in this test method because no material having an accepted reference value is available.

12. Keywords

12.1 chloride; chloride content; concrete; penetration; permeability

APPENDIX

(Nonmandatory Information)

X1. MASS TRANSFER IN CONCRETE

X1.1 This test measures the chloride-ion content at selected depths within a concrete specimen on which a sodium-chloride solution has been maintained over an extended period of time. Differences in the chloride-ion content with depth and over time indicate the movement of chloride ions from the solution ponded on the concrete surface into the specimen being tested. Several different mechanisms are involved to greater or lesser degrees in this transport, depending on the pore structure, moisture condition, and surface treatment of the specimen.

X1.1.1 Permeability is the characteristic that describes the ease with which a fluid moves through concrete.[4] The primary controlling parameter in concrete permeability is the pore system of the paste fraction of the concrete, including the paste-aggregate interface.[3] The connectivity of the pore system depends on the amount of original mixing-water-filled space and the degree to which it has been filled with hydration products. Capillary pores are those voids remaining that were originally filled with mixing water; that is, pores with diameters in the range of 3.2 to 3,000 nm.[5] These capillary pores will cease to be connected at different times in the age of the concrete as a function of w/c and curing conditions.[6] If stored moist, these times are approximately:

w/c	0.4	0.5	0.6	0.7	>0.7
Time	3 d	14 d	6 m	1 y	never

X1.1.2 Concretes containing a pozzolan or ground granulated blast-furnace slag show a continued decrease of pore size and continuity over a longer period of time than do portland-cement concretes not containing pozzzolans or slag.

X1.1.3 Fluid movement in the capillary-pore system depends on the moisture condition of the pore system. When the concrete is at or near saturation, movement is due to laminar flow. The rate of flow depends on the pressure head causing the flow (in this case, gravity) and the tortuosity of the interconnected pore space. As the partial vapor pressure (relative humidity) falls below 1 to a value of about 0.45, vapor diffusion and capillary tension (absorption and wicking) dominate moisture movement. At partial vapor pressures below 0.45, movement is controlled by adsorption and surface diffusion.[3]

X1.1.4 In conditions of incomplete saturation where part of the capillary system is exposed to the atmosphere and the other to water, capillary tension is most important in the movement of water from the saturated zone into the unsaturated zone. In this test method, capillary tension plays an important role in initial chloride penetration if the specimen is subjected to drying prior to ponding. However, even if the specimen is saturated when subjected to ponding, exposure of the non-ponded bottom surface to the atmosphere will result in drying. As a consequence, moisture from the interior will be drawn by capillary tension toward the bottom surface, increasing the flow from the sodium-chloride solution pond.

X1.1.5 Ionic diffusion is the movement of ions through a solution. In this test method, the driving mechanism for chloride-ion diffusion is the concentration gradient between the sodium-chloride solution pond and the interior of the concrete. Most concrete structures have sufficient moisture in the pore system to allow for the diffusion of dissolved ions even though the internal relative humidity is less than 100 %.

[4] Young, J. F., "A Review of the Pore Structure of Cement Paste and Concrete and its Influence on Permeability," *SP-108, Proceedings, Permeability of Concrete*, D. Whiting, Ed., American Concrete Institute, Detroit, MI, 1988, pp. 1–18.

[5] Philleo, R. E., "Freezing and Thawing Resistance of High-Strength Concrete," *NCHRP Synthesis of Highway Practice 129* , Transportation Research Board, 1986, p. 31.

[6] Powers, T. C., Copeland, L. E., and Mann, H. M., "Capillary Continuity or Discontinuity in Cement Paste," *Journal of the PCA Research And Development Lab*, Vol 1, No. 2, 1959, pp. 38-48 (Reprinted as *PCA R&D Bulletin 110* 1988).

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SUMMARY OF CHANGES

Committee C09 has identified the location of selected changes to this test method since the last issue, C1543–02, that may impact the use of this test method. (Approved December 15, 2009)

(*1*) Revised 9.3.

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Designation: C 1546 – 02 (Reapproved 2008)ε1

Standard Guide for Installation of Gypsum Products in Concealed Radiant Ceiling Heating Systems[1]

This standard is issued under the fixed designation C 1546; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

ε[1] NOTE—The units statement in new subsection 1.2 was added editorially in July 2008.

1. Scope

1.1 This guide[2] provides information for trades installing gypsum products in conjunction with a concealed radiant ceiling heating system constructed from thin sheet flexible radiant heating panels, and for the installation of gypsum products after repair of existing concealed radiant ceiling heating systems constructed from heating cable or thin sheet flexible radiant heating panels.

1.2 The values stated in inch-pound units are to be regarded as standard. No other units of measurement are included in this standard.

1.3 This guide does not purport to address any aspect of concealed radiant heating system design or performance, and is limited to the proper installation of gypsum products specified for use in a concealed radiant ceiling heating system.

1.4 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory requirements prior to use.*

1.5 The text of this standard references notes and footnotes which provide explanatory material. These notes and footnotes shall not be considered as requirements of the standard.

2. Referenced Documents

2.1 *ASTM Standards:* [3]

C 840 Specification for Application and Finishing of Gypsum Board

C 841 Specification for Installation of Interior Lathing and Furring

C 842 Specification for Application of Interior Gypsum Plaster

3. Terminology

3.1 *Definitions:*

3.1.1 *concealed radiant heating system*, *n*—a system that operates by heating the building materials that conceal the heat source, which in turn transfer the heat into the heated area by radiant emission.

3.1.2 *facing*, *n*—the finished surface layer through which heat is transferred into a heated area.

3.1.3 *flexible radiant heating panel*, *n*—a thin sheet heating element intended to produce heat when connected to an electrical supply.

3.1.4 *furring*, *n*—spacer elements added to a building structure to facilitate fastening of gypsum panel products.

3.1.5 *gypsum product*, *n*—building material intended for use in radiant heated ceiling construction, containing gypsum in its composition or construction.

3.1.5.1 *Discussion*—The gypsum products most often associated with radiant heating systems are gypsum board and gypsum plaster.

3.1.6 *heating cable*, *n*—an electrically insulated cable intended to produce heat when connected to an electrical supply.

4. Significance and Use

4.1 The purpose of this guide is to provide information to gypsum product installers for the avoidance of hazards associated with the installation of gypsum products adjacent to, or surrounding, electric heating components and conductors; and to avoid damage to gypsum products when used in conjunction with a concealed radiant heating system.

4.2 The information given in this guide is applicable to repair of existing cable heating systems and to new construction of radiant heating systems constructed from flexible radiant heating panels.

[1] This guide is under the jurisdiction of ASTM Committee C11 on Gypsum and Related Building Materials and Systems and is the direct responsibility of Subcommittee C11.03 on Specifications for the Application of Gypsum and Other Products in Assemblies.

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[2] The first edition of this guide replaced Appendix X.7 of Specification C 840 - 99a.

[3] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

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5. Summary of Guide

5.1 *Heating System Design*:

5.1.1 The heating system shall be designed to satisfy the heating needs of the building and to work effectively with all building materials specified for use in the heating system installation.

NOTE 1—The architect bears the responsibility of preparing and correlating complete plans and specifications, and to engage a professional familiar with the heating system to design the system to meet the requirements of 5.1.1 and 5.1.2.

5.1.2 The heating system shall be designed so that a gypsum product is not exposed to a temperature more than 125°F (52°C) for periods of time sufficient to cause calcination.

NOTE 2—The foregoing requirement is intended to provide guidance to heating system designers, consistent with Specification C 840, in the absence of a comprehensive radiant heating system standard.

5.2 *Installation of Heating Equipment*:

5.2.1 Installation of radiant heating and related electrical equipment is governed by codes and regulations, and is the responsibility of other trades.

5.3 *General Installation Guidelines*:

5.3.1 The application of gypsum panel products under this guide shall be performed in accordance with Specification C 840, except as herein modified.

5.3.2 The radiant heating system shall be disconnected from the electric supply prior to the commencement of work.

NOTE 3—Disconnection from the electric supply is accomplished by switching the heating system circuit breakers off, or removing fuses. Lowering a thermostat setting until the heating system turns off is not supply disconnection.

5.3.3 Unless the concealed radiant heating system is no longer in use and has been permanently disconnected from the electrical supply, or unless the previous facing has been removed, gypsum panel products or gypsum plaster shall not be installed as a new facing on the heated area side of an existing concealed radiant heating system.

NOTE 4—The increased thickness resulting from addition of gypsum panel products or gypsum plaster to an existing concealed radiant heating system can impair heat transfer into the heated area, and may cause overheating of the electrical heat source.

5.3.4 All inspection and testing of the heating system shall be completed before application of gypsum facing materials.

5.3.5 Care shall be taken in the installation of fasteners to avoid the penetration of heating equipment and electrical conductors.

5.3.6 The radiant heating system shall not be operated to accelerate the drying of joint compound or texture finishes.

5.3.7 Follow the radiant heat-source manufacturer's start-up and operating instructions when operating the radiant heating system.

5.4 *Repair of Cable Heating Systems*:

5.4.1 Repair of heating cables is the responsibility of other trades.

5.4.2 The application of gypsum plaster shall conform to Specification C 842 except as herein modified.

5.4.3 Filler added to gypsum plaster used to repair a heating cable system, if any, shall be of sand or similar thermally conductive material. Thermal insulating fillers such as vermiculite or perlite, and foaming agents that impair heat transfer shall not be used in plaster applied to radiant heating systems.

5.4.4 Application of metal lath shall conform to Specification C 841. Metal lath and fasteners installed for repair of a cable heating system shall not contact heating cables.

5.4.5 Complete embedding of the heating cable in plaster is necessary after cable repair is completed.

5.5 *Flexible Radiant Heating Panel Systems*:

5.5.1 Application of gypsum panel products shall comply with the requirements for System I or System II of Specification C 840, as applicable, based on the specified number of layers; and with the requirements of System XII where floating interior angles are used.

5.5.2 Application of gypsum panel products to steel framing or furring shall comply with System VIII of Specification C 840.

5.5.3 The thickness of a gypsum panel product installed as a facing shall not exceed the thickness specified in the heating system design specification.

NOTE 5—Installing facing thicker than specified can impair heat transfer into the heated area, and may cause overheating of the electrical heat source.

5.5.4 Furring of any material or construction shall not be installed between gypsum panel product facing and flexible radiant heating panels.

NOTE 6—The air gap produced by furring can impair heat transfer into the heated area, and may cause flexible radiant heating panels to overheat.

5.5.5 All joints and heads of fasteners shall be finished in accordance with Specification C 840, to the specified level of finish.

NOTE 7—When repairing an existing surface, the level of finish of the repair should be the same as that of the original surface.

5.5.6 Foil backed gypsum panel products shall not be installed in contact with thin sheet flexible radiant heating panels.

5.6 *Decoration*:

5.6.1 The heating system shall be turned off and allowed to cool before decorating.

5.6.2 Decoration of finished work, including sizing or sealing, shall not proceed until joint compound has dried.

5.6.3 When texture finishes are used, such finishes must be thoroughly dry prior to heating system operation.

6. Keywords

6.1 furring; gypsum panel product; gypsum plaster; heating cable; heating panel; lath; radiant heat

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Designation: C 1550 – 08

Standard Test Method for Flexural Toughness of Fiber Reinforced Concrete (Using Centrally Loaded Round Panel)[1]

This standard is issued under the fixed designation C 1550; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope*

1.1 This test method covers the determination of flexural toughness of fiber-reinforced concrete expressed as energy absorption in the post-crack range using a round panel supported on three symmetrically arranged pivots and subjected to a central point load. The performance of specimens tested by this method is quantified in terms of the energy absorbed between the onset of loading and selected values of central deflection.

1.2 This test method provides for the scaling of results whenever specimens do not comply with the target thickness and diameter, as long as dimensions do not fall outside of given limits.

1.3 The values stated in SI units are to be regarded as standard. No other units of measurement are included in this standard.

1.4 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

2. Referenced Documents

2.1 *ASTM Standards:*[2]

C 31/C 31M Practice for Making and Curing Concrete Test Specimens in the Field

C 125 Terminology Relating to Concrete and Concrete Aggregates

C 670 Practice for Preparing Precision and Bias Statements for Test Methods for Construction Materials

3. Terminology

3.1 *Definitions*—For definitions of terms used in this test method, refer to Terminology C 125.

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *central deflection*—the net deflection at the center of the panel measured relative to a plane defined by the three pivots used to support the panel; this is a conditioned deflection that excludes extraneous deformations of the load train and local crushing of the panel at the point of load application and points of support.

3.2.2 *compliance*—a measure of the tendency of a structure to deflect under load, found as the inverse of stiffness or deflection divided by the corresponding load.

3.2.3 *load train*—those parts of a testing machine that experience load and undergo straining during a mechanical test, including the actuator, frame, support fixtures, load cell, and specimen.

3.2.4 *toughness*—the energy absorbed by the specimen equivalent to the area under the load-deflection curve between the onset of loading and a specified central deflection.

4. Summary of Test Method

4.1 Molded round panels of cast fiber-reinforced concrete or fiber-reinforced shotcrete are subjected to a central point load while supported on three symmetrically arranged pivots. The load is applied through a hemispherical-ended steel piston advanced at a prescribed rate of displacement. Load and deflection are recorded simultaneously up to a specified central deflection. The energy absorbed by the panel up to a specified central deflection is representative of the flexural toughness of the fiber-reinforced concrete panel.

5. Significance and Use

5.1 The post-crack behavior of plate-like, fiber-reinforced concrete structural members is well represented by a centrally loaded round panel test specimen that is simply supported on three pivots symmetrically arranged around its circumference. Such a test panel experiences bi-axial bending in response to a central point load and exhibits a mode of failure related to the *in situ* behavior of structures. The post-crack performance of round panels subject to a central point load can be represented by the energy absorbed by the panel up to a specified central deflection. In this test method, the energy absorbed up to a specified central deflection is taken to represent the ability of a fiber-reinforced concrete to redistribute stress following cracking.

[1] This test method is under the jurisdiction of ASTM Committee C09 on Concrete and Concrete Aggregates and is the direct responsibility of Subcommittee C09.42 on Fiber-Reinforced Concrete.

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[2] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

***A Summary of Changes section appears at the end of this standard.**

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NOTE 1—The use of three pivoted point supports in the test configuration results in determinate out-of-plane reactions prior to cracking, however the support reactions are indeterminate after cracking due to the unknown distribution of flexural resistance along each crack. There is also a change in the load resistance mechanism in the specimen as the test proceeds, starting with predominantly flexural resistance and progressing to tensile membrane action around the center as the imposed deflection is increased. The energy absorbed up to a specified central deflection is related to the toughness of the material but is specific to this specimen configuration because it is also determined by the support conditions and size of the specimen. Selection of the most appropriate central deflection to specify depends on the intended application for the material. The energy absorbed up to 5 mm central deflection is applicable to situations in which the material is required to hold cracks tightly closed at low levels of deformation. Examples include final linings in underground civil structures such as railway tunnels that may be required to remain water-tight. The energy absorbed up to 40 mm is more applicable to situations in that the material is expected to suffer severe deformation *in situ* (for example, shotcrete linings in mine tunnels and temporary linings in swelling ground). Energy absorption up to intermediate values of central deflection can be specified in situations requiring performance at intermediate levels of deformation.

5.2 The motivation for use of a round panel with three supports is based on the within-batch repeatability found in laboratory[3] and field experience.[4] The consistency of the failure mode that arises through the use of three symmetrically arranged support pivots results in low within-batch variability in the energy absorbed by a set of panels up to a specified central deflection. The use of round panels also eliminates the sawing that is required to prepare shotcrete beam specimens.

5.3 The nominal dimensions of the panel are 75 mm in thickness and 800 mm in diameter. Thickness has been shown to strongly influence panel performance in this test, while variations in diameter have been shown to exert a minor influence on performance.[5] Correction factors are provided to account for actual measured dimensions.

NOTE 2—The target dimensions of the panel specimen used in this test are held constant regardless of the characteristics of aggregate and fibers used in the concrete comprising the specimen. Post-crack performance may be influenced by size and boundary effects if large aggregate particles or long fibers are used in the concrete. These influences are acknowledged and accepted in this test method because issues of size effect and fiber alignment arise in actual structures and no single test specimen can suitably model structures of all sizes. Differences in post-crack behavior exhibited in this test method can be expected relative to cast fiber-reinforced concrete members thicker than 100 mm. Because fiber alignment is pronounced in structures produced by shotcreting, and the maximum aggregate size in shotcrete mixtures is typically 10 mm, post-crack behavior in specimens tested by this method are more representative of *in situ* behavior when they are produced by spraying rather than casting concrete.

[3] Bernard, E. S. "Correlations in the Behaviour of Fibre Reinforced Shotcrete Beam and Panel Specimens," *Materials and Structures*, RILEM, Vol 35, pp. 156-164, April 2002.

[4] Hanke, S. A., Collis, A., and Bernard, E. S., "The M5 Motorway: An Education in Quality Assurance for Fibre Reinforced Shotcrete," *Shotcrete: Engineering Developments*, Bernard (ed.), Swets & Zeitlinger, Lisse, pp. 145-156, 2001.

[5] Bernard, E. S. and Pircher, M., 2001, "The Influence of Thickness on Performance of Fiber-Reinforced Concrete in a Round Determinate Panel Test," *Cement, Concrete, and Aggregates*, CCAGDP, Vol 23, No. 1, pp. 27–33, June 2001 .

6. Apparatus

6.1 *Testing Machine*—A servo-controlled testing machine incorporating an electronic feed-back loop that uses the measured deflection of either the specimen or the loading actuator to control the motion of the actuator shall be used to produce a controlled and constant rate of increase of deflection of the specimen without the intervention of an operator. To avoid unstable behavior after cracking, the system stiffness of the testing machine inclusive of load frame, load cell (if used), and support fixture shall exceed that of the specimen. The system stiffness of the testing machine can be determined in accordance with the procedure described in Annex A1. Load-controlled test machines incorporating one-way hydraulic valves or screw mechanisms lacking an electronic feed-back loop for automatically controlling the rate of increase in displacement shall not be used. The load-sensing device shall have a resolution sufficient to record load to ±50 N.

NOTE 3—Although it is commonly believed that servo-controlled systems, incorporating a feed-back loop in which the measured central displacement of the specimen is used to control the motion of the actuator, are capable of overcoming the disadvantages of a structurally compliant testing machine, this will depend on the speed and sensitivity of the feed-back loop and the mechanical response rate of the loading apparatus. A more reliable configuration comprises a servo-controlled actuator in which the measured displacement of the actuator is used in the feed-back loop to control the motion of the actuator combined with a high load train stiffness. Experience has indicated that the redistribution of stress that occurs in fiber-reinforced concrete panels following cracking of the concrete matrix generally results in stable post-crack behavior provided a testing machine complying with the requirements of this section is used.

6.2 *Support Fixture*—The fixture supporting the panel during testing shall consist of any configuration that includes three symmetrically arranged pivot points on a pitch circle diameter of 750 mm. The supports shall be capable of supporting a load of up to 100 kN applied vertically at the center of the specimen. The supports shall be sufficiently rigid so that they do not displace in the radial direction by more than 0.5 mm between the onset of loading and 40 mm central deflection for a test involving a specimen displaying a peak load capacity of 100 kN. The three supports must also not translate by more than 0.5 mm in the circumferential direction during a test. The pivots shall not restrict rotation of the panel fragments after cracking. The support fixture shall be configured so that the specimen does not come into contact with any portion of the support fixture apart from the three pivots during a test. A photograph of a suggested design is shown in Fig. 1. The contact between the specimen and each pivot shall comprise a steel transfer plate with plan dimensions of approximately 40 × 50 mm with a spherical seat of about 4 mm depth machined into one surface to accept a ball pivot (see Fig. 2). The distance between the surface of the panel and the center of the pivot shall be 20 ± 2 mm. The diameter of the pivot ball shall be 16 ± 2 mm. Grease is permitted to reduce friction in the seat of each pivot, but rollers or grease are not permitted to reduce friction between the transfer plates and specimen.

6.3 *Deflection Measuring Equipment*—Determine the central deflection of the specimen relative to the support points in a manner that excludes extraneous deformations of the testing machine and support fixture. This is achieved by one of two

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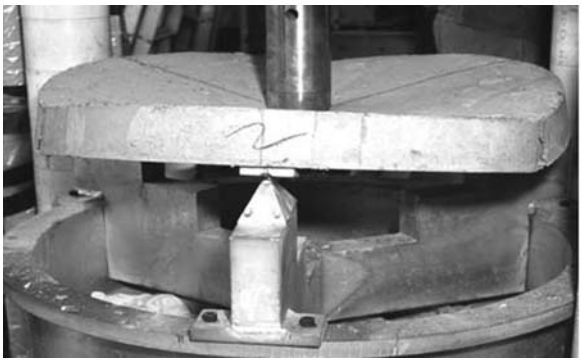

FIG. 1 Photograph of a Suggested Support Fixture

methods. If the displacement of the tensile surface of the panel at the center is measured relative to the pivot supports, then no correction for extraneous deformations of the testing machine and support fixture need be made to the recorded deflections. If the movement of the loading piston relative to the crosshead of the testing machine is used to measure deflection, the deflection record must be adjusted to discount extraneous deformations. A method of adjusting the deflection record to account for extraneous deformations is given in the calculation section. Regardless of the method of deflection measurement selected, use a displacement transducer with a resolution sufficient to record deflection to ±0.05 mm.

NOTE 4—All components of the load train in a test system experience deformation when the specimen is placed under load. If the deflection of the specimen is measured relative to the machine crosshead, then the deformation of the load train is included as extraneous deformations in the deflection record. Additional extraneous deformations may arise from local crushing of concrete under the load point (especially debris on the surface), or from crushing of any debris between the specimen and transfer plates. This second form of extraneous deformation usually results in curvature in the initial portion of the load-deflection curve.

NOTE 5—If the deflection of the center of the tensile surface of the specimen is measured directly with a transducer, an incomplete or erroneous deflection record may occur if a crack opens at the point of measurement. It may be possible to alleviate this problem through the use of a transducer with a probe approximately 20 mm wide. The probe should not exceed this width because off-center cracks may induce exaggerated apparent deflections if they occur adjacent to a wide probe.

6.4 *Data Logging System*—Record the deflection imposed on the panel and corresponding applied load simultaneously at a rate sufficient to record deflection in increments of no more than 0.05 mm if using a digital recording system. For a test up to a specified central deflection of 40 mm, record at least 800 data points. Deflection increments for measurements beyond this point shall be increased to 0.20 mm. For tests in which the assessment deflection is less than 40 mm, applied load and deflection shall be recorded at intervals of no greater than 0.05 mm and at least 100 recorded points shall be used to derive each energy-based assessment parameter. If an analog *X-Y* plotter is used to record behavior, the scales must be chosen so that a 40 mm deflection is reached at not less than 80 % of full-scale deflection in the *X* direction. The peak load capacity of the specimen must be achieved at no less than 50 % of full-scale in the *Y* direction. As a guide, the majority of specimens having standard dimensions and exhibiting normal strength fail at a load of less than 40 kN.

6.5 *Loading Piston*—The load point shall consist of a steel hemispherical piston with the dimensions shown in Fig. 3. The radius of the hemispherical portion of the head shall be 80 ± 5 mm, and that of the piston shaft 50 ± 5 mm.

7. Specimen Preparation and Sampling

7.1 Produce specimens with an overall diameter of 800 ± 10 mm and a thickness of 75 -5/+15 mm. Panels shall not be tested if dimensions are outside of the specified limits. The standard deviation in 10 measures of thickness taken in accordance with the instructions in the procedure section must be less than 3.0 mm. Maintain these dimensions regardless of the size of aggregate or length of fiber used in the concrete or shotcrete. Make the side of the specimen perpendicular relative to the faces.

7.2 Prepare specimens in such a way as to approximate the mode of placement *in situ*. Specimens representing cast concrete shall therefore be cast, while those representing shotcrete shall be sprayed. Specimens shall be screeded to the required thickness before the concrete has hardened (see Appendix X1 for further recommendations regarding specimen production). Remove molds when the concrete has attained sufficient strength so that the specimen can be placed into the testing position without being damaged.

NOTE 6—Grinding or sawing of the surface to reduce an overly thick panel to the required thickness is possible, but may influence the performance of the as-cast or sprayed surface concrete.

7.3 Molds for the production of specimens shall consist of a base and side made of either non-reactive metal or coated plywood. The base and side shall be sufficiently rigid so as not to vibrate or permanently distort during casting or spraying. The interior face of the mold shall be 75 mm deep so that a screed may be run directly across the surface to produce a specimen of correct thickness. See Appendix X1 for recommendations regarding mold design.

7.4 Control the diameter of the mold through careful attention to manufacture. Maintenance of the correct thickness is subject to the skill of personnel charged with finishing the specimens. For normal setting concrete, sufficient time is normally available to screed the surface to obtain a uniform thickness. Accelerated shotcrete may, however, stiffen quickly leaving insufficient time to adequately screed the surface. In such cases, it is necessary to produce several specimens and only retain those that are uniform in thickness.

7.5 *Sampling*—Prepare at least three specimens for each batch of concrete or shotcrete tested. A sample shall consist of at least two successful tests. A successful test involves a failure that includes at least three radial cracks. Specimens occasionally fail in a beam-like mode involving a single crack across the specimen that is characterized by low energy absorption. The result of such a test shall be discarded. Only two specimens need be tested if both specimens fail by the required mode and have a standard deviation in thickness not exceeding 3.0 mm.

8. Conditioning

8.1 The purchaser shall specify the curing and moisture conditioning requirements to be used prior to testing, and the

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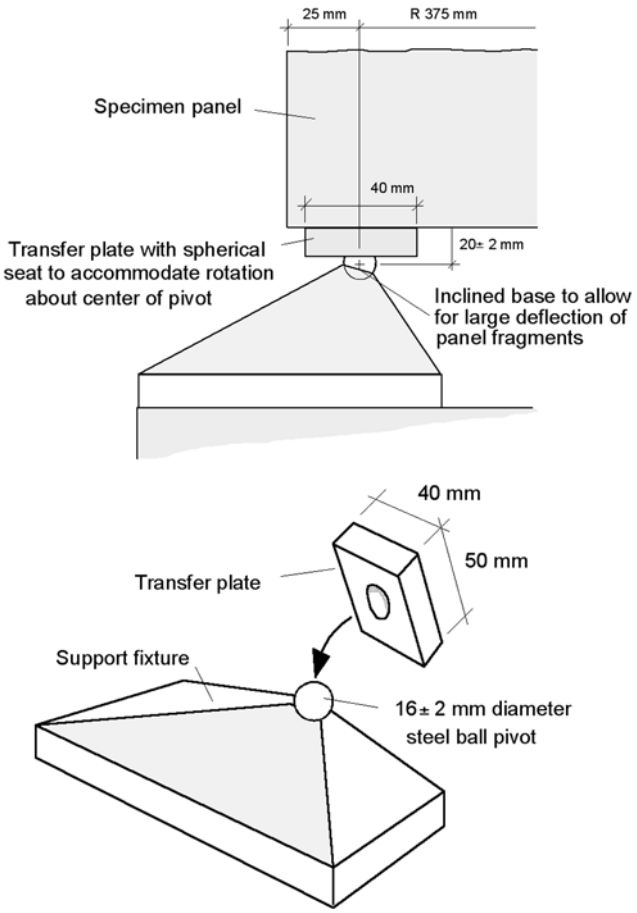

FIG. 2 Detail of Transfer Plate and Pivot Support

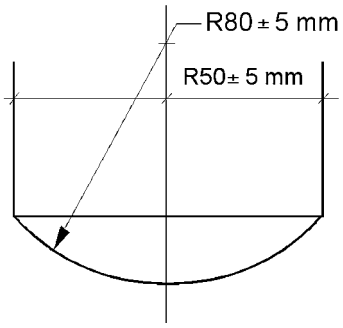

FIG. 3 Hemispherical End of Loading Piston

test age. If the specimens are continuously moist cured and are to be tested in a moist condition, complete testing within 15 min after removal from the moist curing conditions, or apply a curing membrane or wet burlap to control drying from the time of removal until testing is completed.

NOTE 7—Drying shrinkage strains occur in a specimen that is allowed to dry. These strains may result in micro-cracks and may reduce the flexural strength and post-crack energy absorption of the panel.

9. Procedure

9.1 Mount the test specimen in the test apparatus by placing the molded face onto the three transfer plates resting on the pivots. Center the panel with respect to both the supports and loading piston.

9.2 Measure the diameter of the panel to the nearest 2 mm at three places coincident with the intended support locations and calculate the average diameter. If the average diameter of the specimen is less than 790 mm or greater than 810 mm, discard the specimen.

9.3 Operate the testing machine so that the piston advances at a constant rate of 4.0 ± 1.0 mm/min up to a central displacement of at least 45.0 mm.

NOTE 8—The test can be extended to an end-point deflection greater than 45 mm if it is desired to examine behavior at higher levels of deformation.

NOTE 9—The central deflection at which cracking of the concrete matrix first occurs is approximately 0.50 mm for a 75 mm thick concrete specimen of normal strength and composition, exclusive of extraneous displacements. A rate of displacement equal to 4.0 mm/min therefore causes cracking of the concrete matrix in about 8 s. However, if a displacement-controlled testing machine is used and the surface of the

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specimen is rough, as is often the case with shotcrete specimens, the effective displacement rate of the center of the specimen may be less than 4.0 mm/min at the start of a test. Experience has shown that local crushing of concrete under the load point usually occurs within the first few millimetres of movement. Research has also shown that small changes in the effective rate of central displacement have only a minor influence on energy absorption for displacement rates within the range of 0.5 to 10 mm/min.[6]

9.4 Count the number of radial cracks occurring between the center and the perimeter. Any flexural crack occurring on the tensile face of the panel is counted as a full crack provided its average width exceeds 0.5 mm upon completion of the test and removal of the load.

NOTE 10—Energy is absorbed by fiber-reinforced concrete in this test through a number of processes. Minor amounts of energy are absorbed either through elastic deformation of the specimen or as a result of friction between the underside of the specimen and the transfer plates at the three supports. The majority of energy is absorbed through the process of fiber pull-out and deformation that takes place as each crack opens in response to imposed deformation. Cracks that suffer minimal opening do not absorb significant amounts of energy and thus can be ignored. Given that the average maximum crack opening for each of the three radial cracks in this test is 10 mm at 40 mm central deflection, a crack of less than 0.5 mm width is regarded as insignificant. Laboratory experience has also demonstrated that small cracks appear to have little effect on total energy absorption.

9.5 Remove the failed specimen fragments from the test apparatus, and measure the thickness at three points along each of the cracked surfaces and at the center so that the resulting 10 values provide a representative estimate of the average thickness of the specimen. Measure the thickness to the nearest 1 mm and calculate the average thickness to the nearest 1 mm. If the average thickness is less than 70 mm or greater than 90 mm, discard the specimen. Calculate the standard deviation in thickness. If the standard deviation in thickness exceeds 3.0 mm, discard the specimen.

10. Calculation

10.1 Adjust the load-deflection record by subtracting extraneous deformations associated with compliance of the load train and crushing of concrete under the load point and at the supports. If the load-deflection record was obtained using a transducer that measured the deflection of the tensile surface of the specimen relative to the transfer plates, adjustments need only be made for crushing of concrete at the transfer plates. If the deflection of the specimen was measured through the loading mechanism of the testing machine, this record includes extraneous displacements that must be deleted from the deflection record to reveal the net deflection of the specimen.

NOTE 11—The result of a test is a load-deflection record indicating resistance to load between the onset of loading and a central deflection of at least 40 mm. Depending on the method of deflection measurement used, the load-deflection record may include extraneous deformations associated with load train compliance or crushing of the concrete around the load point or supports, or both. Extraneous deformations associated with load train compliance are regarded as systematic errors. These are discounted by computing the deformation of the load train (which is proportional to the load imposed on the specimen) and subtracting this from the recorded deflection at each deflection increment. The adjusted deflection δ of the specimen at a given load P exclusive of extraneous deformations associated with load train compliance can be calculated as:

$$\delta = \delta_m - PC_{LT} \quad (1)$$

where:

δ_m = the measured deflection including extraneous deformation due to compliance of the load train, and

C_{LT} = the compliance of the load train (see Annex A1).

Extraneous deformations associated with crushing of concrete around the load point or supports are specimen-dependent. These are manifested as offsets between the measured and net deflection of the specimen in the load-deflection record. The offset is determined approximately by linear extrapolation of the portion of the load-deflection curve occurring prior to the first peak to the horizontal (deflection) axis as shown in Fig. 4. Once the offset between the nominal and true origin for the deflection record has

[6] Bernard, E. S., "The Influence of Strain Rate on Performance of Fiber-Reinforced Concrete Loaded in Flexure," *Cement, Concrete, and Aggregates* , CCAGDP, Vol 23, No. 1, pp. 11–18, June 2001.

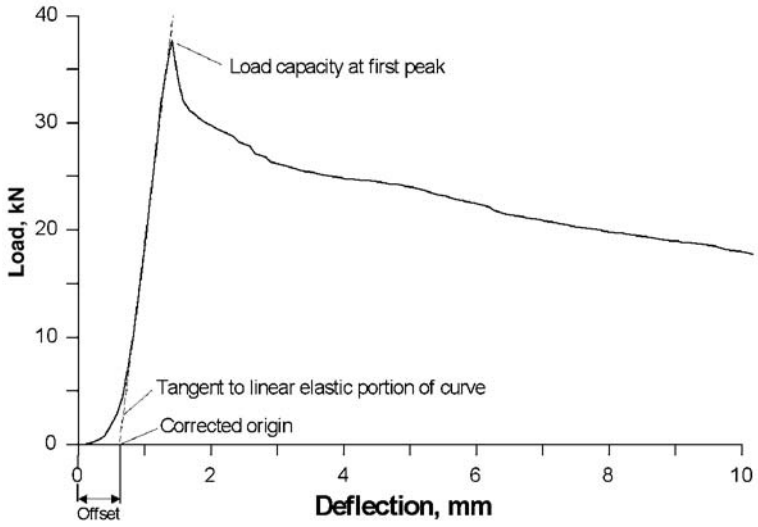

FIG. 4 . Estimation of True Origin of the Load-Deflection Curve

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been determined, the load-deflection curve can be further adjusted by translation to the corrected origin. Because the magnitude of the offset may not become apparent until a test is completed, it is usually necessary to continue a test up to a central deflection that exceeds the specified central deflection by several millimetres.

10.2 Using a load-net deflection curve that has been adjusted so it is free of extraneous deformations, calculate the energy absorption between the onset of loading and the specified central deflection. Determine energy absorption as the area under the load-net deflection curve between the origin and the specified central deflection, as shown in Fig. 5. Toughness in this test is ordinarily defined at central deflections of 5, 10, 20, or 40 mm.

NOTE 12—If the load and net deflection are measured in units of Newtons (N) and metres (m), or kiloNewtons (kN) and millimetres (mm), the resulting measure of energy will be in units of Joules (J).

10.3 Correct the energy absorption using the following equation:

$$W = W'\left(\frac{t_0}{t}\right)^{\beta}\left(\frac{d_0}{d}\right) \quad \text{where } \beta = 2.0 - (\delta - 0.5)/80 \qquad (2)$$

where:

W = the corrected energy absorption,
W' = the measured energy absorption,
t = the average thickness, mm,
t_0 = the nominal thickness of 75 mm,
d = the average diameter, mm,
d_0 = the nominal diameter of 800 mm, and
δ = the specified central deflection at which the capacity to absorb energy is measured, mm.

In Eq 2, the number 0.5 is an estimate of the elastic deflection of the specimen that occurs prior to cracking. If the average dimensions of the specimen lie outside the bounds listed above, discard the specimen and results.

11. Report

11.1 Report the following information:

11.1.1 Type of specimen (cast or sprayed) and specimen identification numbers or symbols,

11.1.2 Type of fiber observed on the cracked surfaces, and dosage rate, if known,

11.1.3 Average thickness of the specimen to the nearest 1 mm, and the standard deviation in thickness to the nearest 0.1 mm,

11.1.4 Average diameter of the specimen to the nearest 5 mm,

11.1.5 The number of radial cracks that occurred in the specimen,

11.1.6 The uncorrected and corrected values of energy absorption between the onset of loading and the specified central deflection, rounded to the nearest Joule.

11.1.7 Age of specimen at test,

11.1.8 Curing history and moisture condition of specimen at test, and

11.1.9 Any defects in specimen prior to test, and abnormalities in specimen behavior during test.

12. Precision and Bias

12.1 *Precision*—Data to establish the precision of this test method in accordance with Practice C 670 have not been determined. Studies of repeatability in energy absorption up to 40 mm central displacement observed within one laboratory indicate single-operator values of the one-sigma within-batch limit (1s %) of 6 %. Therefore, results from two properly conducted tests by the same operator on specimens made from the same batch of concrete are not expected to differ from each other by more than 17 %.

12.2 *Bias*—There is no bias in this test method because the energy absorption of a centrally loaded round panel can only be measured by this method.

13. Keywords

13.1 energy absorption; fiber-reinforced concrete; flexure; post-crack behavior; toughness

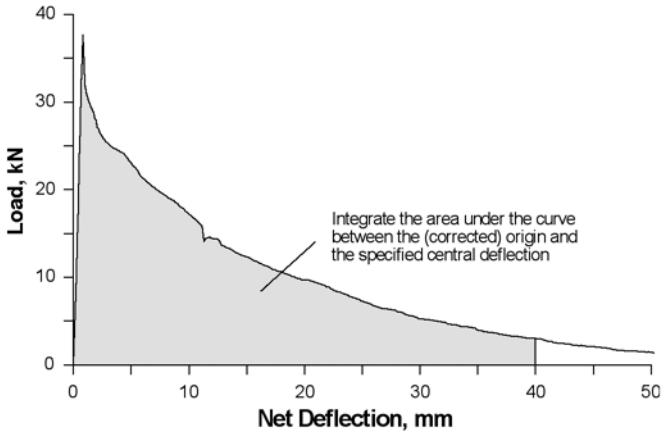

FIG. 5 Integration of Area Under Load-Net Deflection Curve to Obtain Energy Absorption

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ANNEX

(Mandatory Information)

A1. DETERMINATION OF LOAD-TRAIN COMPLIANCE

A1.1 The compliance of the load train is the difference between the apparent compliance of the specimen when deformation of the load train is included and the true compliance of the specimen.

$$C_{LT} = C_{app} - C_{spec} \quad \text{(A1.1)}$$

where:

C_{LT} = the compliance of the load train,
C_{app} = the apparent compliance of the specimen inclusive of load train deformation,
C_{spec} = the true compliance of the specimen.

Compliance shall be measured in units of mm/kN. The term C_{spec} can be determined by dividing the load, P, to cause a given central deflection into the corresponding deflection, Δ_{spec}, measured so as to exclude deformations of the load train and corrected for crushing of concrete. Hence,

$$C_{spec} = \Delta_{spec} / P \quad \text{(A1.2)}$$

The term C_{app} is determined in a similar manner, but the central deflection, Δ_{app}, arising from the load, P, shall include the deformation of the load train.

The use of a large number of data points to determine the compliances C_{app} and C_{spec} is more accurate than the use of a single pair of points. Hence, the inverse of the slope of a line fitted through the straight portion of the load-deflection record prior to cracking is the apparent compliance of the specimen and load train, C_{app}. The inverse of the slope of a line fitted through the straight portion of the load-deflection record obtained by measurement of the deflection of the specimen relative to the support points prior to cracking is the compliance of the specimen, C_{spec}.

A1.2 The deflection of a specimen exclusive of load-train deformation is measured by applying displacement transducers directly to the surface of the specimen during a test so that the deflection of the center of the specimen is measured relative to the supported portions of the specimen. Since local crushing of the surface of the specimen is likely to occur under the load point, it is usually necessary to measure deflection at the center on the tensile face of the specimen relative to the pivot supports by means of a yoke (see Figs. A1.1 and A1.2, and Section 6). The yoke shall be loosely supported at the pivot supported to allow for a slight movement of these during deformation of the specimen. A small extraneous deformation can arise through crushing of concrete at the transfer plates, but this is corrected through attention to the off-set in the load-deflection record shown in Fig. A1.3. A plan view of a suggested test configuration for the measurement of load train compliance is shown in Fig. A1.4.

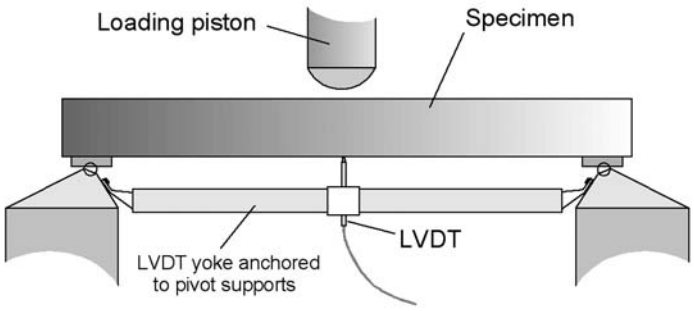

FIG. A1.1 Suggested Method of Deflection Measurement to Exclude Load-Train Deformations and Crushing of Concrete at the Point of Loading Using a Linear Variable Deflection Transducer (LVDT)

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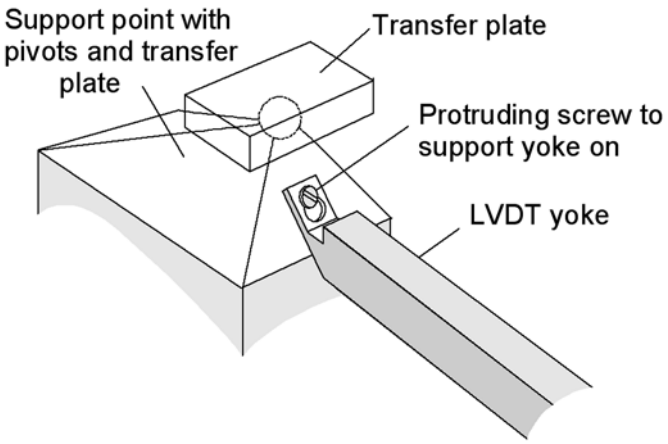

FIG. A1.2 Suggested Method of Connecting LVDT Yoke to Transfer Plates

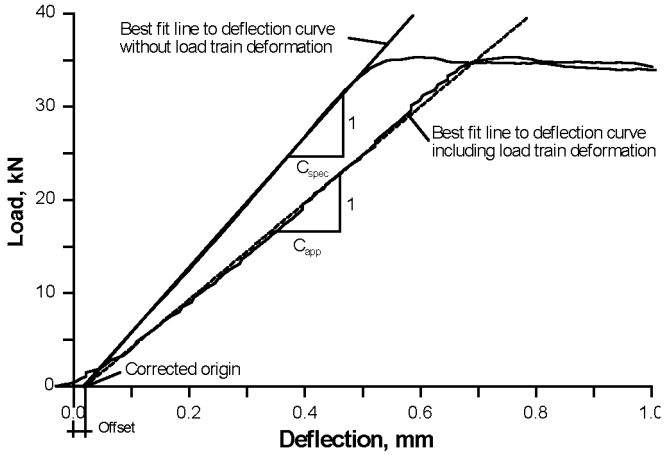

FIG. A1.3 Deflection Record for a Specimen Inclusive and Exclusive of Load Train Deformations

A1.3 The deflection of the specimen inclusive of extraneous deformations is measured by recording the displacement of the actuator relative to its immediate supports during a test. These data are normally measured using a transducer located within the test machine. The displacement of the actuator relative to its immediate supports includes the deformation of the testing machine, load cell, and load transferring fixtures, plus that of the specimen and crushing of concrete at the point of loading. Deformation associated with crushing of concrete around the load point must not be included in the assessment of load train compliance, hence only the portion of the displacement record that displays essentially linear behavior shall be used. A plot of the deflection both inclusive and exclusive of extraneous deformations is shown in Fig. A1.3. The deflection at a given load inclusive of extraneous deformations is always greater than the net deflection of the specimen (hence the magnitude of the compliance will be greater).

A1.4 Determination of the load train compliance using measurements of true and apparent specimen deflection is most reliably undertaken using data from that part of the load-deflection history for a specimen obtained prior to cracking of the concrete matrix.

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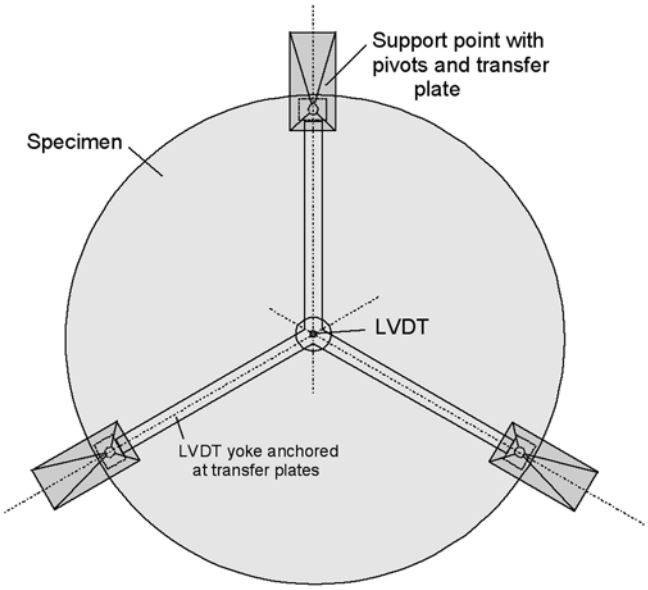

FIG. A1.4 Plan View of Suggested Method of Deflection Measurement

APPENDIX

(Nonmandatory Information)

X1. PREPARING ROUND PANELS FOR TESTING

X1.1 Scope

X1.1.1 This appendix provides recommendations for preparing test panels of concrete or shotcrete intended for testing using Test Method C 1550.

X1.1.2 Round test panels of cast fiber-reinforced concrete or fiber-reinforced shotcrete should be fabricated using the materials and placement equipment, if appropriate, under investigation.

X1.2 Forms for Test Panels

X1.2.1 The form for receiving concrete or shotcrete should be of either wood or steel construction and remain sufficiently rigid to prevent deformation of the form, or dislodging of the concrete or shotcrete through vibration or deformation, during placement. The form shall have an inside diameter of 800 ± 5 mm and an internal depth of 75 ± 2 mm.

X1.2.2 *Wooden Forms*—Wooden forms shall have a backing made of form plywood at least 17-mm thick. Side pieces should be made from a metal, timber, or plastic material having sufficient rigidity to remain in place and maintain the concrete in the form without significant deformation during placement and consolidation operations. The form should be designed in such a way that the filled form can be moved without damaging the specimen. Sheet metal sides can be used if they are stiffened by the base of the form or external stiffeners. Metal sides of at least 3-mm thickness are required if no stiffeners are provided. An acceptable design for a simple wood and sheet metal form is shown in Fig. X1.1.

Concrete will ordinarily bond to timber and metal surfaces during hardening so release oil should be applied prior to placement of concrete. Experience has also shown that wooden forms deteriorate after several cycles of use unless maintained with form oil or a release compound between cycles of use.

X1.2.3 *Steel Forms*—Steel forms should be made using material having a minimum thickness of 3 mm for the flat base of the form. Steel of at least 0.5 mm thickness should be used around the curved side of the form, provided stiffeners are used to limit deformation of the entire form during placement. Steel at least 3 mm thick should be used for the side if no stiffeners are provided to maintain the circular shape of the panel during casting or spraying. Two recommended designs for steel forms are shown in Figs. X1.2 and X1.3. Use of a form with a hoop handle (as depicted in Figs. X1.3 and X1.4) permits the specimen to be moved by a single operator after the specimen has gained sufficient strength to withstand damage due to handling.

X1.3 Filling Mold

X1.3.1 *Cast Concrete*—Prior to casting of panel specimens, the pre-oiled forms should be leveled and checked to ensure that they are flat and free from distortion. The specimens (panels) should be prepared by successively casting fiber reinforced concrete into each of the forms provided for a

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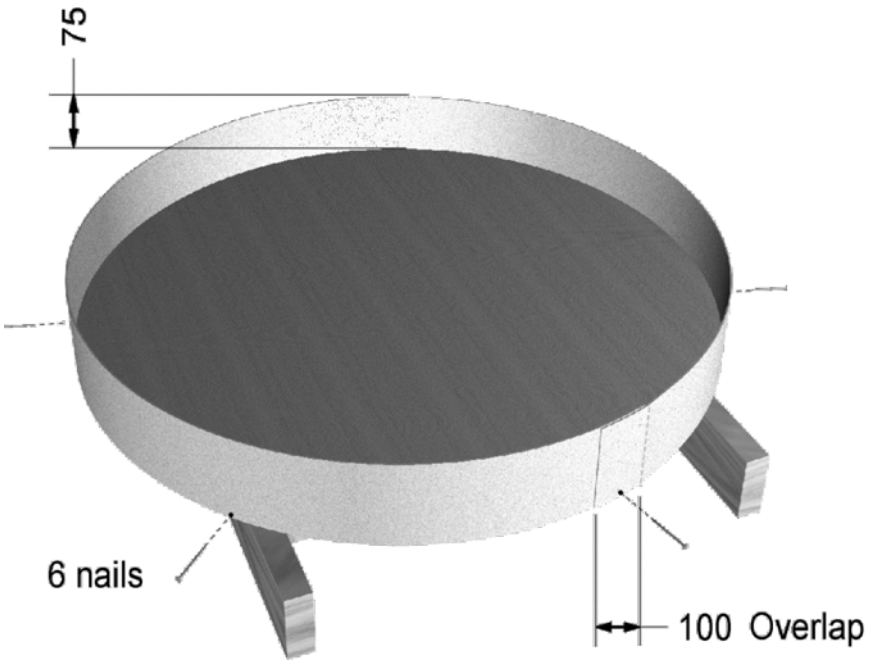

FIG. X1.1 Simple Form Comprising Plywood Base and Sheet or Rolled Steel Side Nailed or Screwed to the Base

FIG. X1.2 Simple Steel Form With Rigid Base and Handles for Transport and Handling

particular job. An amount of concrete sufficient to just fill the form should be placed and then consolidated using a vibrator. The vibrator is to be used to eliminate voids and prevent honey-combing within the specimen, and ensure that no differentiation between successive layers of concrete placed into the form. An external vibrator is recommended, but such a device must be powerful enough to consolidate approximately 100 kg of concrete in a satisfactory period of time. Alternately, an internal vibrator can be used. The internal vibrator should meet the requirements stated in Practice C 31/C 31M with a shaft no greater than 38 mm in diameter. If numerous specimens are produced concurrently, then the same means of vibration and consolidation should be applied to all specimens.

After consolidation has been completed, the surface should be screeded and struck off level with the sides of the form. This should be done by raking a screed in a zig-zagging fashion across the surface of the specimen so that excess concrete above the edge of the form is removed. Care should be taken to ensure that fibers are not withdrawn from within the body of the specimen during this process and that an excessive amount of concrete is not removed during each pass. This can be done

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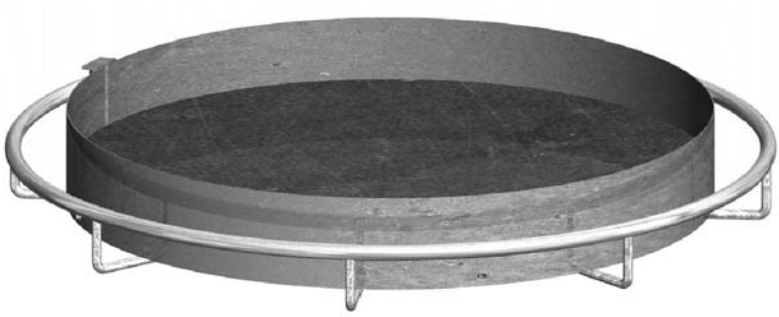

FIG. X1.3 Elaborate Steel Form with Removable Side Allowing a Single Operator to Move the Specimen by Rolling

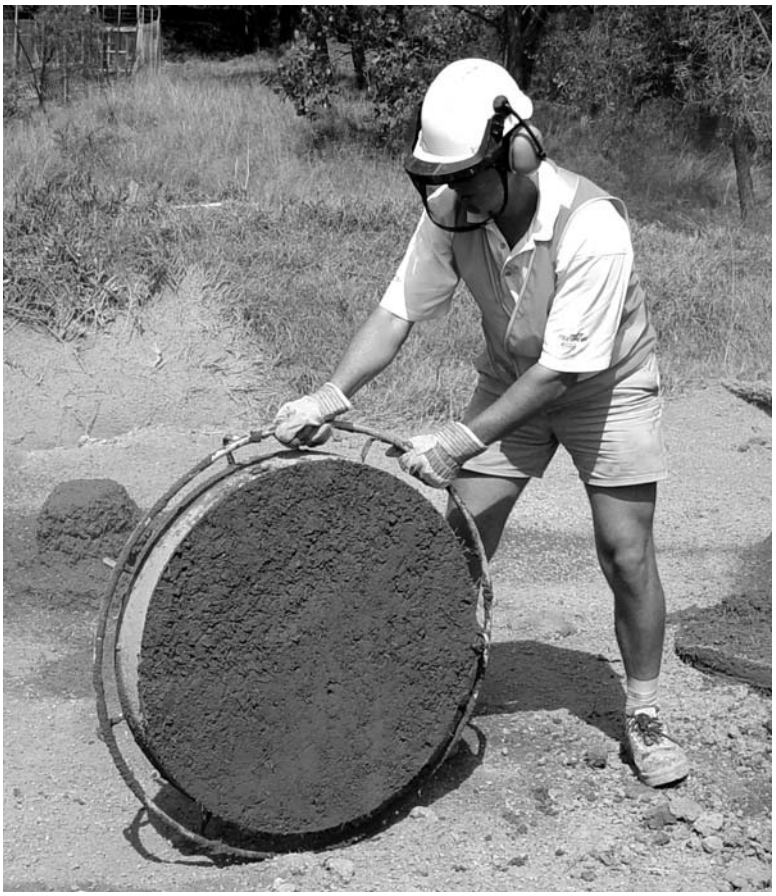

FIG. X1.4 Rolling Steel Form after Specimen Has Gained Sufficient Strength to Withstand Damage

most effectively by screeding the specimen several times, taking about 5 to 10 mm of concrete off during each pass. When the surface of the specimen is level with the side of the form, a final pass of the screed should be carried out with gentle side-to-side motion to leave a relatively smooth surface. A suitable screed will comprise any straight and rigid piece of non-reactive metal, timber, or plastic of sufficient length to bridge the face of the mold.

After screeding is completed, the surface of the panel should be gently floated. It is then to be left undisturbed until bleeding has ceased and initial setting has occurred. A final float should then be performed if required to leave the surface flat and smooth. The specimens should then be subjected to the specified curing condition.

X1.3.2 *Shotcrete*—Prior to production of sprayed specimens, pre-oiled forms should be placed against props and checked to ensure that the bases are flat and free from distortion. The specimens (panels) should then be prepared by successively spraying fiber reinforced shotcrete into each of the forms provided for a particular job until they are full of shotcrete. The specimens should be shot by the same personnel charged with completing the in situ shotcreting required for construction using the same equipment intended for this purpose. An amount of shotcrete sufficient to just over-fill the

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form should be sprayed in by commencing spraying at the base and moving the nozzle in a circular fashion around the form until full. Spraying should be undertaken by a nozzleman familiar with the requirement to minimize rebound and accumulation of rebound in the corners of the form. Once spraying has been completed, the surface of each specimen should be struck off level with the top of the form to obtain a flat surface and uniform thickness.

Initial spraying of the panels should not be undertaken with the nozzle pointing at the form. Spray the concrete away from the form for several seconds, or until a steady and uniform stream of concrete is emerging from the nozzle, and then commence spraying the panel by moving the nozzle in a circular fashion. The nozzle should never be pointed at the form upon commencement of spraying because set accelerator and concrete seldom emerge at the same time, thus the first concrete introduced into the jetstream will not be representative of concrete that emerges later. The edges should be filled first with concrete to minimize entrapment of rebound and then the remainder of the form should be filled using slow to-and-fro passes of the nozzle until the thickness of concrete slightly exceeds the depth of the form.

The nozzle should at all times be maintained perpendicular to the surface being sprayed and at a consistent distance from the surface. Experience has shown that the superior dexterity possible with manual spraying (Fig. X1.5) results in less rebound, a more uniform thickness, and superior quality for fiber reinforced shotcrete panels than is commonly obtained using remotely-controlled nozzles (Fig. X1.6). Remotely-controlled manipulator arms have fewer degrees of freedom of motion than is possible by manual spraying and this commonly results in the requirement for perpendicularity being violated (see Fig. X1.6).

If the shotcrete is stiff, screeding may be performed with the formwork in a propped position. If the shotcrete is relatively fluid, the forms should be moved and placed on a horizontal surface before screeding can take place. Screeding can be performed by raking the screed in a zig-zagging fashion across the surface of the specimen so that excess shotcrete above the edge of the form is removed. Care should be taken to ensure that fibers are not withdrawn from within the body of the specimen during this process and that an excessive amount of shotcrete is not removed during each pass. This can be done most effectively by screeding the specimen several times, taking about 5 to 10 mm of material off during each pass of the screed. When the surface of the specimen is level with the side of the form, a final pass of the screed should be carried out with gentle side-to-side motion to leave a relatively smooth surface.

After screeding is completed, the surface of the panel may be gently floated. It should then be left undisturbed until bleeding has ceased (if this occurs at all) and initial setting has occurred. A final float should then be performed if required to leave the surface flat and smooth. The specimens should then be subjected to the specified curing condition.

FIG. X1.5 Manual Spraying of Panels

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FIG. X1.6 Remotely-Controlled Spraying of Panels

SUMMARY OF CHANGES

Committee C09 has identified the location of selected changes to this test method since the last issue, C 1550 – 05, that may impact the use of this test method. (Approved October 1, 2008)

(*1*) Revised 5.1.

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Designation: C 1556 – 04

Standard Test Method for Determining the Apparent Chloride Diffusion Coefficient of Cementitious Mixtures by Bulk Diffusion[1]

This standard is issued under the fixed designation C 1556; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope*

1.1 This test method covers the laboratory determination of the apparent chloride diffusion coefficient for hardened cementitious mixtures.

1.2 The values stated in SI units are to be regarded as the standard.

1.3 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

2. Referenced Documents

2.1 *ASTM Standards:* [2]

C 31/C 31M Practice for Making and Curing Concrete Test Specimens in the Field

C 42/C 42M Test Method for Obtaining and Testing Drilled Cores and Sawed Beams of Concrete

C 125 Terminology Relating to Concrete and Concrete Aggregates

C 192/C 192M Practice for Making and Curing Concrete in the Laboratory

C 670 Practice for Preparing Precision and Bias Statements for Test Methods for Construction Materials

C 1152/C 1152M Test Method for Acid-Soluble Chloride in Mortar and Concrete

C 1202 Test Method for Electrical Indication of Concrete's Ability to Resist Chloride Ion Penetration

2.2 *NORDTEST Standards:*

NT BUILD 443, Approved 1995-11, Concrete, Hardened: Accelerated Chloride Penetration (in English)[3]

3. Terminology

3.1 *Definitions*:

3.1.1 For definitions of terms used in this test method, refer to Terminology C 125.

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *apparent chloride diffusion coefficient, D_a, n*—a chloride transport parameter calculated from acid-soluble chloride profile data obtained from saturated specimens exposed to chloride solutions, without correction for chloride binding, that provides an indication of the ease of chloride penetration into cementitious mixtures.

3.2.2 *chloride binding, v*—the chemical process by which chloride ion is removed from solution and incorporated into cementitious binder hydration products.

3.2.2.1 *Discussion*—Chloride binding is primarily associated with hydration products formed by the aluminate phase of cement and mixtures containing ground granulated blast furnace slag.

3.2.3 *chloride penetration, v*—the ingress of chloride ions due to exposure to external sources.

3.2.4 *exposure liquid, n*—the sodium chloride solution in which test specimens are stored prior to obtaining a chloride profile.

3.2.5 *exposure time, n*—the time that the test specimen is stored in the solution containing chloride ion.

3.2.6 *initial chloride-ion content, C_i, n*—the ratio of the mass of chloride ion to the mass of concrete for a test specimen that has not been exposed to external chloride sources.

3.2.7 *profile grinding, v*—the process of grinding off and collecting a powder sample in thin successive layers from a test specimen using a dry process.

3.2.8 *surface chloride content, C_s, n*—the theoretical ratio of the mass of chloride ion to the mass of concrete at the interface between the exposure liquid and the test specimen.

4. Summary of Test Method

4.1 Obtain a representative sample of the cementitious mixture prior to exposure to chloride ion. Separate each sample into a test specimen and an initial chloride-ion content specimen. Crush the initial chloride-ion content specimen and determine the initial acid-soluble chloride-ion content. Seal all sides of the test specimen, except the finished surface, with a

[1] This test method is under the jurisdiction of ASTM Committee C09 on Concrete and Concrete Aggregates and is the direct responsibility of Subcommittee C09.66 on Concrete's Resistance to Fluid Penetration.

Current edition approved June 1, 2004. Published July 2004. Originally approved in 2003. Last previous edition approved in 2003 as C 1556 – 03.

[2] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

[3] Published by NORDTEST, P.O. Box 116 FIN-02151 ESPOO Finland, Project 1154-94, e-mail: nordtest @vtt.fi, website: http://www.vtt.fi/nordtest

***A Summary of Changes section appears at the end of this standard.**

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suitable barrier coating. Saturate the sealed specimen in a calcium hydroxide solution, rinse with tap water, and then place in a sodium chloride solution. After a specified exposure time, the test specimen is removed from the sodium chloride solution and thin layers are ground off parallel to the exposed face of the specimen. The acid-soluble chloride content of each layer is determined. The apparent chloride diffusion coefficient and the projected surface chloride-ion concentration are then calculated using the initial chloride-ion content, and at least six related values for chloride-ion content and depth below the exposed surface.

5. Significance and Use

5.1 This test method is applicable to cementitious mixtures that have not been exposed to external chloride ions, other than the negligible quantity of chloride ion exposure from sample preparation using potable water, prior to the test.

5.2 The calculation procedure described in this test method is applicable only to laboratory test specimens exposed to a sodium chloride solution as described in this test method. This calculation procedure is not applicable to specimens exposed to chloride ions during cyclic wetting and drying.

NOTE 1—The diffusion of ionic species in concrete occurs within the fluid-filled pores, cracks and void spaces. The concentration and valence of other ionic species in the pore fluid also influence the rate of chloride diffusion, and therefore, the apparent diffusion coefficient as determined by this test procedure.

5.3 In most cases, the value of the apparent chloride diffusion coefficient for cementitious mixtures changes over time (See Note 2). Therefore, apparent diffusion coefficients obtained at early ages may not be representative of performance in service.

NOTE 2—The rate of change of the apparent diffusion coefficient for cementitious mixtures containing pozzolans or blast-furnace slag is typically different than that for mixtures containing only portland cement.

5.4 The apparent chloride diffusion coefficient is used in Fick's second law of diffusion to estimate chloride penetration into cementitious mixtures that are in a saturated condition.

5.5 The apparent chloride diffusion coefficient is commonly used in chloride ingress models based on Fick's second law of diffusion. The apparent diffusion coefficient determined by this method includes chemically bound chloride, so proper use of the apparent chloride diffusion coefficient to predict chloride ingress requires consideration of chloride binding.

5.6 The resistance to chloride penetration is affected by such factors as the environment, finishing, mixture composition, workmanship, curing, and age.

6. Apparatus

6.1 *Balance*, accurate to at least ±0.01 g.

6.2 *Thermometer*, accurate to at least ±1.0 °C.

6.3 *Controlled Temperature Laboratory or Chamber*. The laboratory or chamber shall maintain the temperature of a water bath at 23 ± 2 °C.

6.4 *Plastic Container*, with tight-fitting lid. Select a container size in accordance with provisions in 9.1.2.

6.5 Equipment for grinding off and collecting powder from concrete, mortar, or grout specimens in layers of approximately 2 mm thickness. Refer to Figs. 1 and 2 for examples of satisfactory equipment (See Note 3).

NOTE 3—A lathe or milling machine equipped with a short-barrel carbide-tipped, or diamond-tipped, core drill bit has been found satisfactory for profile grinding.

6.6 *Resealable Polyethylene Bags*, 200- to 300-mm wide by 250- to 300-mm long, and sheet thickness not less than 0.1 mm.

6.7 Equipment for crushing concrete, mortar or grout. Suitable equipment is described in Test Method C 1152/C 1152M.

6.8 Equipment for chloride analysis as described in Test Method C 1152/C 1152M.

6.9 *Slide Caliper*, accurate to at least ± 0.1 mm.

7. Reagents and Materials

7.1 *Distilled or De-ionized Water*.

7.2 *Calcium Hydroxide [$Ca(OH)_2$]*, technical grade.

7.3 *Calcium Hydroxide Solution*, saturated, (approx. 3 g/L).

7.4 *Sodium Chloride [NaCl]*, technical grade.

7.5 *Exposure Liquid*—An aqueous NaCl solution prepared with a concentration of 165 ± 1 g NaCl per L of solution.

7.6 *Two-component Polyurethane or Epoxy-resin Based Paint*, capable of forming a barrier membrane that is resistant to chloride ion diffusion.

8. Test Specimens

8.1 Drilled cores, molded cylinders, or molded cubes are acceptable test specimens. One sample consists of at least two test specimens representative of the cementitious mixture under test (See Note 4). Specimens must be free of defects such as voids or cracks visible to the unaided eye (See Note 5). The minimum dimension across the finished surface of each test specimen must be at least 75 mm, but not less than three times the nominal maximum aggregate particle size. The specimen depth must be at least 75 mm.

NOTE 4—The material between the exposed surface and the outermost layer of reinforcement is often of interest because it is here that the protection against chloride penetration is needed. Furthermore, the quality of the material in this particular area can deviate from that in the rest of the system, as this region is often affected by construction practices.

NOTE 5—Specimens with voids deeper than the profile layer thickness can increase the apparent rate of chloride penetration, and increases test variability.

8.2 Unless otherwise specified, provide 28 days of laboratory standard moist curing in accordance with Practice C 31/C 31M or C 192/C 192M prior to sample preparation for immersion in the exposure liquid.

8.2.1 Describe any variance from standard curing practice in the report.

8.3 For drilled cores obtained according to Test Method C 42/C 42M, prepare the test specimen by cutting off the outermost 75 mm of the core. The test specimen thus obtained has one face that is the original finished surface, and the other face that is a sawn surface as shown in Fig. 3.

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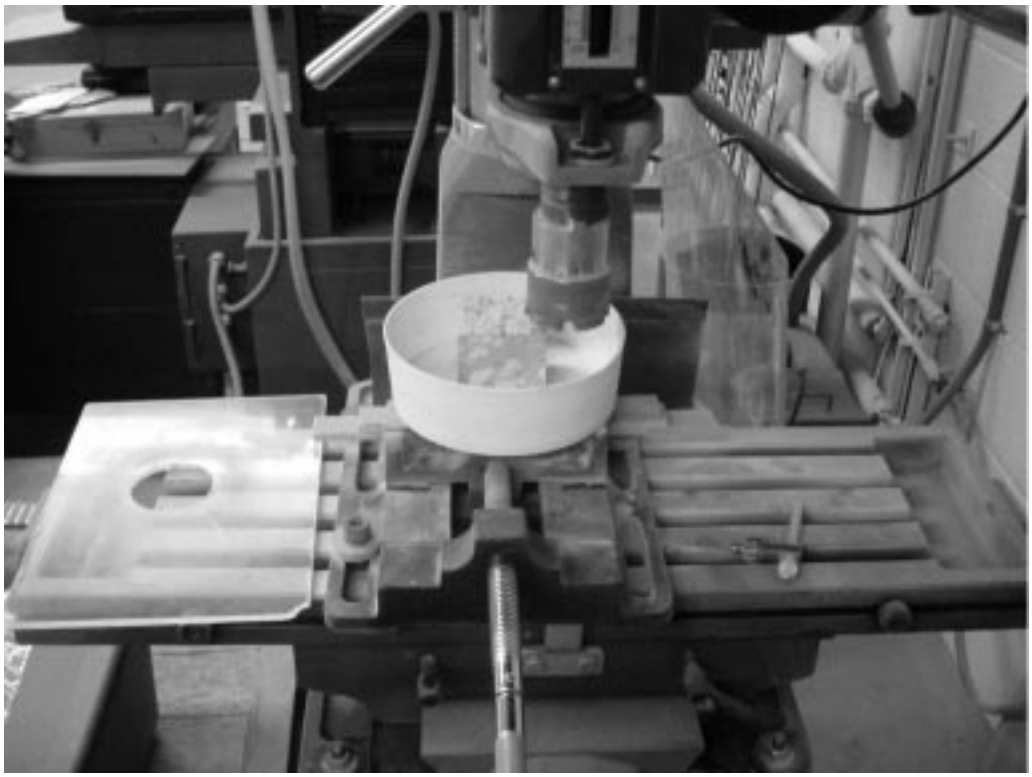

FIG. 1 Profile Grinding Using a Milling Machine

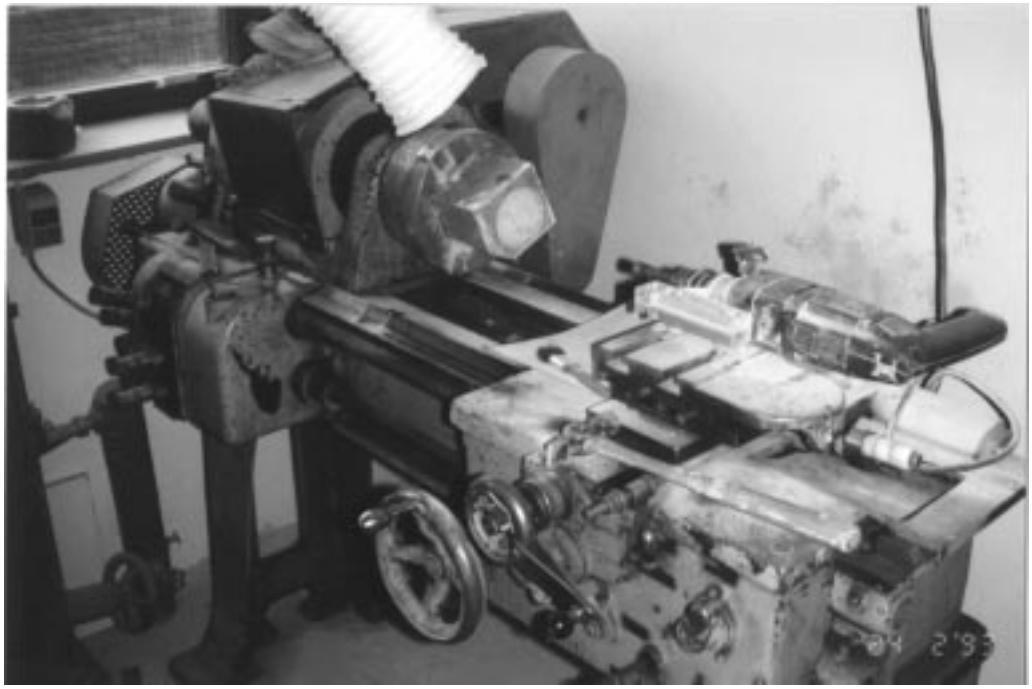

FIG. 2 Profile Grinding Using a Lathe

8.4 For specimens prepared in accordance with Practice C 31/C 31M or C 192/C 192M, the test specimen is prepared by cutting parallel to the finished surface. The top 75 mm is used as the test specimen (see Fig. 3).

8.5 From the remainder of the drilled core, or molded specimen, cut a slice that is at least 20-mm thick. Use this slice to determine the initial chloride-ion content, C_i.

8.6 Rinse the specimens with tap water immediately after cutting. Scrub the surface with a stiff nylon brush, and rinse again. Prior to sealing specimen surfaces, air dry until no moisture can be removed from the surface with a dry paper towel (See Note 6).

8.6.1 Exposure specimens must be surface-dry but internally moist prior to sealing. This condition is satisfied by

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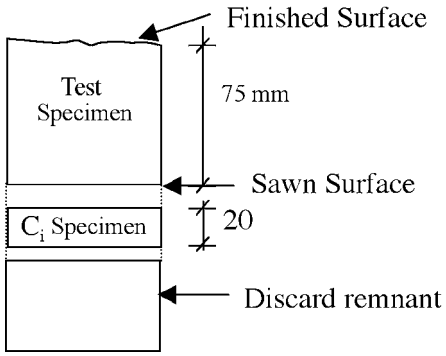

FIG. 3 Sketch of Specimens Obtained from a Typical Sample

standard moist-cured specimens allowed to air dry for no more than 24 h in laboratory air maintained at 23 ± 2 °C and 50 ± 3 % RH.

NOTE 6—Specimens cured in a saturated calcium hydroxide water bath are normally covered by residual lime particles. If this residue is not removed and test specimens are allowed to temporarily dry in air, a calcium carbonate layer can form on the surface of the specimen. This carbonate layer may interfere with the test result, which is why cleansing and rinsing with tap water after cutting or removal from the saturated calcium hydroxide water bath is required.

8.7 Seal all sides of the exposure specimen except for the finished surface following the procedure described in Test Method C 1202.

8.8 Determine the initial mass of the test specimen when the coating has hardened.

8.9 Immerse the test specimen in the saturated calcium hydroxide water bath at 23 ± 2°C in a tightly closed plastic container. The container must be filled to the top to prevent carbonation. After 24 h of immersion, remove the specimen, blot the surface dry with a paper towel, and determine the mass of the specimen in the surface-dry condition.

8.10 The test specimen is immersed in a saturated calcium hydroxide water bath until the mass does not change by more than 0.1 % in 24 h (See Note 7). An acceptable alternative procedure is to vacuum saturate the specimens with saturated calcium hydroxide solution using a vacuum chamber similar to the system described in Test Method C 1202.

NOTE 7—Typically, the mass of moist-cured specimens stabilizes within 48 h.

9. Procedure

9.1 *Exposure*:

9.1.1 Remove the saturated test specimen from the calcium hydroxide water bath, immediately rinse the specimen surface with tap water, place the specimen in the exposure container, fill the container with the exposure liquid, and then seal the container. Place the container in a temperature-controlled chamber or room maintained at 23 ± 2°C. Record the start date and start time to the nearest hour.

9.1.2 It is permitted to place multiple specimens in a single container as long as the specimens are placed in the container such that the entire exposure surface is unobstructed. Maintain the exposed surface area to exposure liquid volume ratio within the range of 50 ± 30 cm^2/L (See Note 8).

NOTE 8—The volume of exposure liquid required for nominal 100-mm diameter cylinder or core exposure specimens is approximately one liter per specimen.

9.1.3 The specimens must remain in the exposure liquid for at least 35 days (See Note 9).

NOTE 9—The exposure time should be extended for mixtures such as those that are more mature, were made with low w/cm, or high-performance mixtures containing supplementary cementitious materials.

9.1.4 If evaporation of water from the exposure liquid or a container leak allows the specimen surface to dry during the exposure time, the test is not valid (See Note 10).

NOTE 10—It is suggested to monitor the mass of the sealed container if evaporation of water from the exposure solution is expected.

9.1.5 Record the exposure time to the nearest hour.

9.2 *Profile Grinding*:

9.2.1 Remove the test specimen from the exposure liquid, rinse with tap water, and dry for at least 24 h in laboratory air maintained at 23 ± 2°C and 50 ± 3 % RH.

9.2.2 When grinding is to be performed longer than 48 h after removal from the exposure solution, store the specimens in watertight resealable polyethylene bags until time of grinding. When grinding is to be performed longer than 7 days after removal from the exposure solution, store the bagged specimens in a freezer maintained at -15 °C (±5 °C) until time of grinding.

9.2.3 Obtain the powder samples by grinding off material in layers parallel to the exposed surface. Do not grind closer than

TABLE 1 Recommended Depth Intervals (in mm) for Powder Grinding[A]

w/cm	0.25	0.30	0.35	0.40	0.50	0.60	0.70
Depth 1	0-1	0-1	0-1	0-1	0-1	0-1	0-1
Depth 2	1-2	1-2	1-2	1-3	1-3	1-3	1-5
Depth 3	2-3	2-3	2-3	3-5	3-5	3-6	5-10
Depth 4	3-4	3-4	3-5	5-7	5-8	6-10	10-15
Depth 5	4-5	4-6	5-7	7-10	8-12	10-15	15-20
Depth 6	5-6	6-8	7-9	10-13	12-16	15-20	20-25
Depth 7	6-8	8-10	9-12	13-16	16-20	20-25	25-30
Depth 8	8-10	10-12	12-16	16-20	20-25	25-30	30-35

[A] Luping, Tang and Sørensen, Henrik, "Evaluation of the Rapid Test Methods for Measuring the Chloride Diffusion Coefficients of Concrete," NORDTEST Project No. 1388-98, Swedish National Testing and Research Institute, SP Report 1998:42.

NOTE—For cementitious mixtures with pozzolan or slag, the depth intervals in the column one place to the left should be applied. For example, use the depth intervals for w/cm = 0.35 for silica fume concrete with w/cm = 0.40.

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5 mm from the edge of the specimen to avoid edge effects and disturbances from the coating.

9.2.4 For the minimum exposure time of 35 days, grind off eight layers in accordance with Table 1. For longer exposure times, select depth increments such that a minimum of 6 points span the range from 1 mm below the exposed surface to a depth with a chloride-ion content equal to, or slightly greater than, the initial chloride-ion content.

9.2.5 The following alternate profiling procedure is permitted if the exposure time is sufficient to allow chloride penetration deeper than 40 mm. Slice the test specimen parallel to the exposure surface using a water-cooled diamond saw in 5- to 6-mm increments, minimizing the time specimens are exposed to water. Dry the slices for 24 h in laboratory air, then crush and prepare the powder sample as described in Test Method C 1152/C 1152M.

9.2.6 Obtain a sample of at least 10 g of powder from each layer. Determine the distance from the exposure surface to the mid-depth of each layer. For example, the layer thickness and mid-depth are determined from measurements of the specimen before and after powder sample collection. Calculate the depth below the exposed surface as the average of five uniformly distributed measurements using a slide caliper.

9.3 *Chloride Analysis*:

9.3.1 Determine the acid-soluble chloride-ion content of the powder samples, C_x (mass %), to ±0.001 % according to Test Method C 1152/C 1152M.

9.3.2 Obtain the initial chloride-ion content, C_i (mass %), from the 20-mm thick slice by crushing and prepare a powder sample as described in Test Method C 1152/C 1152M.

9.4 Record any deviations from the requirements of this method.

10. Calculations

10.1 *Test Results*:

10.1.1 Determine the values of surface concentration and apparent chloride diffusion coefficient by fitting Eq 1 to the measured chloride-ion contents by means of a non-linear regression analysis using the method of least squares. Omit the chloride-ion content determined from the exposure surface layer in the regression analysis. All other chloride-ion content measurements are included in the regression analysis.

$$C(x,t) = C_s - (C_s - C_i) \cdot erf\left(\frac{x}{\sqrt{4 \cdot D_a \cdot t}}\right) \quad (1)$$

where:

$C(x,t)$ = chloride concentration, measured at depth x and exposure time t, mass %,
C_s = projected chloride concentration at the interface between the exposure liquid and test specimen that is determined by the regression analysis, mass %,
C_i = initial chloride-ion concentration of the cementitious mixture prior to submersion in the exposure solution, mass %,
x = depth below the exposed surface (to the middle of a layer), m,
D_a = apparent chloride diffusion coefficient, m^2/s,
t = the exposure time, s, and
erf = the error function described in Eq 2.

$$erf(z) = 2 / \sqrt{\pi} \cdot \int_0^z exp(-u^2)du \quad (2)$$

10.1.2 Tables with values of the error function are given in standard mathematical reference books.[4] The error function is also included as a library function in most electronic calculation software.

10.1.3 The test results are:

10.1.3.1 The initial chloride concentration, C_i (mass %), stated to three significant digits.

10.1.3.2 The projected surface chloride concentration at the exposed surface, C_s (mass %), stated to three significant digits.

10.1.3.3 The apparent chloride diffusion coefficient, D_a (m^2/s), stated to 2 significant digits.

10.2 *Non-linear Regression Analysis*—Perform the regression analysis by minimizing the sum given in Eq 3. Refer to Fig. 4 for clarification.

$$S = \sum_{n=2}^{N} \Delta C^2(n) = \sum_{n=2}^{N} (C_m(n) - C_c(n))^2 \quad (3)$$

where:

S = sum of squares to be minimized, (mass %)^2,
N = the number of layers ground off,
$\Delta C(n)$ = difference between the measured and calculated chloride concentration of the nth layer, mass %,
$C_m(n)$ = measured chloride concentration of the nth layer, mass %, and
$C_c(n)$ = calculated chloride concentration in the middle of the nth layer, mass %.

10.3 *Other Calculations*:

10.3.1 Plot the measured chloride contents at all points versus depth below the surface. Plot the best-fit curve on the same graph (see Fig. 4).

11. Report

11.1 Report the following information if known:

11.1.1 Name and address of the laboratory, and the place at which tests were performed, if different from the laboratory address.

11.1.2 Date and identification number of the test report.

11.1.3 Method of sampling and other circumstances (date and person responsible for sampling).

11.1.4 Description of the tested object including specimen type, identification marks, mixture proportions, the date the tested object was cast, curing regimen employed, and age at the start of exposure.

11.1.5 Start date and duration of the exposure time.

11.1.6 Conditioning of the test specimens, and a description of the exposure conditions during the test, such as temperature, evidence of evaporation.

11.1.7 Identification of the test equipment and instruments used.

11.1.8 Any deviation from the test method together with other information of importance for judging the result.

[4] Beyer, W. H., ed., *CRC Handbook of Mathematical Sciences*, 5th Edition, CRC Press, Boca Raton, FL, 1978.

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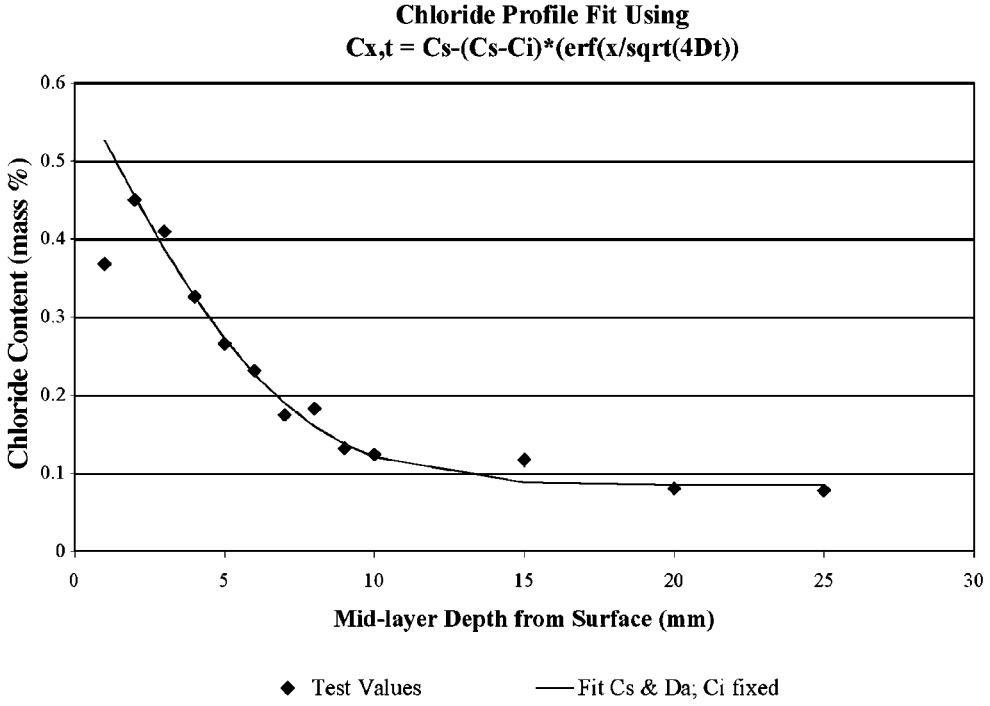

FIG. 4 Sample Regression Analysis

TABLE 2 Example Calculation

C_s (mass %)	C_i (mass %)	D_a (m^2/s)	t (yr)	Sum (Error)^2
0.605	0.085	4.86E-13	1.00	2.2151E-03

x (mm)	Measured Value	Predicted Value	Error, $\Delta C(n)$ (Meas.-Pred.)	(Error)2
1	0.368	0.530		
2	0.450	0.458	-8.19E-03	6.72E-05
3	0.410	0.391	1.94E-02	3.76E-04
4	0.326	0.329	-3.31E-03	1.10E-05
5	0.266	0.275	-9.49E-03	9.01E-05
6	0.231	0.230	1.25E-03	1.55E-06
7	0.175	0.192	-1.71E-02	2.93E-04
8	0.183	0.162	2.08E-02	4.34E-04
9	0.132	0.139	-7.07E-03	5.00E-05
10	0.124	0.122	2.16E-03	4.66E-06
15	0.117	0.089	2.85E-02	8.12E-04
20	0.080	0.085	-5.16E-03	2.66E-05
25	0.078	0.085	-7.00E-03	4.90E-05

11.1.9 A table listing the chloride-ion content measurements of each layer and mid-depth for each layer.

11.1.10 A plot showing the measured chloride-ion contents for each layer and the best-fit curve from the regression analysis.

TABLE 3 Precision Estimates[A]

Coefficient	Statistic	Single Laboratory	Multiple Laboratory
D_a	CV[B]	14.2	20.2
	d2s %	39.8	56.6
C_s	CV	13.3	18.1
	d2s %	37.2	50.7

[A] These statistics represent the CV (1s %) and d2s % statistics as defined in Practice C 670.

[B] Coefficient of variation.

11.1.11 The measured value of C_i and the values of C_s, and D_a determined from the regression analysis.

11.1.12 Date and signature.

12. Precision and Bias

12.1 *Precision*—There has been no interlaboratory study of this test method. However, there are precision data[5] from an interlaboratory study of NORDTEST NT Build 443, from which this test method was developed. The report includes data from two interlaboratory studies involving three concrete mixtures and three to five laboratories participated, depending on the mixture. Average values of D_a among the mixtures ranged from 2.1 to 14.7 $\times$ (10^{-12}) m^2/s. Average values of C_s among the mixtures ranged from 0.61 to 1.0 %. Table 3 summarizes the single-laboratory and multiple-laboratory coefficient of variation and maximum difference expected between duplicate determinations in 95 % of such comparisons. Therefore, the apparent diffusion coefficient results of two properly conducted tests should not differ by more than 39.8 % of the mean value.

12.2 *Bias*—Since there is no accepted reference material suitable for determining the bias of this test method, no statement on bias is made.

13. Keywords

13.1 chloride; concrete; corrosion; diffusion; ion transport; service life

[5] Luping, Tang and Sørensen, Henrik, "Evaluation of the Rapid Test Methods for Measuring the Chloride Diffusion Coefficients of Concrete," NORDTEST Project No. 1388-98, Swedish National Testing and Research Institute, SP Report 1998:42.

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SUMMARY OF CHANGES

Committee C09 has identified the location of selected changes to this test method since the last issue, C 1556 – 03, that may impact the use of this test method. (Approved June 1, 2004)

(*1*) Added Note 1 to Significance and Use, increment reference numbers for all existing notes.

(*2*) Freezing requirement added to 9.2.2.

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Designation: C 1565 – 09

Standard Test Method for Determination of Pack-Set Index of Portland Cement[1]

This standard is issued under the fixed designation C 1565; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope*

1.1 This test method covers the determination of the pack-set index, which provides an indication of the mechanical force needed to overcome the consolidation of portland cement.

1.2 The pack-set index number provides a numerical value useful for manufacturers who desire to measure and control the effect that vibration-induced consolidation has upon the manufactured cement.

1.3 The values stated in SI units are to be regarded as standard. No other units of measurement are included in this standard. Values stated in SI units shall be obtained by measurement in SI units or by appropriate conversion, using the rules of Conversion and rounding given in Standard IEEE/ASTM SI 10, of measurements made in other units.

1.4 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.* (**WARNING**—Fresh hydraulic-cementitious mixtures are caustic and may cause chemical burns to skin and tissue upon prolonged exposure.)[2]

2. Referenced Documents

2.1 *ASTM Standards:*[3]

C 1005 Specification for Reference Masses and Devices for Determining Mass and Volume for Use in the Physical Testing of Hydraulic Cements

IEEE/ASTM SI 10 International System of Units (SI) The Modernized Metric System

3. Terminology

3.1 *Definitions of Terms Specific to This Standard:*

3.1.1 *pack set*, *n*—a condition of hydraulic cement, exhibited in varying degrees, following silo storage or transport in bulk railcars or trucks, that causes the cement to resist flowing until considerable mechanical effort has been applied.

3.1.2 *pack-set index*, *n*—the numerical indication of the degree of pack set a particular cement exhibits when subjected to the procedures of this test method.

3.1.3 *peak voltage*, *n—as pertaining to this method only*, the energy in volts applied to consolidate the sample, which results in the maximum pack-set index for a particular cement and the apparatus used for the measurement.

4. Summary of Test Method

4.1 Portland cement is placed into a flask and then consolidated on a vibrating table by a vibration force controlled by time and volts. The consolidated bed is measured for relative strength by turning the flask to a horizontal position and rotating in 180° increments until the bed collapses from the bottom of the flask. The number of half turns is a relative indication of the force required to overcome the consolidation and is designated the pack-set index, or P.S.I.

5. Significance and Use

5.1 This method is intended to help manufacturers determine the relative pack-set tendency of their cement(s). The test establishes a pack-set index which, when properly correlated with field performance, is useful in predicting or preventing field unloading difficulties.

5.2 The test is an aid to routine control during cement production and is not suitable for specification purposes.

5.3 In general, field performance of cement flowability is satisfactory when the pack-set index as determined on freshly ground cement averages 0 to 15 and is unsatisfactory when the index exceeds 25. Any prediction of field performance of cement flowability measuring 16 to 25 is tenable. These are general ranges and the field performance of individual cements may not necessarily fall within these ranges. Additional conditions, after the cement has left the control of the manufacturing facility, can affect the apparent pack set index as well.

5.4 Any attempt to apply the critical range of pack-set index numbers based on freshly ground cement to job cement without special treatment of the sample would be problematic. The test

[1] This test method is under the jurisdiction of ASTM Committee C01 on Cement and is the direct responsibility of Subcommittee C01.20 on Additions.

Current edition approved June 1, 2009. Published July 2009. Originally approved in 2003. Last previous edition approved in 2004 as C 1565 – 04.

[2] Section on Safety, Manual of Cement Testing, *Annual Book of ASTM Standards*, Vol 04.01.

[3] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

***A Summary of Changes section appears at the end of this standard.**

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is a "GO-NO GO" type of test and should not be used for specification purposes.

5.5 The pack-set index of field cement can be evaluated in terms of the pack-set index ranges of that cement as determined when freshly-ground. This comparison can aid the manufacturer in producing cement that offers the best field performance for pack-set properties.

5.6 Silo storage of cement may result in a greater amount of consolidation than this method is designed to induce, and the resulting forces required to overcome that consolidation are not measured by this test method.

5.7 Pack set is not to be confused with "warehouse set" which results from surface hydration of the cement from adsorbed moisture.

6. Interferences

6.1 Results obtained from the pack-set test are dependent on sample exposure (See Note 1).

NOTE 1—Fresh cement has a greater pack-set tendency. Cement stored in silos for only a day or two will test similar to fresh cement. Cement stored in full silos, where aeration is negligible, may develop lower pack-set indices upon further aging, Even samples in sealed containers may vary.

6.2 Pack-set index determination can be affected by sample temperature (See Note 2).

NOTE 2—Cement with a temperature noticeably hotter than room temperature may produce a different pack-set index number than that same cement cooled to room temperature. Cooling of hot cement samples must be accomplished with minimum aeration to avoid moisture and CO_2 adsorption.

6.3 The testing room humidity can significantly influence the determined pack-set index.

6.4 Keep the apparatus level during the testing procedure.

6.5 The vibration energy transferred to the sample is affected by the support given the apparatus (See Note 3). The determination of pack-set index for unknown samples shall be accomplished on the same physical support that the peak voltage for the test was determined on.

NOTE 3—Apparatus which is not setting firmly on the counter or table may not deliver repeatable results.

6.6 Vibration energy delivered by the table is related to the proper handling and adjustment of the table. See Section 7 for details.

6.7 Vibration energy delivered by the table is related to the frequency of the source voltage. This variation, if present, will result in a poor repeatability and require more frequent determination of the peak voltage.

7. Apparatus

7.1 *Erlenmeyer Flask*, 250 mL capacity, regular wall thickness, fitted with a number 14 (large diameter 32 mm and small diameter 25 mm) cork stopper. Flasks are not interchangeable. Each flask and cork combination must have the peak voltage determined prior to use in the test method (See Note 4).

7.2 *Reference Masses and Devices for Determining Mass* shall conform to the requirements of Specification C 1005 as appropriate for the size of the sample, the mass of which is to be determined, with a sensitivity of no less than 0.1 g and a readability of 0.1 g or less.

NOTE 4—There are enough differences between Erlenmeyer flasks of the same rated capacity to cause significant difference in the pack-set index. It is recommended that several flasks which deliver similar pack-set index numbers for the same cement be kept as spares.

7.3 *Vibrating Table*, (see Fig. 1), capable of generating electromagnetic vibrations at the frequency of 60 Hz, having a wooden or phenolic resin top with dowel pins installed equidistant from each other on the circumference of the circle centered on the table, with a radius slightly greater than the largest radius of the flask (to restrain the flask movement on the table).[4] A device that is capable of stopping any lateral movement of the flask during vibration is required (See Note 5). The air gap setting between the armatures of the vibrating table is critical to the generation of the proper vibrational amplitude and must be adjusted according to the manufacturer's instructions. Manufacturer's recommendations and precautions for proper operation must be followed to assure the accurate determination of the pack set index.

NOTE 5—Three or four dowel pins of 6 to 10 mm diameter and 25 to 30 mm long will be sufficient to restrain the flask. Interconnecting rubber bands or rubber cam-locks can be used to restrain the flask to prevent lateral movement of the flask during vibration.

7.4 *Roto-Tester*, (see Fig. 2), a device on which the Erlenmeyer flask can be mounted in a horizontal position against a vertical, flat, rotating plate that contains frictional hold-down cams to prevent the flask from falling, and capable of smoothly rotating the flask and table while in that horizontal position, in 180° increments at the rate of approximately 40 one-half rotations per minute with a short partial second pause between half-rotations. The device shall be equipped with a counter capable of recording the number of one-half rotations of the table.[5]

7.5 *Voltmeter*, capable of measuring and displaying the voltage delivered to the vibrating table to the nearest 0.5 VAC.

7.6 *Variable-voltage Transformer*, inductance-type, capable of supplying the vibrating table with voltage within the range of 0 v to 100 % of the design voltage of the vibrating table.

7.7 *Automatic Timer*, capable of controlling the "ON" time of the variable-voltage transformer and the vibrating table to 15 ± ½ s.

8. Preparation of Apparatus—Determination of Peak Voltage

8.1 Determine the peak voltage applied to the vibrating table to achieve the maximum pack-set index number for a sample.

8.1.1 Turn the vibrating table ON, and using the voltage adjustment of the variable-transformer, set the voltage so that little or no compaction takes place in the cement sample during the 15 s vibration. Increment the voltage by 2v until the compaction achieved result is a pack-set index value greater

[4] The vibrating table is available from suppliers of the pack set apparatus. A list of suppliers can be obtained from ASTM.

[5] The roto-tester is available from suppliers of the pack set apparatus. A list of suppliers can be obtained from ASTM.

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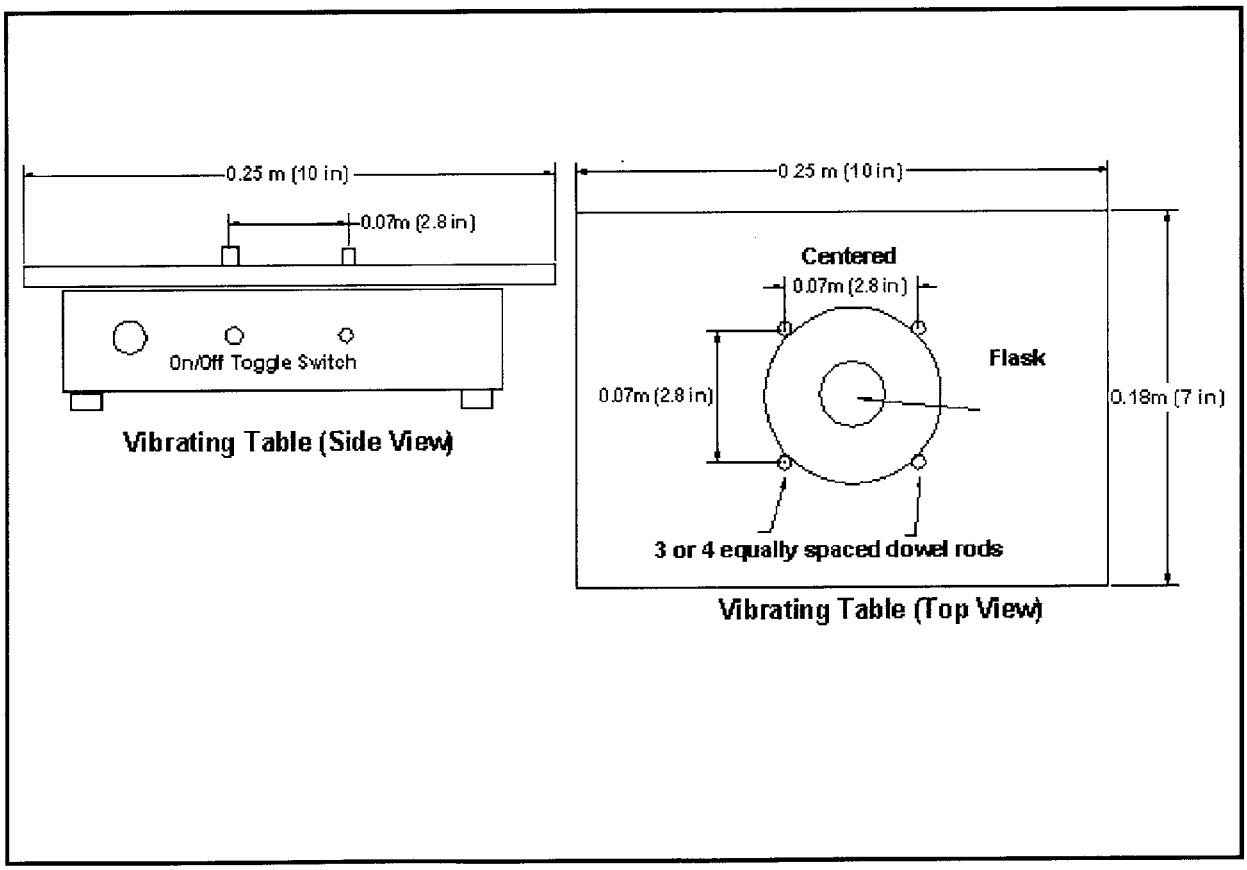

FIG. 1 Vibrating Table

than zero. Continue incrementing the voltage by 2v until a pack-set index is determined that is lower than the index determined using the preceding voltage. The preceding voltage is the peak voltage for that cement and apparatus combination (See Note 6).

NOTE 6—The test method uses the concept of vibration voltage increasing in order to develop cement bed compaction from nearly nothing to that voltage which provides a maximum pack-set index, to that voltage which disrupts the compaction and reduces the pack-set index to below the maximum. A starting voltage somewhere between 40-60 volts will generally satisfy that need.

8.2 Determine the peak voltage for the following conditions:

8.2.1 For each type of cement from a single source.

8.2.2 For samples obtained in the field or for interlaboratory testing.

8.2.3 Whenever the flask or cork is changed.

8.2.4 Whenever the vibrating table, voltmeter, variable-transformer, timer, or Roto-Tester are adjusted or replaced.

8.2.5 No less frequently than every 1 month for any single cement from a single source.

9. Conditioning

9.1 Maintain the temperature of the room and dry materials at 23.0 ± 3.0 °C.

9.2 Maintain the relative humidity of the testing room at a minimum of 50 %.

9.3 Sieve all samples through an 850-µm (No. 20) mesh screen prior to the pack-set determination.

9.4 Prior to each use, clean the inside and outside of the flask, the table top of the vibrating table, and the roto-tester with a dry clean cloth.

10. Procedure

10.1 Place 100.0 ± 0.1 g of cement, or 90.0 ± 0.1 g if Type III cement, into the clean flask. Stopper tightly with the cork stopper to avoid spillage.

10.2 *De-agglomeration*:

10.2.1 Support the flask with the neck maintained in a nearly horizontal position (consider nearly horizontal to be less than 90° but more than 70° from the vertical position of the flask). Rotate the flask one-half turn in the same direction. Continue rotation at the rate of two half-turns per second for a minimum of 10 s (See Note 7).

10.2.2 Level the bed of cement by manually suspending the flask by the neck in an upright position and gently swirling the flask about its longitudinal axis. Avoid excessive shaking or swirling which can cause re-agglomeration of the cement particles.

NOTE 7—Proper and sufficient de-agglomeration is required for acceptable repeatability of the test. Operators should practice the procedure to reduce differences between repeat determinations of the index.

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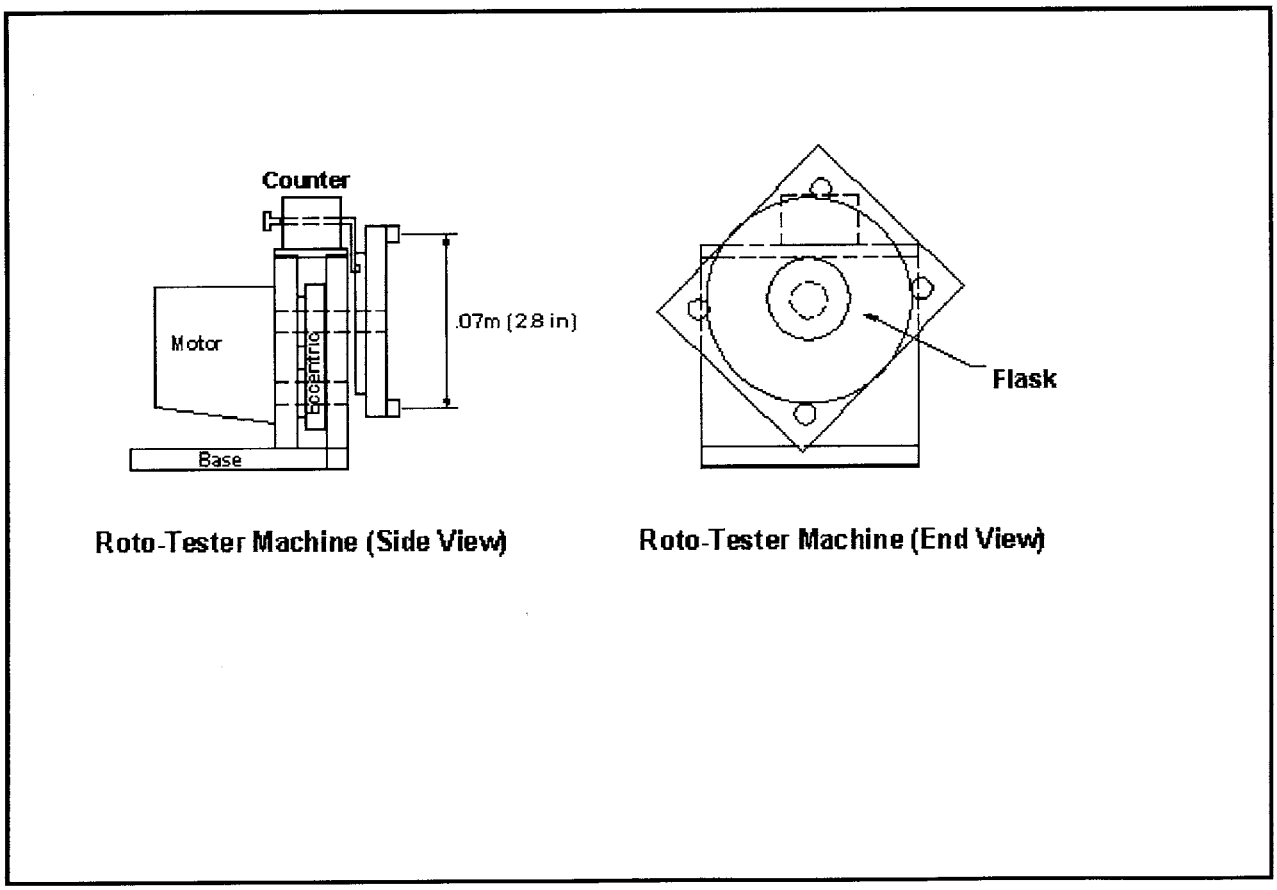

FIG. 2 Roto-Tester

10.3 Insure that the voltage supplied to the vibrating table is set at the predetermined peak voltage. The table must be "ON" for this procedure. Turn the table "OFF" when finished.

10.4 Gently place the flask onto the vibrating table inside of the retaining dowels, engage the restraining device in such a manner as to insure no lateral movement between dowels and flask wall during vibration. Set the timer for 15 s, and operate the vibrating table for the 15 s.

10.5 Remove the flask from the table, gently tip the flask to a horizontal position, place the flask into the roto-tester, carefully fasten the flask into the roto-tester with the friction cam clamps. The bottom of the flask and the roto-tester table must be contacting each other over the entire circumference of the flask. Read the counter on the roto-tester or reset the counter to zero. Operate the roto-tester until the consolidated bed of cement collapses from the bottom of the flask. Turn the roto-tester "off" and read the counter. If the bed only partially collapses, consider the run invalid if the bed does not completely collapse within two additional one-half rotations. Subtract the beginning number from the ending number to determine the number of one-half rotations required to collapse the bed of cement (See Note 8).

10.6 Make five (5) determinations using steps 10.2, 10.4, and 10.5.

NOTE 8—Under some circumstances, the number of half-turns for a single run will go above 50. When the number of turns does go above 50, it is permissible to stop the roto-tester and record the result as "50+."

11. Calculation of Results

11.1 Calculate the pack-set index by averaging the results of the five runs. Round the average to the nearest whole number.

12. Report

12.1 Report the pack-set index as a whole number, abbreviated, if desired, as P.S.I. and the peak voltage used to obtain the result. For example, "P.S.I. = 10 at 56 v."

13. Precision and Bias

13.1 Test data for the determination of pack-set index precision is being evaluated by Subcommittee C01.20. Statements of precision will be included in a later revision of this test method.

13.2 Since there is no accepted reference material suitable for determining any bias that may be associated with this test method, no statement is being made.

14. Keywords

14.1 pack set; pack-set index; peak voltage; portland cement; roto-tester

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SUMMARY OF CHANGES

Committee C01 has identified the location of selected changes to this test method since the last issue, C 1565 – 04, that may impact the use of this test method. (Approved June 1, 2009)

(*1*) Revised 4.1, 7.3, 10.4, and Footnotes 4 and 5.

(*2*) Replaced the term “maximum voltage” with “peak voltage” throughout the standard.

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Designation: C 1567 – 08

Standard Test Method for Determining the Potential Alkali-Silica Reactivity of Combinations of Cementitious Materials and Aggregate (Accelerated Mortar-Bar Method)[1]

This standard is issued under the fixed designation C 1567; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope*

1.1 This test method permits detection within 16 days of the potential for deleterious alkali-silica reaction of combinations of cementitious materials and aggregate in mortar bars. The cementitious materials are composed of various proportions of hydraulic cement, pozzolans and ground granulated blast-furnace slag.

1.2 The test results are only valid for the specific combinations of pozzolan, slag, and reactive aggregates tested.

1.3 This test is not suitable for evaluating the potential for deleterious reaction of combinations of hydraulic cement and aggregate (that is, in the absence of pozzolans or ground granulated blast-furnace slag).

1.4 The values stated in SI units are to be regarded as standard. No other units of measurement are included in this standard.

1.5 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use. A specific precautionary statement is given in the section on Reagents.*

2. Referenced Documents

2.1 *ASTM Standards:*[2]

C 109/C 109M Test Method for Compressive Strength of Hydraulic Cement Mortars (Using 2-in. or [50-mm] Cube Specimens)

C 125 Terminology Relating to Concrete and Concrete Aggregates

C 127 Test Method for Density, Relative Density (Specific Gravity), and Absorption of Coarse Aggregate

C 128 Test Method for Density, Relative Density (Specific Gravity), and Absorption of Fine Aggregate

C 150 Specification for Portland Cement

C 151 Test Method for Autoclave Expansion of Hydraulic Cement

C 305 Practice for Mechanical Mixing of Hydraulic Cement Pastes and Mortars of Plastic Consistency

C 490 Practice for Use of Apparatus for the Determination of Length Change of Hardened Cement Paste, Mortar, and Concrete

C 494/C 494M Specification for Chemical Admixtures for Concrete

C 511 Specification for Mixing Rooms, Moist Cabinets, Moist Rooms, and Water Storage Tanks Used in the Testing of Hydraulic Cements and Concretes

C 618 Specification for Coal Fly Ash and Raw or Calcined Natural Pozzolan for Use in Concrete

C 670 Practice for Preparing Precision and Bias Statements for Test Methods for Construction Materials

C 989 Specification for Ground Granulated Blast-Furnace Slag for Use in Concrete and Mortars

C 1240 Specification for Silica Fume Used in Cementitious Mixtures

C 1260 Test Method for Potential Alkali Reactivity of Aggregates (Mortar-Bar Method)

C 1293 Test Method for Determination of Length Change of Concrete Due to Alkali-Silica Reaction

C 1437 Test Method for Flow of Hydraulic Cement Mortar

D 1193 Specification for Reagent Water

E 11 Specification for Wire Cloth and Sieves for Testing Purposes

3. Terminology

3.1 *Definitions*:

3.1.1 For definitions of terms relating to concrete or aggregates, see Terminology C 125.

3.2 *relative density (OD), n*—as defined in Test Methods C 127 or C 128, for coarse and fine aggregates, respectively.

[1] This test method is under the jurisdiction of ASTM Committee C09 on Concrete and Concrete Aggregates and is the direct responsibility of Subcommittee C09.26 on Chemical Reactions.

Current edition approved Dec. 1, 2008. Published January 2009. Originally approved in 2004. Last previous edition approved in 2007 as C 1567 – 07.

[2] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

***A Summary of Changes section appears at the end of this standard.**

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4. Significance and Use

4.1 This test method provides a means for evaluating the ability of pozzolans and ground granulated blast-furnace slag to control deleterious internal expansion due to alkali-silica reaction when used with an aggregate intended for use in concrete. It is based on the Accelerated Test Method developed at the National Building Research Institute (NBRI) in the Republic of South Africa (**1-4**).[3]

4.2 Results obtained using this test method may overestimate the reactivity of some types of aggregates if used in service with the same pozzolans or slag and hydraulic cement of low alkali content.

4.3 Different levels of pozzolan and ground granulated blast-furnace slag may require testing to determine the amount required to reduce expansion to an acceptable level. Pozzolans and ground granulated blast-furnace slag may be tested separately or in combination.

4.4 It is recommended to test the same aggregate and hydraulic cement (without pozzolans and slag) using Test Method C 1260.

4.5 This test method may underestimate the expansion of cementitious systems containing pozzolans with an alkali content > 4.0 % sodium oxide equivalent (**7-9**). It is recommended that such materials be tested using Test Method C 1293.

5. Apparatus

5.1 The apparatus shall conform to Practice C 490, except as follows:

5.2 *Sieves*—Square hole, woven-wire cloth sieves, shall conform to Specification E 11.

5.3 *Mixer, Paddle, and Mixing Bowl*—Mixer, paddle, and mixing bowl shall conform to the requirements of Practice C 305, except that the clearance between the lower end of the paddle and the bottom of the bowl shall be 5.1 ± 0.3 mm.

5.4 *Tamper and Trowel*—The tamper and trowel shall conform to Test Method C 109/C 109M.

5.5 *Containers*—The containers shall be of such a nature that the bars can be totally immersed in either the water or 1N sodium hydroxide (NaOH) solution. The containers shall be made of material that can withstand prolonged exposure to 80 °C and must be resistant to a 1N NaOH solution (see Note 1). The containers must be so constructed that when used for storing specimens, the loss or gain of moisture is prevented by tight-fitting covers, by sealing, or both (see Note 2). The bars in the solution must be placed and supported so that the solution has access to the entire surface of each bar; therefore, ensure that the specimens do not touch the sides of the container or each other. The specimens, if stood upright in the solution, shall not be supported by the metal gage stud.

NOTE 1—The NaOH solution corrodes glass or metal containers.

NOTE 2—Some microwave-proof food storage containers made of polypropylene or high-density polythylene have been found to be acceptable.

[3] The boldface numbers in parentheses refer to a list of references at the end of the text.

5.6 *Oven, or Water Bath*—A convection oven or water bath with temperature control maintaining 80.0 ± 2.0 °C.

6. Reagents

6.1 *Sodium Hydroxide (NaOH)*—USP or technical grade may be used, provided the Na^+ and OH^- concentrations are shown by chemical analysis to lie between 0.99N and 1.01N.

6.2 *Purity of Water*—Unless otherwise indicated, references to water shall be understood to mean reagent water conforming to Type IV of Specification D 1193.

6.3 *Sodium Hydroxide Solution*—Each litre of solution shall contain 40.0 g of NaOH dissolved in 900 mL of water, and shall be diluted with additional distilled or deionized water to obtain 1.0 L of solution. The volume proportion of sodium hydroxide solution to mortar bars in a storage container shall be 4 ± 0.5 volumes of solution to 1 volume of mortar bars. The volume of a mortar bar may be taken as 184 mL. Include sufficient test solution to ensure complete immersion of the mortar bars.

6.3.1 *Warning*—Before using NaOH, review: (1) the safety precautions for using NaOH; (2) first aid for burns; and (3) the emergency response to spills, as described in the manufacturer's Material Safety Data Sheet or other reliable safety literature. NaOH can cause very severe burns and injury to unprotected skin and eyes. Suitable personal protective equipment must always be used. These include full-face shields, rubber aprons, and gloves impervious to NaOH. Gloves must be checked periodically for pinholes.

7. Conditioning

7.1 Maintain the temperature of the molding room and dry materials at not less than 20 °C and not more than 27.5 °C. The temperature of the mixing water, and of the moist closet or moist room, shall not vary from 23 °C by more than 2 °C.

7.2 Maintain the relative humidity of the molding room at not less than 50 %. The moist closet or room shall conform to Specification C 511.

7.3 Maintain the storage oven or water bath in which the specimens are stored at a temperature of 80.0 ± 2.0 °C.

8. Sampling and Preparation of Test Specimens

8.1 *Selection of Aggregate*—Process materials proposed for use as fine aggregate in concrete as described in 8.2 with a minimum of crushing. Process materials proposed for use as coarse aggregate in concrete by crushing to produce as nearly as practical a graded product from which a sample can be obtained. Grade the sample as prescribed in Table 1. The sample shall represent the composition of the coarse aggregate as proposed for use.

TABLE 1 Grading Requirements

Sieve Size		Mass, %
Passing	Retained on	
4.75 mm (No. 4)	2.36 mm (No. 8)	10
2.36 mm (No. 8)	1.18 mm (No. 16)	25
1.18 mm (No. 16)	600 µm (No. 30)	25
600 µm (No. 30)	300 µm (No. 50)	25
300 µm (No. 50)	150 µm (No. 100)	15

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8.1.1 When a given quarried material is proposed for use both as coarse and as fine aggregate, test only a selection of the fine aggregate, unless there is reason to expect that the coarse aggregate has a different composition than the fine aggregate. If such a difference is expected and if the differences might significantly affect expansion due to reaction with the alkalies in cement or from the environment of service, test the coarse aggregate in a manner similar to that employed in testing the fine aggregate.

8.2 *Preparation of Aggregate*—Grade aggregates to provide a sample meeting the requirements given in Table 1. Crush aggregates in which sufficient quantities of the sizes specified in Table 1 do not exist until the required material has been produced. In the case of aggregates containing insufficient amounts of one or more of the larger sizes listed in Table 1, and if no larger material is available for crushing, the first size in which sufficient material is available shall contain the cumulative percentage of material down to that size as determined from the grading specified in Table 1. When such procedures are required, make a special note thereof in the test report. After the aggregate has been separated into the various sieve sizes, wash each size with a water spray over the sieve to remove adhering dust and fine particles from the aggregate. Dry the portions retained on the various sieves and, unless used immediately, store each such portion individually in a clean container provided with a tight-fitting cover.

8.3 *Selection and Preparation of Cement*:

8.3.1 *Hydraulic Cement*—Use a hydraulic cement meeting the requirements of Specification C 150 (Note 3). In addition, the autoclave expansion in Test Method C 151 shall be less than 0.20 %.

NOTE 3—The alkali content of the cement has been found to have negligible (**3**) or minor (**6**) effects on expansion in this test.

8.3.2 *Preparation of Cement*—Pass cement for use in this test through an 850-µm (No. 20) sieve to remove lumps before use.

8.4 *Selection of pozzolan or ground granulated blast-furnace slag*—Use one, or a combination, of the following:

8.4.1 Fly ash or natural pozzolan meeting the requirements of Specification C 618.

8.4.2 Silica fume meeting the requirements of Specification C 1240.

8.4.3 Ground granulated blast furnace slag meeting the requirements of Specification C 989.

8.5 *Preparation of Test Specimens*:

8.5.1 *Number of Specimens*—Make at least three test specimens for each cementitious materials-aggregate combination.

8.5.2 *Preparation of Molds*—Prepare the specimen molds in accordance with the requirements of Practice C 490 except, the interior surfaces of the molds shall be covered with a release agent (see Note 4). A release agent is acceptable if it serves as a parting agent without affecting the time of setting of the cement and without leaving any residue that will inhibit the penetration of water into the specimen.

NOTE 4—TFE-fluorocarbon tape complies with the requirements for a mold release agent.

8.5.3 *Proportioning of Mortar*—Proportion the dry materials for the test mortar using 1 part of cementitious materials (hydraulic cement plus pozzolan or ground granulated blast-furnace slag) to 2.25 parts of graded aggregate by mass for aggregates with a relative density (OD) at or above 2.45. For aggregates with a relative density (OD) below 2.45, determine the aggregate proportion as follows:

$$\textit{Aggregate Proportion} = 2.25 \times \frac{D}{2.65}$$

where:

D = relative density (OD) of test aggregate.

8.5.3.1 For aggregates with a relative density (OD) equal to or greater than 2.45, the quantities of dry materials to be mixed at one time in the batch of mortar for making three specimens shall be 440 g of cementitious material and 990 g of aggregate made up by recombining the portions retained on the various sieves in the grading prescribed in Table 1. Use a water-cement ratio equal to 0.47 by mass (see Note 5).

8.5.3.2 For aggregates with a relative density (OD) less than 2.45, the quantities of dry materials to be mixed at one time in the batch of mortar for making three specimens shall be 440 g of cementitious material and mass of aggregate shall be 440 g multiplied by the aggregate proportion determined in 8.5.3. This aggregate mass shall be made up by recombining the portions retained on the various sieves in the grading prescribed in Table 1. Use a water-cementitious material ratio equal to 0.47 by mass (see Note 5).

NOTE 5—Ruggedness tests indicated that mortar bar expansions were less variable at a fixed water-cement ratio than when gauged to a constant flow (**3**).

8.5.3.3 If silica fume or metakaolin are used, a high range water reducer (HRWR), meeting the requirements of Specification C 494/C 494M Type F, shall be used (if necessary) to provide adequate dispersion and workability of the mixture. The water-cementitious material ratio shall remain 0.47 by mass and the amount of HRWR shall be that to obtain a flow of ± 7.5 percentage points of a control mortar without silica fume or metakaolin as determined in accordance with Test Method C 1437 using 10 drops of the flow table. If liquid HRWR is used, the water present in the liquid must be included in the calculation of the water-cementitious material ratio.

8.5.4 *Mixing of Mortar*—Mix the mortar in accordance with the requirements of Practice C 305.

8.5.5 *Molding of Test Specimens*—Mold test specimens within a total elapsed time of not more than 2 min and 15 s after completion of the original mixing of the mortar batch. Fill the molds with two approximately equal layers, each layer being compacted with the tamper. Work the mortar into the corners, around the gage studs, and along the surfaces of the mold with the tamper until a homogeneous specimen is obtained. After the top layer has been compacted, cut off the mortar flush with the top of the mold and smooth the surface with a few strokes of the trowel.

9. Procedure

9.1 *Initial Storage and Reading*—Place each mold in the moist cabinet or room immediately after molds have been

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filled. The specimens shall remain in the molds for 24 ± 2 h. Remove the specimens from the molds and, while they are being protected from loss of moisture, properly identify and make an initial comparator reading. Make and record the initial and all subsequent readings to the nearest 0.002 mm. Place the specimens made with each aggregate sample in a storage container with sufficient tap water to totally immerse them. Seal and place the containers in an oven or water bath at 80.0 ± 2.0 °C for a period of 24 h ± 2 h.

9.2 *Zero Readings*—Remove the containers from the oven or water bath one at a time. Remove other containers only after the bars in the first container have been measured and returned to the oven or water bath. The time elapsed between removal and return of the specimens to the oven or water bath shall not exceed 10 min. Remove the bars one at a time from the water and dry their surface with a towel paying particular attention to the two metal gage studs. Take the zero reading (see Note 6) of each bar immediately after drying, and read as soon as the bar is in position. Complete the process of drying and reading within 15 ± 5 s of removing the specimen from the water. After taking comparator readings, leave the specimen on a towel until comparator readings have been taken on the remainder of the bars. Place all specimens made with each unique cementitous materials-aggregate combination in a separate container with sufficient 1N NaOH, at 80.0 ± 2.0 °C for the specimens to be totally immersed. Seal the container and return it to the oven or water bath.

NOTE 6—The reference bar should be read prior to each set of specimens since the heat from the mortar bars may cause the length of the comparator to change.

9.3 *Subsequent Storage and Measurement*—Make subsequent comparator readings of the specimens periodically, with at least three intermediate readings, for 14 days after the zero reading, at approximately the same time each day. If readings are continued beyond the 14-day period, take at least one reading per week. The procedure is identical to that described in the 9.2, except that the specimens are returned to their own container after measurement.

10. Calculation

10.1 Calculate the difference between the zero comparator reading of the specimen and the reading at each period to the nearest 0.001 % of the effective gage length and record as the expansion of the specimen for that period. Report the average expansion of the three specimens of a given cementitious materials-aggregate combination to the nearest 0.01 % as the expansion for the combination for a given period.

11. Report

11.1 Report the following information:

11.1.1 Type and source of aggregate,

11.1.2 Type and source of hydraulic cement,

11.1.3 Type, source, and proportions of pozzolan

11.1.4 Grade, source, and proportions of ground granulated blast-furnace slag

11.1.5 Autoclave expansion and alkali content of cement as percent potassium oxide (K_2O), sodium oxide (Na_2O), and calculated sodium oxide (Na_2O) equivalent (Na_2O_{eq}= $\%Na_2O + 0.658 \times \%K_2O$),

11.1.6 Average length change in percent at each reading of the specimens,

11.1.7 Any relevant information concerning the preparation of aggregates, including the grading of the aggregate when it differs from that given in 8.2,

11.1.8 Any significant features revealed by examination of the specimens during and after test,

11.1.9 Amount of mixing water expressed as a mass fraction of the total cementitious material,

11.1.10 A graph of the length change data from the time of the zero reading to the end of the 16 day period.

12. Precision and Bias

12.1 The following precision statements are taken from Test Method C 1260, and are based on tests without pozzolans or ground slag.

12.2 *Within-Laboratory Precision*—It has been found that the average within-laboratory coefficient of variation for materials with an average expansion greater than 0.1 % at 14 days is 2.94 % **(5)** (Note 7). Therefore, the results of two properly conducted tests within the same laboratory on specimens of a sample of aggregate should not differ by more than 8.3 % (Note 7) of the mean expansion.

12.3 *Multi-Laboratory Precision*—It has been found that the average multilaboratory coefficient of variation for materials with an average expansion greater than 0.1 % at 14 days is 15.2 % **(5)** (Note 7). Therefore, the results of two properly conducted tests in different laboratories on specimens of a sample of aggregate should not differ by more than 43 % (Note 7) of the mean expansion.

NOTE 7—These numbers represent, respectively, the (1s %) and (d2s %) limits as described in Practice C 670.

12.4 *Bias*—Since there is no accepted reference material for determining the bias of this test method, no statement on bias is being developed.

13. Keywords

13.1 aggregate; alkali-silica reactivity; length change; mortar; pozzolans, slag, sodium hydroxide

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APPENDIX

(Nonmandatory Information)

X1. INTERPRETATION OF TEST RESULTS

X1.1 There is good agreement in the published literature (**2, 10-12**) for the following expansion limits:

X1.1.1 Combinations of cement, pozzolan, or ground granulated blast-furnace slag, and aggregate that expand less than 0.10 % at 16 days after casting are likely to produce acceptable expansions when tested in concrete (that is, Test Method C 1293) and to have a low risk of deleterious expansion when used in concrete under field conditions.

X1.1.2 Combinations of cement, pozzolan, or ground granulated blast-furnace slag, and aggregate that expand more than 0.10 % at 16 days after casting are indicative of potentially deleterious expansion. However, the potential for deleterious reaction should be confirmed by testing the same combination of materials in concrete (that is, Test Method C 1293). The expansion may be reduced by retesting the material combination using the pozzolan or ground granulated blast-furnace slag at a higher replacement level.

REFERENCES

(**1**) Oberholster, R. E., and Davies, G., "An Accelerated Method for Testing the Potential Alkali Reactivity of Siliceous Aggregates." *Cement and Concrete Research*, Vol 16, 1986, pp. 181–189.

(**2**) Davies, G., and Oberholster, R. E., "Use of the NBRI Accelerated Test to Evaluate the Effectiveness of Mineral Admixtures in Preventing the Alkali-Silica Reaction," *Cement and Concrete Research*, Vol 17, 1987, pp. 97–107.

(**3**) Davies, G., and Oberholster, R. E., "An Interlaboratory Test Programme on the NBRI Accelerated Test to Determine the Alkali-Reactivity of Aggregates," National Building Research Institute, CSIRO, Special Report BOU 92-1987, Pretoria, RSA, 1987, 16 pp.

(**4**) Oberholster, R. E., "Alkali Reactivity of Siliceous Rock Aggregates: Diagnosis of the Reaction, Testing of Cement and Aggregate and Prescription of Preventative Measures," *Alkali in Concrete, Research and Practice*, Copenhagen, 1983, Danish Concrete Association, pp. 419–433.

(**5**) Rogers, C.A., "Multi-laboratory Study of the Accelerated Mortar Bar Test (ASTM Test Method C 1260) for Alkali-Silica Reaction," *Cement, Concrete, and Aggregates*, Vol 21, 1999, pp. 185–194.

(**6**) Hooton, R. D., "Interlaboratory Study of the NBRI Rapid Test Method and CSA Standardization Status," *Report EM-92*, Ontario Ministry of Transport, March 1990, pp. 225–240.

(**7**) Shehata, M.H. and Thomas, M.D.A. "The Effects of Fly Ash Composition on the Expansion of Concrete Due to Alkali-Silica Reaction." *Cement and Concrete Research*, Vol. 30, July 2000, pp. 1063-1072.

(**8**) Mehland, I. and Dahl, P.A. "Recycling glass cullet as concrete aggregates: applicability and durability." *Proceedings of the International Symposium: Recycling and Reuse of Glass Cullet*, (Ed. R. Dhir et al), Dundee, Scotland, 2001, pp. 167-177.

(**9**) Baxter, S. "Recycled glass in concrete: the good news and the bad news." *Beneficial Use of Recycled Materials in Transportation Applications*, (Ed. T. Eighmy), Virginia, 2001, pp. 747-756.

(**10**) Berra, M., Mangialardi, T. and Paolini, A. E. "Application of the NaOH bath test method for assessing the effectiveness of mineral admixtures against reaction of alkali with artificial siliceous aggregate." *Cement & Concrete Composites,* Vol. 16, 1994, pp. 207-218.

(**11**) Bérubé, M-A., Duchesne, J., and Chouinard, D. "Why the accelerated mortar bar method ASTM C 1260 is reliable for evaluating the effectiveness of supplementary cementing materials in suppressing expansion due to alkali-silica reactivity." *Cement, Concrete, and Aggregates*, Vol. 17, No. 1, 1995, pp. 26 - 34.

(**12**) Thomas, M.D.A. and Innis, F.A. "Use of the accelerated mortar bar test for evaluating the efficacy of mineral admixtures for controlling expansion due to alkali-silica reaction." *Cement, Concrete, and Aggregates*, Vol. 21 (2), 1999, pp. 157-164.

SUMMARY OF CHANGES

Committee C09 has identified the location of selected changes to this test method sine the last issue, C 1567 – 07, that may impact the use of this test method. (Approved December 1, 2008)

(*1*) Revised 8.5.3.3.

Committee C09 has identified the location of selected changes to this test method sine the last issue, C 1567 – 04, that may impact the use of this test method. (Approved July 15, 2007)

(*1*) Revised 9.2.
(*2*) Revised Section 3.
(*3*) Revised 8.5.3, added new 8.5.3.1 and 8.5.3.2, and moved some of the text from 8.5.3 into new 8.5.3.3.

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Designation: C 1579 – 06

Standard Test Method for Evaluating Plastic Shrinkage Cracking of Restrained Fiber Reinforced Concrete (Using a Steel Form Insert)[1]

This standard is issued under the fixed designation C 1579; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope

1.1 This test method compares the surface cracking of fiber reinforced concrete panels with the surface cracking of control concrete panels subjected to prescribed conditions of restraint and moisture loss that are severe enough to produce cracking before final setting of the concrete.

1.2 This test method can be used to compare the plastic shrinkage cracking behavior of different concrete mixtures containing fiber reinforcement.

1.3 The values stated in SI units are to be regarded as the standard.

1.4 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use. (***Warning**— fresh hydraulic cementitious mixtures are caustic and may cause chemical burns to skin and tissue upon prolonged exposure.)[2]

2. Referenced Documents

2.1 *ASTM Standards:* [3]

C 125 Terminology Relating to Concrete and Concrete Aggregates

C 143/C 143M Test Method for Slump of Hydraulic-Cement Concrete

C 192/C 192M Practice for Making and Curing Concrete Test Specimens in the Laboratory

C 403/C 403M Test Method for Time of Setting of Concrete Mixtures by Penetration Resistance

C 670 Practice for Preparing Precision and Bias Statements for Test Methods for Construction Materials

C 995 Test Method for Time of Flow of Fiber-Reinforced Concrete Through Inverted Slump Cone

3. Summary of Test Method

3.1 Panels of control concrete and fiber reinforced concrete are prepared in a prescribed manner and are exposed to controlled drying conditions after finishing. The drying conditions (See Note 1) are intended to be severe enough to induce plastic shrinkage cracking in test panels made of control concrete. The evaporation rate from a free water surface is monitored by pans placed next to the panels in the environmental chamber.

NOTE 1—An important parameter in this method is the rate of evaporative water loss, which is controlled by the atmospheric conditions surrounding the test specimens. Since the concrete specimens will not always have the same rate of water evaporation as the pan of water (due to evaporative and bleeding effects), the rate of evaporation of 1.0 kg/m^2·h from the pan of water represents the minimum evaporation rate that must be attained for this test (**1**).[4] The moisture loss from the concrete test panels can also be monitored and reported, however, the rate of evaporation from the free surface of the water in the pan is the parameter that should be used to quantify the drying environment.

3.2 The test is terminated at the time of final setting of the concrete determined in accordance with Test Method C 403/C 403M. At 24 h from initial mixing, the average crack width is determined.

3.3 A cracking reduction ratio (CRR) is computed from the average crack width for the fiber-reinforced concrete panels and the average crack width for the control concrete panels.

4. Significance and Use

4.1 The test method is intended to evaluate the effects of evaporation, settlement, and early autogenous shrinkage on the plastic shrinkage cracking performance of fiber reinforced concrete up to and for some hours beyond the time of final setting (See Terminology C 125).

4.2 The measured values obtained from this test may be used to compare the performance of concretes with different mixture proportions, concretes with and without fibers, concretes containing various amounts of different types of fibers, and concretes containing various amounts and types of admixtures. For meaningful comparisons, the evaporative conditions during test shall be sufficient to produce an average crack width

[1] This test method is under the jurisdiction of ASTM Committee C09 on Concrete and Concrete Aggregates and is the direct responsibility of Subcommittee C09.42 on Fiber-Reinforced Concrete.

Current edition approved Feb. 15, 2006. Published March 2006.

[2] Section on Safety Precautions, Manual of Aggregate and Concrete Testing, *Annual Book of ASTM Standards*, Vol. 04.02.

[3] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

[4] The boldface numbers in parentheses refer to the list of references at the end of this standard.

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of at least 0.5 mm in the control specimens (**2, 5**) (See Note 2). In addition, the evaporation rate from a free surface of water shall be within ± 5 % for each test.

NOTE 2—To achieve evaporation rates that result in a crack of at least 0.5 mm in the control specimens, it may be necessary to use an evaporation rate higher than that discussed in Note 1.

4.3 This method attempts to control atmospheric variables to quantify the relative performance of a given fresh concrete mixture. Since many other variables such as cement fineness, aggregate gradation, aggregate volume, mixing procedures, slump, air content, concrete temperature and surface finish can also influence potential cracking, attention shall be paid to keep these as consistent as possible from mixture to mixture.

5. Apparatus

5.1 *Molds*:

5.1.1 For maximum coarse aggregate size equal to or less than 19 mm, use a mold with a depth of 100 ± 5 mm and rectangular dimensions of 355 ± 10 mm by 560 ± 15 mm (See Fig. 1). The mold can be fabricated from metal, plastic, or plywood.

NOTE 3—If plywood is used for molds, the plywood should have low moisture absorption. The mold should be constructed to be lightweight and stiff. The molds, when properly constructed, should last for approximately 50 uses.

5.1.2 This test method is designed for aggregate less than or equal to 19 mm. For coarse aggregate greater than 19 mm, the depth of the mold shall be at least 65 mm plus at least 2 times the maximum coarse aggregate size.

5.2 *Stress Riser and Internal Restraints*—The internal restraints and stress riser shall be bent from one piece of sheet metal, as illustrated in Fig. 1, or made from a solid piece of steel. The sheet metal shall have a thickness of 1.2 ± 0.05 mm (18 gauge) (See Fig. 1 and Ref **2**). Two 32 ± 1 mm high restraints are placed 90 ± 2 mm inward from each end of the mold. The central stress riser is 64 ± 2 mm high and serves as

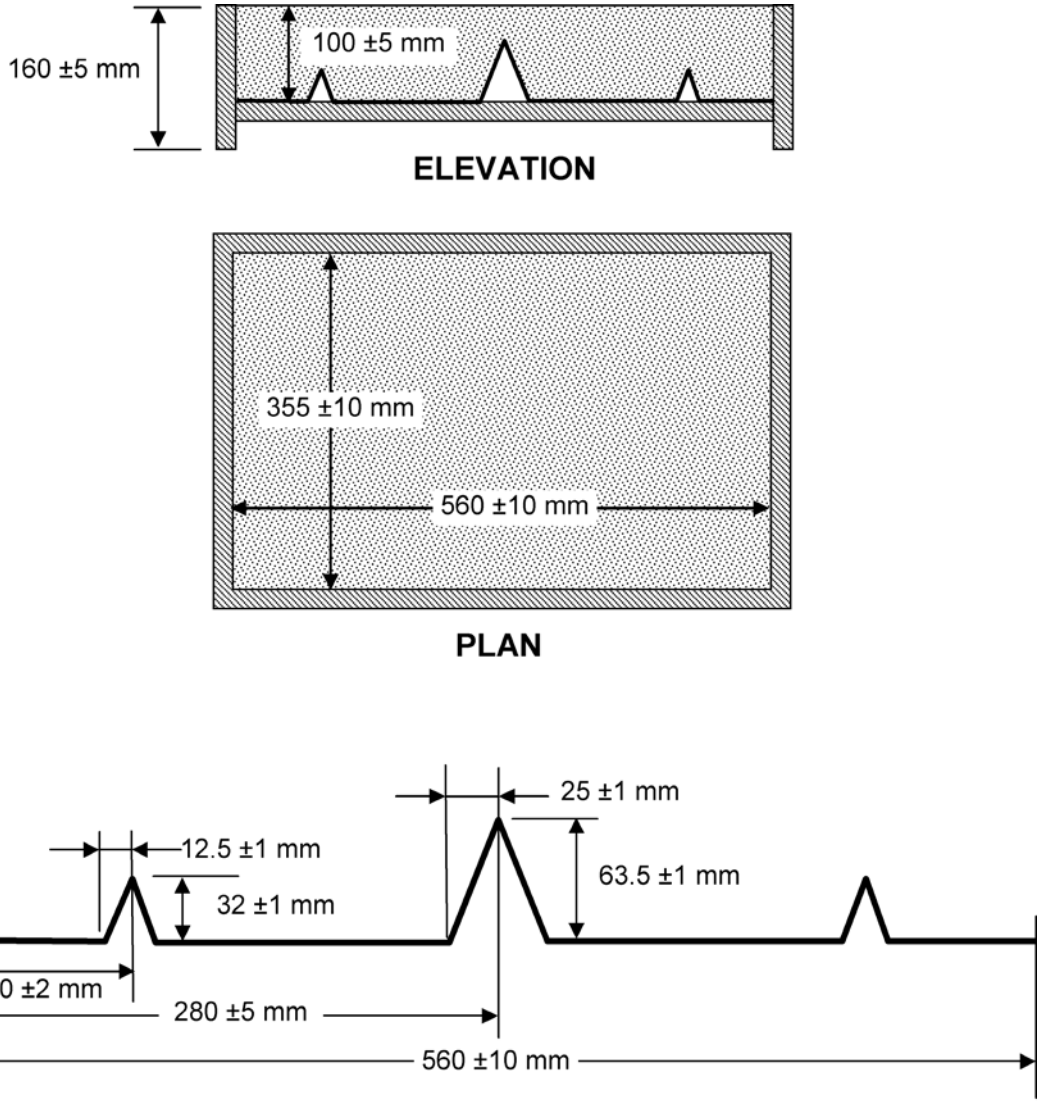

FIG. 1 Specimen and Stress Riser Geometry (4, 5)

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an initiation point for cracking. This sheet metal stress riser with internal restraints shall fit at the bottom of the mold.

5.2.1 Use form release oil to coat the metal insert and mold sides to reduce bond with concrete. The insert and mold are considered to be properly oiled when the entire surface is coated and excess oil has been removed with a clean, dry rag.

5.3 *Variable Speed Fan(s)*—The fan(s) used shall be capable of achieving a wind speed of more than 4.7 m/s over the entire test panel surface area.

5.4 *Environmental Chamber*—The use of a fan box in an environmental chamber is a method for producing a uniform airflow over the panel surface (See Fig. 2). A clear cover over the panels will aid in obtaining uniform airflow and allow for observation of cracking. Another method of producing uniform airflow is to use a specifically designed environmental chamber as shown in Fig. 3. A commercially available heater, humidifier, and dehumidifier can be used to maintain the specified environmental condition. This test is conducted using either apparatus shown in Fig. 2 or Fig. 3 by exposing the panels to an evaporation rate of at least 1.0 kg/m^2·h (See Note 1). For the standard test, the temperature must be maintained at 36 ± 3 °C, the relative humidity must be 30 ± 10 %, and the wind velocity must be sufficient to maintain the minimum evaporation rate during the test.

NOTE 4—Before casting the concrete panels, atmospheric variables in the environmental facility should be checked to determine that the necessary evaporative conditions can be achieved. A wind velocity of 4.7 m/s should be sufficient to achieve the minimum specified evaporation rate, but a higher wind velocity may be needed to obtain sufficient average crack width in some control panels.

5.5 *Sensors*—Use temperature, humidity, and wind velocity sensors to measure ambient air and concrete surface temperature to the nearest 0.5 °C, relative humidity to the nearest 1 %, and air speed to the nearest 0.1 m/s.

5.6 *Vibrating Platform*—Any device that can fully consolidate the test panel that meets minimum frequency requirements as stated in Practice C 192/C 192M for an external vibrator is suitable.

5.7 *Surface Finishing Equipment*—An angle iron screed shall be used for the concrete after vibration. A magnesium, steel, or wood trowel shall be used for finishing the surface of the specimen after screeding.

5.8 *Monitoring Pan*—A pan suitable for exposing water to the air stream for each concrete test panel is required. The sides of the pan shall be vertical. The pan shall be of sufficient size to expose at least 0.1 ± 0.01 m^2 of water to the air stream. The exposed lip of the pan shall not extend more than 5 mm above the water level at the start of the test.

NOTE 5—The test panels and monitoring pans can be placed in an environmental chamber designed for this test method (See Fig. 3) or the pans can be placed downstream from panels in a fan box (See Fig. 2).

5.9 *Scale*—If the rate of moisture loss from test panels is required by the specifier of tests, weigh test panels with a scale having a capacity of at least 100 kg and accurate to within 0.1 % of the test load. Weigh the evaporation rate monitoring pans with a balance or scale having a capacity of at least 3 kg and accurate to within 5 g.

5.10 *Crack Measurement Tool*—Optical hand-held microscope, crack comparator, or image analysis system can be used. The measurement tool should be capable of measuring crack width to at least the nearest 0.05 mm. If an automated image analysis system is used, it should be demonstrated to provide an accurate measurement. To demonstrate the accuracy of the measurement, the system shall be used to measure a 0.5 mm notch that is machined into a piece of steel and the reported notch width shall be within ± 0.05 mm of the machined width.

6. Sampling, Test Specimens, and Test Units

6.1 *Test Panels*—Cast test panels in accordance with the applicable provisions of Practice C 192/C 192M, using the same source of materials, preparation, mixing and finishing procedures.

6.2 *Test Unit*—A test unit is comprised of at least two control specimens and at least two fiber reinforced concrete specimens with the same mixture proportions. A group of two control specimens has to be tested each time in order to determine the plastic shrinkage crack reduction of fiber reinforced concrete.

7. Procedure

7.1 Determine the slump of each mixture in accordance with Test Method C 143/C 143M. If the slump is too low for a concrete mixture containing fibers, use the time of flow through an inverted slump cone to measure workability in accordance with Test Method C 995.

7.2 Fabricate specimens for setting time determination in accordance with Test Method C 403/C 403M. If fiber reinforced concrete cannot be wet sieved readily, use the control concrete specimen to measure time of final setting of both the control and the fiber-reinforced mixtures. Place the time of setting specimens in the air stream so that they are exposed to the same environmental conditions as the plastic shrinkage panels.

7.3 Fill the panel molds using one layer. Consolidate the concrete with external vibration until the concrete is approximately level with the top of the mold. Screed each specimen perpendicular to the stress riser three times.

7.4 After screeding, trowel specimens using a predetermined number of passes. If moisture loss from the panel is to be determined, remove any waste concrete adhering to the outside of the mold and weigh each panel while in the mold.

7.5 Place a fiber reinforced concrete mixture panel and control mixture panel in the environmental chamber downstream from the fan(s) (See arrangements in Figs. 2 and 3).

7.6 Turn on the fan(s), which have been preset to achieve the air speed to obtain the required evaporative conditions (See Note 4). The evaluation of cracking commences at this time.

7.7 At the start of the test and at 30-min intervals, record air temperature, relative humidity, and air flow speed at a location 100 ± 5 mm above each panel surface. If required by the specifier of tests, record the time at which cracking is first observed for each panel surface. Perform penetration tests at regular time intervals according to Test Method C 403/C 403M. Continue recording the environmental variables until the time of final setting.

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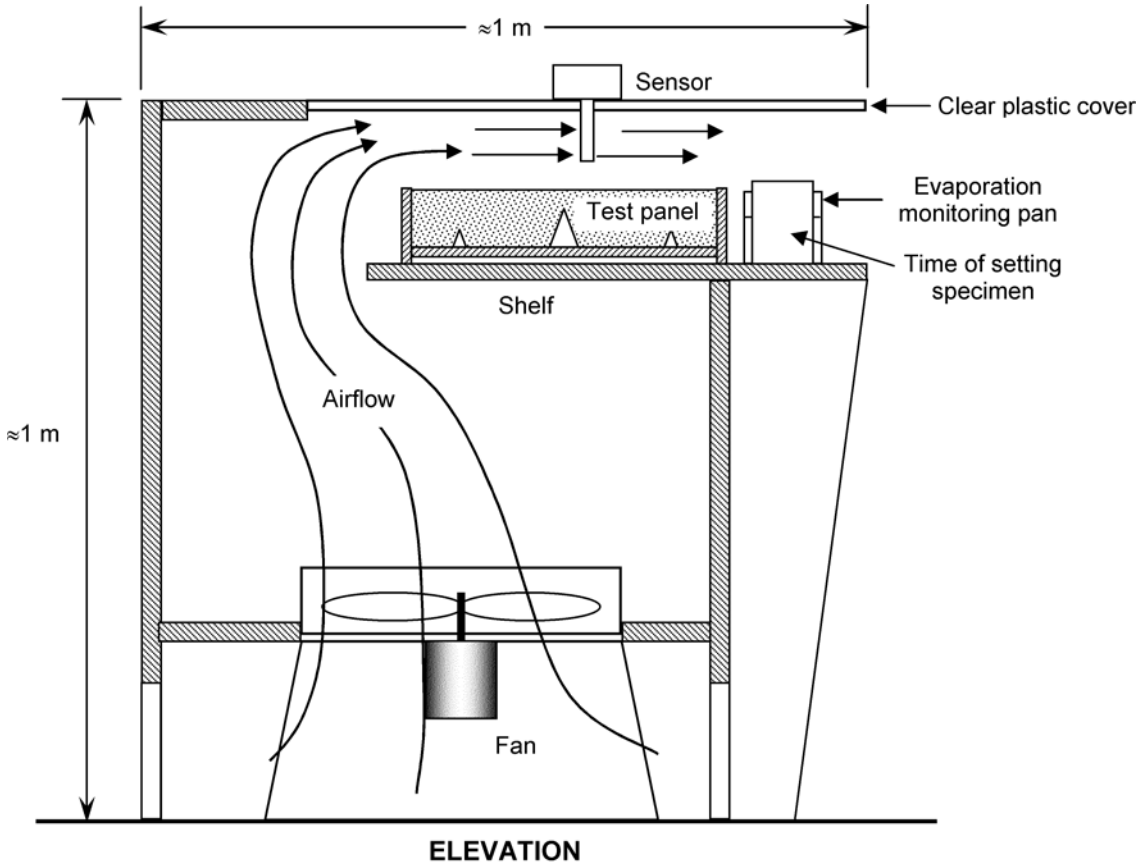

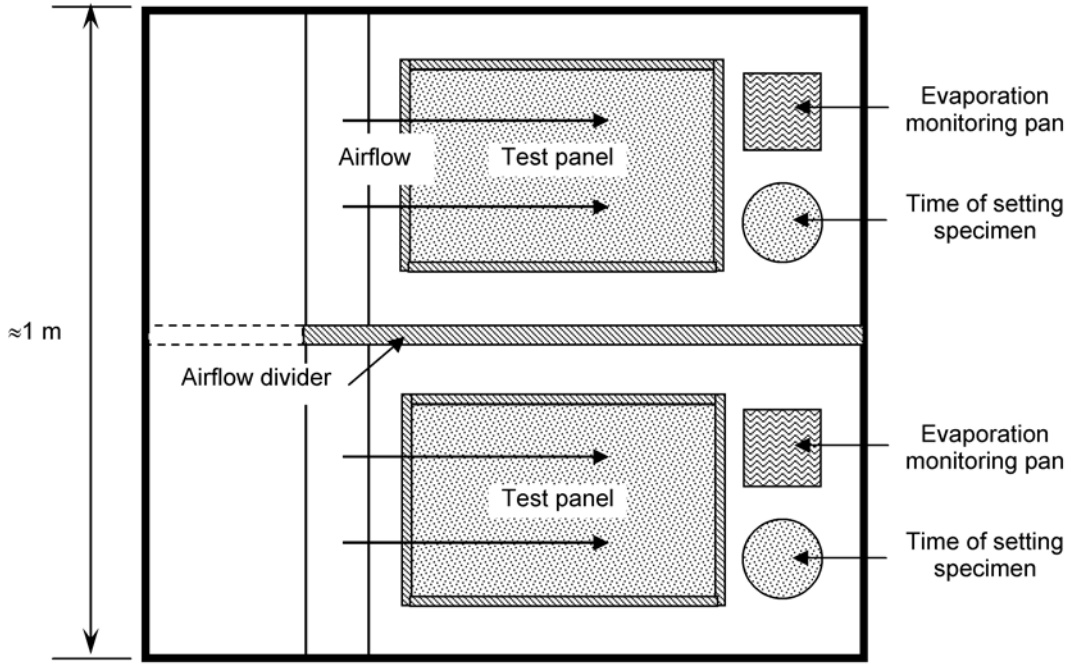

FIG. 2 Example of Fan Box to Maintain Environmental Conditions (2) (Not to Scale)

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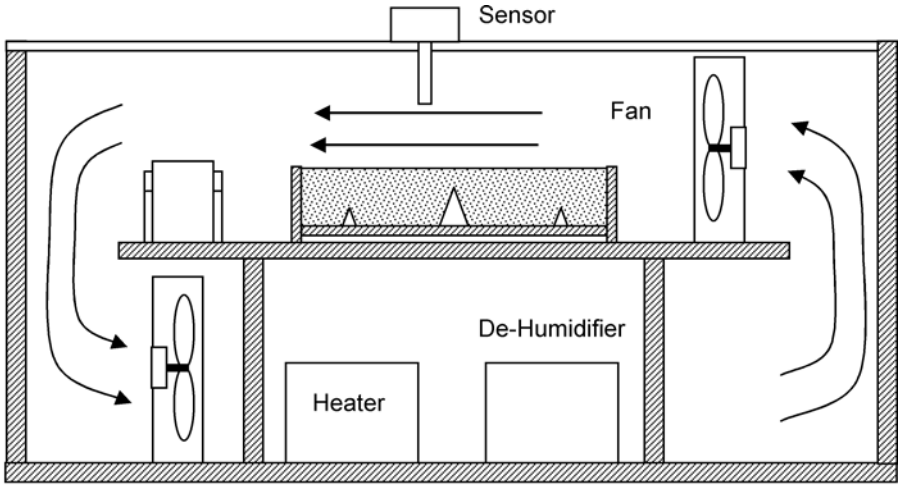
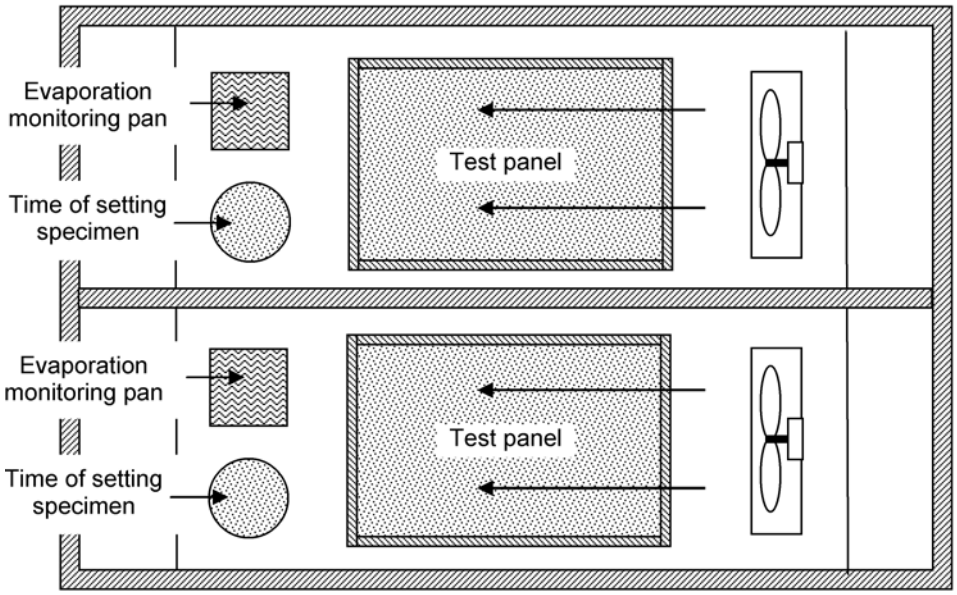


ELEVATION



PLAN

FIG. 3 Example of Chamber to Maintain Environmental Conditions (4)

7.8 The evaporation rate is determined by initially weighing the full monitoring pans at the start of the test and at 30-min intervals thereafter (**3**). Record the mass loss to the nearest 5 g at each weighing. To determine the evaporation rate during each time interval, divide the mass loss between successive weighings by the surface area of the water in the weighing pan and the time interval between successive weighings (See Note 6). The test is not valid if the average evaporation rate is less than 1.0 kg/m^2·h.

NOTE 6—Adjustments to wind velocity should be made if necessary to maintain the evaporation rate at the required level. It is suggested that the monitoring pans be placed on scales in the air stream for continuous monitoring without periodic removal during testing. If this is not possible, the monitoring pan should be removed from the air stream, weighed, and returned to the air stream within 15 seconds.

7.9 After final setting occurs (use the later of the measured time of setting in the two specimens), record the atmospheric variables, stop the fans, record the time, and determine the total water loss from the monitoring pans. If panel moisture loss is to be determined, weigh the test panels in their molds. Store the

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panels in the laboratory at 23 ± 2 °C and under plastic sheets to minimize evaporation until time of crack width measurement.

8. Quantification of Cracking

8.1 Quantify the amount of cracking by measuring crack widths at the surface of the panels 24 ± 2 h after mixing.

NOTE 7—Studies have shown that, when panels are covered with plastic, there is no appreciable change in average crack width from a time of six hours to 24 h after mixing (**5**).

8.2 To avoid possible effects of panel boundaries on crack width, do not measure crack widths within 25 mm of test panel boundaries.

8.3 Measure the width of each crack along the cracking path over the stress riser in a progressive order from one side of the panel to the other. If a manual crack width measuring procedure is used, use a crack comparator or crack microscope to measure crack widths. Measure crack width to the nearest 0.1 mm at 10 ± 1 mm intervals along the length of the crack. Repeat the above procedure until all cracks have been measured. If an imaging analysis procedure is used for crack width measurement, record crack widths over the same measuring distance (See Note 8). Overlap between adjacent images shall be cut off to avoid duplicated measurements (**4**). Record all crack widths to calculate average crack width.

NOTE 8—A grid mask can be used to sample crack widths at predetermined locations (**4**).

8.4 Calculate the average crack width to the nearest 0.05 mm. If an average crack width of at least 0.5 mm is not observed on the control panels (average of at least two panels), with no single control panel under 0.4 mm average crack width, the test is not valid. Increase the evaporation rate to achieve this minimal average crack width, and repeat the test (See Note 10).

NOTE 9—Requiring a minimum crack width of the control panel will help to prevent marginal modifications to the concrete mixture from showing a statistically significant performance improvement, which may not be sufficient to control cracking under field conditions.

NOTE 10—Refer to ACI 305R (**1**) for guidance on how wind speed affects evaporation rate.

8.5 Calculate the crack reduction ratio (CRR) using the following equation:

$$CRR = \left[1 - \frac{\text{Average Crack Width of Fiber Reinforced Concrete Mixture}}{\text{Average Crack Width of Control Concrete Mixture}}\right] \times 100\ \% \quad (1)$$

9. Report

9.1 Report the following for each mixture tested:

9.1.1 The mixture proportions in kg/m^3 of water, cement (or cementitious materials): aggregates; admixtures in L/m^3; water-cement ratio (w/c) to the nearest 0.01; and slump in mm (or time of flow in seconds when used for fiber-reinforced concrete mixtures).

9.1.2 The fiber characteristics (if available) including fiber material, length, cross-sectional area, fiber shape, and addition rate in kg/m^3.

9.1.3 Length, depth, and width of panels in mm.

9.1.4 Cracking value of each panel as the average crack width to the nearest 0.05 mm.

9.1.5 The temperature, relative humidity, wind velocity, and measured evaporation rate during the test.

9.1.6 If required, the moisture loss of each panel in kilograms of water per square meter of surface (kg/m^2). Report the time interval between panel weighings.

9.1.7 The cracking reduction ratio (CRR) to the nearest percent (%).

10. Precision and Bias

10.1 *Precision*—A multi-laboratory study of precision has not been completed. Information on repeatability of this test method was derived from within-laboratory testing using a single operator and replicate panels (**5**) (See Practices C 670). Table 1 shows the number of replicate panels, average of the average crack width, and standard deviation of the average crack width for control panels and panels made with concretes having different amounts of fiber. The standard deviation appears to be constant and is used as the measure of repeatability. When three panels were used to determine the Crack Reduction Ratio (CRR), the value of the single operator standard deviation was 4.6 %.

10.2 *Bias*—The procedure for measuring the cracking value has no bias because the cracking value is defined only in terms of this test method.

TABLE 1 Single-Operator Average Crack Width Repeatability (22 Crack Width Measurements per Panel Using Manual Measurement Procedure)

NOTE—The results in this table correspond with the behavior of a mixture using a single type of fiber as described in Ref **5**.

Mixture Identification	Fiber Volume	Number of Panels	Average Crack Width (mm)	Standard Deviation of Average Crack Width (mm)
A	0 % Fiber	6	0.67	0.04
B	0.05 % Fiber	4	0.44	0.05
C	0.10 % Fiber	4	0.33	0.05
D	0.15 % Fiber	4	0.08	0.04
E	0.20 % Fiber	2	0.03	0.02

11. Keywords

11.1 crack width; evaporation; fiber-reinforced concrete; plastic shrinkage cracking; restrained shrinkage cracking

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REFERENCES

(1) "Hot Weather Concreting," *ACI 305.R-99, ACI Manual of Concrete Practice*, American Concrete Institute, Farmington Hills, MI, 2004.

(2) Berke, N. S., and Dalliare, M. P., "The Effect of Low Addition Rate of Polypropylene Fibers on Plastic Shrinkage Cracking and Mechanical Properties of Concrete," *Fiber Reinforced Concrete: Development and Innovations, ACI SP-142*, American Concrete Institute, Farmington Hills, MI, 1994, pp.19-41.

(3) Nanni, A., Ludwig, D. A., and Mcgillis, M. T., "Plastic Shrinkage Cracking of Restrained Fiber-Reinforced Concrete," *Transportation Research Record*, 1382, 1993, pp. 69-72.

(4) Qi, C., Weiss, J., and Olek, J., "Characterization of Plastic Shrinkage Cracking in Fiber-Reinforced Concrete Using Semi-Automated Image Analysis," *RILEM Materials and Structures*, Vol 36, No. 260, July 2003, pp. 386-395.

(5) Qi, C., Weiss, J., and Olek, J., "Statistical Significance of the Restrained Slab with a Stress Riser for Quantifying Plastic Cracking in Fiber Reinforced Concrete," *ASTM Journal of Testing and Evaluation*, July 2005.

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Designation: C 1580 – 09

Standard Test Method for Water-Soluble Sulfate in Soil[1]

This standard is issued under the fixed designation C 1580; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope*

1.1 This test method is for the determination of water-soluble sulfate in soils.

1.2 This test method was developed for concentrations of water-soluble sulfate in soils between 0.02 and 3.33 % sulfate by mass.

1.3 This test method does not determine sulfur in any form except as sulfate.

1.4 Some governing bodies regulate the movement of soils from one area to another. It is up to the sampler and laboratory to comply with all regulations.

1.5 The values stated in SI units are to be regarded as standard. No other units of measurement are included in this standard.

1.6 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and to determine the applicability of regulatory limitations prior to use.*

2. Referenced Documents

2.1 *ASTM Standards:*[2]

C 114 Test Methods for Chemical Analysis of Hydraulic Cement

D 1193 Specification for Reagent Water

E 60 Practice for Analysis of Metals, Ores, and Related Materials by Molecular Absorption Spectrometry

E 275 Practice for Describing and Measuring Performance of Ultraviolet and Visible Spectrophotometers

3. Significance and Use

3.1 This test method can be used to determine if soils could have an adverse reaction with hydraulic cement concrete.

4. Apparatus

4.1 *Photometer*—One of the following, given in order of preference:

4.1.1 Nephelometer or turbidimeter,

4.1.2 Spectrophotometer for use at 420 nm with light path of 4 to 5 cm, and

4.1.3 Filter photometer with a violet filter having a maximum near 420 nm and a light path of 4 to 5 cm. Filter photometers and photometric practices prescribed in this test method shall conform to Practice E 60; spectrophotometer practices shall conform to Practice E 275.

4.2 *Stopwatch*, readable to 0.1 minutes.

4.3 *Measuring Spoon*, capacity 0.2 to 0.3 mL.

4.4 *Drying oven*, capable of continuously heating at 110 ± 5 ºC.

4.5 *Balance*, shall be capable of reproducing results within 0.0002 g with an accuracy of ±0.0002 g. Direct-reading balances shall have a sensitivity not exceeding 0.0001 g. Conventional two-pan balances shall have a maximum sensibility reciprocal of 0.0003 g. Any rapid weighing device that may be provided, such as a chain, damped motion, or heavy riders, shall not increase the basic inaccuracy by more than 0.0001 g at any reading and with any load within the rated capacity of the balance.

4.6 *Stirrer*, magnetic variable speed, with a TFE-fluorocarbon coated magnetic stirring rod or an overhead stirrer with a propeller.

5. Reagents and Materials

5.1 *Purity of Reagents*—All reagents shall conform to the specifications of the Committee on Analytical Reagents of the American Chemical Society.[3]

5.2 *Purity of Water*—Unless otherwise indicated, reference to water shall be understood to mean reagent water conforming to Specification D 1193, Type I. Other reagent water types (See Note 1) may be used, provided it is first ascertained that the

[1] This test method is under the jurisdiction of ASTM Committee C09 on Concrete and Concrete Aggregates and is the direct responsibility of Subcommittee on C09.69 Miscellaneous Tests.

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[2] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For Annual Book of ASTM Standards volume information, refer to the standard's Document Summary page on the ASTM website.

[3] *Reagent Chemicals, American Chemical Society Specifications*, American Chemical Society, Washington, DC. For suggestions on the testing of reagents not listed by the American Chemical Society, see *Analar Standards for Laboratory Chemicals*, BDH Ltd., Poole, Dorset, U.K., and the *United States Pharmacopeia and National Formulary*, U.S. Pharmaceutical Convention, Inc. (USPC), Rockville, MD.

***A Summary of Changes section appears at the end of this standard.**

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water is of sufficiently high purity to permit its use without adversely affecting the precision and bias of the test method.

NOTE 1—Type II water was specified at the time of round robin testing of this test method.

5.3 *Barium Chloride*—Crystals of barium chloride ($BaCl_2 \cdot 2H_2O$) screened to 850 to 600 µm. To prepare in the laboratory, spread crystals over a large watch glass, desiccate for 24 h, screen to remove any crystals that are not 850 to 600 µm, and store in a clean, dry jar.

5.4 *Conditioning Reagent*—Place 30 mL of concentrated hydrochloric acid (HCl, sp gr 1.19), 300 mL reagent water, 100 mL 95 % ethanol or isopropanol and 75 g sodium chloride (NaCl) in a container. Add 50 mL glycerol and mix.

5.5 *Sulfate Solution, Standard* (1 mL = 0.100 mg SO_4)—Dissolve 0.1479 g of anhydrous sodium sulfate (Na_2SO_4) in water, and dilute with water to 1 L in a volumetric flask.

5.6 *pH paper*, readable to at least 0.5 pH units.

5.7 *Sodium Hydroxide, (0.1N)*—Dissolve 4 g of sodium hydroxide (NaOH) in water and dilute with water to 1L

5.8 *Hydrochloric Acid (0.1N)*—Dilute 8.6 mL of concentrated hydrochloric acid (HCl sp gr 1.19) to 1L with water

6. Permissible Variations

6.1 Both the referee method and qualified methods as described in Test Methods C 114 are permissible as alternatives to the turbidimetric procedure.

7. Calibration and Standardization

7.1 Prepare standards by diluting 0.0, 2.0, 5.0, 10.0, 15.0, 20.0, 30.0, and 40.0 mL of standard sulfate solution with water to 100-mL volumes in volumetric flasks. These solutions will have sulfate ion concentrations of 0.0, 2.0, 5.0, 10.0, 15.0, 20.0, 30.0, and 40.0 mg/L, respectively. Follow the procedure given in Section 8 using appropriate amounts of the standard sulfate solution prepared in accordance with 5.5 and prepare a calibration curve showing sulfate ion content in mg/L plotted against the corresponding photometer readings.

7.2 A separate calibration curve must be prepared for each photometer and a new curve must be prepared if it is necessary to change the cell, lamp, or filter, or if any other alterations of instrument or reagents are made. Check the curve with each series of tests by running two or more solutions of known sulfate concentrations in the range of 5 to 40 mg SO_4/L.

NOTE 2—The slope of the curve may not be linear below 5 or above 40 mg SO_4/L for this method.

8. Procedure

8.1 Collect at least 100 g of representative soil for analysis. Dry the sample for 18 to 24 h at 110 °C. Crush to pass a 600 µm sieve. In a 400 mL beaker labeled Sample A, put a sample consisting of approximately 30 g. In a second 400 mL beaker labeled Sample B, place a sample of approximately 3 g. Record the mass of each sample to the nearest 0.001 g. Add 250 mL of deionized water to each beaker, and stir on a magnetic stirrer for at least 1.0 h but no more than 1.2 h. Filter the extraction through two dry medium texture filter papers under suction. Do not wash the residue. Repeat the filtration if solution is not clear. Check the pH of the filtrate using pH paper and, if needed, neutralize each filtrate to pH of 7 ± 1 using either 0.1N HCl or 0.1N NaOH.

8.2 Adjust the temperature of the solution in the volumetric flasks to between 20 and 25 °C [68 to 77 °F].

8.3 Use an aliquot of 10 mL for specimen A1, 20 mL for specimen A2, 10 mL for specimen B1, and 20 mL for specimen B2. Dilute to a volume of 100 mL in a volumetric flask and follow the procedure below or Test Methods C 114. Pour the 100 mL into a 250 mL beaker. Add 5.0 mL of conditioning reagent. Mix by stirring with a stir bar and magnetic stirrer. Add 0.3 g of the prepared $BaCl_2$ crystals using a measuring spoon and start the timer.

8.4 Stir exactly 1.0 min, at the same constant speed for all determinations.

8.5 Remove the beaker from the stirrer, pour solution into the cell, and put the cell into the photometer. Record the turbidity at 4.0 min after pouring the solution into the cell.

8.6 Determine the mg of SO_4 from the calibration curve.

9. Calculation or Interpretation of Results

9.1 Calculate the sulfate content (% by mass) for each specimen as follows:

.

$$P = \frac{2.5*M}{A*W} \quad (1)$$

Where:

P = % SO_4 in dried soil
M = mg/L of SO_4 calculated from calibration curve
W = mass of soil placed into 400 mL beaker, in g
A = volume of aliquot specimen, in mL

9.2 Limits of values for results to be valid. (See Note 3)

Specimen	Lower Limit	Upper Limit
A1	0.04%	0.33%
A2	0.02%	0.17%
B1	0.41%	3.33%
B2	0.21%	1.67%

1. Determine which results fall within the above limits
2. Discard those that do not
3. Average all results that comply

NOTE 3—These values were derived from the limits on the sulfate test of 5 to 40 mg/L, and a solubility of sulfate of 1.6 g/L at pH 7 when calcium sulfate is present. The method is not applicable for soils outside this range. For those samples, see the Annex.

10. Report

10.1 Report the average obtained as % sulfate by mass of sample. If milligrams sulfate in kilograms of soil (mg SO_4/kg soil) is desired, multiply % sulfate by 10 000. Report results to nearest 0.01 % or 100 mg/kg.

11. Precision and Bias

11.1 *Precision*—The standard deviation was found to vary with concentration, so therefore, a coefficient of variation was used for the precision statement. The single operator coefficient of variation was found to be 4.4 %. Therefore, results of two properly conducted tests by the same operator on the same material should not differ by more than 12.4 % of their average. The multilaboratory coefficient of variation was found

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to be 21.2 %. Therefore, results of two different laboratories on identical samples of a material should not differ from each other by more than 60 % of their average.

11.2 *Bias*—Since there is no accepted reference material suitable for determining bias, bias can not be determined.

12. Keywords

12.1 hydraulic cement; soil; Sulfate; turbidimeter

ANNEX

(Mandatory Information)

A1. REDUCING THE NUMBER OF SUB-SAMPLES AND SAMPLES OUT OF COMPLIANCE

A1.1 This procedure was written to accommodate laboratories that are not familiar with the soil under test. If prior knowledge is available, a lesser number of sub-samples, and/or dilutions may be used.

A1.2 If a sample falls above 3.33 % sulfate, then different sample masses and/or dilutions can be used. If this procedure is followed, then the mg SO_4 from the turbidimeter reading shall be maintained within 5 to 40 mg/L. If another procedure is used, then validation shall be provided showing that the results are within the linear range of the calibration.

SUMMARY OF CHANGES

Committee C09 has identified the location of selected changes to this test method since the last issue, C 1580 – 05, that may impact the use of this test method. (Approved April 1, 2009)

(*1*) Revised 8.1.

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Designation: C 1581 – 04

Standard Test Method for Determining Age at Cracking and Induced Tensile Stress Characteristics of Mortar and Concrete under Restrained Shrinkage[1]

This standard is issued under the fixed designation C 1581; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope

1.1 This test method covers the laboratory determination of the age at cracking and induced tensile stress characteristics of mortar or concrete specimens under restrained shrinkage. The procedure can be used to determine the effects of variations in the proportions and material properties of mortar or concrete on cracking due to both drying shrinkage and deformations caused by autogenous shrinkage and heat of hydration.

1.2 This test method is not intended for expansive materials.

1.3 The values stated in inch-pound units are to be regarded as standard. The values shown in parenthesis are in SI units and are given for information only.

1.4 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and to determine the applicability of regulatory limitations prior to use.* (**Warning—**Fresh hydraulic cementitious mixtures are caustic and may cause chemical burns to skin and tissue upon prolonged exposure.)

2. Referenced Documents

2.1 *ASTM Standards:* [2]

C 33 Specification for Concrete Aggregates

C 138/C 138 M Test Method for Density (Unit Weight), Yield and Air Content (Gravimetric) of Concrete

C 143/C 143 M Test Method for Slump of Hydraulic-Cement Mortar

C 150 Specification for Portland Cement

C 171 Specification for Sheet Materials for Curing Concrete

C 192/C 192 M Practice for Making and Curing Concrete Test Specimens in the Laboratory

C 387 Specification for Packaged Dry, Combined Materials for Mortar and Concrete

C 595 Specification for Blended Hydraulic Cements

C 1157 Performance Specification for Hydraulic Cement

C 1437 Test Method for Flow of Hydraulic Cement Mortar

F 441 Specification for Chlorinated Poly (Vinyl Chloride) (CPVC) Plastic Pipe, Schedules 40 and 80

2.2 *ASME Standards:*[3]

B 46.1 Surface Texture (Surface Roughness, Waviness and Lay)

3. Summary of Test Method

3.1 A sample of freshly mixed mortar or concrete is compacted in a circular mold around an instrumented steel ring. The compressive strain developed in the steel ring caused by the restrained shrinkage of the mortar or concrete specimen is measured from the time of casting **(1-6)**[4]. Cracking of the test specimen is indicated by a sudden decrease in the steel ring strain. The age at cracking and the rate of tensile stress development in the test specimen are indicators of the material's resistance to cracking under restrained shrinkage.

4. Significance and Use

4.1 This test method is for relative comparison of materials and is not intended to determine the age at cracking of mortar or concrete in any specific type of structure, configuration, or exposure.

4.2 This test method is applicable to mixtures with aggregates of 0.5-in. (13-mm) maximum nominal size or less.

4.3 This test method is useful for determining the relative likelihood of early-age cracking of different cementitious mixtures and for aiding in the selection of cement-based materials that are less likely to crack under retrained shrinkage. Actual cracking tendency in service depends on many variables

[1] This test method is under the jurisdiction of ASTM Committee C09 on Concrete and Concrete Aggregates and is the direct responsibility of Subcommittee C09.68 on Volume Change.

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[2] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

[3] Available from American Society of Mechanical Engineers, 22 Law Drive, Fairfield, NJ 07007-2900.

[4] The boldface numbers in parenthesis refer to the list of references at the end of this test method

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including type of structure, degree of restraint, rate of property development, construction and curing methods, and environmental conditions.

4.4 This test method can be used to determine the relative effects of material variations on induced tensile stresses and cracking potential. These variations can include, but are not limited to, aggregate source, aggregate gradation, cement type, cement content, water content, supplementary cementing materials, or chemical admixtures.

4.5 For materials that have not cracked during the test, the rate of tensile stress development at the time the test is terminated provides a basis for comparison of the materials.

5. Apparatus

5.1 *Steel ring*—Structural steel pipe with a wall thickness of 0.50 ± 0.05 in. (13 ± 0.12 mm), an outside diameter of 13.0 ± 0.12 in. (330 ± 3.3 mm) and a height of 6.0 ± 0.25 in. (152 ± 6 mm) (see Fig. 1). Machine the inner and outer faces to produce smooth surfaces with a texture of 63 microinches (1.6 micrometres) or finer, as defined in ASME B 46.1.

5.2 *Strain gages*—As a minimum, use two electrical resistance strain gages to monitor the strain development in the steel ring. Each strain gage shall be wired in a quarter-bridge configuration (that is, one leg of a full Wheatstone bridge). See Note 1 for additional information.

5.3 *Data acquisition system*—The data acquisition system shall be compatible with the strain instrumentation and automatically record each strain gage independently. The resolution of the system shall be ±0.0000005 in./in. (m/m). The system shall be capable of recording strain data at intervals not to exceed 30 minutes.

NOTE 1—Use of a precision resistor, to balance the leg of the bridge, a strain conditioner input module, to complete the other half of the bridge, and a 16-channel interface board has been found to adequately provide the required resolution of the system.

5.4 *Base*—Epoxy-coated plywood or other non-absorptive and non-reactive surface.

5.5 *Outer ring*—Use one of the following alternative materials as the outer ring.

5.5.1 *PVC pipe*—Schedule 80-18 PVC pipe, in accordance with Specification F 441, with a 16.0 ± 0.12-in. (406 ± 3-mm) inside diameter and 6.0 ± 0.25-in. (152 ± 6-mm) height (see Fig. 1).

5.5.2 *Steel outer ring*—0.125-in. (3-mm) thick steel sheeting formed to obtain a 16.0 ± 0.12-in. (406 ± 3-mm) inside diameter and 6.0 ± 0.25-in. (152 ± 6-mm) height.

5.5.3 *Other materials*—Other suitable non-absorptive and non-reactive materials formed to obtain a 16.0 ± 0.12-in. (406 ± 3-mm) inside diameter and 6.0 ± 0.25-in. (152 ± 6-mm) height.

5.6 *Testing environment*—Store the specimens in an environmentally controlled room with constant air temperature of 73.5 ± 3.5 °F (23.0 ± 2.0 °C) and relative humidity of 50 ± 4 %.

6. Materials and Mixing

6.1 *Materials*:

6.1.1 *Cement*—Cement shall conform to Specifications C 150, C 595, or C 1157.

6.1.2 *Aggregates*—Aggregates shall conform to Specification C 33. The maximum nominal size of the coarse aggregate shall be 0.5-in. (13-mm) or less.

6.2 *Mixing*:

6.2.1 *Concrete mixtures*—Machine mix the concrete as prescribed in Practice C 192/C 192M.

6.2.2 *Mortar mixtures*—Mix the mortar as prescribed in Specification C 387.

7. Properties of Fresh Mixtures

7.1 *Concrete mixtures*—Samples of freshly mixed concrete shall be tested in accordance with the following methods:

7.1.1 *Density (unit weight) and air content*—Test Method C 138/C 138M.

7.1.2 *Slump*—Test Method C 143/C 143M.

7.2 *Mortar mixtures*—Samples of freshly mixed mortar shall be tested in accordance with the following methods:

7.2.1 *Density*—Specification C 387.

7.2.2 *Flow*—Test Method C 1437.

8. Specimen Fabrication and Test Setup

8.1 Bond two strain gages at midheight locations on the interior surface of the steel ring along a diameter; that is, mount the second gage diametrically opposite the first gage. Orient the gages to measure strain in the circumferential direction. Follow the manufacturer's procedures for mounting and waterproofing the gages on the steel ring and connecting leadwires to the strain gage tabs.

8.2 *Test specimen mold*—The test specimen mold consists of a base, an inner steel ring and an outer ring.

8.2.1 Fabricate a base for each test specimen as described in Section 5.4. The top surface of each base shall minimize frictional restraint of the specimen.

NOTE 2—Use of an epoxy coating or a Mylar sheet covering has been found to provide a suitable surface between the test specimen and the base.

8.2.2 Secure the steel ring to the base before casting using bolts with eccentric washers (see Fig. 1).

8.2.2.1 Coat the outer surface of the steel ring with a release agent.

8.2.3 Coat the inner surface of the outer ring with a release agent.

8.2.4 Secure the outer ring to the base to complete the test specimen mold using bolts with eccentric washers. Maintain a 1.50 ± 0.12-in. (38 ± 3-mm) space between the inner steel ring and the outer ring (see Fig. 1).

8.3 Make and cure at least three test specimens for each material and test condition following the applicable requirements of Practice C 192/C 192 M. In making a specimen, place the test specimen mold on a vibrating table, fill the mold in two approximately equal layers, rod each layer 75 times using a ⅜-in. (10-mm) diameter rod, and vibrate each layer to consolidate the mixture.

8.4 Strike-off the test specimen surface after consolidation. Finish with the minimum manipulation necessary to achieve a flat surface. Remove any fresh concrete or mortar that has spilled inside the steel ring or outside the outer ring so that the

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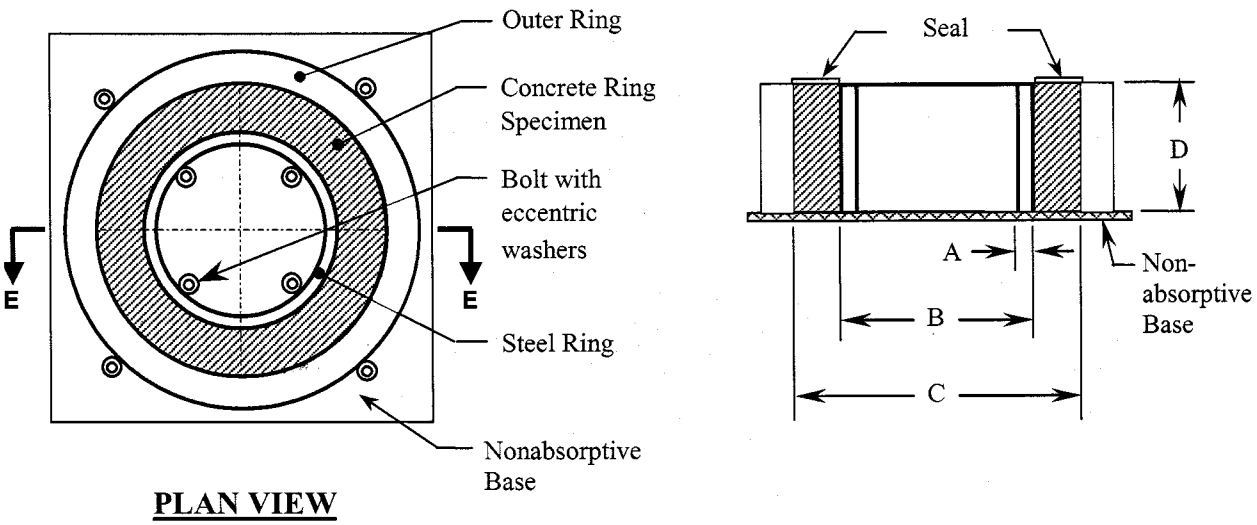

Figure Dimensions	Inch-Pound Units	SI Units
A	0.50 ± 0.12 in.	12.5 ± 0.13 mm
B	13.0 ± 0.12 in.	330 ± 3 mm
C	16.0 ± 0.12 in.	406 ± 3 mm
D	6.0 ± 0.25 in.	150 ± 6 mm

Notes:

1. Not to scale.

2. Bolts with eccentric washers for securing steel ring and outer ring to the base during casting of the test specimen (8 required).

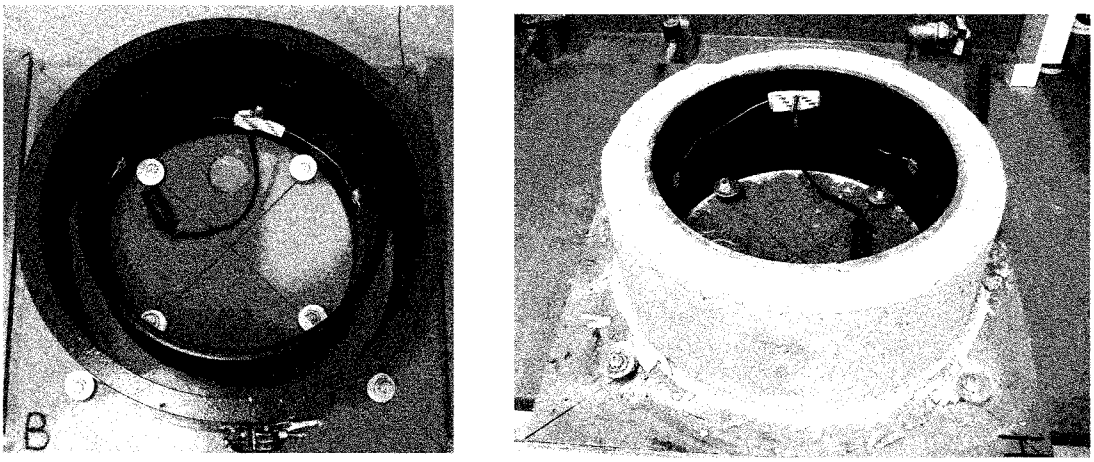

FIG. 1 Test specimen dimensions (top), specimen mold (bottom left), and specimen (bottom right).

base is clean. Transfer the test specimens to the testing environment within 10 minutes after completion of casting.

8.5 Upon transfer of the test specimens to the testing environment, immediately loosen the bolts with eccentric washers and rotate the washers so they are not in contact with the steel ring and outer ring. Within 2 minutes after loosening the bolts with eccentric washers, connect the strain gage lead-wires to the data acquisition system, record the time, and begin monitoring the strain gages at intervals not greater than 30 minutes. Ensure that the strain gage connecting wires are

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clean of loose material before making the connections. The time of the first strain measurement is taken as zero age of the specimen.

NOTE 3—Monitoring the strain gages soon after casting provides information on the internal deformations caused by autogenous shrinkage and heat of hydration **(4)**.

8.6 *Curing*—Unless otherwise specified, test specimens shall be moist cured in the molds for 24 h at 73.5 ± 3.5 °F (23.0 ± 2.0 °C) using wet burlap covered with polyethylene film meeting the requirements of Specification C 171. Begin the curing process within 5 minutes after the first strain reading. If the curing period is longer than 24 h, remove the outer ring at 24 h and continue the curing process.

8.7 At the end of curing and between strain measurements, prepare the test specimens for drying as follows. Complete the test specimen preparation within 15 minutes.

8.7.1 Remove the outer ring, if it is still in place, and/or remove the polyethylene film and burlap.

8.7.2 Gently remove loose material, if present, from the top surface of the test specimen.

8.7.3 Seal the top surface of the test specimen using one of the following alternative procedures.

NOTE 4—With the top surface sealed, and the specimen resting on its base, the test specimen dries from the outer circumferential surface only.

8.7.3.1 *Paraffin wax*—Coat the top surface of the test specimen with molten paraffin wax. Take precautions to ensure that the outer circumference of the test specimen is not coated with the paraffin wax.

NOTE 5—Use of a 1.5-in. (38-mm) wide brush has been found to be an appropriate means of applying the paraffin wax to the top surface of the test specimens.

8.7.3.2 *Adhesive aluminum-foil tape*—Seal the top surface of the test specimen with adhesive aluminum-foil tape.

8.7.4 For the calculations outlined subsequently, the age when drying is initiated is the time when the first strain reading is made after the test specimens have been sealed.

9. Measurement Procedure

9.1 Record the time at the start of strain monitoring as stated in Section 8.5.

9.2 Record ambient temperature and relative humidity of the testing environment every day.

9.3 Monitor the strains in the steel rings at intervals not to exceed 30 minutes, recording the output of each strain gage separately with the data acquisition system. Record both the time and the strain at each measurement. A sudden decrease in compressive strain in one or both strain gages indicates cracking (see Note 6) **(1-5)**. Review the strain measurements and visually inspect the specimens for cracking at time intervals not greater than 3 days.

NOTE 6—The sudden decrease in compressive strain at cracking is usually greater than 30 microstrains (see Fig. 2).

9.4 Monitor and record the strain in the steel rings for at least 28 days after initiation of drying, unless cracking occurs prior to 28 days.

9.5 Plot the steel ring strain for each strain gage against specimen age (see Fig. 2).

10. Calculation

10.1 *Age at cracking*—Determine the age at cracking as the age of each test specimen (measured from the time of casting) when a sudden decrease in strain occurs. Report the age at cracking to the nearest 0.25 day. If a test specimen does not crack within the duration of the test, report the result as “no cracking” and record the age when the test was terminated.

10.1.1 *Average age at cracking*—Calculate the average age at cracking for the test specimens to the nearest day.

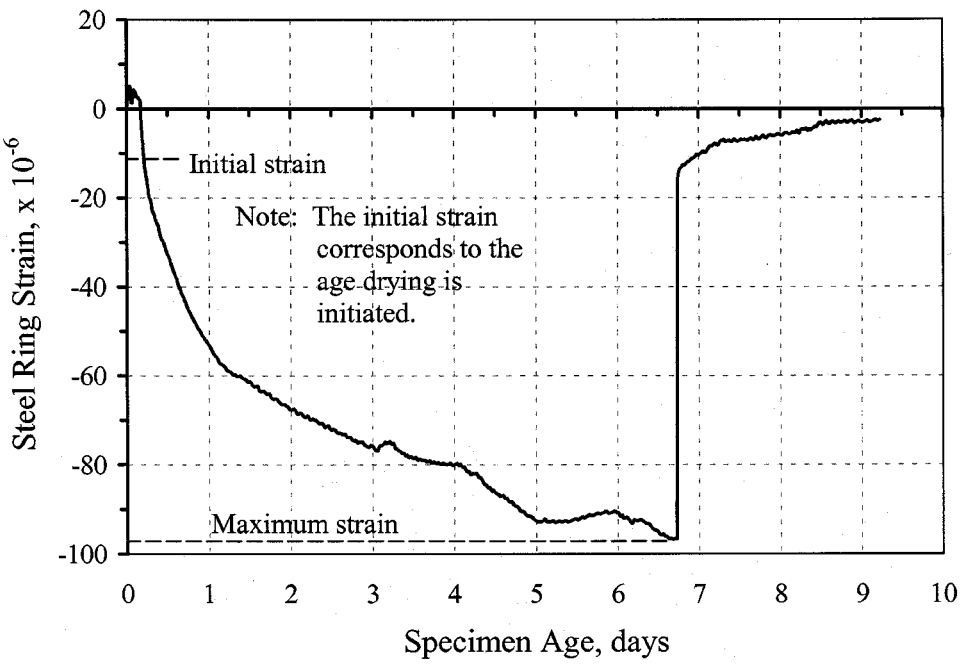

FIG. 2 Steel ring strain versus specimen age.

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10.2 *Initial strain*—From the time-strain data for each strain gage, record the initial strain as the strain corresponding to the age when drying was initiated (see Fig. 2).

10.2.1 *Average initial strain*—Calculate the average initial strain for the test specimens.

NOTE 7—The average initial strain indicates the net effect of deformations caused by early-age autogenous shrinkage and heat of hydration under the restrained conditions **(4)**.

10.3 *Maximum strain*—From the time-strain data for each strain gage on each test specimen, record the maximum strain as the strain corresponding to the age at cracking or the age when the test is terminated.

10.3.1 When cracking occurs, the maximum strain is the strain value just prior to the sudden decrease in strain (see Fig. 2).

10.4 *Average maximum strain,* ϵ_{max}—Calculate the average maximum strain for the test specimens.

NOTE 8—The average maximum strain relates to the magnitude of stress buildup in the material under the conditions of restraint provided in this test method.

10.5 *Stress rate, S*—For the test material, use the following procedure to calculate the rate of tensile stress development that corresponds to the age at cracking or the age when the test is terminated (see Section 4.5).

10.5.1 *Elapsed time, t*—Calculate the elapsed time for each test specimen as the difference between each recorded time and the age drying was initiated.

10.5.2 *Net strain*—For each strain gage on the test specimen, calculate the net strain at each recorded time, starting from the age drying was initiated, as the difference between the strain in the steel ring at each recorded time and the initial strain.

10.5.3 *Strain rate factor,* α—Plot the net strain against the square root of elapsed time for each strain gage on the test specimen and use linear regression analysis to fit a straight line through the data. The strain rate factor is the slope of the line (see Eq 1):

$$\epsilon_{net} = \alpha \sqrt{t} + k \quad (1)$$

where:

ϵ_{net} = net strain, in./in. (m/m),
α = strain rate factor for each strain gage on the test specimen (in./in.)/day$^{1/2}$ ((m/m)/day$^{1/2}$),
t = elapsed time, days, and
k = regression constant

NOTE 9—The square root function has been found to consistently provide a good fit to the test data **(3)**.

10.5.4 *Average strain rate factor,* α_{avg}—Calculate the average strain rate factor for each test specimen.

10.5.5 *Stress rate, q*—Calculate the stress rate in each test specimen at cracking or at the time the test is terminated **(3)**:

$$q = \frac{G\,|\alpha_{avg}|}{2\sqrt{t_r}} \quad (2)$$

where:

q = stress rate in each test specimen, psi/day (MPa/day),
G = 10.47×10^6 psi (72.2 GPa),
$|\alpha_{avg}|$ = absolute value of the average strain rate factor for each test specimen, (in./in.)/day$^{1/2}$ ((m/m)/day$^{1/2}$), and
t_r = elapsed time at cracking or elapsed time when the test is terminated for each test specimen, days

NOTE 10—G in Eq 2 is a constant based on the ring dimensions used in this test method **(1-4)**.

10.5.6 *Average stress rate, S*—Calculate the average stress rate for the test specimens to the nearest psi/day (0.01 MPa/day).

11. Report

Record in the report the following data as pertinent to the variables studied:

11.1 Properties of the material being tested: mixture proportions, air content, slump and density of concrete mixtures, and mixture proportions, flow, and density of mortar mixtures.

11.2 Type and duration of curing;

11.3 Daily ambient temperature and relative humidity data for the test environment;

11.4 Plots of steel ring strain vs. specimen age for each test specimen;

11.5 Average age at cracking;

11.6 Age when the test was terminated for specimens that have not cracked during the test;

11.7 Average initial strain;

11.8 Average maximum strain;

11.9 Plots of net strain vs. square root of elapsed time for each specimen; and

11.10 Average stress rate at cracking or at the time the test was terminated.

12. Precision and Bias

12.1 *Precision*—The precision of this test method has not been determined. The single laboratory repeatability standard deviation of the age at cracking is 2 days. The single laboratory repeatability standard deviation of the stress rate at cracking is 4 psi/day (0.03 MPa/day) for materials with an average stress rate equal to or less than 40 psi/day (0.28 MPa/day). The single laboratory repeatability standard deviation of the stress rate at cracking is 11 psi/day (0.08 MPa/day) for materials with an average stress rate greater than 40 psi/day (0.28 MPa/day) **(3)**.

12.2 *Bias*—No statement on bias is being made since there is no accepted reference material suitable for determining the bias of these procedures.

13. Keywords

13.1 Cracking; restrained shrinkage; ring test; shrinkage; tensile stress.

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APPENDIX

(Nonmandatory Information)

X1. Interpretation of Results

TABLE X1.1 Potential for cracking classification

Net Time-to-Cracking, t_{cr}, days	Average Stress Rate, S (psi/day)	Average Stress Rate, S (MPa/day)	Potential for Cracking
$0 < t_{cr} \leq 7$	$S \geq 50$	$S \geq 0.34$	High
$7 < t_{cr} \leq 14$	$25 \leq S < 50$	$0.17 \leq S < 0.34$	Moderate-High
$14\ t_{cr} \leq 28$	$15 \leq S < 25$	$0.10 \leq S < 0.17$	Moderate-Low
$t_{cr} > 28$	$S < 15$	$S < 0.10$	Low

X1.1 *Net Time-to-cracking, t_{cr}*—Calculate the net time-to-cracking for the material as the difference between the age at cracking and the age drying was initiated. Note that if a test material cracks during the period of curing (that is, before drying is initiated), the net time-to-cracking is zero.

X1.2 *Potential for cracking*—A classification table for cracking potential based on the net time-to-cracking and the average stress rate at cracking or at the time the test is terminated is provided to aid in the comparison of materials **(3)**.

X1.2.1 The net time-to-cracking classification in Table X1.1 can be used to assess the relative performance of materials that crack during the test.

X1.2.2 For materials with average stress rates lower than 15 psi/day (0.10 MPa/day) that have not cracked during the test, the magnitudes of average stress rate can be compared to assess the relative potential for cracking. This allows for an appropriate comparison of materials where time constraint does not permit testing to be carried out until cracking occurs.

REFERENCES

(**1**) See, H. T., Attiogbe, E. K. and Miltenberger, M. A., "Shrinkage Cracking Characteristics of Concrete Using Ring Specimens," *ACI Materials Journal*, V. 100, No. 3, May-June 2003, pp. 239-245.

(**2**) Attiogbe, E. K., See, H. T. and Miltenberger, M. A., "Tensile Creep in Restrained Shrinkage," *Creep, Shrinkage and Durability Mechanics of Concrete and other Quasi-Brittle Materials, Proceedings of the Sixth International Conference*, F.J. Ulm, Z.P. Bazant and F.H. Wittmann (eds.), Elsevier Science, Aug. 2001, pp. 651-656.

(**3**) See, H. T., Attiogbe, E. K. and Miltenberger, M. A., "Potential for Restrained Shrinkage Cracking of Concrete and Mortar," *Proceedings of the ASTM Symposium on Early-Age Cracking of Concrete, Dec. 2003.*

(**4**) Hossain A. B., Pease B. and Weiss W. J., "Quantifying Early-Age Stress Development and Cracking in Low w/c Concrete Using the Restrained Ring Test with Acoustic Emission," *Proceedings of the 82nd Annual Meeting of the Transportation Research Board*, 2003.

(**5**) Whiting, D. A., Detwiler, R. J. and Lagergren, E. S., "Cracking Tendency and Drying Shrinkage of Silica Fume Concrete for Bridge Deck Applications," *ACI Materials Journal*, V. 97, No. 1, January-February 2000, pp. 71-77.

(**6**) Grzybowski, M. and Shah, S. P., "Shrinkage Cracking of Fiber Reinforced Concrete," *ACI Materials Journal*, V. 87, No. 2, March-April 1990, pp. 138-148.

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Designation: C 1582/C 1582M – 04

Standard Specification for Admixtures to Inhibit Chloride-Induced Corrosion of Reinforcing Steel in Concrete[1]

This standard is issued under the fixed designation C 1582/C 1582M; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope

1.1 This specification covers material for use as chloride-corrosion-inhibiting admixtures for concrete.

1.2 Results of the tests conducted to meet this specification are not to be used to rank the expected field performance of various chloride-corrosion-inhibiting admixtures.

1.3 The values stated in either inch-pound or SI units shall be regarded separately as standard. The values stated in each system may not be exact equivalents; therefore, each system must be used independently of the other without combining values in any way.

1.4 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory requirements prior to use.* (**Warning**—Fresh hydraulic cementitious mixtures are caustic and may cause chemical burns to skin and tissue upon prolonged exposure.[2])

2. Referenced Documents

2.1 *ASTM Standards:* [3]

C 39/C 39M Test Method for Compressive Strength of Cylindrical Concrete Specimens

C 78 Test Method for Flexural Strength of Concrete (Using Simple Beam with Third-Point Loading)

C 125 Terminology Relating to Concrete and Concrete Aggregates

C 143/C 143M Test Method for Slump of Hydraulic-Cement Concrete

C 150 Specification for Portland Cement

C 157/C 157M Test Method for Length Change of Hardened Hydraulic-Cement Mortar and Concrete

C 231 Test Method for Air Content of Freshly Mixed Concrete by the Pressure Method

C 260 Specification for Air-Entraining Admixtures for Concrete

C 403/C 403M Test Method for Time of Setting of Concrete Mixtures by Penetration Resistance

C 494/C 494M Specification for Chemical Admixtures for Concrete

C 666 Test Method for Resistance of Concrete to Rapid Freezing and Thawing

C 1152/C 1152M Test Method for Acid-Soluble Chloride in Mortar and Concrete

G 15 Terminology Relating to Corrosion and Corrosion Testing

G 109 Test Method for Determining the Effects of Chemical Admixtures on the Corrosion of Embedded Steel Reinforcing in Concrete Exposed to Chloride Environments

2.2 *American Concrete Institute Standard:*

ACI 211.1 Practice for Selecting Proportions of Normal, Heavyweight, and Mass Concrete[4]

3. Terminology

3.1 *Definitions*—Refer to Terminologies C 125 and G 15 for definitions of terms used in this specification.

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *chloride-ion content*—the acid-soluble chloride-ion content, measured according to Test Method C 1152/C 1152M, of a powder sample taken at a depth equal to the depth of reinforcement.

3.2.2 *completion of testing*—when the following conditions are satisfied: *(1)* the mean integrated macrocell current in the control beams is greater than or equal to 150 coulombs (C); and *(2)* the mean chloride-ion content of the test beams is greater than or equal to the critical chloride-ion content.

3.2.2.1 *Discussion*—Refer to the Appendix for additional explanation of the methodology used to evaluate the performance of a chloride-corrosion-inhibiting admixture.

3.2.3 *control beams*—beams subjected to the treatment in Test Method G 109 that are made from concrete without the chloride-corrosion-inhibiting admixture.

[1] This specification is under the jurisdiction of ASTM Committee C09 on Concrete and Concrete Aggregates and is the direct responsibility of Subcommittee C09.23 on Chemical Admixtures.

Current edition approved Aug. 1, 2004. Published September 2004.

[2] Section on Safety Precautions, Manual of Aggregate and Concrete Testing, *Annual Book of ASTM Standards*, Vol 04.02.

[3] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

[4] Available from the American Concrete Institute, P.O. Box 9094, Farmington Hills, MI 48333-9094.

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3.2.4 *critical chloride-ion content*—the mean chloride-ion content in the unreinforced control beams at t_{50} plus the standard deviation.

3.2.5 *reinforced beams*—beams used to measure macrocell corrosion current according to Test Method G 109.

3.2.6 t_{50}—time when the mean integrated macrocell current of the control beams reaches 50 C.

3.2.7 t_{150}—time when the mean integrated macrocell current of the control beams reaches 150 C.

3.2.8 *test beams*—beams subjected to the treatment in Test Method G 109 that are made from concrete with the chloride-corrosion-inhibiting admixture.

3.2.9 *unreinforced beams*—beams without reinforcement that are subjected to the cyclic ponding and drying treatment in Test Method G 109 and used to determine chloride-ion content.

4. General Requirements

4.1 For initial compliance with this specification, test-concrete made with the chloride-corrosion-inhibiting admixture shall conform to the requirements prescribed in Table 1.

4.2 The purchaser is allowed to require a limited retesting to confirm current compliance of the admixture to specification requirements. The limited retesting covers physical and chemical properties and performance of the admixture.

4.2.1 The physical properties retesting shall consist of uniformity and equivalence tests for infrared analysis, residue by oven drying, and specific gravity as described in Specification C 494/C 494M.

TABLE 1 Physical Requirements of Concrete Containing a Chloride-Corrosion-Inhibiting Admixture

Time of setting, allowable deviation from control, h:min		
Initial: not more than 3:30 earlier or later		
Final: not more than 3:30 earlier or later		
Strength:		
Age	Compressive strength, min. % of control:[A,B]	Flexural strength, min. % of control:[A,B]
3 days	80	80
7 days	80	80
28 days	80	80
6 months	80	
1 year	80	
Length change, max. shrinkage (alternative requirements)[C]		
Percent of control: 135		
Increase over control, percentage points: 0.010		
Relative durability factor, minimum %: 80		

[A] The values in the table include allowance for normal variation in test results. The objective of the 80 % relative strength is to require a level of performance comparable to that of the control concrete. Reinforced concrete, subjected to brackish water, salt spray and/or deicers, requires a water-cement ratio of 0.40 or less for long-term durability. This durability requirement results typically in compressive strengths in excess of what is required structurally. If high-strength concrete is needed for structural purposes, mixture proportions may need to be adjusted when using a chloride-corrosion-inhibiting admixture.

[B] The compressive and flexural strength of the concrete containing the admixture under test at any test age shall not be less than 90 % of that attained at any previous test age. The objective of this limit is to require that the compressive or flexural strength of the concrete containing the admixture under test shall not decrease with age.

[C] For the alternative requirements (see Specification C 494/C 494M), the percent of control limit applies when length change of the control concrete is 0.030 % or greater, and the increase over control limit applies when length change of the control concrete is less than 0.030 %.

4.2.2 The performance property retesting shall consist of time of setting and compressive strength at 3, 7, and 28 days. Purchasers having special requirements are allowed to require additional tests currently in this standard.

4.3 At the request of the purchaser, the manufacturer shall state in writing that the admixture supplied for use in the project is identical in all essential respects, including concentration, to the admixture tested under this specification and found to comply therewith.

4.4 Tests for uniformity and equivalence shall be made on the initial sample in accordance with Specification C 494/C 494M, and the results retained for reference and comparison with the results of tests of samples taken from elsewhere within the lot or subsequent lots of admixture supplied for use in the project.

5. Corrosion-Inhibiting Performance

5.1 In addition to producing concrete that meets the requirements in Table 1, the test admixture must show corrosion-inhibiting performance as summarized in Table 2 when tested in accordance with Test Method G 109 with reinforcing bar depths and mixture proportions as specified in Sections 10 and 11 of this specification. The following requirements must be attained.

5.2 At completion of testing (see 3.2.2), the mean integrated macrocell current of the test beams must be less than or equal to 50 C.

5.3 At completion of testing, the mean corroded area of the top reinforcing steel in the test beams must be less than or equal to ⅓ of the mean corroded area of the top steel in the control beams.

5.4 At the completion of testing, the mean chloride-ion content of the test beams must be greater than or equal to the critical chloride-ion content.

6. Packaging and Package Marking

6.1 When the admixture is delivered in packages or containers, the proprietary name of the admixture and the net mass or volume shall be plainly marked thereon. Similar information shall be provided in the shipping information accompanying packaged or bulk shipments of admixtures.

7. Storage

7.1 Store the admixture so as to permit easy access for proper inspection and identification of each shipment, and in a suitable weather-tight building that will protect the admixture from dampness and freezing.

8. Sampling and Inspection

8.1 Sampling and inspection shall be in accordance with Specification C 494/C 494M.

TABLE 2 Corrosion Inhibiting Requirements

Mean integrated macrocell current of test beams, C[A]	≤ 50
Mean corroded area of test beams, fraction of control[A]	≤ ⅓

[A] At completion of testing using Test Method G 109 and based on a minimum of three specimens of control and test concrete, and discarded specimens are not included.

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9. Rejection

9.1 For initial compliance testing, the purchaser is allowed to reject the admixture if it fails to meet any of the applicable requirements for this specification.

9.2 For limited retesting, the purchaser is allowed to reject the admixture if it fails to meet any of the requirements of the Uniformity and Equivalence Section of Specification C 494/C 494M and of the applicable parts of Table 1 of this standard.

9.3 An admixture stored at the point of manufacture, for more than 6 months prior to shipment, or an admixture in local storage in the hands of a vendor for more than 6 months, after completion of tests, shall be retested before use when requested by the purchaser and is allowed to be rejected if it fails to conform to any of the applicable requirements of this specification.

9.4 Packages or containers varying more than 5 % from the specified mass or volume are allowed to be rejected. If the average mass or volume of 50 packages taken at random is less than that specified, the entire shipment is allowed to be rejected.

9.5 When the admixture is to be used in non-air-entrained concrete, it shall be rejected when the purchaser desires if the test concrete containing it has an air content greater than 3.5 %; when the admixture is to be used in air-entrained concrete, it shall be rejected when the purchaser desires if the test concrete containing it has an air content greater than 7.0 %.

TEST METHODS

NOTE 1—These tests are based on arbitrary stipulations which make possible highly standardized testing in the laboratory and are not intended to simulate actual job conditions.

10. Test Specimens

10.1 Two types of concrete are used to make test specimens. One, the control concrete, is made without the chloride-corrosion-inhibiting admixture. The other concrete, the test concrete, is made with the chloride-corrosion-inhibiting admixture. Do not use cement that causes the air content of the control concrete made without the subject admixture to exceed 3.0 %.

10.2 Make specimens for measuring compressive strength, flexural strength, resistance to freezing and thawing, and length change in accordance with Specification C 494/C 494M. Prepare three separate batches of each concrete mixture in accordance with Specification C 494/C 494M, and report the mean test results from the three batches.

10.3 Make specimens for corrosion testing and chloride-ion analysis from a separate batch of each concrete. For each concrete mixture, make at least three beams with steel reinforcement in accordance with Test Method G 109, and make at least three beams of the same size without reinforcement (Note 2). The reinforcement shall be deformed bars designation No. 4 [13] with a nominal diameter of ½ in. [12.7 mm] and the cover depth shall be 1.0 ± 0.1 in. [25 ± 3 mm]. Subject all beams to the same cyclic ponding and drying treatment described in Test Method G 109.

NOTE 2—The reinforced beams are used to determine the macrocell corrosion current as a function of time, and the unreinforced beams are used to determine the chloride-ion content at specified times.

11. Specimen Preparation

11.1 *Mixture Proportions*—Proportion all concrete mixtures to conform to the requirements described in 11.1.1 through 11.1.5. Unless otherwise specified, include the chloride-corrosion-inhibiting admixture with the first increment of mixing water that is added to the mixer.

11.1.1 The water-cement ratio shall be 0.50 ± 0.01 and the cement content shall be between 550 and 650 lb/yd^3 [325 and 385 kg/m^3]. The test and control mixtures are to have water and cement contents equivalent to within ± 1 % by mass.

11.1.2 Cement shall meet the requirements of a Type II cement according to Specification C 150.

NOTE 3—Type II cement is used to limit the tricalcium aluminate (C_3A) content and is not intended as design guidance for specific projects.

11.1.3 The grading of the coarse aggregate shall comply with size number 7 or 8 of Specification C 33, that is, the nominal maximum size is ½ in. [12.5 mm] or ⅜ in. [9.5 mm]. For the first trial mixture, refer to ACI 211.1 for guidance on the amount of coarse aggregate to use based on the fineness modulus of the fine aggregate.

NOTE 4—Tabulated values of coarse aggregate content given in ACI 211.1 are intended to ensure workable mixtures with the least favorable combinations of aggregate likely to be used. It is suggested, therefore, that for a closer approximation of the required proportions, the volume of coarse aggregate (in the dry-rodded condition) per unit volume of concrete selected from ACI 211.1 be increased by about 0.07 for the first trial mixture.

11.1.4 For air-entrained concrete, the air content of the fresh concrete shall be 6 ± 1 % as measured according to Test Method C 231. For concrete that is not air-entrained, the air content of the fresh concrete shall be less than 3.5 % as measured according to Test Method C 231.

11.1.5 The slump shall be greater than or equal to 3 in. [75 mm] and less than or equal to 8 in. [200 mm] as measured according to Test Method C 143/C 143M. The use of a water-reducing admixture is not prohibited to obtain the required slump, but the same quantity must be used in the control concrete and in the test concrete.

11.2 *Quantity of Concrete*—Prepare concrete mixtures with and without the chloride-corrosion-inhibiting admixture in sufficient volume to produce specimens needed for performing the tests listed in Table 1 and for corrosion testing.

NOTE 5—The required quantity of concrete for each batch depends on the number of extra specimens that are cast. It is recommended that more than the required minimum number of specimens be cast in case some of them are faulty. If one time of setting specimen and the minimum number of 6- by 12-in. [150- by 300-mm] cylinders, 3- by 4- by 16-in. [75- by 100- by 410-mm] freezing and thawing prisms, 6- by 6- by 21-in. [150- by 150- by 535-mm] flexural beams, and 3- by 3- by 11.25-in. [75- by 75- by 285-mm] length-change prisms are made, the required volume of concrete is 3.1 ft^3 [0.087 m^3]. Twice this amount is used typically to allow for extra specimens. The minimum of three reinforced beams and three unreinforced beams for corrosion testing requires about 1.1 ft^3 [0.029 m^3] of concrete. Additional unreinforced beams are recommended for chloride ion analysis in the event that specimens are faulty, and additional reinforced beams are recommended to ensure that the criterion in 14.6.3 is satisfied at the completion of testing. Each additional beam requires about 0.2 ft^3 [0.005 m^3] of concrete.

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11.3 *Admixture Dosage*—Add the chloride-corrosion-inhibiting admixture at the dosage recommended by the manufacturer.

11.4 *Specimen Fabrication and Curing*—Make and cure test specimens for measuring strength, resistance to freezing and thawing, and length change in accordance with Specification C 494/C 494M. Make and cure specimens for corrosion testing and chloride-ion determination in accordance with Test Method G 109.

12. Tests of Freshly Mixed Concrete

12.1 *Slump*—Test Method C 143/C 143M.

12.2 *Air Content*—Test Method C 231.

12.3 *Time of Setting*—Test Method C 403/C 403M. Store the time-of-setting specimens at 73.5 ± 3.5 °F [23.0 ± 2.0 °C] during the test period.

13. Tests of Hardened Concrete

13.1 *Compressive Strength*—Test Method C 39/C 39M. Measure compressive strength at ages of 3 days, 7 days, 28 days, 6 months, and 1 year. For each test age, divide the mean strength of the test concrete specimens by the mean strength of the control concrete specimens and multiply the quotient by 100.

13.2 *Flexural Strength*—Test Method C 78. Measure flexural strength at ages of 3, 7, and 28 days. For each test age, divide the mean strength of the test concrete specimens by the mean strength of the control concrete specimens and multiply the quotient by 100.

13.3 *Resistance to Freezing and Thawing*—Test Method C 666, Procedure A. Calculate the relative durability factor in accordance with Specification C 260.

13.4 *Length Change*—Test Method C 157/C 157M as modified by Specification C 494/C 494M.

14. Corrosion Testing

14.1 *General*—Test the corrosion performance of the reinforced control beams and the reinforced test beams according to Test Method G 109, except as noted in this specification. Subject the reinforced and unreinforced beams to the same cyclic ponding and drying process that is described in Test Method G 109. Chloride-ion content measurements are made when the mean integrated macrocell current in the control beams reaches 50 C and 150 C. The criteria for completion of testing are specified in 3.2.2.

NOTE 6—Appendix X1 provides a flowchart to explain further the corrosion testing procedure. The flowchart includes references to the corresponding section numbers in this specification.

14.2 *Tests at* t_{50}—Measure the integrated macrocell current in the reinforced beams as specified in Test Method G 109. When the mean integrated macrocell current of the reinforced control beams reaches 50 C, determine the mean chloride-ion content of the companion unreinforced control beams in accordance with 14.2.1 and 14.2.2.

14.2.1 Obtain powder samples for chloride-ion content analysis by drilling into the sides of three unreinforced control beams at the level of the reinforcing steel in the reinforced beams. For each beam, drill holes at three locations directly below the plastic dam (see Fig. 1(a)). Use a ½-in. [13-mm] drill bit, and locate the center of each hole so that it coincides with the depth of the center of the bar in the reinforced beams. Discard the powder obtained from the outermost 1.0 ± 0.1 in. [25 ± 3 mm] of each hole, clean powder from the drill bit, and collect at least a 10-g powder sample from each hole. Discontinue cyclic ponding of the tested unreinforced control beam after chloride-ion content sampling.

14.2.2 Measure the acid-soluble chloride-ion content of each powder sample in accordance with Test Method C 1152/C 1152M. Compute the mean and standard deviation of the nine chloride-ion measurements. Calculate the critical chloride-ion content as the mean plus the standard deviation of the nine measurements.

14.3 *Tests at* t_{150}—Continue the cyclic ponding and drying process and measurement of the integrated macrocell current in accordance with Test Method G 109. When the mean integrated macrocell current of the reinforced control beams reaches 150 C, determine the mean chloride-ion content of the unreinforced test beams in accordance with 14.3.1 and 14.3.2.

14.3.1 Obtain one 10-g powder sample from each of three unreinforced test beams using the sampling procedure in 14.2.1. Drill the hole in each beam so that it is below the dam and near one end (see Fig. 1(b)). If additional cyclic ponding and drying is required in accordance with 14.5, fill the holes with the epoxy of the kind that was used to seal the beams. Ensure that surfaces surrounding the holes are sealed.

14.3.2 Measure the acid-soluble chloride-ion content of each powder sample in accordance with Test Method C 1152/C 1152M. Calculate the mean chloride-ion content of the three samples from the test beams.

14.4 *Completion of Testing*—If the mean chloride-ion content of the test beams at t_{150} is greater than the critical chloride-ion content, testing is completed. Perform a destructive examination of the control and test beams as described in 14.6.

14.5 *Additional Testing*—If the mean chloride-ion content of the test beams at t_{150} is less than the critical chloride-ion content and the mean integrated macrocell current of the test beams is less than 50 C, continue corrosion testing according to Test Method G 109 for the additional number of cycles determined in 14.5.1. If the mean integrated macrocell current of the test beams at t_{150} is more than 50 C, the admixture fails to meet this specification.

14.5.1 Based on the mean chloride-ion content of the test beams determined at t_{150} and assumed chloride-ion content of zero at start of testing, estimate the additional cyclic ponding time required to obtain a chloride-ion content equal to or greater than the critical chloride-ion content. Use linear extrapolation for this estimate. If the estimated time is more than 12 cycles of ponding and drying, obtain powder samples according to 14.5.2 after an additional testing time of 12 cycles. If one or more of the control beams crack before reaching the planned additional cycles of ponding and drying, stop testing, obtain powder samples from the unreinforced test beams according to 14.5.2, and perform a destructive examination of the control and test beams as described in 14.6.

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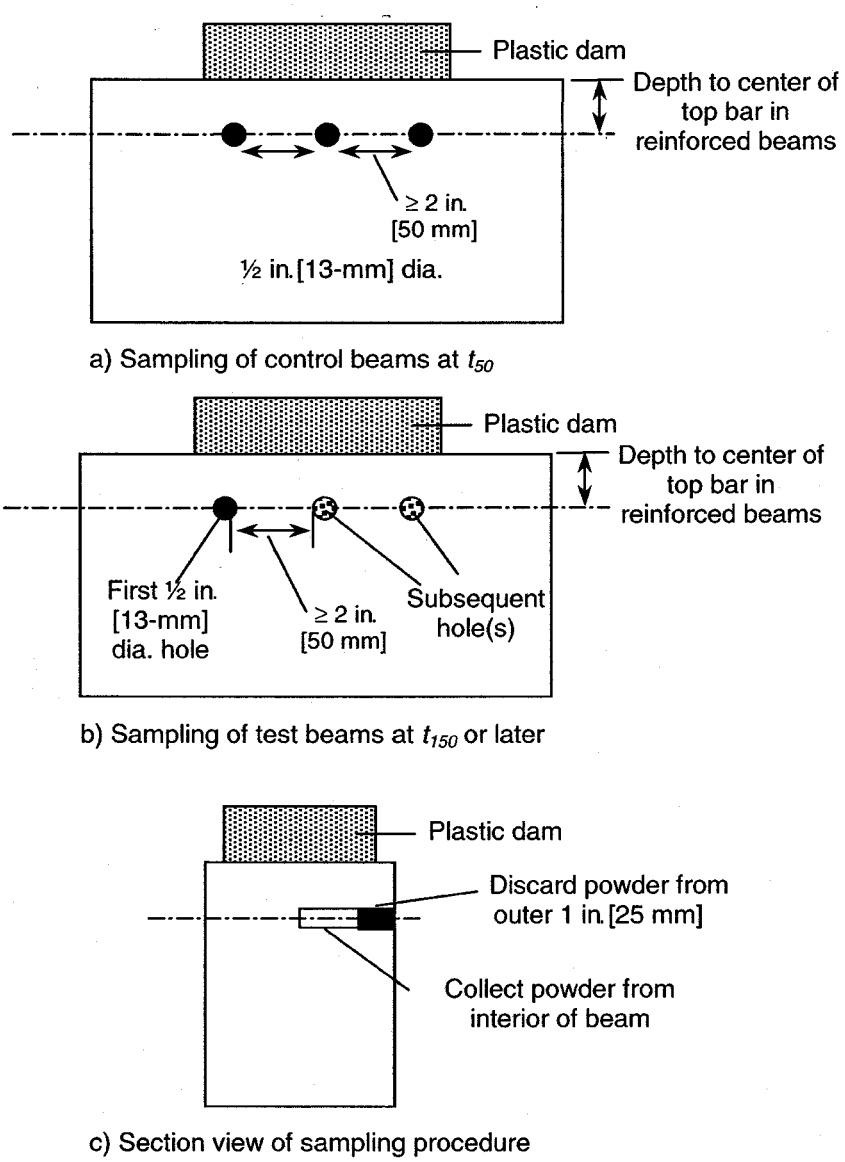

FIG. 1 Sampling of Unreinforced Beams for Chloride-Ion Content Determination

14.5.2 After additional cyclic ponding and drying, determine the chloride-ion content in the test beams by sampling from one drill hole in each of three unreinforced test beams as described in 14.2.1. Locate the center of the new hole in each beam so that it is below the dam but no closer than 2 in. [50 mm] to the hole drilled previously (see Fig. 1(b)). If additional cyclic ponding and drying is required in accordance with 14.5.6, fill the holes with epoxy, and ensure that surfaces surrounding the holes are sealed.

14.5.3 Measure the acid soluble chloride-ion content of each powder sample in accordance with Test Method C 1152/C 1152M. Calculate the mean chloride-ion content of the three samples from the test beams.

14.5.4 If the mean chloride-ion content calculated in 14.5.3 is equal to or greater than the critical chloride-ion content, testing is completed. Perform a destructive evaluation of the control and test beams in accordance with 14.6.

14.5.5 If the mean chloride-ion content is less than the critical chloride-ion content and the control beams are not cracked, make a new estimate of the time to reach the critical chloride-ion content. Repeat the procedure starting at 14.5.2 until the mean chloride-ion content is equal to or greater than the critical chloride-ion content, or the total time of corrosion testing exceeds five years.

14.5.6 If testing is stopped because of cracking in control beams and the mean chloride-ion content of the test beams is equal to or greater than the critical chloride-ion content, perform a destructive evaluation in accordance with 14.6.

14.6 *Destructive Examination*—Cut each reinforced beam longitudinally above and below the top reinforcing bar using a water-cooled diamond tipped concrete saw. Use care not to cut the bar. Break the test beam in half and extract the top reinforcing bar. Avoid wetting the top bar during extraction. If

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the bar is wetted, dry immediately and store in an environment at less than 50 % relative humidity until inspection according to 14.6.2.

14.6.1 Make additional saw cuts, and extract the bottom bars from each beam. If the bars are wetted, dry immediately and store in an environment at less than 50 % relative humidity until inspection according to 14.6.2.

14.6.2 Visually inspect the top- and bottom-reinforcing bars, photograph the bars, and estimate the percentage of corroded area on each bar as instructed in Test Method G 109.

14.6.3 If the corroded area on the bottom bars from any test beam is greater than 1 % of the exposed area, the test results from that beam are invalid. Substitute the results of a valid backup beam if available.

NOTE 7—Bottom bar corrosion can occur in situations such as: when an aggressive agent is present in the concrete; the exterior coating does not properly seal around the bottom bars; or the bottom of the test specimen is cracked.

14.7 *Evaluation of Results*—At completion of testing, evaluate whether the test concrete satisfies the performance criteria.

14.7.1 If the mean integrated macrocell current of the test beams is less than 50 C, the performance criterion in 5.2 is satisfied.

14.7.2 If the mean percentage of corroded area of the top reinforcing bars extracted from the test beams is less than ⅓ the mean percentage of corroded area of the control beams, the performance criterion in 5.3 is satisfied.

14.7.3 If after five years of corrosion testing, the chloride-ion content in the test beams is less than the critical chloride-ion content, the admixture does not qualify as a chloride-corrosion-inhibiting admixture under this specification.

14.7.4 If one or more of the control beams crack and the mean chloride-ion content of the test beams is less than the critical chloride-ion content, the admixture does not qualify as a chloride-corrosion-inhibiting admixture under this specification.

15. Report

15.1 For each mixture, report:

15.1.1 The mixture proportions, cement content, water-cement ratio, quantities of admixtures, slump, and air content.

15.1.2 The mean values of the tests listed in Table 1.

15.1.3 Corrosion data including individual macrocell current values for all beams as described in Test Method G 109.

15.1.4 The times in weeks from start of cyclic ponding and drying for control beams to reach an integrated macrocell current of 50 C and 150 C (t_{50} and t_{150}, respectively) and the total time at completion of testing, if longer than t_{150}.

15.1.5 The mean integrated macrocell current of the reinforced control and test beams at completion of testing calculated according to Test Method G 109.

15.1.6 The percentage of corroded area for all reinforcing bars, and include photographs of the extracted reinforcing bars.

15.1.7 The average percentage of corroded area for the control beams and the test beams.

15.1.8 The acid-soluble chloride-ion content values, the calculated mean, and standard deviation from the unreinforced control beams sampled at t_{50}.

15.1.9 The acid-soluble chloride-ion content values and the calculated mean from unreinforced test beams at t_{150}, any intermediate sampling time, and the completion of testing.

16. Keywords

16.1 admixture; chloride; corrosion inhibitor; corrosion testing; macrocell current

APPENDIX

(Nonmandatory Information)

X1. TEST PROTOCOL FOR EVALUATING CHLORIDE-CORROSION-INHIBITING ADMIXTURES

X1.1 General

X1.1.1 The testing procedure used to evaluate a chloride-corrosion-inhibiting admixture is complex. This appendix provides supplementary information to explain the process.

X1.1.2 When reinforced concrete is exposed to chloride ions, the reinforcement is vulnerable to corrosion if the chloride-ion content exceeds a threshold value. For the same exposure, the onset of corrosion can be delayed by restricting the penetration of chloride ions or by altering the electrochemical reactions at the surface of the steel bars so that higher chloride-ion content is needed to initiate corrosion. The latter condition is the basis of a chloride-corrosion-inhibiting admixture covered by this specification. An admixture that only restricts chloride-ion penetration, under the prescribed testing conditions, is not classified as a chloride-corrosion-inhibiting admixture.

X1.1.3 Performance of chloride-corrosion-inhibiting admixtures is evaluated by means of Test Method G 109. Beams are made with a top reinforcing bar and two bottom reinforcing bars. The top bar is connected to the bottom bars by an external circuit. Under the conditions of test, a corrosion macrocell is created in which the top bar (the anode) undergoes corrosion. The rate of corrosion is evaluated by measuring the current between the top bar and the bottom bars. Corrosion is induced by subjecting the beams to a cyclic treatment composed of ponding with a salt solution and air drying. At the middle of the ponding cycle, the corrosion current is measured. From the history of current versus time, the total charge is calculated (integrated macrocell current), and this quantity (measured in coulombs) is indicative of the amount of corrosion that has occurred from the start of the cyclic ponding and drying treatment.

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X1.1.4 The corrosion performance of the test concrete containing the chloride-corrosion-inhibiting admixture is compared with that of the control concrete. The two mixtures are similar in all respects, except for the presences of chloride-corrosion-inhibiting admixture. For each mixture, two types of beams are used: one is reinforced in accordance with Test Method G 109 and the other is made without reinforcement. The reinforced beams are used to evaluate the corrosion activity, and the unreinforced beams are used to evaluate the chloride-ion content at a depth corresponding to the depth of the top reinforcement. Both types of beams are subjected to the same ponding and drying treatment. At least three replicate beams of each type are used for each measurement, but it is recommended that more beams be made in case specimens have to be discarded. The evaluation can be time-consuming and costly. Therefore, it is wise to have back up specimens rather than having to repeat the entire evaluation.

X1.2 Completion of Testing

X1.2.1 The cyclic ponding and drying procedure is continued and corrosion current is measured according to Test Method G 109 until the mean integrated macrocell current in the reinforced control beams reaches 50 coulombs (C). The time when this occurs is called t_{50}, and at this time the chloride-ion content is measured in the unreinforced control beams. Powder samples are obtained by drilling holes in the sides of the unreinforced control beams at a depth corresponding to the depth of the steel reinforcement in the test beams. The three powder samples from each beam are tested for acid-soluble chloride ion according to Test Method C 1152/C 1152M. The average and standard deviation(s) of the nine chloride-ion determinations are calculated. The standard deviation of these determinations is used to establish the critical chloride-ion content in the test beams (see the definitions in 3.2).

X1.2.2 The cyclic ponding and drying treatment is continued until the mean integrated macrocell current in the control beams reaches 150 C, and this time is called t_{150}. At t_{150} the chloride-ion contents of the test beams are measured and the mean integrated macrocell current of the test beams is determined. One powder sample is taken from each of three beams. The average chloride-ion content in the unreinforced test beams determines whether corrosion testing is completed. If the mean chloride-ion content in the test beams exceeds the critical chloride-ion content, testing is completed and the corrosion performance of the test concrete is evaluated. This situation is indicated as Case 1 on the left side of Fig. X1.1. The top graph is a schematic plot of the integrated macrocell current versus time, and the lower graph is a schematic of the chloride-ion content. The bottom graph shows that at time t_{150} the chloride-ion content in the test beams exceeds the critical value.

X1.2.3 If at t_{150} the mean chloride-ion content in the test beams is less than the critical value, the cyclic-ponding drying treatment is continued until the chloride-ion content exceeds the critical value. This condition is indicated as Case 2 on the right side of Fig. X1.1. When the chloride-ion content in the unreinforced test beams exceeds the critical value, the corrosion performance of the test concrete is evaluated. If one or more control beams crack, testing is stopped and the chloride-ion content of the test beams is evaluated. If the chloride-ion content is less that the critical value, the admixture is not classified as a chloride-corrosion-inhibiting admixture. In addition, if after 5 years of corrosion testing, the chloride-ion content of the test beams is less than the critical value, the admixture is not classified as a chloride-corrosion-inhibiting admixture.

X1.3 Chloride-Corrosion-Inhibiting Criteria

X1.3.1 At the completion of testing, the mean chloride-ion content of the test beams has to be equal to or greater than the critical value. The integrated macrocell current of the test beams is calculated and the corrosion area of the top steel is compared with the control beams. To satisfy this specification, two conditions have to be satisfied:

X1.3.1.1 The integrated macrocell current of the test beams has to be less than or equal to 50 C; and

X1.3.1.2 The mean percentage of corroded area of the top bar has to be less than ⅓ of the mean percentage of corroded area in the control beams.

X1.4 Flowchart

X1.4.1 Fig. X1.2 is a flow chart to summarize the corrosion testing process used to evaluate a chloride-corrosion-inhibiting admixture. The numbers within the boxes refer to the sections within the text.

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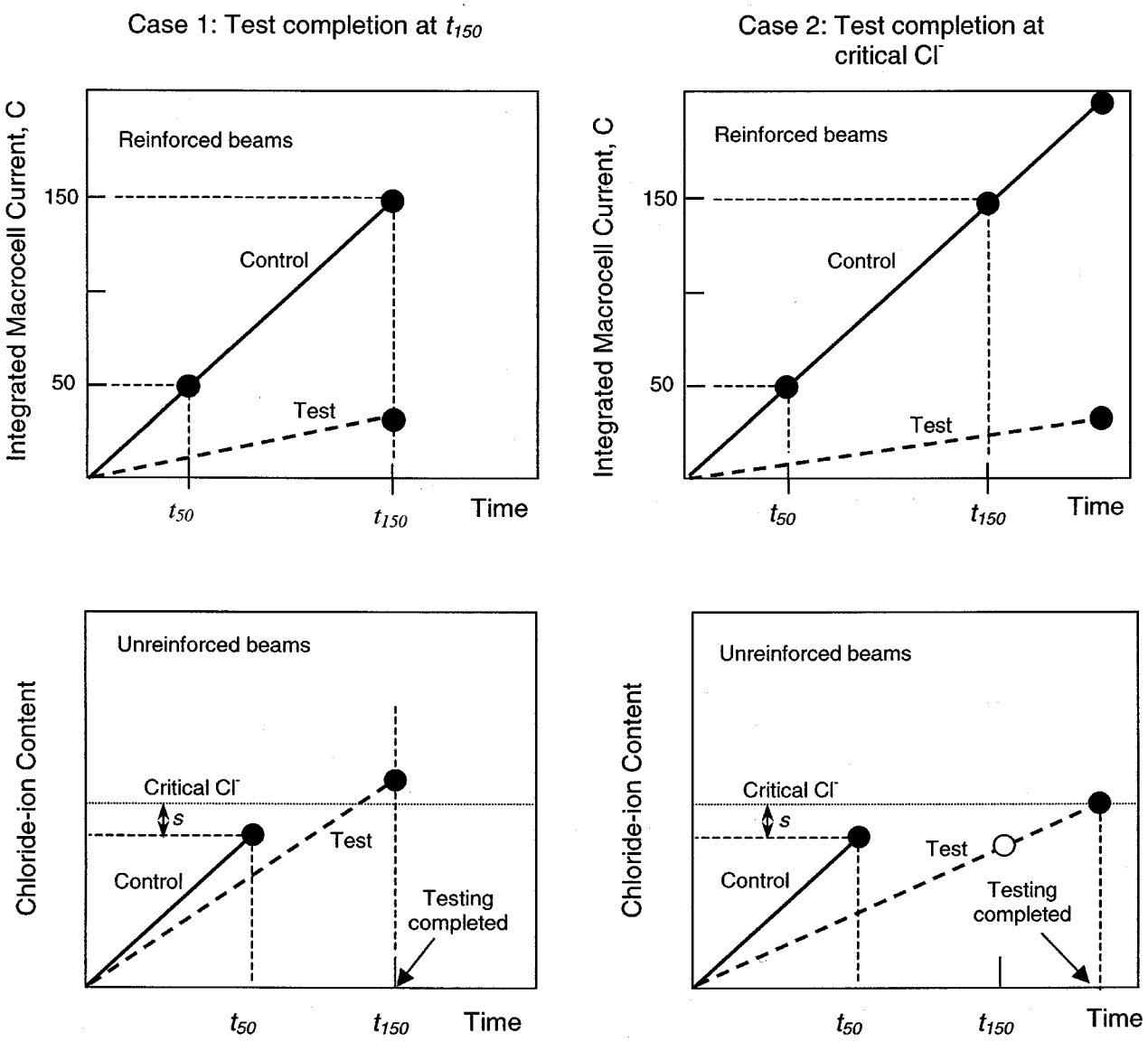

NOTE—The top graphs show the integrated corrosion current history, and the bottom graphs show the chloride-ion content.

FIG. X1.1 Schematic to Illustrate when Corrosion Testing is Completed and to Illustrate the Required Performance in Terms of Integrated Macrocell Current

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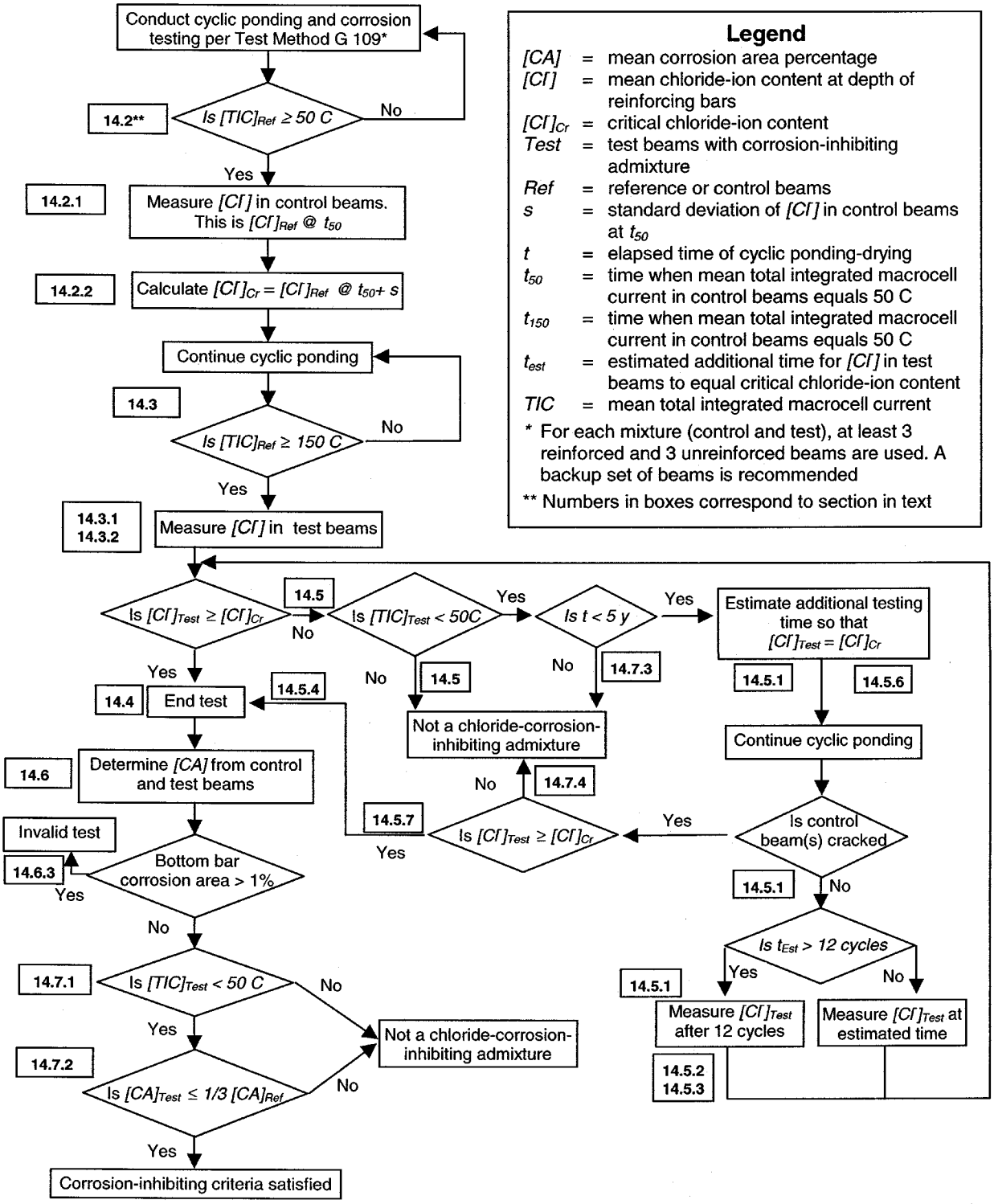

FIG. X1.2 Flowchart of Corrosion Testing Procedure

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Designation: C 1583/C 1583M – 04ε1

Standard Test Method for Tensile Strength of Concrete Surfaces and the Bond Strength or Tensile Strength of Concrete Repair and Overlay Materials by Direct Tension (Pull-off Method)[1]

This standard is issued under the fixed designation C 1583/C 1583M; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

ε[1] NOTE—The designation was changed editorially to agree with the existing values statement in the Scope in March 2008.

1. Scope

1.1 This test method is suitable for both field and laboratory use to determine one or more of the following:

1.1.1 The near-surface tensile strength of the substrate as an indicator of the adequacy of surface preparation before application of a repair or overlay material.

1.1.2 The bond strength of a repair or an overlay material to the substrate.

1.1.3 The tensile strength of a repair or overlay material, or an adhesive used in repairs, after the material has been applied to a surface.

1.2 The values stated in either SI units or inch-pound units are to be regarded separately as standard. The values stated in each system may not be exact equivalents; therefore, each system shall be used independently of the other. Combining values from the two systems may result in non-conformance with the standard.

1.3 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

2. Referenced Documents

2.1 *ASTM Standards:* [2]

C 125 Terminology Relating to Concrete and Aggregates

C 881/C 881M Specification for Epoxy-Resin Base Bonding Systems for Concrete

C 900 Test Method for Pullout Strength of Hardened Concrete

3. Terminology

3.1 *Definitions*—For definitions of terms used in this test method refer to Terminology C 125 and ACI 503R[3].

4. Summary of Test Method

4.1 This test is performed on the surface of a prepared concrete base before application of a concrete repair or overlay material, or on the surface of a concrete repair or overlay material after the material has been applied to the prepared concrete surface.

4.2 The test specimen is formed by drilling a shallow core into and perpendicular to the surface of the substrate, and leaving the intact core attached to the concrete. A steel disk is bonded to the top surface of the test specimen.

4.3 A tensile load is applied to the steel disk until failure occurs. The failure load and the failure mode are recorded and the nominal tensile stress at failure is calculated.

5. Significance and Use

5.1 This test method determines the tensile strength of concrete near to the prepared surface, which can be used as an indicator of the adequacy of surface preparation before applying a repair or an overlay material.

5.2 When the test is performed on the surface of a repair or an overlay material, it determines the bond strength to the substrate or the tensile strength of either the overlay or substrate, whichever is weaker.

5.3 The method may also be used to evaluate the adhesive strength of bonding agents.

5.4 When the test is performed on the surface of a material applied to the substrate, the measured strength is controlled by the failure mechanism requiring the least stress. Thus it is not possible to know beforehand which strength will be measured by the test. For this reason, the failure mode has to be reported

[1] This test method is under the jurisdiction of ASTM Committee C09 on Concrete and Concrete Aggregates and is the direct responsibility of Subcommittee C09.25 on Organic Materials for Bonding.

Current edition approved Feb. 1, 2004. Published March 2004.

[2] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

[3] ACI 503R-93 (Reapproved 1998), "Use of Epoxy Compounds with Concrete," American Concrete Institute (ACI), P.O. Box 9094, Farmington Hills, MI 48333.

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for each individual test result, and tests results are averaged only if the same failure mode occurs.

6. Apparatus

6.1 *Core Drill*, for preparing test specimen.

6.2 *Core Barrel*, with diamond impregnated bits - nominally 50 mm [2.0 in.] inside diameter.

6.3 *Steel Disk*, nominally 50 mm [2.0 in.] diameter and at least 25 mm [1.0 in.] thick.

6.4 *Tensile Loading Device*, with a load-indicating system and nominal capacity of 22 k N (5,000 lbf) and capable of applying load at the specified rate. The loading device includes a tripod or bearing ring for distributing the force to the supporting surface.

6.4.1 Within the operating range, the indicated tensile force shall be within ± 2 % of the force measured by a calibrated testing machine or load cell. Verify the tensile loading device at least once a year and after repairs and adjustments.

NOTE 1—See Test Method C 900 for suitable verification schemes.

6.4.2 A coupling device shall be used to connect the steel disk to the tensile loading device. The coupling device shall be designed to withstand the tensile load capacity without yielding, and to transmit the tensile force parallel to and in line with the axis of the cylindrical test specimen without imparting torsion or bending to the test specimen.

7. Materials

7.1 Epoxy adhesive material for bonding the steel disk to the test specimen. It shall be a fast-curing paste or gel meeting the requirements of Specification C 881/C 881M for Type IV, Grade 3, except that a shorter gel time is permitted.

8. Sampling

8.1 Three individual test results with similar failure modes shall be obtained for each test site.

8.2 The field test site shall be large enough so that all methods to be used in the full-scale repair or overlay operation, including surface preparation, are used for preparing test specimens. The test site shall be at least 1 by 1 m [3 by 3 ft]. It shall be selected to be representative of actual field conditions.

8.3 If concrete cover is less than 20 mm [¾ in.], do not locate test specimens directly over bars in the layer of reinforcement nearest to the surface.

NOTE 2—The location of reinforcement may be established using reinforcement locators or metal detectors. Follow the manufacturer's recommendations for proper operation of such devices.

8.4 The center-to-center distance of adjacent test specimens shall be at least two disk diameters. The distance from the center of a test specimen and a free edge of the test object shall be at least one disk diameter.

9. Preparation of Surface

9.1 *Preparation to Determine Tensile Strength of Substrate*:

9.1.1 Remove all surface contaminants and loose or deteriorated concrete to obtain a clean, undamaged surface.

9.1.2 Prepare the surface using the same method to be used in the full-scale repair or overlay.

9.1.3 The surface must be in the same condition regarding dryness and cleanliness as specified for the actual work.

9.2 *Preparation to Determine Bond or Tensile Strength of the Repair or Overlay Material*:

9.2.1 Prepare the surface in accordance with 9.1.

9.2.2 Apply and cure the repair or overlay material in accordance with specifications for the repair or overlay operation.

10. Preparation of Test Specimen

10.1 Using the coring equipment, drill a circular cut perpendicular to the surface. For tests of substrate concrete, drill to a depth of at least 10 mm [0.5 in.]. For tests of repair or overlay materials, drill to at least 10 mm [0.5 in.] below the concrete-overlay interface. The test specimen is left intact, attached to the substrate. Measure the diameter of the test specimen in two directions at right angles to each other. Record the average diameter to the nearest 0.2 mm [0.01 in.].

10.2 Remove any standing water; clean the surface of any debris from the drilling operation and allow to dry.

10.3 Attach the steel disk to the top of the test specimen using the epoxy adhesive. Ensure that the disk is centered with the test specimen and that the axis of the disk is parallel to the axis of the test specimen. Cure the epoxy adhesive following manufacturer's instructions (see Note 4). Do not allow the adhesive to run down the side of the test specimen into the annular cut; if this occurs, the specimen is not tested and another is prepared. At temperatures below 20°C [70°F], it is permitted to gently heat the steel disk to no more than 50°C [120°F] to facilitate spreading of the adhesive and to accelerate curing. The test specimen shall not be heated with a direct flame.

NOTE 3—Figs. 1 and 2 are schematics of the tests for determining tensile strength of the substrate and bond or tensile strength of the repair or overlay material, respectively. These schematics are not intended to indicate specific equipment designs.

NOTE 4—Guidance on applying and curing the epoxy adhesive may be found in ACI 503R.

11. Test Procedure

11.1 Attach the tensile loading device to the steel disk using the coupling device.

11.2 Apply the tensile load to the test specimen so that the force is parallel to and coincident with the axis of the specimen.

11.3 Apply the tensile load at a constant rate so that the tensile stress increases at a rate of 35 ± 15 kPa/s [5 ± 2 psi/s].

11.4 Record the failure load and the failure mode. Record the failure mode as *(a)* in the substrate, *(b)* at the bond line between the substrate and the repair or overlay material, *(c)* in the repair or overlay material, or *(d)* at the bond line between the repair or overlay material and the epoxy adhesive used to bond the steel disk. If failure occurs at the bond line between the steel disk and the epoxy adhesive, discard the test result and perform another test. Refer to Fig. 3 for schematics of the different failure modes.

11.5 Report results as bond strength when failure occurs in the bond line between the substrate and the repair or overlay material. Report results as tensile strength when the failure

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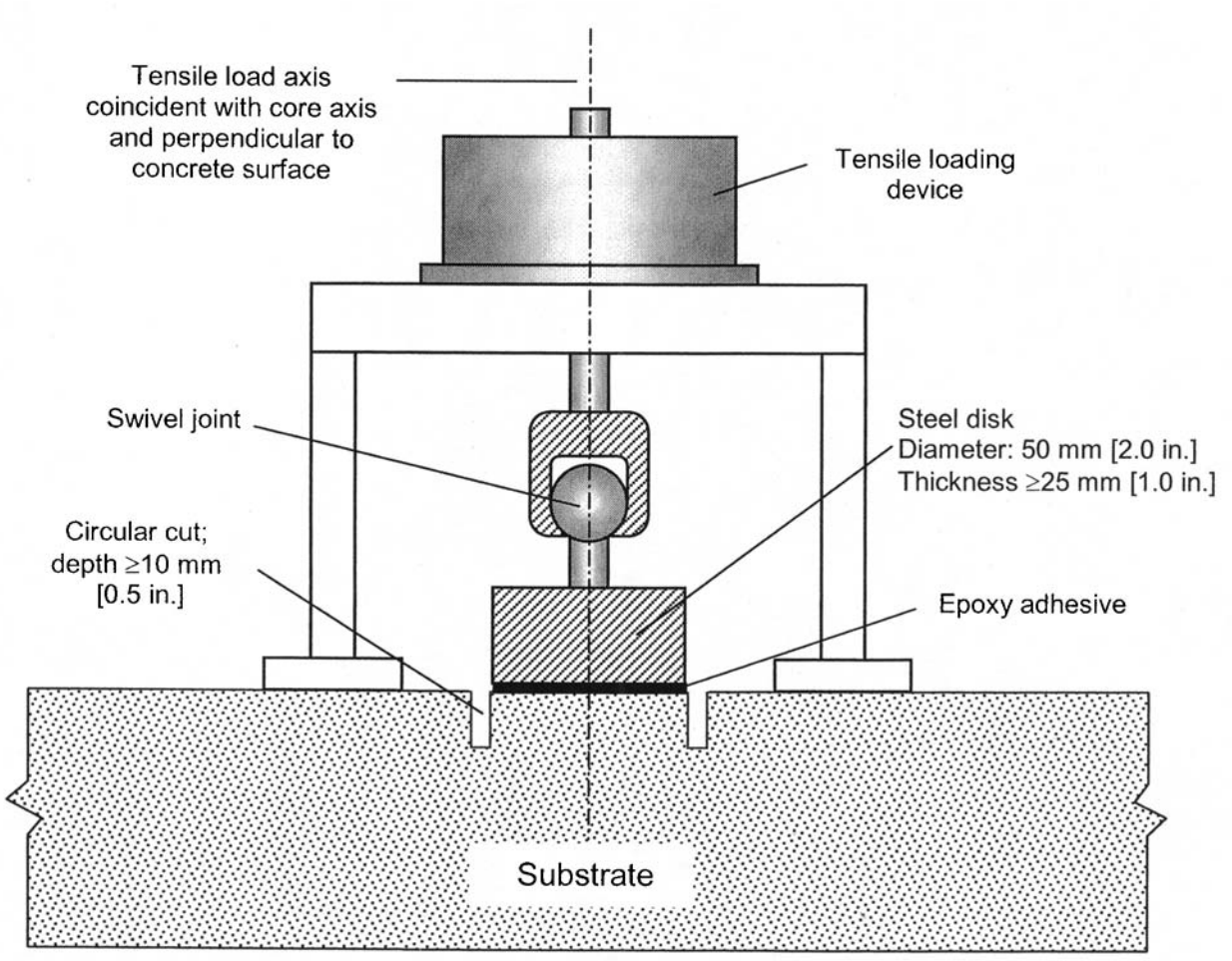

FIG. 1 Schematic of Setup to Test Substrate

occurs in the substrate or the repair or overlay material. Calculate the bond strength or tensile strength by dividing the tensile load at failure by the area of the test specimen:

$$\text{Bond or Tensile Strength (MPa [psi])} = \frac{\text{Tensile load (N [lbf])}}{\text{Area of test specimen (mm}^2\text{ [in.}^2\text{])}} \quad (1)$$

11.6 Record the individual strengths to the nearest 0.01 MPa [1 psi].

11.7 Record ambient weather conditions and surface temperatures during testing.

12. Report

12.1 The test report shall contain the following:

12.1.1 Purpose of the test:

12.1.1.1 To assess the substrate before application of repair or overlay material with regards to the adequacy of surface preparation and the strength of the near-surface region of the substrate;

12.1.1.2 To determine the controlling failure mode and corresponding strength when a repair or an overlay material is bonded to the substrate; or

12.1.1.3 To determine the controlling failure mode and corresponding strength when an adhesive is bonded to the substrate.

12.1.2 Identification of all materials used in the test,

12.1.3 Test conditions—location of test, weather conditions, and surface temperatures, and

12.1.4 The failure mode and the tensile or bond strength for each individual test reported to the nearest 0.01 MPa [1 psi].

13. Precision and Bias

13.1 *Precision*—An interlaboratory testing program to determine the precision of this test method has not yet been carried out. There are, however, published data[4] to provide an estimate of within-test repeatability. The referenced study involved pull-off tests of repair materials applied to concrete substrates. Three replicate tests were conducted for each condition, and the mean pull-off strength ranged from 0.41 to 3.44 MPa [60 to 500 psi]. Two instruments were used with disk diameters of 75 mm [3 in.] and 50 mm [2 in.]. Replicate tests with the same failure modes were used to determine the within-test standard deviations for each condition. There was no statistically significant difference in repeatability for failures

[4] Vaysburd, A. M., and McDonald, J. E., "An Evaluation of Equipment and Procedures for Tensile Bond Testing of Concrete Repairs," *Technical Report REMR-CS-61*, U.S. Army Corps of Engineers, Waterways Experiment Station, June 1999, p. 84.

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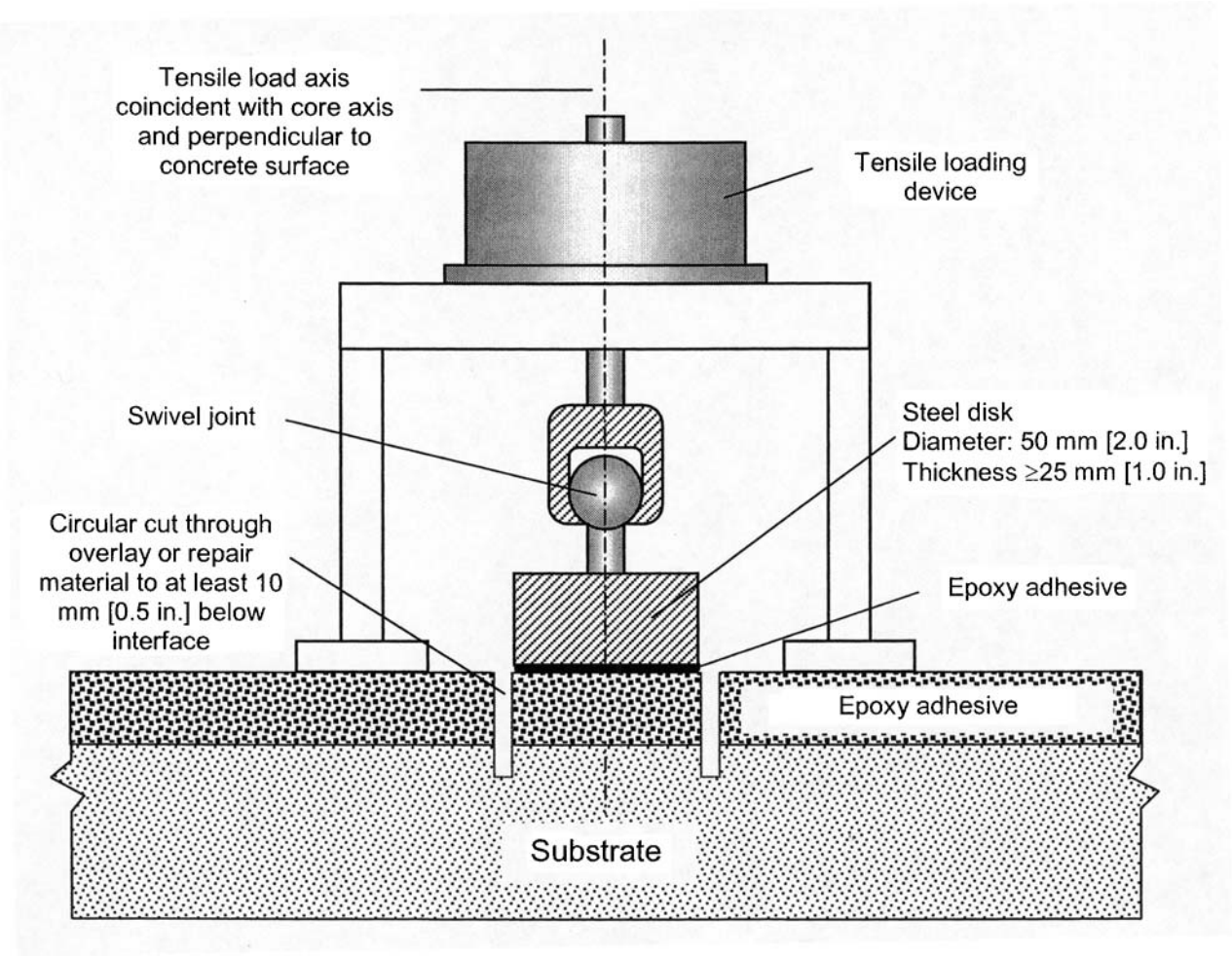

FIG. 2 Schematic of Setup to Test Material Applied to Substrate

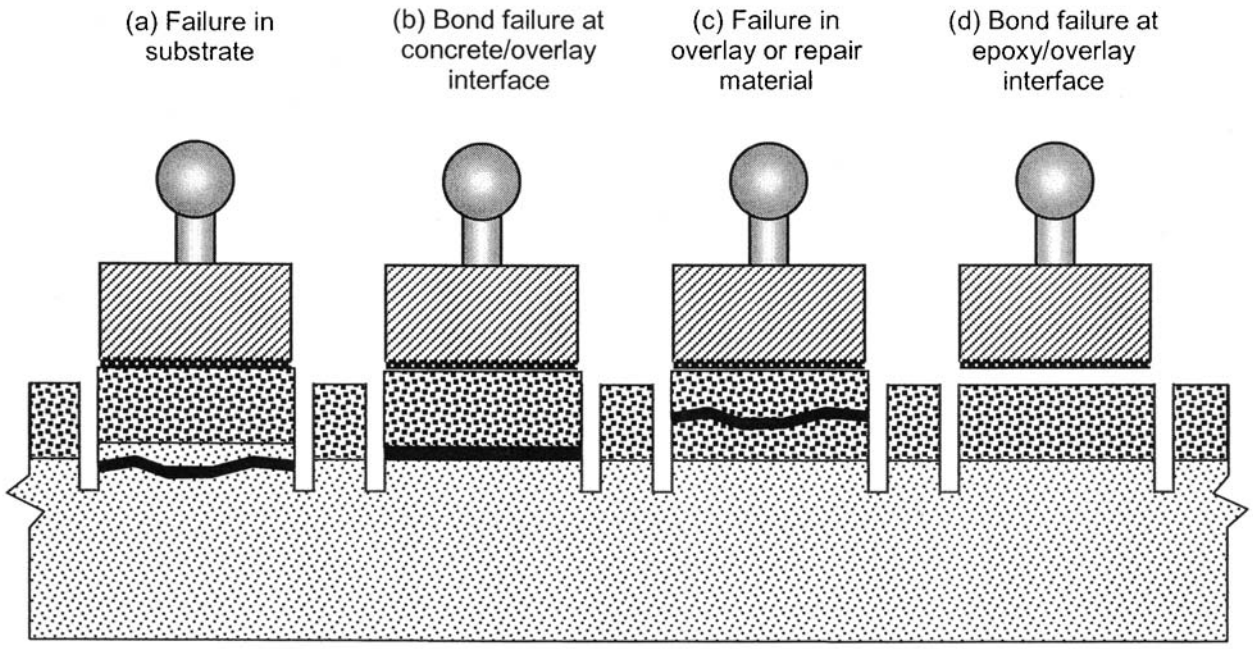

FIG. 3 Schematic of Failure Modes

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in the substrate, the repair material, or at the interface. The overall pooled standard deviation was found to be 0.29 MPa [42 psi].

13.2 *Bias*—This method has no bias because pull-off tensile strength or pull-off bond strength are defined only in terms of this method.

14. Keywords

14.1 adhesives; overlay materials; pull-off tensile strength; pull-off test; repair materials; tensile bond strength

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Designation: C 1585 – 04$^{\epsilon 1}$

Standard Test Method for Measurement of Rate of Absorption of Water by Hydraulic-Cement Concretes[1]

This standard is issued under the fixed designation C 1585; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

ε[1] NOTE—A typo in Eq 1 was corrected editorially in December 2007.

1. Scope

1.1 This test method is used to determine the rate of absorption (sorptivity) of water by hydraulic cement concrete by measuring the increase in the mass of a specimen resulting from absorption of water as a function of time when only one surface of the specimen is exposed to water. The exposed surface of the specimen is immersed in water and water ingress of unsaturated concrete dominated by capillary suction during initial contact with water.

1.2 The values stated in SI units are to be regarded as the standard.

1.3 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

2. Referenced Documents

2.1 *ASTM Standards:* [2]

C 31/C 31M Practice for Making and Curing Concrete Test Specimens in the Field

C 42/C 42M Test Method for Obtaining and Testing Drilled Cores and Sawed Beams of Concrete

C 125 Terminology Relating to Concrete and Concrete Aggregates

C 192/C 192M Practice for Making and Curing Concrete Test Specimens in the Laboratory

C 642 Test Method for Density, Absorption, and Voids in Hardened Concrete

C 1005 Specification for Reference Masses and Devices for Determining Mass and Volume for Use in the Physical Testing of Hydraulic Cements

3. Terminology

3.1 For definitions of terms used in this standard, refer to Terminology C 125.

4. Significance and Use

4.1 The performance of concrete subjected to many aggressive environments is a function, to a large extent, of the penetrability of the pore system. In unsaturated concrete, the rate of ingress of water or other liquids is largely controlled by absorption due to capillary rise. This test method is based on that developed by Hall[3] who called the phenomenon "water sorptivity."

4.2 The water absorption of a concrete surface depends on many factors including: *(a)* concrete mixture proportions; *(b)* the presence of chemical admixtures and supplementary cementitious materials; *(c)* the composition and physical characteristics of the cementitious component and of the aggregates; *(d)* the entrained air content; *(e)* the type and duration of curing; *(f)* the degree of hydration or age; *(g)* the presence of microcracks; *(h)* the presence of surface treatments such as sealers or form oil; and *(i)* placement method including consolidation and finishing. Water absorption is also strongly affected by the moisture condition of the concrete at the time of testing.

4.3 This method is intended to determine the susceptibility of an unsaturated concrete to the penetration of water. In general, the rate of absorption of concrete at the surface differs from the rate of absorption of a sample taken from the interior. The exterior surface is often subjected to less than intended curing and is exposed to the most potentially adverse conditions. This test method is used to measure the water absorption rate of both the concrete surface and interior concrete. By drilling a core and cutting it transversely at selected depths, the absorption can be evaluated at different distances from the exposed surface. The core is drilled vertically or horizontally.

4.4 This test method differs from Test Method C 642 in which the specimens are oven dried, immersed completely in

[1] This test method is under the jurisdiction of ASTM Committee C09 on Concrete and Concrete Aggregates and is the direct responsibility of Subcommittee C09.66 on Concrete's Resistance to Fluid Penetration.

Current edition approved Feb. 1, 2004. Published March 2004.

[2] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

[3] Hall, C., "Water Sorptivity of Mortars and Concretes: A Review," *Magazine of Concrete Research*, Vol. 41, No. 147, June 1989, pp. 51-61.

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water at 21°C, and then boiled under water for 5 h. In this test method, only one surface is exposed to water at room temperature while the other surfaces are sealed simulating water absorption in a member that is in contact with water on one side only. Test Method C 642, on the other hand, is used to estimate the maximum amount of water that can be absorbed by a dry specimen and therefore provides a measure of the total, water permeable pore space.

5. Apparatus

5.1 *Pan*, a watertight polyethylene or other corrosion-resistant pan large enough to accommodate the test specimens with the surfaces to be tested exposed to water.

5.2 *Support Device*, rods, pins, or other devices, which are made of materials resistant to corrosion by water or alkaline solutions, and which allow free access of water to the exposed surface of the specimen during testing. Alternatively, the specimens can be supported on several layers of blotting paper or filter papers with a total thickness of at least 1 mm.

5.3 *Top-pan Balance*, complying with Specification C 1005 and with sufficient capacity for the test specimens and accurate to at least ± 0.01 g.

5.4 *Timing Device*, stop watch or other suitable timing device accurate to ± 1 s.

5.5 *Paper Towel or Cloth*, for wiping excess water from specimen surfaces.

5.6 *Water-Cooled Saw*, with diamond impregnated blade to cut test specimens from larger samples.

5.7 *Environmental Chamber*, a chamber allowing for air circulation and able to maintain a temperature of 50 ± 2°C and a relative humidity at 80 ± 3 %. Alternatively, an oven able to maintain a temperature of 50 ± 2°C and a dessicator large enough to contain the specimens to be tested is permitted. The relative humidity (RH) is controlled in the dessicator at 80 ± 0.5 % by a saturated solution of potassium bromide. The solubility of potassium bromide is 80.2 g/100 g of water at 50°C. The solution shall be maintained at the saturation point for the duration of the test. The presence of visible crystals in the solution provides acceptable evidence of saturation.

5.8 *Polyethylene Storage Containers*, with sealable lids, large enough to contain at least one test specimen but not larger than 5 times the specimen volume.

5.9 *Caliper*, to measure the specimen dimensions to the nearest 0.1 mm.

6. Reagents and Materials

6.1 *Potassium Bromide, Reagent Grade*, required if the oven and dessicator system described in 5.7 is used.

6.2 *Sealing Material*, strips of low permeability adhesive sheets, epoxy paint, vinyl electrician's tape, duct tape, or aluminium tape. The material shall not require a curing time longer than 10 minutes.

6.3 *Plastic Bag or Sheeting*, any plastic bag or sheeting that could be attached to the specimen to control evaporation from the surface not exposed to water. An elastic band is required to keep the bag or sheeting in place during the measurements.

7. Test Specimens

7.1 The standard test specimen is a 100 ± 6 mm diameter disc, with a length of 50 ± 3 mm. Specimens are obtained from either molded cylinders according to Practices C 31/C 31M or C 192/C 192M or drilled cores according to Test Method C 42/C 42M. The cross sectional area of a specimen shall not vary more than 1 % from the top to the bottom of the specimen. When cores are taken, they should be marked (see Note 1) so that the surface to be tested relative to the original location in the structure is clearly indicated.

NOTE 1—The surface to be exposed during testing shall not be marked or otherwise disturbed in such a manner as may modify the absorption rate of the specimen.

7.2 The average test results on at least 2 specimens (Note 2) shall constitute the test result. The test surfaces shall be at the same distance from the original exposed surface of the concrete.

NOTE 2—Concrete is not a homogeneous material. Also, an exterior surface of a concrete specimen seldom has the same porosity as the interior concrete. Therefore, replicate measurements are taken on specimens from the same depth to reduce the scatter of the data.

8. Sample Conditioning

8.1 Place test specimens in the environmental chamber at a temperature of 50 ± 2°C and RH of 80 ± 3 % for 3 days. Alternatively, place test specimens in a dessicator inside an oven at a temperature of 50 ± 2°C for 3 days. If the dessicator is used, control the relative humidity in the dessicator with a saturated solution of potassium bromide (see 5.7), but do not allow test specimens to contact the solution.

NOTE 3—To control the RH using the potassium bromide solution, the solution should be placed in the bottom of the dessicator, to ensure the largest surface of evaporation possible.

8.2 After the 3 days, place each specimen inside a sealable container (as defined in 5.8). Use a separate container for each specimen. Precautions must be taken to allow free flow of air around the specimen by ensuring minimal contact of the specimen with the walls of the container.

8.3 Store the container at 23 ± 2°C for at least 15 days before the start of the absorption procedure.

NOTE 4—Storage in the sealed container for at least 15 days results in equilibration of the moisture distribution within the test specimens and has been found[4] to provide internal relative humidities of 50 to 70 %. This is similar to the relative humidities found near the surface in some field structures.[5,6]

9. Procedure

9.1 Remove the specimen from the storage container and record the mass of the conditioned specimen to the nearest 0.01 g before sealing of side surfaces.

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[4] Bentz D. P., Ehlen M. A., Ferraris C. F., and Winpigler J. A., "Service Life Prediction Based on Sorptivity for Highway Concrete Exposed to Sulfate Attack and Freeze-Thaw Conditions," FHWA-RD-01-162, 2001.

[5] DeSouza S. J., Hooton R. D., and Bickley J. A., "Evaluation of Laboratory Drying Procedures Relevant to Field Conditions for Concrete Sorptivity Measurements," *Cement Concrete Aggr* 19: (2), Dec 1997, pp. 59-63.

[6] DeSouza S. J., Hooton R. D., and Bickley J. A., "A Field Test for Evaluating High Performance Concrete Covercrete Quality," *Can J Civil Eng*, 25: (3), Jun 1998, pp. 551-556.

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9.2 Measure at least four diameters of the specimen at the surface to be exposed to water. Measure the diameters to the nearest 0.1 mm and calculate the average diameter to the nearest 0.1 mm.

9.3 Seal the side surface of each specimen with a suitable sealing material. Seal the end of the specimen that will not be exposed to water using a loosely attached plastic sheet (see 6.2). The plastic sheet can be secured using an elastic band or other equivalent system (see Fig. 1).

9.4 Use the procedure below to determine water absorption as a function of time. Conduct the absorption procedure at 23 ± 2°C with tap water conditioned to the same temperature.

9.5 *Absorption Procedure*:

9.5.1 Measure the mass of the sealed specimen to the nearest 0.01 g and record it as the initial mass for water absorption calculations.

9.5.2 Place the support device at the bottom of the pan and fill the pan with tap water so that the water level is 1 to 3 mm above the top of the support device. Maintain the water level 1 to 3 mm above the top of the support device for the duration of the tests.

NOTE 5—One method for keeping the water level constant is to install a water-filled bottle upside down such that the bottle opening is in contact with the water at the desired level.

9.5.3 Start the timing device and immediately place the test surface of the specimen on the support device (see Fig. 1). Record the time and date of initial contact with water.

9.5.4 Record the mass at the intervals shown in Table 1 after first contact with water. Using the procedure in 9.5.5, the first point shall be at 60 ± 2 s and the second point at 5 min ± 10 s. Subsequent measurements shall be within ± 2 min of 10 min, 20 min, 30 min, and 60 min. The actual time shall be recorded to within ± 10 s. Continue the measurements every hour, ± 5 min, up to 6 h, from the first contact of the specimen with water and record the time within ± 1 min. After the initial 6 h, take measurements once a day up to 3 days, followed by 3 measurements at least 24 h apart during days 4 to 7; take a final measurement that is at least 24 h after the measurement at 7 days. The actual time of measurements shall be recorded within ± 1 min. This will result in seven data points for contact time during days 2 through 8. Table 1 gives the target times of measurements and the tolerances for the times.

9.5.5 For each mass determination, remove the test specimen from the pan, stop the timing device if the contact time is less than 10 min, and blot off any surface water with a dampened paper towel or cloth. After blotting to remove excess water, invert the specimen so that the wet surface does not come in contact with the balance pan (to avoid having to dry the balance pan). Within 15 s of removal from the pan, measure the mass to the nearest 0.01 g. Immediately replace the specimen on the support device and restart the timing device.

10. Calculations

10.1 The absorption, I, is the change in mass divided by the product of the cross-sectional area of the test specimen and the density of water. For the purpose of this test, the temperature dependence of the density of water is neglected and a value of 0.001 g/mm^3 is used. The units of I are mm.

$$I = \frac{m_t}{a*d} , \quad (1)$$

where:

I = the absorption,
m_t = the change in specimen mass in grams, at the time t,
a = the exposed area of the specimen, in mm^2, and
d = the density of the water in g/mm^3.

10.2 The initial rate of water absorption (mm/s$^{1/2}$) is defined as the slope of the line that is the best fit to I plotted against the square root of time (s$^{1/2}$). Obtain this slope by using least-squares, linear regression analysis of the plot of I versus time$^{1/2}$. For the regression analysis, use all the points from 1 min to 6 h, excluding points for times after the plot shows a clear change of slope. If the data between 1 min and 6 h do not follow a linear relationship (a correlation coefficient of less

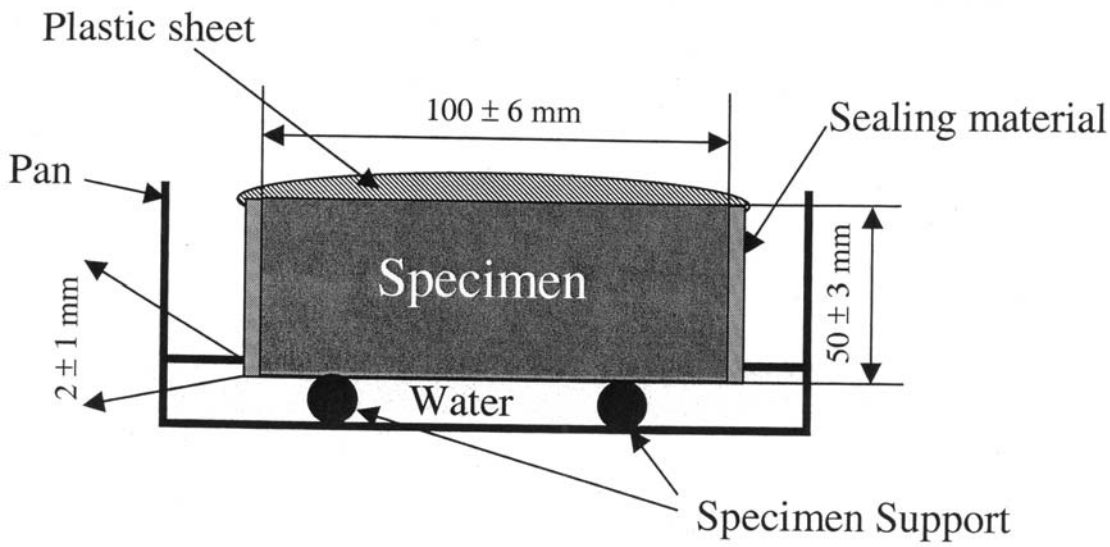

FIG. 1 Schematic of the Procedure

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TABLE 1 Times and Tolernaces for the Measurements Schedule

Time	60 s	5 min	10 min	20 min	30 min	60 min	Every hour up to 6 h	Once a day up to 3 days	Day 4 to 7 3 measurements 24 h apart	Day 7 to 9 1 (one) measurement
Tolerance	2 s	10 s	2 min	2 min	2 min	2 min	5 min	2 h	2 h	2 h

than 0.98) and show a systematic curvature, the initial rate of absorption cannot be determined.

NOTE 6—Appendix X1 gives an example of absorption data and the results of regression analysis.

10.3 The secondary rate of water absorption ($mm/s^{1/2}$) is defined as the slope of the line that is the best fit to *I* plotted against the square root of time ($s^{1/2}$) using all the points from 1 *d* to 7 *d*. Use least-square linear regression to determine the slope. If the data between 1 *d* and 7 *d* do not follow a linear relationship (a correlation coefficient of less than 0.98) and show a systematic curvature, the secondary rate of water absorption cannot be determined.

11. Report

11.1 Report the following:

11.1.1 Date when concrete was sampled or cast,

11.1.2 Source of sample,

11.1.3 Relevant background information on sample such as mixture proportions, curing history, type of finishing, and age, if available,

11.1.4 Dimensions of specimen before sealing,

11.1.5 Mass of specimen before and after sealing,

11.1.6 A plot of absorption, *I*, in mm versus square root of time in $s^{1/2}$,

11.1.7 The average initial rate of water absorption calculated to the nearest 0.1×10^{-4} $mm/s^{1/2}$ and the individual initial absorption rates for the two or more specimens, and

11.1.8 The average secondary rate of water absorption calculated to the nearest 0.1×10^{-4} $mm/s^{1/2}$ and the individual absorption rates of the two or more specimens tested.

12. Precision and Bias

12.1 *Precision*—The repeatability coefficient of variation has been determined to be 6.0 % in preliminary measurements for the absorption as measured by this test method for a single laboratory and single operator. An interlaboratory program is being organized to develop the repeatability and reproducibility values.

12.2 *Bias*—The test method has no bias because the rate of water absorption determined can only be defined in terms of the test method.

13. Keywords

13.1 concrete; initial rate of water absorption; mortar; rate of absorption; secondary rate of water absorption

APPENDIX

(Nonmandatory Information)

X1. EXAMPLE RATE OF WATER ABSORPTION TEST

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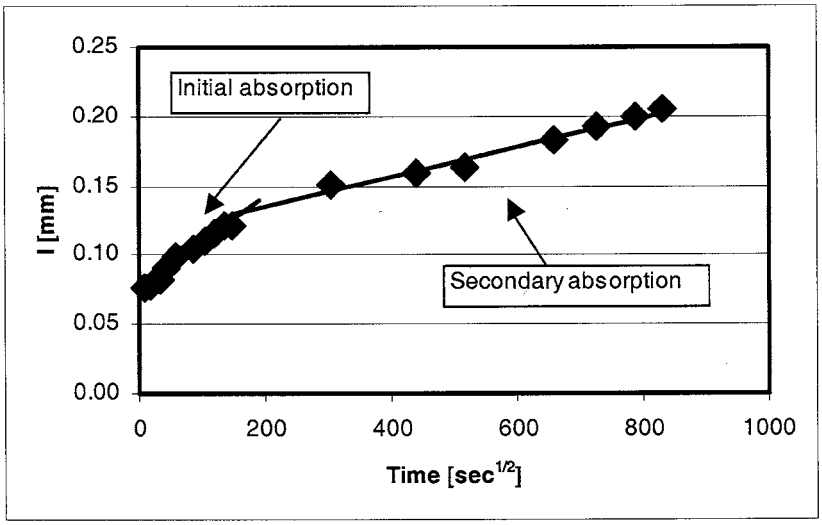
TABLE X1.1 Example of Data Collected and Calculations

Cast Date: 3/2/99 Test Date: 3/14/00
Sample No. F-68
Concrete Mixture: Standard mixture I
Sample Conditioning: Cast, steam cured, test face = top surface
Sample: Age 378 days
Age at coring: Unknown
Mass of Conditioned disc: 750.5 g (prior to sealing sides)
Mass after sealing specimen: 761.8 g
Diameter (mm): 101.6
Exposed Area: 8107 mm^2
Thickness (mm): 50.8
Water temp: 20.7°C

Test Time		√Time ($s^{1/2}$)	Mass (g)	ΔMass (g)	ΔMass/area/density of water = *I* (mm)
Days	s				
	0	0	761.83	0.00	0.0000
	60	8	762.45	0.62	0.0765
	300	17	762.46	0.63	0.0777
	600	24	762.48	0.65	0.0802
	1200	35	762.50	0.67	0.0826
	1800	42	762.57	0.74	0.0913
	3600	60	762.63	0.80	0.0987
	7200	85	762.68	0.85	0.1048
	10800	104	762.73	0.90	0.1110
	14400	120	762.77	0.94	0.1159
	18000	134	762.81	0.98	0.1209
	21600	147	762.82	0.99	0.1221
1	92220	304	763.05	1.22	0.1505
2	193200	440	763.12	1.29	0.1591
3	268500	518	763.15	1.32	0.1628
5	432000	657	763.31	1.48	0.1826
6	527580	726	763.39	1.56	0.1924
7	622200	789	763.45	1.62	0.1998
8	691200	831	763.5	1.67	0.2060



Calculations:

Initial Absorption:
$I = S_i \sqrt{t} + b$ (points measured up to 6 h are used)
The initial rate of absorption is: $S_i = 3.5 \times 10^{-4}$ mm/√s $r = 0.99$

Secondary Absorption:
$I = S_s \sqrt{t} + b$ (points measured after the first day are used)
The secondary rate of absorption is: $S_s = 1.1 \times 10^{-4}$ mm/√s

FIG. X1.1 Example of Plot of The Data Shown in Table X1.1

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Designation: C 1597M – 04 (Reapproved 2009)ε1

Standard Specification for Gypsum Wallboard (Hard Metric Sizes)[1]

This standard is issued under the fixed designation C 1597M; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

ε[1] NOTE—Specification C 36/C 36M was replaced with Specification C 1396/C 1396M editorially in 1.2 and Referenced Documents in September 2009.

1. Scope

1.1 This specification covers gypsum wallboard which is designed to be used for walls, ceilings, or partitions and affords a surface suitable to receive decoration.

NOTE 1—Specification C 840 contains application procedures for gypsum wallboard.

1.2 The values stated in SI units are to be regarded as standard. No other units of measurement are included in this standard. For gypsum wallboard produced to inch-pound units see Specification C 1396/C 1396M.

1.3 The text of this standard references notes and footnotes that provide explanatory material. These notes and footnotes (excluding those in tables and figures) shall not be considered as requirements of the standard.

2. Referenced Documents

2.1 *ASTM Standards:*[2]

C 11 Terminology Relating to Gypsum and Related Building Materials and Systems

C 473 Test Methods for Physical Testing of Gypsum Panel Products

C 645 Specification for Nonstructural Steel Framing Members

C 840 Specification for Application and Finishing of Gypsum Board

C 1264 Specification for Sampling, Inspection, Rejection, Certification, Packaging, Marking, Shipping, Handling, and Storage of Gypsum Panel Products

C 1396/C 1396M Specification for Gypsum Board

E 84 Test Method for Surface Burning Characteristics of Building Materials

E 96/E 96M Test Methods for Water Vapor Transmission of Materials

E 119 Test Methods for Fire Tests of Building Construction and Materials

3. Terminology

3.1 Definitions of terms shall be in accordance with Terminology C 11.

4. Materials and Manufacture

4.1 Gypsum wallboard shall consist of a noncombustible core, essentially gypsum, surfaced with paper bonded to the core.

4.2 Foil backed gypsum wallboard shall consist of gypsum wallboard with a layer of aluminum foil laminated to the back surface.

4.3 Gypsum wallboard, type X (special fire resistant) designates gypsum wallboard complying with this specification that provides not less than 1 hour fire-resistance for boards 16 mm thick or ¾ hour fire-resistance for boards 13 mm thick, applied parallel with and on each side of load bearing 2 × 4 wood studs spaced 400 mm o.c. with coated nails, 50 mm long, 2.0 mm diameter shank, 6.0 mm diameter heads, spaced 200 mm o.c. with wallboard joints staggered 400 mm on each side of the partition and tested in accordance with the requirements of Test Methods E 119.

NOTE 2—Consult producers for independent test data on assembly details and fire resistance classifications for other types of construction. See fire test reports or listings from recognized fire testing laboratories for assembly particulars, materials, and classifications.

4.4 Gypsum wallboard shall have a flame spread index of not more than 25 when tested in accordance with Test Method E 84.

5. Physical Properties

5.1 Specimens shall be taken from the samples obtained in accordance with Specification C 1264.

5.2 Specimens shall be tested in accordance with Test Methods C 473.

5.2.1 *Flexural Strength*—The specimens shall be tested face up and face down. The average breaking load shall be not less than the following:

[1] This specification is under the jurisdiction of ASTM Committee C11 on Gypsum and Related Building Materials and Systems and is the direct responsibility of Subcommittee C11.01 on Specifications and Test Methods for Gypsum Products.

Current edition approved Sept. 1, 2009. Published September 2009. Originally approved in 2004. Last previous edition approved in 2004 as C 1597M – 04.

[2] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

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Thickness, in. [mm]	Method A Load, N Bearing Edges Across Fiber of Surfacing	Method A Load, N Bearing Edges Parallel to Fiber of Surfacing	Method B Load, N Bearing Edges Across Fiber of Surfacing	Method B Load, N Bearing Edges Parallel to Fiber of Surfacing
6.5	220	90	200	70
10.0	360	140	340	120
13.0	500	180	480	160
16.0	660	220	640	200
20.0	760	260	740	240

5.2.2 *Humidified Deflection*—The specimens shall have an average deflection of not more than the following:

Thickness, mm	Humidified Deflection, mm
6.5	not required
10.0	40
13.0	30
16.0	15
20.0	15

5.2.3 *Core, End, and Edge Hardness*—The specimens shall have an average hardness of not less than 60 N when tested by Method A and 50 N when tested by Method B.

5.2.4 *Nail Pull Resistance*—The specimens shall have an average nail-pull resistance of not less than the following:

Thickness, mm	Method A Nail Pull Resistance, N	Method B Nail Pull Resistance, N
6.5	180	160
10.0	280	260
13.0	360	340
16.0	400	390
20.0	440	430

5.3 *Foil Backed Gypsum Wallboard*

5.3.1 Foil-backed gypsum wallboard shall meet all of the requirements for gypsum wallboard.

5.3.2 When tested in accordance with Test Methods E 96/E 96M, the permeance of foil-backed gypsum wallboard shall be not more than 20 ng/Pa·s·m^2 (Desiccant Method) for the condition of 50 % relative humidity on the face of the board and 0 % relative humidity on the foil-covered back side of the board.

6. Dimensions and Tolerances

6.1 Specimens shall be taken from the samples obtained in accordance with Specification C 1264.

6.2 Thickness, width, length, and end squareness shall be determined in accordance with Test Methods C 473.

6.2.1 *Thickness*—The thickness shall be 6.5, 10.0, 13.0, 16.0, 20.0 mm with tolerances in the nominal thickness of ± 0.5 mm with local variations of ± 1.0 mm from the nominal thickness.

6.2.2 *Width*—The width shall be up to 1400 mm, with a tolerance of 3 mm under the specified width.

6.2.3 *Length*—The length and tolerance shall be as follows:

Thickness mm	Length mm	Variation mm
6.5	1200 to 4000	± 6
10.0	1200 to 5000	± 6
13.0	1200 to 5000	± 6
16.0	1200 to 5000	± 6
20.0	1200 to 5000	± 6

6.2.4 *Tapered Edge Depth*—The average thickness of the edge of recessed or tapered edge shall be not less than 0.50 mm but not more than 2.5 mm less than the average thickness of the gypsum wallboard.

6.2.5 *End Squareness*—Corners shall be square with a tolerance of ± 3 mm in the full width of the board.

6.3 *Edges and Ends*—The edges and ends shall be straight and either square, beveled, featured, tapered, or featured and tapered.

7. Finish and Appearance

7.1 The surfaces of gypsum wallboard shall be true and free from imperfections that render the gypsum wallboard unfit for use with or without decoration.

8. Sampling, Inspection, Rejection, Certification, Packaging, Marking, Shipping, Handling and Storage

8.1 Shall be in accordance with Specification C 1264.

9. Keywords

9.1 ceiling; foil-backed; gypsum; gypsum wallboard; gypsum wallboard, type X; metric units; partitions; wall

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APPENDIX

(Nonmandatory Information)

X1. ALTERNATE DEFINITION FOR TYPE X

INTRODUCTION

This Appendix gives general information and also suggestions for inclusions to be made elsewhere by the specifier. They are not part of this specification.

The definition of type X as given in 4.3 and the alternate definition given in this appendix, are intended only as a test to define the gypsum wallboard as meeting the requirements of type X. These tests do not indicate a preferred application nor do they limit the use of the product in other fire rated assemblies.

All gypsum panel products, except lath, shaftliner, and coreboard, use the same test for type X products, therefore the type X designation indicates a consistent level of fire resistance.

X1.1 Gypsum wallboard, type X (special fire-resistant) designates gypsum wallboard providing a greater fire resistance than regular gypsum wallboard of the same thickness. Type X (special fire-resistant) gypsum wallboard, when tested in accordance with Test Methods E 119, shall provide the following minimum fire resistance for the assemblies described:

X1.1.1 One hour for a 16.0 mm thickness applied to a partition in a single layer application on each side of 90 mm deep non-loadbearing galvanized steel studs complying with Specification C 645, spaced 600 mm on center. The 16.0 mm thick gypsum wallboard 1200 mm wide shall be attached using 25 mm long drywall screws spaced 200 mm on center along the edges and ends, and 300 mm along intermediate studs. All joints shall be oriented parallel to and located over studs and staggered on opposite sides of the assembly, and

X1.1.2 Two hours for a 13.0 mm thickness applied to a partition in a double layer application on each side of 65 mm deep non-loadbearing galvanized steel studs complying with Specification C 645, spaced 600 mm on center. The 1200 mm wide base layer shall be attached using 25 mm long drywall screws spaced 300 mm on center along board edges, ends, and along intermediate studs. Joints shall be oriented parallel to and located over studs and staggered on opposite sides of the assembly. The 1200 mm wide face layer shall be attached using 40 mm long drywall screws spaced 300 mm along board edges, ends, and along intermediate studs. Joints shall be oriented parallel to and located over studs, offset 600 mm from the base layer joints, and staggered on opposite sides of the assembly.

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Designation: C 1600/C 1600M – 08

Standard Specification for Rapid Hardening Hydraulic Cement[1]

This standard is issued under the fixed designation C 1600/C 1600M; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope*

1.1 This specification is for rapid hardening hydraulic cements. This is a specification giving performance requirements. There are no restrictions on the composition of the cement or its constituents.

1.2 The specification classifies cements by type based on specific requirements for very early compressive strength development.

1.3 The values stated in either SI units or inch-pound units shall be regarded separately as standard. The values stated in each system are not exact equivalents; therefore, each system shall be used independently of the other. Combining values from the two systems may result in nonconformance with the standard.

1.4 The text of this standard refers to notes and footnotes that provide explanatory material. These notes and footnotes (excluding those in tables and figures) are not requirements of the standard.

1.5 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.* (**Warning—**Fresh hydraulic cementitious mixtures are caustic and may cause chemical burns to skin and tissue upon prolonged exposure.[2])

2. Referenced Documents

2.1 *ASTM Standards:* [3]

C 109/C 109M Test Method for Compressive Strength of Hydraulic Cement Mortars (Using 2-in. or [50-mm] Cube Specimens)

C 114 Test Methods for Chemical Analysis of Hydraulic Cement

C 151 Test Method for Autoclave Expansion of Hydraulic Cement

C 183 Practice for Sampling and the Amount of Testing of Hydraulic Cement

C 186 Test Method for Heat of Hydration of Hydraulic Cement

C 191 Test Methods for Time of Setting of Hydraulic Cement by Vicat Needle

C 219 Terminology Relating to Hydraulic Cement

C 227 Test Method for Potential Alkali Reactivity of Cement-Aggregate Combinations (Mortar-Bar Method)

C 441 Test Method for Effectiveness of Pozzolans or Ground Blast-Furnace Slag in Preventing Excessive Expansion of Concrete Due to the Alkali-Silica Reaction

C 596 Test Method for Drying Shrinkage of Mortar Containing Hydraulic Cement

C 1012 Test Method for Length Change of Hydraulic-Cement Mortars Exposed to a Sulfate Solution

C 1038 Test Method for Expansion of Hydraulic Cement Mortar Bars Stored in Water

C 1437 Test Method for Flow of Hydraulic Cement Mortar

3. Terminology

3.1 *Definitions*:

3.1.1 For definitions of terms used in this specification, see Terminology C 219.

3.2 *Definitions of Terms Specific to This Standard:*

3.3 *Rapid Hardening Hydraulic Cement*, *n*—a hydraulic or blended hydraulic cement which exhibits rapid strength gain during the first 24 h of hydration, with or without other constituents, processing additions, and functional additions.

4. Nomenclature, Classifications and Use

4.1 Cements conforming to this specification shall be designated "Rapid Hardening Hydraulic Cement" with the high early strength gain characteristic indicated by type in accordance with the types described in section 4.2. When the type is not specified, the requirement of Type GRH shall apply.

4.2 The specification is for four types of rapid hardening cement as follows:

4.2.1 *Type URH*—Ultra Rapid Hardening For use where *ultra high* early strength is desired (See Table 1).

[1] This test method is under the jurisdiction of ASTM Committee C01 on Cement and is the direct responsibility of Subcommittee C01.13 on Special Cements.

Current edition approved Sept. 1, 2008. Published October 2008. Originally approved in 2007. Last previous edition approved in 2007 as C 1600/C 1600M – 07.

[2] See the section on Safety, Manual of Cement Testing, *Annual Book of ASTM Standards*, Vol 04.01.

[3] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

***A Summary of Changes section appears at the end of this standard.**

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TABLE 1 Standard Physical Requirements

(must be reported on manufacturer's certification)

	Cement Type			
	URH	VRH	MRH	GRH
Compressive Strength (See Section 9 for procedures), min, MPa [psi]				
1½ h	21 [3000]	12 [1700]	. . .	. . .
3 h	28 [4100]	15 [2200]	10 [1500]	7 [1000]
6 h	. . .	. . .	14 [2000]	10 [1500]
1 day	35 [5100]	24 [3500]	17 [2500]	14 [2000]
7 days	41 [6000]	28 [4100]	28 [4100]	24 [3500]
28 days	57 [8300]	35 [5100]	31 [4500]	28 [4100]
Drying Shrinkage, max %				
7 days	0.06	0.06	0.08	0.10
28 days, air storage	0.07	0.07	0.09	0.12
Min Time of Final Set C 191 apparatus Minutes[A]	10	10	10	10
Autoclave, max expansion %	0.8	0.8	0.8	0.8

[A]The initial setting time typically ranges from 10 to 45 min for rapid hardening cements of various types and composition.

4.2.2 *Type VRH*—Very Rapid Hardening For use where *very high* early strength is desired (See Table 1).

4.2.3 *Type MRH*—Medium Rapid Hardening for use where *mid-range* rapid hardening high early strength is desired (See Table 1).

4.2.4 *Type GRH*—General Rapid Hardening for use when the higher strength properties of a Type VRH or a Type MRH cement is not required (See Table 1).

5. Ordering Information

5.1 Orders for cement meeting the requirements of this specification shall include the following:

5.1.1 This specification designation and date.

5.1.2 The quantity of cement desired.

5.1.3 The type of cement desired.

5.1.4 A request for the manufacturer's certification, if desired.

6. 6. Chemical Composition

6.1 The chemical composition for the cement is not specified. However, the purchaser shall have the option to request the cement composition from the producer. If analyzed, the procedure used shall be Test Methods C 114.

7. Physical Properties

7.1 Cement of the type specified shall conform to all of the applicable standard physical requirements in Table 1.

7.2 The water/cement ratio used to determine strength requirement compliance shall be reported in the manufacturer's certification.

7.3 The density for the cement is not specified. However, the density shall be determined by the manufacturer and reported in the manufacturer's certification.

8. Sampling

8.1 When the purchaser desires that the cement be sampled and tested to verify compliance with this specification, the finished cement shall be sampled in accordance with Practice C 183 at the mill or at the job site in accordance with the purchaser's requirements (See Note 1).

NOTE 1—Practice C 183 is not designed for manufacturing quality control and is not required for manufacturer's certification.

9. Test Methods

9.1 When testing cement for compliance with this specification, use the following methods, with modifications or exceptions as indicated:

9.1.1 *Autoclave Expansion*—Determine autoclave expansion by Test Method C 151 as specified in Table 1.

9.1.2 *Time of Setting*—Determine the time of setting using Test Method C 191 as specified in Table 1. Immediately after molding the test specimen in the conical ring, determine the penetration of the needle at this time and every 3 min. until the needle no longer penetrates to the bottom of the specimen, then every 1 min. until final set is determined.

9.1.3 *Compressive Strength*—Determine compressive strength using Test Method C 109/C 109M as modified herein. Tests shall be run at each age specified in Table 1. The mixing water requirement in Test Method C 109/C 109M shall be adjusted to produce a flow of 110 ± 5 as determined using Test Method C 1437.

9.1.4 *Drying Shrinkage of Mortar*—Determine drying shrinkage of mortar as specified in Table 1 using Test Method C 596.

9.1.5 *Heat of Hydration*—Determine heat of hydration using Test Method C 186 (See Table 2).

9.1.6 *Sulfate Resistance*—Determine sulfate resistance using Test Method C 1012 (See Table 2).

9.1.7 *Alkali Silica Reactivity*—Determine reactivity of cement with alkali-reactive aggregate (Option R) using Test Method C 227 using crushed borosilicate glass, as described in Test Method C 441, as aggregate (See Table 2).

9.1.8 *Expansion in Water*—Determine expansion of hydraulic cement mortar bars stored in water by Test Method C 1038 (See Table 2).

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TABLE 2 Optional Requirements

Sulfate expansion[A] (C 1012)				
6 months, max %	0.05	0.05	0.05	0.05
1 year, max %	0.10	0.10	0.10	0.10
ASR Expansion[B] (C 441)				
14 days, max %	0.020	0.020	0.020	0.020
56 days, max %	0.060	0.060	0.060	0.060
Heat of Hydration (C 186)				
7 days, max, kJ/kg (kcal/kg)	250 [60]	250 [60]	250 [60]	250 [60]
28 days, max, kJ/kg (kcal/kg)	290 [70]	290 [70]	290 [70]	290 [70]
Expansion in Water (C 1038)				
14 days, max %	0.10	0.10	0.10	0.10

[A] In the testing of these cements, testing at one year shall not be required when the cement meets the 6-month limit. Cement failing the 6-month limit shall not be rejected unless it also fails the one-year limit.

[B] The test for mortar expansion is an optional requirement to be applied only at the purchaser's request and is not required unless the cement will be used with alkali-reactive aggregate.

10. Testing Time

10.1 The age of the specimens is to be determined from the time when the cement contacts the mixing water.

10.2 Specimens to be tested at 1½ , 3, and 6 h shall be removed from the molds a maximum of 10 min. prior to time of test. After the specimens are removed from the molds, keep them covered with a damp towel until time to be tested. The cubes must be tested within 10 min. of the time specified.

10.3 All other specimens shall be removed from the molds at 22 h, ± 2 h. If the specimens are removed from the molds before 24 h, keep them on the shelves of the moist closet or moist room until they are 24 h old, and then immerse the specimens except for the 24-h test, in saturated limewater for storage.

10.4 The 24-h, 7-d, and 28-d test specimens shall be broken within the permissible time tolerances prescribed in Test Method C 109/C 109M.

10.5 Record and calculate the compressive strength in accordance with the Calculation Section of Test Method C 109/C 109M.

10.6 Apply the sampling and testing requirements of Practice C 183.

10.7 For testing of samples taken subsequent to shipment, the purchaser shall make necessary arrangements for shipment of samples to the testing laboratory. Add the time required for transport to the laboratory to the minimum time intervals allowed from receipt of the samples by the testing laboratory.

10.8 The minimum time allowed from receipt of samples by the testing laboratory to the report of test results shall be determined by the required age of specimen at the time of testing plus seven days.

10.9 A written report of results of applicable tests shall be available within not more than three days after the interval specified in 10.8.

10.10 These time limits do not apply to retesting or additional testing (See Note 2).

NOTE 2—Aging effects on small samples or quantities of cement stored for long periods of time can produce test results that are not representative of the fresh cement nor of cement stored in large quantity for equal periods of time.

11. Testing by the Manufacturer

11.1 Secure representative samples of cement during production or transfer and test them for compliance with this specification. Location and frequency of sampling are at the discretion of the manufacturer. Sampling and testing shall be either part of, or in addition to, the manufacturer's normal quality control.

12. Inspection

12.1 Inspection of the material shall be as agreed upon between the purchaser and the seller as part of the purchase contract.

12.2 All packages shall be in good condition at the time of inspection.

13. Certification

13.1 When specified in the purchase order or contract, furnish the manufacturer's certification at the time of shipment stating the results of tests made on cement sampled during production or transfer and certifying that the applicable requirements of this specification have been met.

14. Package Marking

14.1 When the cement is delivered in packages, the words "Rapid Hardening Hydraulic Cement," the type of cement, the specification designation, the name and brand of manufacturer and the mass of cement contained therein shall be plainly marked on each package. Similar information shall be provided in the manufacturer's certification accompanying the shipment of packaged or bulk cement.

15. Storage

15.1 The cement shall be stored in such a manner as to permit reasonable access for proper inspection and identification of each shipment and in a suitable weather-tight building, container, or package that will protect the cement from dampness and minimize warehouse set.

16. Keywords

16.1 blended hydraulic cement; high early strength; hydraulic cement; rapid hardening hydraulic cements

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SUMMARY OF CHANGES

Committee C01 has identified the location of selected changes to this specification since the last issue, C 1600/C 1600M – 07, that may impact the use of this specification. (Approved September 1, 2008)

(*1*) Revised Table 1.

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Designation: C 1602/C 1602M – 06

Standard Specification for Mixing Water Used in the Production of Hydraulic Cement Concrete[1]

This standard is issued under the fixed designation C 1602/C 1602M; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope*

1.1 This specification covers the compositional and performance requirements for water used as mixing water in hydraulic cement concrete. It defines sources of water and provides requirements and testing frequencies for qualifying individual or combined water sources. In any case where the requirements of the purchaser differ from these in this specification, the purchaser's specification shall govern.

1.2 This specification does not purport to cover methods of storage, transportation, or blending of water, or to address the development and maintenance of quality control programs sponsored or managed by the manufacturer.

1.3 The values stated in either SI units, shown in brackets, or inch-pound units are to be regarded separately as standard. The values stated in each system may not be exact equivalents; therefore, each system shall be used independently of the other. Combining values from the two systems may result in nonconformance with the standard.

1.4 The text of this specification references notes and footnotes that provide explanatory material. These notes and footnotes (excluding those in tables and figures) shall not be considered as requirements of the standard.

1.5 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and to determine the applicability of regulatory limitations prior to use.*

2. Referenced Documents

2.1 *ASTM Standards:* [2]

C 31/C 31M Practice for Making and Curing Concrete Test Specimens in the Field

C 39/C 39M Test Method for Compressive Strength of Cylindrical Concrete Specimens

C 94/C 94M Specification for Ready-Mixed Concrete

C 114 Test Methods for Chemical Analysis of Hydraulic Cement

C 125 Terminology Relating to Concrete and Concrete Aggregates

C 192/C 192M Practice for Making and Curing Concrete Test Specimens in the Laboratory

C 403/C 403M Test Method for Time of Setting of Concrete Mixtures by Penetration Resistance

C 1603 Test Method for Measurement of Solids in Water

2.2 *ACI Documents:*[3]

ACI 318 Building Code Requirements for Structural Concrete and Commentary

3. Terminology

3.1 *Definitions:* For definitions of terms used in this specification, refer to Terminology C 125

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *combined water*—a mixture of two or more sources of water blended together, before or during introduction into the mixture, for use as mixing water in the production of concrete.

3.2.2 *hydration stabilizing admixtures*—extended set retarding admixtures that control the hydration of cement in applications of managing returned concrete and water from concrete production

3.2.3 *non-potable*—water sources that are not fit for human consumption, or if it contains quantities of substances that discolor it or make it smell or have objectionable taste but does not contain water from concrete production operations.

3.2.4 *potable water*—water suitable for human consumption

3.2.5 *water from concrete production operations*—water recovered from processes of hydraulic cement concrete production that includes wash water from mixers or that was a part of a concrete mixture; water collected in a basin as a result of storm water runoff at a concrete production facility; or water that contains quantities of concrete ingredients.

4. Requirements for Use

4.1 Mixing water shall consist of:

[1] This specification is under the jurisdiction of ASTM Committee C09 on Concrete and Concrete Aggregates and is the direct responsibility of Subcommittee C09.40 on Ready-Mixed Concrete.

Current edition approved Feb. 15, 2006. Published March 2006. Originally approved in 2004. Last previous edition approved in 2005 as C 1602/C 1602M – 05.

[2] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

[3] Available from American Concrete Institute (ACI), P.O. Box 9094, Farmington Hills, MI 48333.

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4.1.1 Batch water (water weighed or metered through the batch plant),

4.1.2 Ice,

4.1.3 Water added by truck operator,

4.1.4 Free moisture on the aggregates, and

4.1.5 Water introduced in the form of admixtures when this water increases the water-cementitious materials ratio by more than 0.01.

4.2 Potable water is permitted to be used as mixing water in concrete without testing for conformance with the requirements of this specification.

4.3 Mixing water that is wholly or partially composed of sources of water that are non-potable or from concrete production operations are permitted to be used in any proportions to the limits qualified to meet the requirements of Table 1. At the option of the purchaser and when appropriate for the construction, any of the optional limits found within Table 2 shall be specified at the time of concrete ordering according to the section on *Ordering Information* of Specification C 94/C 94M.

4.3.1 Non-potable sources of water shall be qualified for use in accordance with 5.1. When the non-potable water source is blended with a potable source, the qualification of the mixing water shall be at the highest percentage of the non-potable source in the combined mixing water anticipated during production.

4.3.2 Combined water blended from two or more sources, where one of the sources includes that from concrete production, shall be qualified for use in accordance with 5.2. The combined water shall be qualified at the highest solids content in the total mixing water anticipated during production. Mixing water containing total solids equal to or less than the level qualified by testing shall be permitted.

5. Testing and Requirements

5.1 For sources of non-potable mixing water (as defined in 3.2.3) proposed for use as total mixing water or in the combined mixing water (as defined in 3.2.1), the following shall apply to the total combined mixing water:

5.1.1 Water shall be tested for compliance with Table 1 before first use and thereafter every three months or more often when there is reason to believe that a change has occurred in the characteristics of the source. Testing is permitted to be at a lower frequency, but not less than annually when results from four consecutive tests indicate compliance with Table 1.

5.1.2 The manufacturer shall maintain documented evidence that the characteristics of the combined mixing water are in compliance with Table 2. These tests shall be conducted before first use and thereafter every 6 months or more often when there is reason to believe that a change has occurred in the characteristics of the source. These records shall be provided to the purchaser on request.

TABLE 1 Concrete Performance Requirements for Mixing Water

	Limits	Test Methods
Compressive strength, min % control at 7 days[A,B]	90	C 31/C 31M, C 39/C 39M
Time of set, deviation from control, h: min[A]	From 1:00 early to 1:30 later	C 403/C 403M

[A] Comparisons shall be based on fixed proportions for a concrete mix design representative of questionable water supply and a control mix using 100 % potable water or distilled water. (See Annex A1).

[B] Compressive strength results shall be based on at least two standard test specimens made from a composite sample.

5.2 For sources of water from concrete production operations (as defined in 3.2.5) proposed for use as the total mixing water or in the combined mixing water (as defined in 3.2.1), the following shall apply to the total combined mixing water:

5.2.1 The density of the source of water from ready mixed concrete shall be tested at least on a daily basis in accordance with Test Method C 1603 or monitored with a hydrometer that has been verified in accordance with Test Method C 1603. Manufacturers that use automated devices shall maintain at the production facility documentation on the procedures and calibration of systems, as needed (See Note 1).

NOTE 1—Blending proportions of water sources can be determined in accordance with Appendix A1 of Test Method C 1603 for achieving a target solids content.

5.2.2 Combined water shall be tested for compliance with the requirements of Table 1 at the highest solids content anticipated to be used during production in accordance with the following testing frequencies:

5.2.2.1 When the density of the combined water is less than 1.01 g/mL, the water shall be tested before first use and thereafter once every six months. Testing frequency is permitted to be reduced to once every 12 months when the results of two consecutive tests indicate compliance with the requirements of Table 1 (See Note 2).

NOTE 2—This condition is intended to cover the use of clarified wash water that has been passed through a settling pond system.

5.2.2.2 When the density of the combined water is between 1.01 and 1.03, the water shall be tested before first use and thereafter monthly. Testing frequency is permitted to be reduced to once every three months when the results of 4 consecutive tests indicate compliance with the requirements of Table 1 (See Note 3).

NOTE 3—Water density of 1.03 approximately represents a total solids content of 50,000 ppm.

5.2.2.3 When the density of the combined water exceeds 1.03, the water shall be tested weekly or more often when there is reason to believe that there is a change in the water characteristics for compliance with the requirements of Table 1. Testing frequency is permitted to be reduced to once every month when the results of two months of consecutive tests indicate compliance with the requirements of Table 1.

5.2.2.4 Testing for water with density exceeding 1.05 shall be the same as that of 5.2.2.3 whether the water includes or does not include a set stabilizing admixture (See Note 4).

NOTE 4—Water density exceeding approximately 1.05, where the solids are essentially composed of cementitious materials, may require the use of hydration stabilizing admixtures to maintain compliance with the requirements of Table 1. The producer should have a documented process in place to verify the effectiveness of the admixtures and dosages employed.

5.2.3 The manufacturer shall maintain documentation on the characteristics of the water in compliance with the requirements of Table 2, other than the total solids requirement. These requirements shall apply to the combined water at the highest

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TABLE 2 Optional Chemical Limits for Combined Mixing Water[A]

	Limits	Test Method
Maximum concentration in combined mixing water, ppm[B]		
A. Chloride as Cl^-, ppm		
1 in prestressed concrete, bridge decks, or otherwise designated	500[C]	C 114
2 other reinforced concrete in moist environments or containing aluminum embedments or dissimilar metals or with stay-in-place galvanized metal forms	1000[C]	C 114
B. Sulfate as SO_4, ppm	3000	C 114
C. Alkalies as (Na_2O + 0.658 K_2O), ppm	600	C 114
D. Total solids by mass, ppm	50 000	C 1603

[A]Specification limits from this table are not prohibited from being specified as individual items or as a whole per paragraph 4.1.6 of Specification C 94/C 94M.
[B]ppm is the abbreviation for parts per million
[C]The requirements for concrete in ACI 318 shall govern when the manufacturer can demonstrate that these limits for mixing water can be exceeded. For conditions allowing the use of calcium chloride ($CaCl_2$) accelerator as an admixture, the chloride limitation is permitted to be waived by the purchaser.

solids content anticipated for use. These tests shall be conducted before first use and thereafter once every 6 months. These records shall be provided to the purchaser on request (See Note 5).

5.3 Concrete testing to verify compliance with the requirements of Table 1 shall be conducted on concrete samples obtained from production batches or in laboratory batches in accordance with Practice C 192/C 192M (See Note 5).

NOTE 5—The sampling of total combined water in its final form from either the batch plant or transportation unit is impractical. Therefore, for the purposes of testing for compliance to the requirements of Table 1 and Table 2, it is acceptable to sample, proportion, and combine the individual sources of water to produce a test sample that is representative of the actual combined mixing water used in production.

6. Keywords

6.1 combined water; density; hydration stabilizing admixture; mixing water; recycled water

ANNEX

(Mandatory Information)

A1. GUIDE FOR THE COMPARISON BETWEEN TWO CONCRETE MIXTURES NECESSARY FOR COMPLIANCE WITH Table 1

INTRODUCTION

To comply with the performance requirements in Table 1, comparison between two concrete mixtures is required: one as a control batch using a potable water source, and a second as a test batch using the water source(s) proposed for use. The following shall apply:

A1.1 Water for the test batch as defined in 3.2 with a density greater than 1.01 g/mL, or as close in approximation to density as used during actual production.

A1.2 Water for the test batch as defined in 3.2 shall be as close as possible to the actual age of water used during actual production.

A1.3 Air entraining and water reducing admixtures are permitted in test and control batches. The air-entraining admixture shall be adjusted to produce the target air content with a tolerance of ±1.5 %. The dosage of water reducing admixture shall be the same in both batches.

A1.4 Hydration stabilizing admixtures are permitted for use in the mixing water for the test batch. No other set controlling admixtures are permitted.

A1.5 Mixing water content of the test batch shall not be less than the mixing water content of the control batch.

A1.6 Mixture proportions shall be made available upon request.

A1.7 Each batch for concrete comparison purposes to determine compliance with Table 1 shall be within ± 1 °C at the time of mixing and shall be conditioned the same for the duration of the test.

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APPENDIX

(Nonmandatory Information)

X1. GUIDE FOR TESTING FREQUENCY AS RELATED TO WATER SOURCE USED IN MIXING WATER.

Water Sources	Combined Water Density (g/mL)	Testing Frequency		
		Density, C 1603	Table 1	Table 2
Potable	N/A	N/A	N/A	N/A
Non-Potable[A]	N/A	N/A	3 months; after 4 tests annually (5.1.1)	6 months (5.1.2)
Concrete	<1.01	Daily (5.2.1)	6 months; annually after 2 tests (5.2.2.1)	6 months (5.2.3)
Production[A]	1.01 – 1.03		Monthly; 3 months after 4 tests (5.2.2.2)	
	> 1.03		Weekly; monthly after 8 tests (5.2.2.3)	

[A]Testing frequencies apply to the combined mixing water when it is wholly or partially composed of the listed source as defined in Section 3.

SUMMARY OF CHANGES

Committee C09 has identified the location of selected changes to this specification since the last issue, C 1602/C 1602M – 05, that may impact the use of this specification. (Approved February 15, 2006)

(*1*) Added new footnote A in Table 2.

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Designation: C 1603 – 05a

Standard Test Method for Measurement of Solids in Water[1]

This standard is issued under the fixed designation C 1603; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope

1.1 This test method covers the measurement of the solids content in water for use as mixing water in ready-mixed concrete and the measurement of its density. Solids content is expressed in terms of parts per million (ppm) or in terms of percent by mass of the water sample.

1.2 The values stated in SI units are to be regarded as standard; inch-pound units are shown in parenthesis for information only.

1.3 The text of this standard references notes and footnotes that provide explanatory material. These notes and footnotes (excluding those in tables and figures) shall not be considered as requirements of the standard.

1.4 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and to determine the applicability of regulatory limitations prior to use.*

2. Referenced Documents

2.1 *ASTM Standards:* [2]

C 29/ C 29M Test Method for Bulk Density ("Unit Weight") and Voids in Aggregate

C 670 Practice for Preparing Precision and Bias Statements for Test Methods for Construction Materials

C 1602/C 1602M Standard Specification for Mixing Water Used in the Production of Hydraulic Cement Concrete

3. Significance and Use

3.1 This test method is used to determine the solids content of mixing water used to produce concrete when one or more of the water sources is wash water from concrete production operations or water that contains solids when batched as mixing water in concrete.

3.2 The test method provides a means to determine the relationship between the density and solids content of water for compliance with solids content limits of mixing water such as in Specification C 1602/C 1602M.

3.3 During production of concrete, the water property measured is its density, which can then be used to estimate the solids content from procedures described in this test method.

3.4 To develop a correlation between the density and solids content of water, water samples should be tested that cover the range of solids concentrations anticipated during production.

4. Apparatus

4.1 Density Measure: A cylindrical container (Note 1) with a volume of 200 ± 25 mL (7 ± 1 fl. oz.) with a glass or hard plastic plate that is placed over it. The glass or plastic plate shall be at least 6 mm (¼ in.) thick and 40 mm (1½-in.) larger than the outer diameter of the measure. The top of the density measure shall be flat such that it does not leak when the plate is placed over it.

NOTE 1—A commonly available smaller size mason jar with top ground smooth is acceptable.

4.2 The volume of the density measure shall be determined to nearest 0.1 mL in accordance with procedures used for calibrating air or density measures, as in Test Method C 29/ C 29M.

4.3 A microwave oven with at least 900 W of power capacity.

4.4 A microwave-safe glass dish large enough to contain the water sample and fiberglass cloth (See Note 2).

NOTE 2—A 450 × 450 × 25 mm (9 × 9 × 1 in.) dish is acceptable. Fiberglass cloth commonly used with fiberglass resin for boat or auto body repair is found in most hardware stores.

4.5 A balance or scale with a minimum capacity of 2000 g accurate to 0.1 g

4.6 A rubber syringe

5. Measurement of Density

5.1 Obtain the mass of the empty density measure and plate to the nearest 0.1g.

[1] This test method is under the jurisdiction of ASTM Committee C09 on Concrete and Concrete Aggregates and is the direct responsibility of Subcommittee C09.40 on Ready-Mixed Concrete.

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[2] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

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5.2 If the water contains solids in suspension, ensure that the water is sampled while the water source is being agitated. Take a representative sample of water and fill the density measure to overflowing. Slide the cover plate over the measure ensuring that there are no air bubbles. Wipe the outside of the plate and measure dry and obtain the mass of the filled density measure covered with the plate.

5.3 Calculate the density of the water sample to 0.001 g/mL

$$D_W = \frac{M_W}{V} \quad (1)$$

Where:
D_W = Density of the water, g/mL,
M_W = Net mass of water in the density measure, g, and
V = Volume of the density measure, mL.

6. Measurement of Solids Content

6.1 Obtain the mass of the empty dish and a piece of fiber glass cloth about 500 mm (20 in.) square to the nearest 0.1 g.

6.2 Keep the glass plate over the density measure and shake the water suspension. Pour the water sample into the glass dish. Using the rubber syringe, wash solids adhered in the measure into the dish using a minimum amount of water. Cover the water with the fiberglass cloth to prevent loss of solids during drying.

6.3 Place the dish in a microwave oven and heat it for approximately 20 min or until the water has evaporated. Determine the mass of the dish and place it back in the microwave oven for 2 min increments until the mass determined in two subsequent determinations do not differ by more than 0.5 g.

6.4 Determine the mass of the dish and cloth with the dried solids.

6.5 Calculate the percent solids in terms of percent by mass to the nearest 0.1 % and in ppm to the nearest 1000 ppm.

$$S_W,\% = \frac{M_s}{M_W} \times 100 \quad (2)$$

$$S_{ppm} = S_W \times 10\,000 \quad (3)$$

Where:
M_s = Mass of dry solids,
M_W = Mass of water with solids,
S_W = Solids content in water, in percent, and
S_{ppm} = Solids content in water, in ppm.

6.6 Repeat these measurements for water with different solids content. Test water at 4 or more different levels of solids content.

7. Relationship Between Density and Solids Content

7.1 Establish a relationship using linear regression analysis (See Note 3) between the measured density and solids content of water sample measurements for a range of solid concentrations that cover the anticipated range in the production facility.

NOTE 3—The linear regression analysis can be performed using spreadsheet software.

7.1.1 Express the relationship between the density of the water and the solids content as follows, such that the measured density on a particular production day can be used to determine the solids content of the water.

$$S_{ppm} = A + B \times D_W \quad (4)$$

Where: A and B are regression constants

NOTE 4—Eq 4 provides an approximate linear relationship between solids content and measured density. The relationship between solids content and density is non-linear (see Eq 5) and Eq 4 should not be used to estimate the solids content of water outside the range of values used to establish the relationship in Eq 4.

NOTE 5—During concrete production, a producer might choose to monitor the density of a water source using a hydrometer. It is recommended that the density of the water using a hydrometer be determined on the water at the time of this density measurement to obtain a relationship, if needed, or to calibrate the hydrometer. The water sample should be placed in a transparent volumetric measuring flask. The hydrometer measurement should be taken within 10 s after filling the water in the flask. This is to ensure that significant settlement of solids has not occurred before the measurement is taken as that will affect the measured density.

7.2 When the relationship between density and solids content is not determined by testing, calculate the solids content of the water in ppm from the measured density using the following:

$$S_{ppm} = \left(\frac{D_W - 1}{D_S - 1}\right) \times \frac{D_S}{D_W} \times 1\,000\,000 \quad (5)$$

where:
D_S = Density of solids in the water, g/mL

7.2.1 When the density of solids in the water is unknown, assume it to be 2.6 g/mL, and determine the solids content of the water in ppm from the measured density using the simplified form of Eq 5 as follows:

$$S_{ppm} = 1\,625\,000 \times \left(1 - \frac{1}{D_W}\right) \quad (6)$$

NOTE 6—Guidance for blending two sources of water with different solids content is provided in Appendix X1.

8. Report

8.1 For the water samples tested to establish the relationship of water density to solids content, maintain a record of the density of water to the nearest 0.001 g/mL; and the solids content of the same water sample in ppm to the nearest 1000 ppm or percent by mass of water to the nearest 0.1 %. Include the dates of these tests and maintain a record of the regression equation used to establish the relationship of water density to solids content.

8.2 For tests of water samples during production of concrete or to calibrate automated measuring devices, maintain a record of water density tests to the nearest 0.001 g/mL or solids content to the nearest 1000 ppm. Include the date and time of these tests. Record the calculated solids content of the tested water sample and the method (7.1 or 7.2) used to determine the solids content.

9. Precision and Bias

9.1 *Precision*—The estimates of precision for this test method are based on results from tests on wash water samples with a range of solids content between 25 000 and 140 000 ppm. Four operators tested the same water samples in triplicate for the density and in duplicate for solids content.

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9.1.1 *Single Operator Precision*—The single-operator standard deviation (1s) is shown in Table 1 by average density and solids content; therefore, results of two properly conducted tests on the same sample by the same operator are not expected to differ by more than the d2s values listed in Table 1.

9.1.2 *Multi-Operator Precision*—The multi-operator standard deviation (1s) is shown in Table 1 by average density and solids content; therefore, results of two properly conducted tests on the same sample by two different operators are not expected to differ by more than the d2s values listed in Table 1.

9.2 *Bias*—Since there is no accepted reference material for determining the bias of the results from this test method, no statement on bias is made.

10. Keywords

10.1 concrete mixing water; density; recycled water; solids

TABLE 1 *Table Precision*

	Standard Deviation (1s)[A]	Acceptable Range of Two Results (d2s)[A]
Single Operator Precision		
Density, g/mL		
1.016	0.0005	0.0015
1.033	0.0010	0.0030
1.052	0.0017	0.0047
1.101	0.0014	0.0039
Solids Content, ppm		
22,300	740	2,100
46,600	970	2,700
71,500	600	1,700
134,500	2,300	6,300
Multi-Operator Precision		
Density, g/mL		
1.016	0.0009	0.0026
1.033	0.0018	0.0050
1.052	0.0025	0.0069
1.101	0.0020	0.0056
Solids Content, ppm		
22,300	1,080	3,000
46,600	1,110	3,100
71,500	2,250	6,300
134,500	2,530	7,100

[A]These numbers represent, respectively, the (1s) and (d2s) limits as described in Practice C 670

APPENDIX

(Nonmandatory Information)

X1. Determination of Blending Percentages of Combined Water

X1.1 Use the following relationships to determine the mixing percentage (Note X1.1) of each of two water sources to be blended to ensure that the added mixing water to concrete is at a target limit of solids content or the respective target density.

X1.1.1 When the solids content of the two sources of water is known and water is batched by mass or by volume, use Eq X1.1:

$$P_1 = \frac{S_T - S_2}{S_1 - S_2} \times 100 \quad \text{(X1.1)}$$

X1.1.2 When the density of the two sources of water is known, use Eq X1.2 when water is batched by mass and Eq X1.3 when water is batched by volume:

$$P_1 = \frac{D_T - D_2}{D_1 - D_2} \times \frac{D_1}{D_T} \times 100 \quad \text{(X1.2)}$$

$$P_1 = \frac{D_T - D_2}{D_1 - D_2} \times 100 \quad \text{(X1.3)}$$

Where:

P_1 = Percentage of water from source 1 in the blended mixing water,

S_T *and* D_T = Target solids content in ppm and density in g/mL of the blended mixing water,

S_1 *and* D_1 = Solids content in ppm and density in g/mL of the water from source 1, and

S_2 *and* D_2 = Solids content in ppm and density in g/mL of the water from source 2.

NOTE X1.1—The target solids content may be a limit established in a specification or one that the quality control function of the ready mixed concrete producer establishes. The solids content, typically dissolved, of municipal water may be considered to be 0 ppm and the density may be considered to be 1.0 g/mL, to simplify this calculation.

X1.2 When wash water from concrete production is used at a higher percentage of solids content, there will be necessary corrections in the quantity of mixing water and the volume of solids to account for the solids content in the total mixing water.

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Designation: C 1604/C 1604M – 05

Standard Test Method for Obtaining and Testing Drilled Cores of Shotcrete[1]

This standard is issued under the fixed designation C 1604/C 1604M; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope

1.1 This test method covers obtaining, preparing, and testing cores drilled from shotcrete for length, compressive strength, or splitting tensile strength determinations.

1.2 The values stated in either inch-pound units or SI units shall be regarded separately as standard. SI units are shown in brackets. The values stated in each system may not be exact equivalents; therefore, each system must be used independently of the other. Combining values from the two systems may result in nonconformance with the standard.

1.3 The text of this standard references notes and footnotes that provide explanatory material. These notes and footnotes (excluding those in tables and figures) shall not be considered as requirements of the standard.

1.4 *This standard does not purport to address the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

2. Referenced Documents

2.1 *ASTM Standards:* [2]

C 39/C 39M Test Method for Compressive Strength of Cylindrical Concrete Specimens

C 42/C 42M Test Method for Obtaining and Testing Drilled Cores and Sawed Beams of Concrete

C 125 Terminology Relating to Concrete and Concrete Aggregates

C 174/C 174M Test Method for Measuring Thickness of Concrete Elements Using Drilled Concrete Cores

C 496/C 496M Test Method for Splitting Tensile Strength of Cylindrical Concrete Specimens

C 617 Practice for Capping Cylindrical Concrete Specimens

C 670 Practice for Preparing Precision and Bias Statements for Test Methods for Construction Materials

C 823 Practice for Examination and Sampling of Hardened Concrete in Constructions

C 1140 Practice for Preparing and Testing Specimens from Shotcrete Test Panels

C 1231/C 1231M Practice for Use of Unbonded Caps in Determination of Compressive Strength of Hardened Concrete Cylinders

2.2 *ACI Standards:*[3]

318 Building Code Requirements for Structural Concrete

506.2 Specification for Shotcreting

506.4R Guide for the Evaluation of Shotcrete

3. Terminology

3.1 For definitions of terms used in this standard, refer to Terminology C 125.

4. Significance and Use

4.1 This test method provides standardized procedures for obtaining cored specimens to determine the compressive strength and splitting tensile strength of shotcrete during pre-construction, during construction, and from older shotcrete structures.

4.2 Generally, test specimens are obtained *in situ* when doubt exists about the in-place shotcrete quality due either to low strength test results during construction or signs of distress in the structure. Other uses of this method are to provide specimens for acceptance testing, construction control and to assess the condition, quality and uniformity of the shotcrete in accordance with Practice C 823 (see Note 1).

4.3 Specimens obtained by this method are used to verify the thickness of shotcrete and aid in the visual assessment of the shotcrete quality, workmanship, defects, shotcrete-to-substrate bond and the condition of any reinforcement used in the shotcrete[4].

4.4 Shotcrete strength is affected by the location of the shotcrete in a structure. Vertical, sub-horizontal and overhead elements of the shotcrete structure may show variability. Core strength is affected by core orientation relative to direction of shotcrete application. These factors shall be considered in

[1] This test method is under the jurisdiction of ASTM Committee C09 on Concrete and Concrete Aggregates and is the direct responsibility of Subcommittee C09.46 Shotcrete.

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[2] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

[3] Available from American Concrete Institute, P.O. Box 9094, Farmington Hills, MI 48333

[4] Bartlett, F.M. and MacGregor, J.G., "Effect of Core Diameter on Concrete Core Strengths," *ACI Materials Journal,* Vol. 91, No. 5, September-October 1994, pp. 460-470.

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planning the locations for obtaining shotcrete samples and in interpreting strength test results.

4.5 Shotcrete is applied in single or multiple layers, as plain shotcrete, reinforced shotcrete, or fiber-reinforced shotcrete. Core samples containing wire-mesh and reinforcing bars shall not be used for compressive strength testing.

4.6 The strength of shotcrete is affected by moisture content, the specified moisture conditioning procedure for cores is intended to provide test specimens with reproducible moisture contents that minimize within-laboratory and between-laboratory variations.

4.7 Sample acquisition may require a combination of core-drilling, sawing, and grinding that may have the potential to adversely affect the sample condition if care is not taken during sampling and testing.

4.8 A sampling plan shall be established that indicates the number of samples and their locations (see Note 1). The acceptance criteria for shotcrete core strengths shall be established by the specifier of tests (see Note 2).

NOTE 1—Practice C 823 provides guidance on the development of a sampling plan for concrete in constructions. A number of methods that supplement the examination of hardened shotcrete by means of representative core samples and testing are discussed in ACI 506.4R.

NOTE 2—The core strength acceptance criteria cited in ACI 318 are based on a comparison of molded cylinder specimens and cores. Shotcrete strengths are always based on core specimens, therefore the 85 % factor used in core to cylinder comparisons is not relevant to the evaluation of shotcrete core strengths. A typical shotcrete specification reflecting standard industry practice is contained in ACI 506.2.

5. Apparatus

5.1 *Core Drill*, for obtaining cylindrical core specimens with diamond impregnated bits attached to a core barrel. The core drill shall have a rigid mounting base and be capable of being operated in any orientation normal to the shotcrete structure that is being sampled. The core drill shall be free from excessive vibration when in operation and shall have sufficient torque and consistent rotational speed to sustain uniform rates of penetration of the core drill. The core barrel shall be cooled and core cuttings flushed with water during operation.

5.2 *Saw*, for cutting core specimens to size for compressive strength. The saw shall have a diamond or silicon carbide cutting edge and shall be capable of cutting plain and reinforced specimens in a single pass that conform with the prescribed dimensions, without excessive heating or shock.

5.3 *Grinding wheel*, to trim and clean plain and fiber-reinforced shotcrete specimens that conform to prescribed tolerances without significantly disturbing the aggregates, matrix or fiber-reinforcement.

6. Sampling

6.1 *General*:

6.1.1 Sampling shall be planned in accordance with the applicable provisions of Practice C 823. The number of samples, sample locations and sampling procedures shall be established in the plan.

6.1.2 Shotcrete samples obtained from test panels shall be in accordance with the applicable provisions of Practice C 1140.

6.1.3 Samples of hardened shotcrete for use in the preparation of strength test specimens shall not be taken until the shotcrete is strong enough to permit sample removal without disturbing the bond between the mortar, coarse aggregate (see Note 3) and fiber-reinforcement. When preparing strength test specimens from samples of hardened shotcrete, samples that have been damaged in the process of removal shall not be used. Specimens of defective shotcrete that cannot be tested shall be reported as such if the defects are representative of the in-place condition of the shotcrete (see ACI 506.4R).

NOTE 3—It is not possible to specify a minimum age when shotcrete is strong enough to withstand damage during removal, because the strength at any age depends on the strength grade and curing of the shotcrete. If accelerating admixtures are used during shotcrete application, core specimens may be obtained for testing at approximately 6 h. If this is not practical, removal of shotcrete can proceed if cored or cut surfaces do not display erosion of the mortar and the exposed coarse aggregate particles are embedded firmly in the mortar. Nondestructive test methods may be used to estimate level of in-place strength development prior to attempting removal of shotcrete core samples (see ACI 506.4R).

6.1.4 Specimens containing embedded reinforcement shall not be used for determining compressive or splitting tensile strength.

6.2 *Core Drilling*—Drill core specimens perpendicular to the surface and avoid drilling near formed joints or edge placement. Record the approximate angle between the drilled core axis and the plane of the shotcrete as placed.

7. Measuring the Length of Drilled Cores

7.1 Cores for determining the thickness of shotcrete layers or other structural elements shall have a diameter of at least 3.0 in.. [75 mm] when the lengths of such cores are to be measured in accordance with Test Method C 174/C 174M.

7.2 For cores that are not intended for determining structural dimensions, measure the longest and shortest lengths on the cut surface along lines parallel to the core axis. Record the average length to the nearest ¼ in. [5 mm].

8. Cores for Compressive Strength

8.1 *Diameter*—The diameter of core specimens for the determination of compressive strength in load bearing structural members shall be at least 3.0 in. [75 mm] (see Note 4). Core diameters less than 3.0 in. [75 mm] shall be permitted as directed by the specifier of the tests.

NOTE 4—The compressive strengths of 2-in [50-mm] diameter cores are known to be somewhat lower and more variable than those of 3-in. [75-mm] diameter cores. In addition, smaller diameter cores appear to be more sensitive to the effect of the length-diameter ratio[4].

8.2 *Length*—The preferred length of the capped or ground specimen is nominally two times the diameter.

8.2.1 If the ratio of the length to the diameter (L/D) of the core exceeds 2.1, reduce the length of the core so that the ratio of the capped or ground specimen is between 1.9 and 2.1. Core specimens with length-diameter ratios equal to or less than 1.75 require corrections to the measured compressive strength (see. 8.8.1). A strength correction factor is not required for L/D greater than 1.75. A core having a length of less than 95 % of its diameter before capping or a length less than its diameter after capping or end grinding shall not be tested unless so directed by the specifyer of the tests.

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8.2.2 For non-load bearing structural members or when it is impossible to obtain shotcrete cores with length-diameter ratio (L/D) greater than or equal to 1.0, core specimens shall be subject to the approval of the specifier of the tests.

8.3 *Moisture Conditioning*—The following procedure is intended to preserve the moisture of the drilled core and to provide a reproducible moisture condition that minimizes the effects of moisture gradients introduced by wetting during drilling and specimen preparation.

8.3.1 The following procedure is used to obtain cores having a moisture condition that is representative of the in-place shotcrete. After cores have been drilled, wipe off surface water on the drilled core with a dry cloth and allow remaining surface moisture to evaporate. When surfaces appear dry, but not later than 1 h after drilling, place cores in separate plastic bags or nonabsorbent containers and seal to prevent moisture loss. Maintain cores at ambient temperature, and protect cores from exposure to direct sunlight. Transport the cores to the testing laboratory as soon as practicable. Keep cores in the sealed plastic bags or nonabsorbent containers at all times except during end preparation and for a maximum time of 2 h to permit capping before testing.

8.3.2 If water is used during sawing or grinding of core ends, complete these operations as soon as practicable, but no later than 2 days after drilling of cores. After completing end preparation, use a dry cloth to remove surface moisture, allow the surfaces to dry, and place the cores in sealed plastic bags or nonabsorbent containers. Minimize the duration of exposure to water during end preparation.

8.3.3 Allow cores aged 28 days or more to remain in the sealed plastic bags or nonabsorbent containers for at least 5 days after last being wetted and before testing (See Note 5). For early strength testing of specimens aged 28 days or less, test specimens as directed by the specifier of the tests.

NOTE 5—The waiting period of at least 5 days is intended to reduce moisture gradients introduced when the core is drilled or wetted during sawing or grinding.

8.3.4 When the specifier of the tests so directs, test cores in a moisture condition other than achieved by conditioning according to 8.3.3. Report the alternative moisture conditioning procedure.

8.4 *Sawing of Ends*—The ends of core specimens to be tested in compression shall be flat, and perpendicular to the longitudinal axis. If necessary, saw the ends of cores that will be capped so that the following requirements are met:

8.4.1 Projections, if any, shall not extend more than 0.2 in. [5 mm] above the end surfaces.

8.4.2 The end surfaces shall not depart from perpendicularity to the longitudinal axis by a slope of more than 1:8*d* [or 1:0.3*d*], where *d* is the average core diameter in inches [or mm].

NOTE 6—This limitation is intended to avoid cap thicknesses that exceed the requirements of Practice C 617.

8.5 *Capping*—If the ends of the cores do not conform to the perpendicularity and planeness requirements of Test Method C 39/C 39M, they shall be sawn or ground to meet those requirements or capped in accordance with Practice C 617. If cores are capped in accordance with Practice C 617, the capping device shall accommodate actual core diameters and produce caps that are concentric with the core ends. Measure core lengths to the nearest 0.1 in. [2 mm] before capping. Unbonded caps in accordance with Practice C 1231 are not permitted.

NOTE 7—Before capping, the density of a core may be estimated by weighing it and dividing the mass by the volume calculated from the average diameter and length.

8.6 *Measurement*—Before testing, measure the length of the capped or ground specimen to the nearest 0.1 in. [2 mm] and use this length to compute the length-diameter (L/D) ratio. Determine the average diameter by averaging two measurements taken at right angles to each other at the mid-height of the specimen. Measure core diameters to the nearest 0.01 in. [0.2 mm] when the difference in core diameters does not exceed 2 % of their average; otherwise, measure to the nearest 0.1 in. [2 mm]. Do not test cores if the difference between the largest and smallest diameter exceeds 5 % of their average.

8.7 *Testing*—Test the specimens in accordance with Test Method C 39/C 39M. Test the specimens within 7 days after coring, unless so directed by the specifier of the tests.

8.8 *Calculation*—Calculate the compressive strength of each specimen using the computed cross-sectional area based on the average diameter of the specimen.

8.8.1 If the ratio of the core length to diameter (L/D) of the specimen is 1.75 or less, correct the results obtained in 8.8 by multiplying by the appropriate correction factor shown in the following table (see Note 8).

Ratio of Length to Diameter (L/D)	Strength Correction Factor
1.75	0.98
1.50	0.96
1.25	0.93
1.00	0.87

Use interpolation to determine correction factors for L/D values not given in the table.

NOTE 8—Correction factors depend on various conditions such as moisture condition, strength level, and elastic modulus. Average values are given in the table. These correction factors apply to normal density shotcrete. They are applicable to both dry and wet shotcrete for nominal concrete strengths between 2000 psi and 6000 psi [14 MPa and 42 MPa]. For strengths above 10 000 psi [70 MPa], test data on concrete cores show that the correction factors may be larger than the values listed above[5].

8.9 *Report*—Report the results as required by Test Method C 39/C 39M with the addition of the following information:

8.9.1 Length of core as drilled to the nearest ¼ in. [5 mm],

8.9.2 Length of test specimen before and after capping or end grinding to the nearest 0.1 in. [2 mm], and average diameter of core to the nearest 0.01 in. [0.2 mm] or 0.1 in. [2 mm],

8.9.3 Compressive strength to the nearest 10 psi [0.1 MPa] when the diameter is measured to the nearest 0.01 in. [0.2 mm]

[5] Bartlett, F.M. and MacGregor, J.G, "Effect of Core Length-to-Diameter Ratio on Concrete Core Strengths," *ACI Materials Journal*, Vol. 91, No. 4, July-August 1994, pp. 339-348.

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and to the nearest 50 psi [0.5 MPa] when the diameter is measured to the nearest 0.1 in. [2 mm], after correction for length-diameter ratio when required,

8.9.4 Direction of application of the load on the specimen with respect to the horizontal plane of the shotcrete as placed,

8.9.5 The moisture conditioning history:

8.9.5.1 The date and time core was obtained and first placed in sealed bag or nonabsorbent container;

8.9.5.2 If water was used during end preparation, the date and time end preparation was completed and core placed in sealed bag or nonabsorbent container,

8.9.6 The date and time when tested,

8.9.7 Nominal maximum size of shotcrete aggregate,

8.9.8 If determined, the estimated density,

8.9.9 If applicable, description of defects in cores that could not be tested, and

8.9.10 If any deviation from this test method was required, describe the deviation and explain why it was necessary.

8.10 *Precision*

8.10.1 The precision of compressive strength of shotcrete cores measured by this test method has not been established, but is believed to be similar to that of concrete cores[6]. Therefore, the following provisional statements taken from the Test Method C 42/C 42M are provided until an inter-laboratory study of shotcrete cores are completed.

8.10.2 The single-operator coefficient of variation on concrete cores has been found to be 3.2 %[7] for a range of compressive strength between 4500 psi [32.0 MPa] and 7000 psi [48.3 MPa]. Therefore, results of two properly conducted tests of single cores by the same operator on the same sample of material should not differ from each other by more than 9 %[7] of their average.

8.10.3 The multi-laboratory coefficient of variation on cores has been found to be 4.7 %[7] for a range of compressive strength between 4500 psi [32.0 MPa] and 7000 psi [48.3 MPa]. Therefore, results of two properly conducted tests on cores sampled from the same hardened concrete (where a single test is defined as the average of two observations (cores), each made on separate adjacent drilled 4-in. [100-mm] diameter cores) and tested by two different laboratories should not differ from each other by more than 13 %[7] of their average.

8.11 *Bias*—Since there is no accepted reference material suitable for determining the bias for the procedure in this test method, no statement on bias is being made.

9. Cores for Splitting Tensile Strength

9.1 *Test Specimens*—The specimens shall conform to the dimensional requirements in 8.1, 8.2, 8.4.1, and 8.4.2. Ends are not to be capped.

9.2 *Moisture Conditioning*—Condition the specimens as described in 8.3, or as directed by the specifier of the tests.

9.3 *Bearing Surfaces*—The line of contact between the specimen and each bearing strip shall be straight and free of any projections or depressions higher or deeper than 0.01 in. [0.2 mm]. When the line of contact is not straight or contains projections or depressions having heights or depths greater than 0.01 in [0.2 mm], grind or cap the specimen so as to produce bearing lines meeting these requirements. Do not test specimens with projections or depressions greater than 0.1 in. [2 mm]. When capping is employed, the caps shall be as thin as practicable and shall be formed of high-strength gypsum cement.

NOTE 9—Fig. 1 illustrates a device suitable for applying caps to the bearing surfaces of core specimens.

9.4 *Testing*—Test the specimens in accordance with Test Method C 496/C 496M.

9.5 *Calculation and Report*—Calculate the splitting tensile strength and report the results as required in Test Method C 496/C 496M. When grinding or capping of the bearing surfaces is required, measure the diameter between the finished surfaces. Indicate that the specimen was a core and provide the moisture conditioning history as in 8.9.5.

9.6 *Precision*

9.6.1 The precision of splitting tensile strength of shotcrete cores measured by this test method has not been established, but is believed to be similar to that of concrete cores[8]. Therefore, the following provisional statements taken from the Test Method C 42/C 42M are provided until an inter-laboratory study of shotcrete cores is completed.

9.6.2 The within-laboratory single operator coefficient of variation for splitting tensile strength between 520 psi [3.6 MPa] and 590 psi [4.1 MPa] of cores has been found to be 5.3 %[9]. Therefore, results of two properly conducted tests by the same operator in the same laboratory on the same sample of material should not differ by more than 14.9 %[9] of their average.

9.6.3 The multi-laboratory coefficient of variation for splitting tensile strength between 520 psi [3.6 MPa] and 590 psi [4.1 MPa] of cores has been found to be 15 %.[9] Therefore, results of two properly conducted tests on the same sample of material of hardened concrete and tested by two different laboratories should not differ from each other by more than 42.3 %[9] of their average.

9.7 *Bias*—Since there is no accepted reference material suitable for determining the bias of the procedure in this test method, no statement on bias is being made.

10. Keywords

10.1 compressive strength; core; shotcrete; splitting tensile strength

[6] Bollin, G.E. "Development of Precision and Bias Statements for Testing Drilled Cores in Accordance with ASTM C 42." *Journal of Cement. Concrete, and Aggregates*, Vol. 15, No. 1, 1993.

[7] These numbers represent, respectively, the (1s %) and (d2s %) limits as described in ASTM Practice C 670.

[8] Steele, G.W. "Portland Cement Concrete Core Proficiency Sample Program." Strategic Highway Research Program, SHHP-P-636, National Research Council, Washington D.C., 1993.

[9] These numbers represent, respectively, the (1s %) and (d2s %) limits a described in ASTM Practice C 670.

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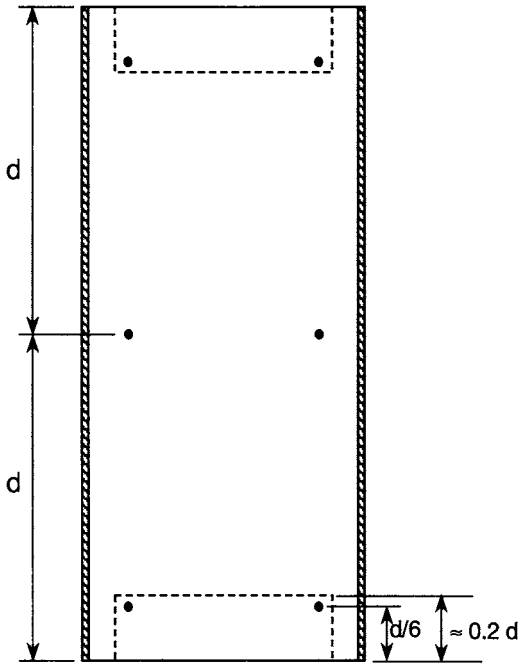

FIG. 1 Suitable Capping Device for Splitting Tensile Strength Test

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Designation: C 1608 – 07

Standard Test Method for Chemical Shrinkage of Hydraulic Cement Paste[1]

This standard is issued under the fixed designation C 1608; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope*

1.1 This test method measures the internal (absolute) volume change of hydraulic cement paste that results from the hydration of the cementitious materials. This volume change is known as *chemical shrinkage*.

1.1.1 Procedure A, volumetric method.

1.1.2 Procedure B, the density method.

1.2 The values stated in SI units are to be regarded as the standard.

1.3 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.* (**Warning**—Fresh hydraulic cementitious mixtures are caustic and may cause chemical burns to skin and tissue upon prolonged exposure.[2])

2. Referenced Documents

2.1 *ASTM Standards:* [3]

C 186 Test Method for Heat of Hydration of Hydraulic Cement

C 188 Test Method for Density of Hydraulic Cement

C 219 Terminology Relating to Hydraulic Cement

C 305 Practice for Mechanical Mixing of Hydraulic Cement Pastes and Mortars of Plastic Consistency

C 511 Specification for Mixing Rooms, Moist Cabinets, Moist Rooms, and Water Storage Tanks Used in the Testing of Hydraulic Cements and Concretes

C 670 Practice for Preparing Precision and Bias Statements for Test Methods for Construction Materials

C 1005 Specification for Reference Masses and Devices for Determining Mass and Volume for Use in the Physical Testing of Hydraulic Cements

3. Terminology

3.1 *Definitions:*

3.1.1 *chemical shrinkage*, *n*—the absolute (internal) volume change accompanying the hydration of cement, due to the fact that the cement hydration products occupy less physical volume than the reactants.

3.1.2 All other terms are as defined in Terminology C 219.

4. Significance and Use

Numerous properties of cementitious materials are controlled by their initial hydration rate. Examples include early-age strength development, heat release, and crack resistance. One direct and convenient measure of this initial hydration rate is provided by the measurement of the chemical shrinkage of the cement paste during its hydration. As cement hydrates, the hydration products occupy less volume than the initial reacting materials (cement and water). Due to this volume change, a hydrating cement paste will sorb water from its immediate surroundings, when available. At early times, this sorption is in direct proportion to the amount of hydration that has occurred.[4] This method is based on the one developed by Geiker.[5] The results are relevant to understanding the hydration behavior of cements. This method does not measure the bulk volume changes (autogenous shrinkage) associated with chemical shrinkage nor the cracking potential of concretes produced with the evaluated cement.

5. Apparatus

5.1 *Devices for Determining Mass*, conforming to the requirements of Specification C 1005 and evaluated for precision and accuracy at a total load of 100 g.

5.2 *Constant Temperature Water Bath*—a water bath capable of maintaining a temperature of 23.0 ± 0.5 °C, with a

[1] This test method is under the jurisdiction of ASTM Committee C01 on Cement and is the direct responsibility of Subcommittee C01.31 on Volume Change.

Current edition approved June 15, 2007. Published July 2007. Originally approved in 2005. Last previous edition approved in 2006 as C 1608 – 06.

[2] See the section on Safety, Manual of Cement Testing, *Annual Book of ASTM Standards*, Vol. 04.01.

[3] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

[4] L.J. Parrott, M. Geiker, W.A. Gutteridge, and D. Killoh, "Monitoring Portland Cement Hydration: Comparison of Methods," Cement and Concrete Research, Vol. 20, 919-926, 1990.

[5] M. Geiker, "Studies of Portland Cement Hydration: Measurements of Chemical Shrinkage and a Systematic Evaluation of Hydration Curves by Means of the Dispersion Model," Ph.D. Thesis, Technical University of Denmark, Copenhagen, Denmark, 1983.

***A Summary of Changes section appears at the end of this standard.**

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sufficient capacity to hold the specimens being evaluated. To avoid evaporative cooling, the surface of the water in the bath shall be covered with floating plastic balls or fitted with an insulated lid.

5.3 *Timing Device*—Clock that can measure time to the nearest minute.

5.4 For procedure A

5.4.1 *Capillary Tube*—A graduated glass capillary tube with graduations of 0.01 mL or smaller, and typically a capacity of 1.0 mL.

5.4.2 *Small Glass Vials (e.g., 22-mm diameter and 55-mm height) with Rubber Stoppers* that fit tightly into the glass vials and have a hole placed in each stopper with the graduated capillary tube inserted through the hole (as shown in Fig. 1). Fix the capillary tube in the stopper using a two-component epoxy or other suitable adhesive applied at the stopper's top and bottom surfaces.

5.5 For Procedure B

5.5.1 *Density bottle*, glass, capacity approximately 20 ml with internally conical glass stopper as shown in Fig. 2.

6. Reagents and Materials

6.1 Paraffin oil.

6.2 De-aerated water (prepared by boiling water and sealing it in a closed container before it has cooled.)

7. Procedure

7.1 *Preparation of Cement Paste*—Prepare the cement paste in accordance with the proportions and procedure described in Test Method C 186 (Note 1). The pastes shall be prepared in a mixing room meeting the temperature and humidity requirements outlined in Specification C 511. Record to the nearest minute the time when the water first contacts the dry cement powder.

NOTE 1—Other mixing procedures such as mixing in a Hobart mixer (see Practice C 305) or kneading by hand in a sealed plastic bag may be used. The standard paste mixture uses 150 g of cement and 60 ml of water (water-cement ratio of 0.40). Adjust the volume of paste mixed to match the mixing equipment used. Other water-cement ratios may be used as long as they are stated in the test report; higher water-cement ratios may produce significant bleeding of the cement paste which will influence the results (by changing the effective water-cement ratio, etc.); lower water-cement ratios may lead to difficulties in preparing a fully compacted, homogeneous paste for subsequent evaluation and self-desiccation may occur.

7.2 Prepare a minimum of two replicate specimens as described below for either Procedure A or Procedure B.

7.3 Procedure A

7.3.1 Determine the mass of each empty glass vial to the nearest 0.01 g.

7.3.2 Carefully place the prepared cement paste into the glass vial to achieve a paste height between 5 mm and 10 mm in the vial. Consolidate the paste in the vial by tapping the vial on a laboratory countertop, or placing it on a vibrating table, or some similar procedure.

7.3.3 Determine the mass of each glass vial with the cement paste to the nearest 0.01 g.

7.3.4 Carefully, without disturbing the cement paste, add clean, de-aerated water to fill the glass vial to the top.

7.3.5 Place the rubber stopper with the inserted capillary tube tightly into the glass vial. Be careful to avoid the entrapment of air bubbles when the bottom rubber stopper surface encounters the water in the glass vial. As the rubber stopper is inserted, the water level in the graduated capillary tube will rise. Optimally, the water level should rise near to but not beyond the top mark of the graduations on the capillary tube. If the water level is not near enough to the top mark, clean, de-aerated water can be added via the top of the capillary

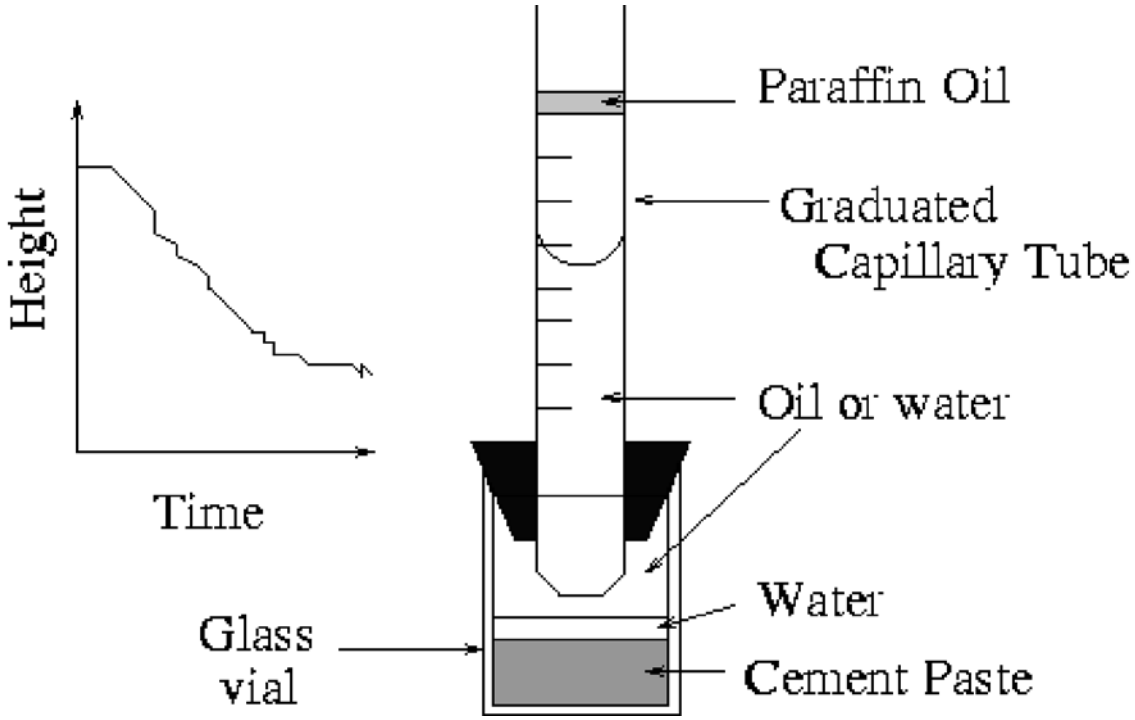

FIG. 1 Illustration of One Experimental Setup for Monitoring Chemical Shrinkage of Hydrating Cement Paste Using Procedure A.

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tube to achieve the desired initial water height. Once the rubber stopper has been fitted to the vial, the completed assembly shall be handled only by the vial (not by the capillary tube) to avoid loosening of the rubber stopper which will result in an apparent volume change of the specimen.

7.3.6 Place a drop of paraffin oil in the top of the graduated capillary tube to minimize water evaporation from the tube during the testing period.

7.3.7 Place the prepared specimens in the constant temperature water bath at 23 °C such that the tops of the glass vials are just above the water level in the bath. Maintain the temperature of the laboratory at 23 ± 2 °C. Record the time and initial level (height) of water, to the nearest 0.0025 mL, in the capillary tubes.

7.3.8 Periodically (every 30 min or every hour, as convenient) record the time to the nearest minute and water level in the capillary tubes to the nearest 0.0025 mL for a total period of at least 24 h. After the first 8 h, the recording intervals can be lengthened to 8 h or more to avoid taking readings during the night, as long as a 24 h reading is obtained the following day. Be sure to take a reading 1 h after the paste was first mixed to use as a zero point in all calculations (this allows time for the specimen to achieve temperature equilibrium within the water bath).

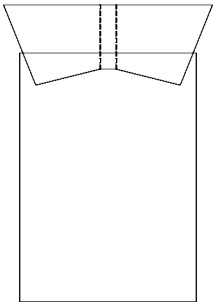

FIG. 2 Illustration of a Density Bottle for Use in Procedure B.

7.4 Procedure B

7.4.1 Determine the mass of each empty density bottle to the nearest 0.0001 g.

7.4.2 Carefully place the prepared cement paste into the density bottle to achieve a paste height between 5 mm and 10 mm in the bottle. Consolidate the paste in the bottle by tapping the bottle on a laboratory countertop, or placing it on a vibrating table or some similar procedure. Determine the mass of the density bottle with the consolidated cement paste to the nearest 0.0001 g.

7.4.3 Carefully, without disturbing the cement paste, add clean, de-aerated water to fill the bottle to the top.

7.4.4 Place the stopper tightly into the bottle. Be careful to remove any entrapped air bubbles when the bottom of the stopper encounters the water in the bottle. Add clean, de-aerated water via the perforated stopper to fill the bottle and stopper to excess (leave a bead of water on the top of the stopper to overfill the capillary tube). The filled assembly shall be handled only by the bottle (not by the stopper) to avoid loosening the stopper, which will result in an apparent change in the specimen, and not with bare fingers (e.g., wear latex gloves) which will cause an increase in mass due to transfer of oil.

7.4.5 Remove the excess water from the top of the stopper using absorbent paper, wiping quickly to avoid sucking water out of the capillary tube.

7.4.6 Immediately determine the mass of the density bottle filled with water to the top of the capillary tube. Determine the mass to the nearest 0.0001 g.

7.4.7 Place the filled density bottles in the constant temperature water bath at 23 °C such that the tops of the stoppers are just above the water level in the bath.

7.4.8 At 1 h after the paste was first mixed, remove the density bottle from the water bath and wipe dry, fill to excess with water, remove the excess and determine the mass to the nearest 0.0001 g.

7.4.9 Periodically (every 30 or 60 min, as convenient) for a period of at least 24 h, remove the density bottle from the water bath and wipe dry, fill to excess with water, remove the excess and determine the mass to the nearest 0.0001 g. After the first eight hours, the recording intervals can be lengthened to 8 h or more to avoid taking readings during the night, as long as a 24 h reading is obtained the following day.

8. Calculation

8.1 The chemical shrinkage is computed as the measured mL of sorbed water per gram of cement in the paste specimen. The mass of cement powder in the vial is given by:

$$M_{cement} = \frac{(M_{vial+paste} - M_{vialempty})}{\left(1.0 + \frac{w}{c}\right)} \quad (1)$$

where

M_{cement} = mass of cement in the vial (g),
$M_{vial+paste}$ = mass of the glass vial with the added cement paste (g),
$M_{vialempty}$ = mass of the empty vial (g),
w/c = water-cement ratio by mass of the prepared paste (e.g., 0.40) and a density of 1000 kg/m^3 is assumed for water.

8.2 Procedure A

8.2.1 The chemical shrinkage per unit mass of cement at time t is computed as:

$$CS(t) = \frac{[h(t) - h(60\text{min})]}{M_{cement}} \quad (2)$$

where

$CS(t)$ = chemical shrinkage at time t (mL/g cement) (Note 2).
$h(t)$ = water level in capillary tube at time t (mL)

NOTE 2—If it is desired to report the chemical shrinkage per unit volume of cement powder, the values from Eq 2 can be converted to mL/mL cement using the density of the cement powder determined using Test Method C 188.

8.3 Procedure B

8.3.1 The chemical shrinkage per unit mass of cement at time t is computed as:

$$CS(t) = \left(\frac{[M(t) - M(60\text{min})]}{M_{cement}}\right)/\rho W \quad (3)$$

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where:
$CS(t)$ = chemical shrinkage at time t (mL/g cement)
$M(t)$ = mass of filled density bottle at time t (g)
ρW = density of water (mL/g) (0.99754 at 23 °C)

9. Report

9.1 Report the following:

9.1.1 Date and time paste specimen is prepared;

9.1.2 Cementitious material sources and names;

9.1.3 Mixing and compaction procedure employed and water-cement ratio by mass;

9.1.4 Mass of each empty vial and mass of each vial with cement paste;

9.1.5 A table of the water level in each capillary tube or the mass of each filled density bottle vs. time;

9.1.6 A table and/or plot of the chemical shrinkage per gram of cement (reported to the nearest 0.0001 mL/g) vs. time.

10. Precision and Bias

10.1 *Precision*—The precision statements for this test method are listed in Table 1 and are based on the results obtained in an interlaboratory study described in Research Report C01-1010.[6]

10.2 *Bias*—Since there is no accepted reference material suitable for determining the bias of this procedure, no statement on bias is made.

11. Keywords

11.1 chemical shrinkage; hydration.

[6] Supporting data have been filed at ASTM International Headquarters and may be obtained by requesting Research Report RR: C01-1010.

TABLE 1 Precision

	Standard Deviation 1s[A]	Acceptable Range of Test Results d2s[A]
Measurements made between 4 and 8 h after mixing		
Repeatability	0.00084	0.00236
Reproducibility	0.00090	0.00253
Measurements made 24 h after mixing		
Repeatability	0.00193	0.00541
Reproducibility	0.00240	0.00672

[A] These numbers represent, respectively, the (1s) and (d2s) limits as described in Practice C 670.

SUMMARY OF CHANGES

Committee C01 has identified the location of selected changes to this test method since the last issue, C 1608 – 06, that may impact the use of this test method. (Approved June 15, 2007)

(*1*) Revised 10.1 and added new Table 1.

Committee C01 has identified the location of selected changes to this test method since the last issue, C 1608 – 05, that may impact the use of this test method. (Approved November 1, 2006)

(*1*) Revised 7.3.4 and 7.4.3.

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Designation: C 1609/C 1609M – 07

Standard Test Method for Flexural Performance of Fiber-Reinforced Concrete (Using Beam With Third-Point Loading)[1]

This standard is issued under the fixed designation C 1609/C 1609M; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope*

1.1 This test method evaluates the flexural performance of fiber-reinforced concrete using parameters derived from the load-deflection curve obtained by testing a simply supported beam under third-point loading using a closed-loop, servo-controlled testing system.

1.2 This test method provides for the determination of first-peak and peak loads and the corresponding stresses calculated by inserting them in the formula for modulus of rupture given in Eq 1. It also requires determination of residual loads at specified deflections, and the corresponding residual strengths calculated by inserting them in the formula for modulus of rupture given in Eq 1 (see Note 1). At the option of the specifier of tests, it provides for determination of specimen toughness based on the area under the load-deflection curve up to a prescribed deflection (see Note 2).

NOTE 1—Residual strength is not a true stress but an engineering stress computed using simple engineering bending theory for linear elastic materials and gross (uncracked) section properties.

NOTE 2—Specimen toughness expressed in terms of the area under the load-deflection curve is an indication of the energy absorption capability of the particular test specimen, and its magnitude depends directly on the geometry of the test specimen and the loading configuration.

1.3 This test method utilizes two preferred specimen sizes of 100 by 100 by 350 mm [4 by 4 by 14 in.] tested on a 300 mm [12 in.] span, or 150 by 150 by 500 mm [6 by 6 by 20 in.] tested on a 450 mm [18 in.] span. A specimen size different from the two preferred specimen sizes is permissible.

1.4 *Units*—The values stated in either SI units or inch-pound units are to be regarded separately as standard. The values stated in each system may not be exact equivalents; therefore, each system shall be used independently of the other. Combining values from the two systems may result in non-conformance with the standard.

1.5 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

2. Referenced Documents

2.1 *ASTM Standards:* [2]

C 31/C 31M Practice for Making and Curing Concrete Test Specimens in the Field

C 42/C 42M Test Method for Obtaining and Testing Drilled Cores and Sawed Beams of Concrete

C 78 Test Method for Flexural Strength of Concrete (Using Simple Beam with Third-Point Loading)

C 125 Terminology Relating to Concrete and Concrete Aggregates

C 172 Practice for Sampling Freshly Mixed Concrete

C 192/C 192M Practice for Making and Curing Concrete Test Specimens in the Laboratory

C 823 Practice for Examination and Sampling of Hardened Concrete in Constructions

C 1140 Practice for Preparing and Testing Specimens from Shotcrete Test Panels

3. Terminology

3.1 *Definitions*—The terms used in this test method are defined in Terminology C 125.

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *end-point deflection*—the deflection value on the load-deflection curve equal to 1/150 of the span length, or a larger value as specified at the option of the specifier of tests.

3.2.2 *first-peak load, P_1*—the load value at the first point on the load-deflection curve where the slope is zero.

3.2.3 *first-peak deflection, δ_1*—the net deflection value on the load-deflection curve at first-peak load.

3.2.4 *first-peak strength f_1*—the stress value obtained when the first-peak load is inserted in the formula for modulus of rupture given in Eq 1.

3.2.5 *load-deflection curve*—the plot of load versus net deflection of a flexural beam specimen loaded to the end-point deflection.

[1] This test method is under the jurisdiction of ASTM Committee C09 on Concrete and Concrete Aggregates and is the direct responsibility of Subcommittee C09.42 on Fiber-Reinforced Concrete.

Current edition approved Dec. 15, 2007. Published January 2008. Originally approved in 2005. Last previous edition approved in 2006 as C 1609/C 1609M – 06.

[2] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

***A Summary of Changes section appears at the end of this standard.**

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3.2.6 *net deflection*—the deflection measured at mid-span of a flexural beam specimen exclusive of any extraneous effects due to seating or twisting of the specimen on its supports or deformation of the support and loading system.

3.2.7 *peak load,* P_P—the maximum load on the load-deflection curve.

3.2.8 *peak-load deflection,* δ_P—the net deflection value on the load-deflection curve at peak load.

3.2.9 *peak strength,* f_P—the stress value obtained when the peak load is inserted in the formula for modulus of rupture given by Eq 1.

3.2.10 *D*—nominal depth of the beam specimen in mm.

NOTE 3—To simplify nomenclature, the nominal beam depth is shown in units of mm for both the SI and inch-pound version of this test method.

3.2.11 *L*—span length or distance between the supports.

3.2.12 *residual load,* P^D_{600} —the load value corresponding to a net deflection of L/600 for a beam of nominal depth D.

3.2.13 *residual load,* P^D_{150} —the load value corresponding to a net deflection of L/150 for a beam of nominal depth D.

3.2.14 *residual strength,* f^D_{600} —the stress value obtained when the residual load P^D_{600} is inserted in the formula for modulus of rupture given in Eq 1.

3.2.15 *residual strength,* f^D_{150} —the stress value obtained when the residual load P^D_{150} is inserted in the formula for modulus of rupture given in Eq 1.

3.2.16 *specimen toughness,* T^D_{150} —toughness of beam specimen of nominal depth D at a net deflection of L/150.

4. Summary of Test Method

4.1 Molded or sawn beam specimens having a square cross-section of fiber-reinforced concrete are tested in flexure using a third-point loading arrangement similar to that specified in Test Method C 78 but incorporating a closed-loop, servo-controlled testing system and roller supports that are free to rotate on their axes. Load and net deflection are monitored and recorded to an end-point deflection of at least 1/150 of the span. Data are recorded and plotted by means of an X-Y plotter, or they are recorded digitally and subsequently used to plot a load-deflection curve. Points termed first-peak, peak, and residual loads at specified deflections are identified on the curve, and are used to calculate flexural performance parameters.

5. Significance and Use

5.1 The first-peak strength characterizes the flexural behavior of the fiber-reinforced concrete up to the onset of cracking, while residual strengths at specified deflections characterize the residual capacity after cracking. Specimen toughness is a measure of the energy absorption capacity of the test specimen. The appropriateness of each parameter depends on the nature of the proposed application and the level of acceptable cracking and deflection serviceability. Fiber-reinforced concrete is influenced in different ways by the amount and type of fibers in the concrete. In some cases, fibers may increase the residual load and toughness capacity at specified deflections while producing a first-peak strength equal to or only slightly greater than the flexural strength of the concrete without fibers. In other cases, fibers may significantly increase the first-peak and peak strengths while affecting a relatively small increase in residual load capacity and specimen toughness at specified deflections.

5.2 The first-peak strength, peak strength, and residual strengths determined by this test method reflect the behavior of fiber-reinforced concrete under static flexural loading. The absolute values of energy absorption obtained in this test are of little direct relevance to the performance of fiber-reinforced concrete structures since they depend directly on the size and shape of the specimen and the loading arrangement.

5.3 The results of this test method may be used for comparing the performance of various fiber-reinforced concrete mixtures or in research and development work. They may also be used to monitor concrete quality, to verify compliance with construction specifications, obtain flexural strength data on fiber-reinforced concrete members subject to pure bending, or to evaluate the quality of concrete in service.

5.4 The results of this standard test method are dependent on the size of the specimen.

NOTE 4—The results obtained using one size molded specimen may not correspond to the performance of larger or smaller molded specimens, concrete in large structural units, or specimens sawn from such units. This difference may occur because the degree of preferential fiber alignment becomes more pronounced in molded specimens containing fibers that are relatively long compared with the cross-sectional dimensions of the mold. Moreover, structural members of significantly different thickness experience different maximum crack widths for a given mid-span deflection with the result that fibers undergo different degrees of pull-out and extension.

6. Apparatus

6.1 *Testing Machine*—The testing machine shall be capable of servo-controlled operation where the net deflection of the center of the beam is measured and used to control the rate of increase of deflection. Testing machines that use stroke displacement control or load control are not suitable for establishing the portion of the load-deflection curve immediately after first-peak. The loading and specimen support system shall be capable of applying third-point loading to the specimen without eccentricity or torque. The fixtures specified in Test Method C 78 are suitable with the qualification that supporting rollers shall be able to rotate on their axes and shall not be placed in grooves or have other restraints that prevent their free rotation.

6.2 *Deflection-Measuring Equipment*—Devices such as electronic transducers or electronic deflection gages shall be located in a manner that ensures accurate determination of the net deflection at the mid-span exclusive of the effects of seating or twisting of the specimen on its supports. One acceptable arrangement employs a rectangular jig, which surrounds the specimen and is clamped to it at mid-depth directly over the supports (Figs. 1 and 2). Two electronic displacement transducers or similar digital or analog devices mounted on the jig at mid-span, one on each side, measure deflection through contact with appropriate brackets attached to the specimen. The average of the measurements represents the net deflection.

6.3 *Data Recording System*—An X-Y plotter coupled directly to electronic outputs of load and deflection is an acceptable means of obtaining the relationship between load and net deflection—that is, the load-deflection curve. A data

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FIG. 1 Arrangement to Obtain Net Deflection by Using Two Transducers Mounted on Rectangular Jig Clamped to Specimen Directly Above Supports

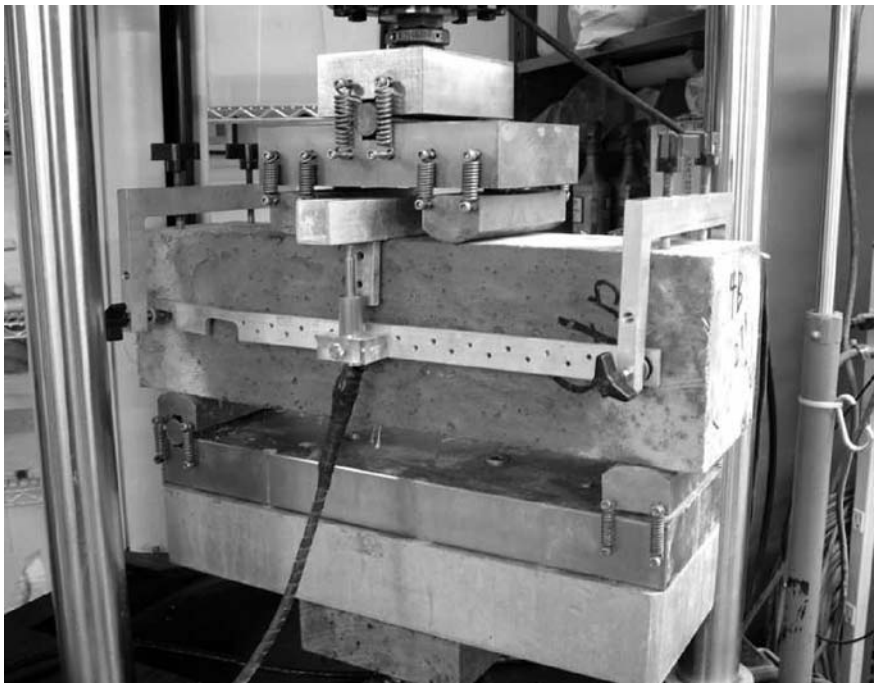

FIG. 2 Arrangement to Obtain Net Deflection by Using Two Transducers Mounted on Jig Secured to Specimen Directly Above Supports

acquisition system capable of digitally recording and storing load and deflection data at a sampling frequency of at least 2.5 Hz is an acceptable alternative. After a net deflection of L/600 has been exceeded, it is permissible to decrease the data acquisition sampling and recording frequency to 1 Hz.

NOTE 5—For X-Y plotters, accurate determination of the area under the load-deflection curve and the loads corresponding to specified deflections is only possible when the scales chosen for load and deflection are reasonably large. A load scale chosen such that 25 mm [1 in.] corresponds to a flexural stress of the order of 1 MPa [150 psi], or no more than 20 % of the estimated first-peak strength, is recommended. A recommended deflection scale is to use 25 mm [1 in.] to represent about 10 % of the end-point deflection of $\frac{1}{150}$ of the span, which is 2 mm [0.08 in.] for a 350 by 100 by 100 mm [14 by 4 by 4 in.] specimen size, and 3 mm [0.12 in.] for a 500 by 150 by 150 mm [20 by 6 by 6 in.] specimen size. When data are digitally stored, the test parameters may be determined directly from the stored data or from a plot of the data. In the latter case, use a plot scale similar to that recommended for an X-Y plotter.

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7. Sampling, Test Specimens, and Test Units

7.1 *General Requirements*—The nominal maximum size of aggregate and cross-sectional dimensions of test specimens shall be in accordance with Practice C 31/C 31M or Practice C 192/C 192M when using molded specimens, or in accordance with Test Method C 42/C 42M when using sawn specimens, provided that the following requirements are satisfied:

7.1.1 The length of test specimens shall be at least 50 mm [2 in.] greater than three times the depth, and in any case not less than 350 mm [14 in.]. The length of the test specimen shall not be more than two times the depth greater than the span.

7.1.2 The tolerances on the cross-section of the test specimens shall be within ± 2 %. The test specimens shall have a square cross-section within these tolerances.

7.1.3 The width and depth of test specimens shall be at least three times the maximum fiber length.

7.1.4 When the specimen size is not large enough to meet all the requirements of 7.1-7.1.3, specimens of square cross-section large enough to meet the requirements shall be used. The three times maximum fiber length requirement for width and depth may be waived at the option of the specifier of tests to permit specimens with a width and depth of 150 mm [6 in.] when using fibers of length 50 to 75 mm [2 to 3 in.].

NOTE 6—The results of tests on beams with relatively stiff fibers, such as steel fibers, longer than one-third the width and depth of the beam may not be comparable with test results of similar-sized beams with fibers shorter than one-third the width and depth because of preferential fiber alignment, and different size beams may not be comparable because of size effects. The degree of preferential fiber alignment may be less for fibers that are flexible enough to be bent by contact with aggregate particles or mold surfaces than for rigid fibers that remain straight during mixing and specimen preparation.

7.2 *Freshly Mixed Concrete*—Obtain samples of freshly mixed fiber-reinforced concrete for the preparation of test specimens in accordance with Practice C 172.

7.2.1 Mold specimens in accordance with Practice C 31/C 31M or Practice C 192/C 192M, except that consolidation shall be by external vibration. Consolidation may be considered to be adequate when entrapped air voids are no longer observed rising to the surface of the specimen. Fill the mold in one layer by using a wide shovel or scoop parallel to the length of the mold to place the layer uniformly along the length of the mold.

NOTE 7—Make sure that the time of vibration is sufficient to ensure adequate consolidation, as fiber-reinforced concrete requires a longer vibration time than concrete without fibers, especially when the fiber concentration is relatively high.

7.2.2 When filling the mold, attempt to add an amount of concrete that will exactly fill the mold after consolidation. When screeding the top surface, continue external vibration to ensure that fibers do not protrude from the finished surface.

7.2.3 Curing shall be in accordance with Practice C 31/C 31M or Practice C 192/C 192M.

7.3 *Hardened Concrete*—Select samples of hardened fiber-reinforced concrete from structures in accordance with Practice C 823.

7.3.1 Prepare and condition sawn specimens in accordance with Test Method C 42/C 42M.

7.4 Prepare specimens from shotcrete panels in accordance with Practice C 1140.

7.5 *Test Unit*—Prepare and test at least three specimens from each sample of fresh or hardened concrete.

8. Evaporation Control

8.1 When the time between removal of test specimens from a moist curing environment and the start of testing is likely to exceed 15 min, minimize drying by covering with wet burlap, applying a curing compound, or by other appropriate techniques.

9. Procedure

9.1 Molded or sawn specimens shall be turned on their side with respect to the position as cast before placing on the support system. Specimens representing shotcrete shall be loaded in the same direction as the specimen was shot.

9.2 Arrange the specimen and the loading system so that the specimen is loaded at the third points in accordance with Test Method C 78. The span length shall be three times the specimen depth or 300 mm [12 in.], whichever is greater.

NOTE 8—If full contact cannot be reasonably assured between the specimen, the load-applying devices, and the supports before loading, grind the contact surfaces of the specimen so that full contact is achieved. Alternatively, use capping materials at the load or support points.

9.3 Operate the testing machine so that the net deflection of the specimen increases at a constant rate. For a 350 by 100 by 100 mm [14 by 4 by 4 in.] specimen size, the rate of increase of net deflection shall be within the range 0.05 to 0.10 mm/min [0.002 to 0.004 in./min] until a net deflection of L/600 is reached. After that, the rate of increase of net deflection shall be within the range 0.05 to 0.20 mm/min [0.002 to 0.008 in./min] until the specified end-point deflection is reached. For a 500 by 150 by 150 mm [20 by 6 by 6 in.] specimen size, the rate of increase of net deflection shall be within the range 0.06 to 0.12 mm/min [0.002 to 0.005 in./min] until a net deflection of L/600 is reached. After that, the rate of increase of net deflection shall be within the range 0.06 to 0.24 mm/min [0.002 to 0.010 in./min] until the specified end-point deflection is reached. The corresponding rate for other sizes and shapes of specimens shall be based on reaching the first-peak deflection 30 to 60 s after the start of the test.

NOTE 9—First-peak deflection for third-point loading is estimated assuming linear-elastic behavior up to first peak from the equation:

$$\delta_1 = \frac{23P_1L^3}{1296EI}\left[1 + \frac{216d^2(1+\mu)}{115L^2}\right]$$

where:

δ_1 = the first peak deflection, mm [in.]
P_1 = the first-peak load, N [lbf]
L = the span length, mm [in.]
E = the estimated modulus of elasticity of the concrete, MPa [psi]
I = the cross-sectional moment of inertia, mm^4 [$in.^4$]
d = the average depth of specimen at the fracture, as oriented for testing, mm [in.] and
μ = Poisson's ratio

For a Poisson's ratio of 0.20 and a d to L ratio of 1/3, the value of the portion of the equation in brackets is 1.25.

NOTE 10—For a 350 by 100 by 100 mm [14 by 4 by 4 in.] specimen

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size, the net deflection at first-peak load is approximately 0.04 mm [0.0016 in.], and for a 500 by 150 by 150 mm [20 by 6 by 6 in.] specimen size, it is approximately 0.05 mm [0.002].

9.4 When using deflection-measuring equipment for the first time, or after alterations or maintenance, confirm the reliability of the measured net deflection by comparing the measured deflection at first-peak load with the value estimated from the formula in Note 9.

9.5 Unless otherwise required by the specifier of tests, terminate the test at a net deflection of 1/150 of the span.

9.6 Further testing to a greater end-point deflection shall be specified at the option of the specifier of tests, and shall be specified as the span divided by some whole number less than 150.

9.7 Make two measurements of the specimen depth and width adjacent to the fracture (one on each face of the specimen) to the nearest 1 mm [0.05 in.] to determine the average depth and width.

9.8 Determine the position of the fracture by measuring the distance along the middle of the tension face from the fracture to the nearest point of support.

9.9 When the fracture occurs outside the middle third of the span, discard the results.

10. Calculation

10.1 Values of load and deflection used in subsequent calculations shall be obtained from the load-deflection curve, or from stored digital data.

10.2 Determine the first-peak load as that value of load corresponding to the first point on the load-deflection curve where the slope is zero, that is, the load is a local maximum value. Determine the corresponding deflection value. See Figs. 3 and 4.

NOTE 11—Small ripples or fluctuations in the load-deflection curve due to electronic noise or mechanical vibration should not be confused with a definite change in the slope of the load-deflection curve in the vicinity of first peak load, particularly when the portion of the curve in question is magnified.

10.3 Calculate the first-peak strength using the first-peak load determined in 10.2, the average specimen dimensions determined in 9.7, and the following formula for modulus of rupture:

$$f = \frac{PL}{bd^2} \quad (1)$$

where:

f = the strength, MPa [psi],
P = the load, N [lbf],
L = the span length, mm [in.],
b = the average width of the specimen at the fracture, as oriented for testing, mm [in.], and
d = the average depth of the specimen at the fracture, as oriented for testing, mm [in.].

10.3.1 Record the number rounded to the nearest 0.05 MPa [5 psi] as the first-peak strength, f_1.

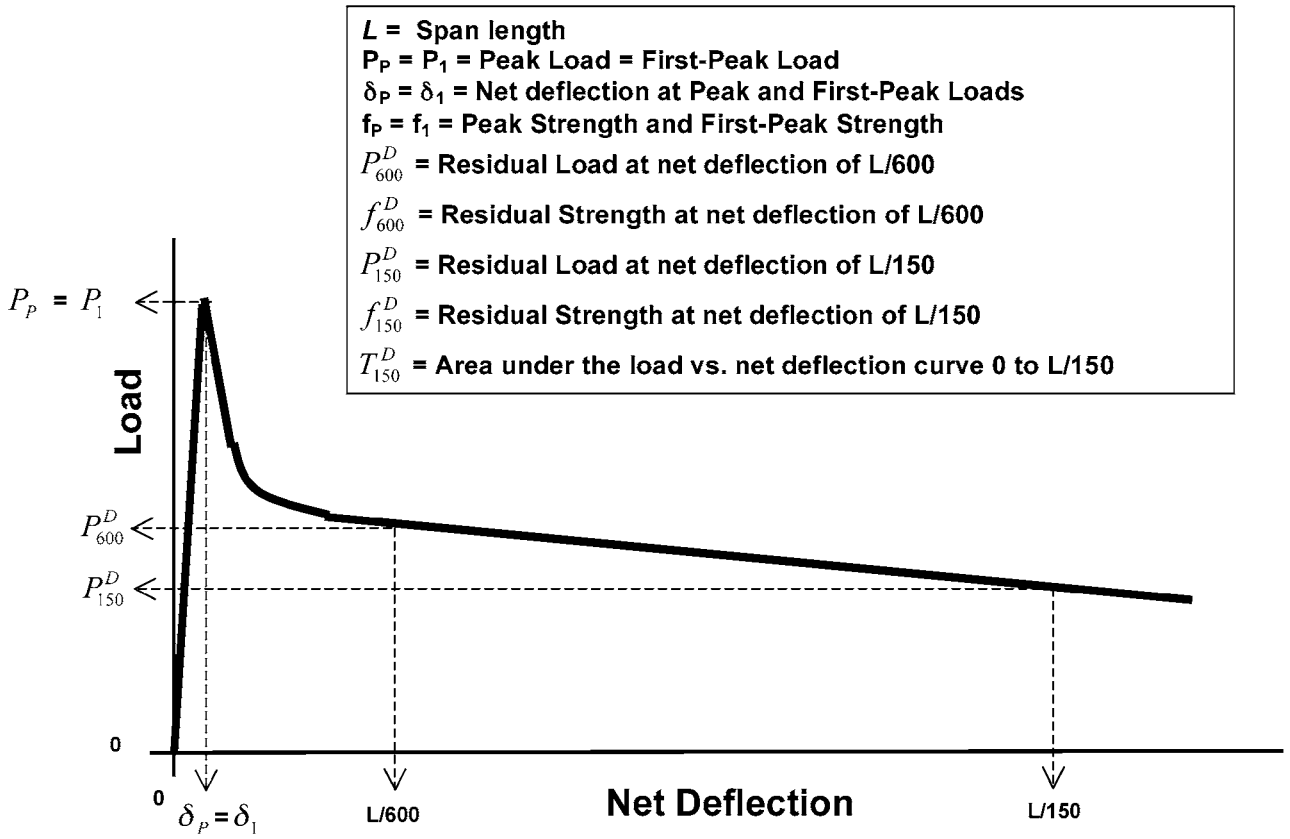

FIG. 3 Example of Parameter Calculations for First-Peak Load Equal to Peak Load (Not to Scale)

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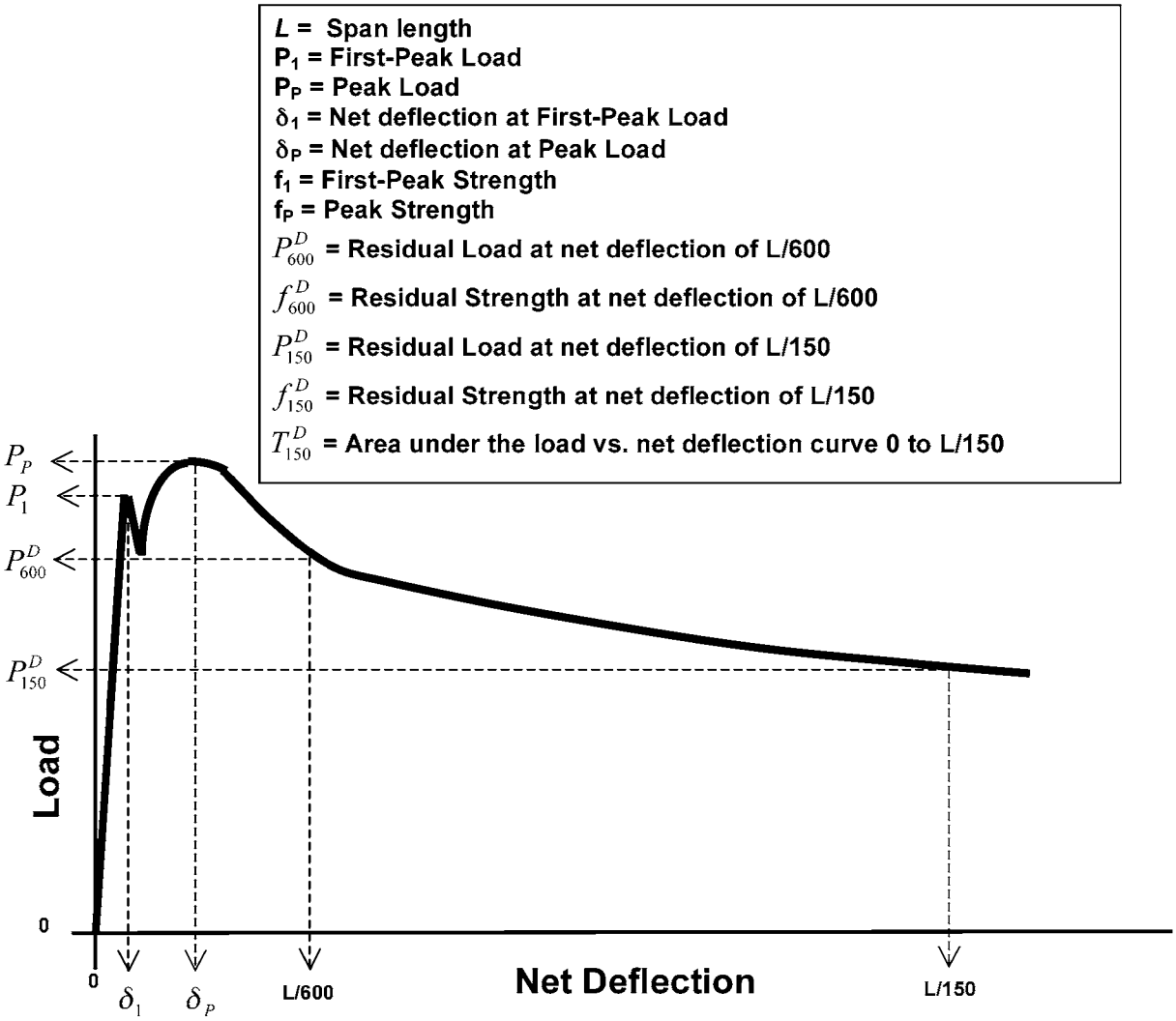

FIG. 4 Example of Parameter Calculations when Peak Load is Greater than First-Peak Load (Not to Scale)

10.4 Determine the peak load as that value of load corresponding to the point on the load-deflection curve that corresponds to the greatest value of load obtained prior to reaching the end-point deflection. Determine the corresponding deflection value.

10.5 Calculate the peak strength using the peak load determined in 10.4, the average specimen dimensions determined in 9.7, and Eq 1. Record the number rounded to the nearest 0.05 MPa [5 psi] as the peak strength, f_P.

10.6 Determine the residual load values, P^D_{600} and P^D_{150} as appropriate for the specimen depth, corresponding to net deflection values of 1/600 and 1/150 of the span length.

10.7 Calculate the residual strengths, f^D_{600} and f^D_{150} using the residual loads determined in 10.6, the average specimen dimensions determined in 9.7, and Eq 1. Record the numbers rounded to the nearest 0.05 MPa [5 psi] as the residual strengths, f^D_{600} and f^D_{150} as appropriate for the specimen depth.

10.8 When required by the specifier of tests, determine the residual load(s) and calculate the residual strength(s) at the values of net deflection required by the specifier of tests at value(s) greater than 1/600 of the span length using the procedures in this section. Record the calculated value(s) rounded to the nearest 0.05 MPa [5 psi] using the appropriate superscript and subscript(s) to indicate the specimen depth and net deflection(s) selected.

For a specified net deflection δ the subscript XXX is calculated as:

$$XXX = \frac{L}{\delta} \quad (2)$$

10.9 When required by the specifier of tests, calculate the total area under the load-deflection curve up to a net deflection of 1/150 of the span length. Record the number rounded to the nearest Joule [10 in.-lb] as toughness, T^D_{150} as appropriate for the specimen depth.

NOTE 12—If the load and deflection are measured in consistent units, such as Newtons (N) and metres (m), or kilonewtons (kN) and millimetres (mm), the resulting measure of energy will be in units known as Joules (J).

11. Report

11.1 Report the following information:

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11.1.1 Type of specimen (molded or sawn) and specimen identification numbers or symbols,

11.1.2 Average width and depth of specimen at the point of fracture to the nearest 1 mm [0.05 in.],

11.1.3 Span length to the nearest 2 mm [0.1 in.],

11.1.4 First-peak load, P_1, rounded to the nearest N (lbf), first-peak strength, f_1, to the nearest 0.05 MPa [5 psi], and first-peak deflection, δ_1, to the nearest 0.01 mm [0.0005 in.],

11.1.5 Peak load, P_P, rounded to the nearest N [lbf], peak strength, f_P, to the nearest 0.05 MPa [5 psi], and peak-load deflection, δ_P, to the nearest 0.01 mm [0.0005 in.],

11.1.6 Residual loads, P^D_{600} and P^D_{150} rounded to the nearest N [lbf],

11.1.7 Residual strengths, f^D_{600} and f^D_{150} rounded to the nearest 0.05 MPa [5 psi],

11.1.8 When required by the specifier of tests, toughness, T^D_{150} to the nearest Joule [10 in.-lb],

11.1.9 When required by the specifier of tests, the residual load(s), P^D_{XXX} and corresponding residual strength(s), f^D_{XXX}, rounded to the nearest N [lbf] and 0.05 MPa [5 psi],

11.1.10 Age of the specimens at the time of testing, in days,

11.1.11 Curing history and moisture condition of specimen at test,

11.1.12 Whether the specimen contact surfaces were ground or capped,

11.1.13 Defects in specimen prior to test and abnormalities in specimen behavior during test, and

11.1.14 The load-deflection curve.

12. Precision and Bias

12.1 *Precision*—Tables 1 and 2 provide the repeatability standard deviations for the various parameters measured in this test method (see Note 13). The reproducibility of this test method is being determined.

NOTE 13—The repeatability standard deviations were developed from analysis of a database composed of 26 sets of three or four replicate test specimens that were tested by one operator using a closed-loop, servo-controlled hydraulic universal-testing machine. A test result is the mean value for each set of replicate test specimens. The concrete mixtures tested contained various steel fibers (10 sets) or synthetic fibers (16 sets) at different fiber contents. All test specimens had nominal dimensions of 102 mm by 102 mm by 356 mm [4 in. by 4 in. by 14 in.] and were tested on a 305 mm [12 in.] span. The test specimens for each set were either molded beams (19 sets) or beams cut from shotcrete panels (7 sets).

12.2 *Bias*—This test method has no bias since the properties determined can only be defined in terms of this test method.

13. Keywords

13.1 fiber-reinforced concrete; first-peak strength; flexural toughness; peak strength; residual load; residual strength

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TABLE 1 Single-Operator Standard Deviations (SI units)

	Minimum Test Result	Maximum Test Result	Pooled Within-Batch Standard Deviation, 1s	COV, %
P_1, N	9868	27071	1543	7.7
f_1, MPa	2.44	7.12	0.47	8.3
δ_1, mm	0.03	0.06	0.01	20.0
P_p, N	9869	27071	1922	9.2
f_p, MPa	2.44	7.46	0.57	9.7
δ_p, mm	0.03	2.44	0.52	71.1
P_{150}^{100} , N	5193	18588	2108	17.6
f_{150}^{100} , MPa	1.29	5.41	0.60	17.8
P_{600}^{100} , N	4828	24076	2034	15.2
f_{600}^{100} , MPa	1.20	7.00	0.63	16.4
T_{600}^{100} , J	10	42	4	16.0

TABLE 2 Single-Operator Standard Deviations (inch-pound units)

	Minimum Test Result	Maximum Test Result	Pooled Within-Batch Standard Deviation, 1s	COV, %
P_1, lbf	2218	6086	347	7.7
f_1, psi	354	1031	67	8.2
δ_1, in.	0.0013	0.0023	0.0002	10.0
P_p, lbf	2219	6086	432	9.2
f_p, psi	354	1081	82	9.7
δ_p, in.	0.0013	0.0960	0.0204	140.61
P_{150}^{100} , lbf	1167	4179	474	17.6
f_{150}^{100} , psi	186	784	87	17.8
P_{600}^{100} , lbf	1085	5413	457	15.2
f_{600}^{100} , psi	173	1015	91	16.4
T_{600}^{100} , in.-lbf	92	368	39	17.3

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SUMMARY OF CHANGES

Committee C09 has identified the location of selected changes to this test method since the last issue, C 1609/C 1609M – 06, that may impact the use of this test method. (Approved December 15, 2007)

(*1*) Simplified nomenclature (deleted old 3.2.10–3.2.19 and replaced it with new 3.2.10-3.2.16).

(*2*) Added new Note 3.

(*3*) Added new Eq 2.

(*4*) Updated residual load(s), residual strength(s), and toughness parameters according to new nomenclature throughout the standard (including Figs. 3 and 4 and Tables 1 and 2).

(*5*) Changed "D" to "d" in new Note 9 and Eq 1.

(*6*) Changed "(in-lb units)" to "[in-lb units]" throughout the standard.

Committee C09 has identified the location of selected changes to this test method since the last issue, C 1609/C 1609M – 05, that may impact the use of this test method. (Approved December 15, 2006)

(*1*) Added new 1.3.
(*2*) Revised 4.1.
(*3*) Added new 5.4.
(*4*) Revised 6.3.
(*5*) Added new 7.1.2.
(*6*) Revised Section 9.
(*7*) Revised 10.3.
(*8*) Revised Section 11.

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Designation: C 1610/C 1610M – 06a

Standard Test Method for Static Segregation of Self-Consolidating Concrete Using Column Technique[1]

This standard is issued under the fixed designation C 1610/C 1610M; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope*

1.1 This test method covers the determination of static segregation of self-consolidating concrete by measuring the coarse aggregate content in the top and bottom portions of a cylindrical specimen (or column).

1.2 This test method is not applicable to self-consolidating concrete containing lightweight aggregate.

1.3 The values stated in either inch-pounds or SI units are to be regarded separately as standard. Within the text, the SI units are shown in brackets. The values stated in each system are not exact equivalents; therefore, each system shall be used independently of the other. Combining values from the two systems may result in nonconformance with the standard.

1.4 The text of this standard references notes and footnotes that provide explanatory material. These notes and footnotes (excluding those in tables and figures) shall not be considered as requirements of the standard.

1.5 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.* (**Warning—**Fresh hydraulic cementitious mixtures are caustic and may cause chemical burns to skin and tissue upon prolonged exposure.[2])

2. Referenced Documents

2.1 *ASTM Standards:* [3]

C 125 Terminology Relating to Concrete and Concrete Aggregates

C 127 Test Method for Density, Relative Density (Specific Gravity), and Absorption of Coarse Aggregate

C 173/C 173M Test Method for Air Content of Freshly Mixed Concrete by the Volumetric Method

C 192/C 192M Practice for Making and Curing Concrete Test Specimens in the Laboratory

C 231 Test Method for Air Content of Freshly Mixed Concrete by the Pressure Method

D 1785 Specification for Poly(Vinyl Chloride) (PVC) Plastic Pipe, Schedules 40, 80, and 120

3. Terminology

3.1 *Definitions:*

3.1.1 For definitions of terms used in this test method, refer to Terminology C 125.

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *Static Segregation*, *n*—settlement of coarse aggregate particles in an undisturbed mass of fresh concrete.

4. Summary of Test Method

4.1 A sample of freshly-mixed self-consolidating concrete is placed in a cylindrical mold without tamping or vibration. The mold is separated into three sections representing different levels of the cylindrical specimen (or column). Portions of concrete from the top and bottom section are washed on a 4.75 mm [No. 4] sieve, leaving the coarse aggregate on the sieve. The masses of coarse aggregate in the top and the bottom sections are determined and the percent static segregation is calculated.

5. Significance and Use

5.1 This test method provides users with a laboratory procedure to determine the potential static segregation of self-consolidating concrete.

5.2 This test method shall be used to develop self-consolidating concrete mixtures with segregation not exceeding specified limits. Self-consolidating concrete is a fluid concrete that can be prone to segregation if not proportioned to be cohesive. A cohesive self-consolidating concrete is important for all applications but is especially critical for deep-section applications such as walls or columns. Therefore, the degree of segregation can indicate if a mixture is suitable for the application.

[1] This test method is under the jurisdiction of ASTM Committee C09 on Concrete and Concrete Aggregates and is the direct responsibility of Subcommittee C09.47 on Self-Consolidating Concrete.

Current edition approved Dec. 15, 2006. Published January 2007. Originally approved in 2006. Last previous edition approved in 2006 as C 1610/C 1610M – 06.

[2] Section on Safety Precautions, Manual of Aggregate and Concrete Testing, *Annual Book of ASTM Standards*, Vol. 04.02.

[3] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

***A Summary of Changes section appears at the end of this standard.**

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NOTE 1—Some level of segregation is tolerable as long as the desired strength and durability performance is achieved.

6. Apparatus

6.1 *Balance*—as described in Test Method C 127.

6.2 *Column Mold*—The column portion of the mold shall be poly(vinyl chloride) (PVC) plastic pipe Schedule 40 meeting the requirements of Specification D 1785. The column shall be 8 in. [200 mm] in diameter × 26 in. [660 mm] in height and separated into 3 sections. The top section shall be 6.5 in. [165 mm] in height, the middle section 13 in. [330 mm] in height, and the bottom section 6.5 in. [165 mm] in height, as shown in Fig. 1. Each section shall have its ends flat and plane and be marked as "Top", " Middle", or "Bottom" relative to its location in the column. Couplers, brackets, clamps, or other equivalent fastening systems shall be used for securing the column sections together to form a mortar-tight joint and to secure the column to the base plate. The column mold shall be securely attached to a non-absorbent, rigid base plate measuring at least 12 in. [300 mm] × 12 in. [300 mm] square.

NOTE 2—Experience has shown that a base plate made from sealed or laminated plywood at least 0.75 in. [20 mm] thick is suitable for securing the column.

6.3 *Collector Plate*—The collector plate, used to obtain concrete from the top section of the column, shall be made of any nonabsorbent, rigid material measuring at least 20 in. [510 mm] × 20 in. [510 mm] square. The plate shall contain a cut out section in the center measuring 8.5 in. [215 mm] across and it shall contain a rigid lip that is at least 2 in. [50 mm] high running around three sides of the perimeter of the plate, as shown in Fig. 2.

NOTE 3—To facilitate the ease with which the test can be performed, the collector plate may contain legs or another support system so that only one person is needed to perform the concrete collection process from the top section.

6.4 *Strike-off Bar*—As described in Test Method C 173/C 173M or Test Method C 231.

6.5 *Sieve*—A 4.75 mm [No. 4] rectangular sieve with minimum dimensions of 13 in. [330 mm] × 25 in. [630 mm].

6.6 *Sample Receptacle*—The receptacle shall be a heavy-gage metal pan, wheelbarrow, or flat, clean nonabsorbent board of sufficient capacity to allow easy remixing of the entire sample with a shovel, trowel, or scoop.

6.7 *Small Tools*—Tools and items such as shovels, plastic pails, trowels, scoops and rubber gloves shall be provided.

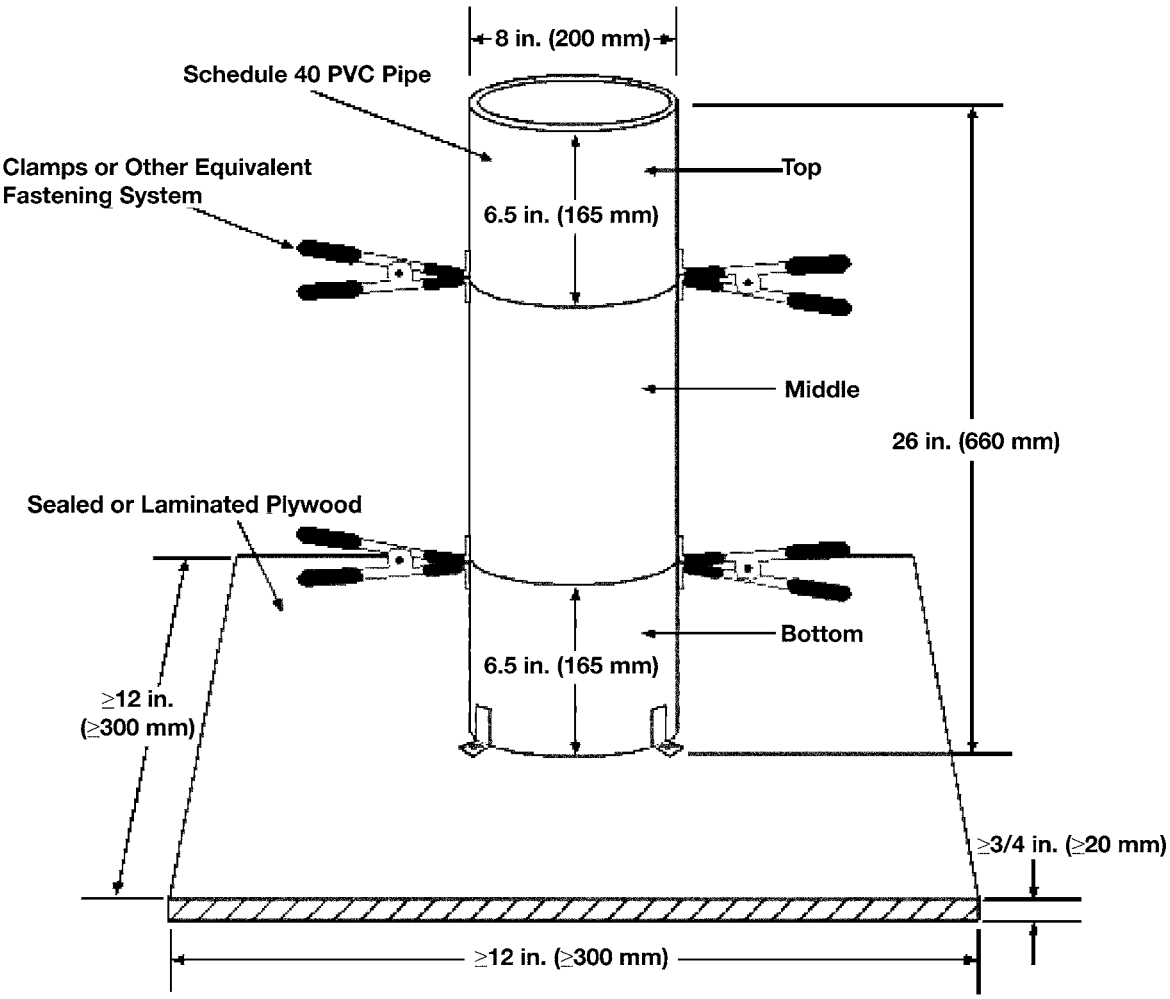

FIG. 1 Detail of Column Mold

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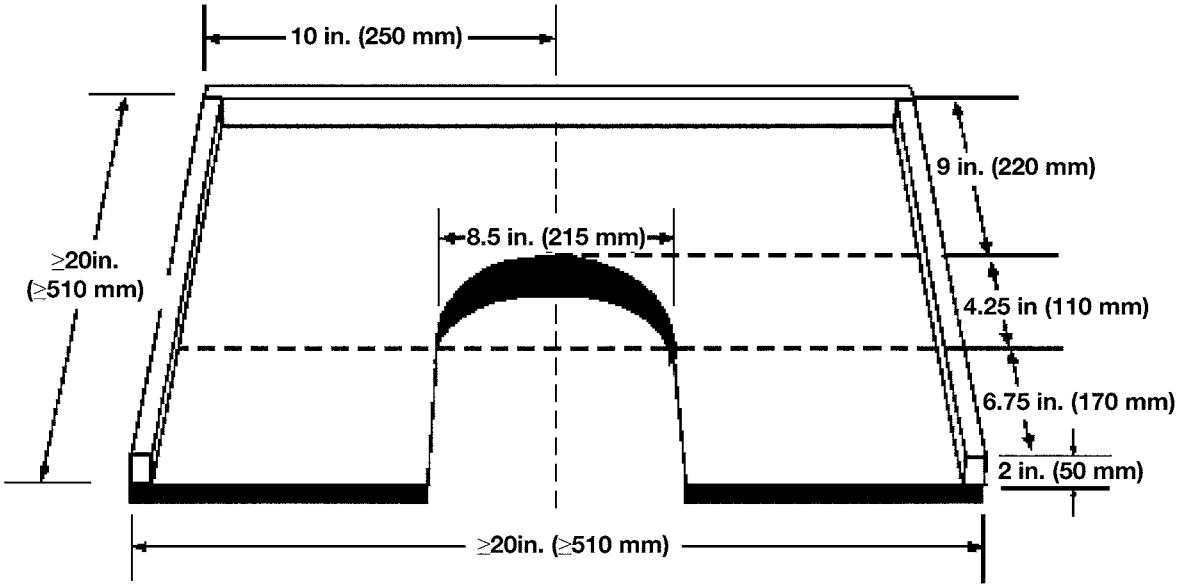

FIG. 2 Detail of Collector Plate

7. Sample

7.1 Obtain a sample of freshly-mixed self-consolidating concrete in accordance with Practice C 192/C 192M and place it in the sample receptacle.

8. Procedure

8.1 Perform the column segregation test on a flat, level surface. Do not subject the testing surface and the column mold to any vibration or disturbance.

8.2 *Remixing of Sample:* Remix the sample obtained in accordance with Section 7.1 in the sample receptacle using a shovel or scoop so that the concrete is homogeneous.

8.3 *Filling Procedure:* Using a shovel, scoop, or plastic pail, immediately fill the column mold with concrete completely and above the rim, within 2 min.

8.4 After filling the mold, strike off the top surface by sliding the strike-off bar across the top rim of the mold with a sawing motion until the concrete surface is level with the top of the mold.

8.5 Allow the concrete to stand undisturbed in the column mold for 15 ± 1 min.

8.6 Immediately following the standing period, securely hold the top section of the mold and remove the fastening system. Complete Steps 8.7 – 8.14 within 20 min thereafter.

8.7 Place the cut out section of the collector plate around the column just below the joint between the "Top" and "Middle" sections to catch and collect concrete.

8.8 Grasp the upper section of the column mold and, using a horizontal rotating motion, screed the concrete from the top section of the column on to the collector plate and then deposit it into a plastic pail.

8.9 Repeat Steps 8.6 – 8.8 to remove the concrete from the middle section of the column mold and discard the concrete.

8.10 Place the concrete sample collected from the upper section of the column onto the 4.75 mm [No. 4] sieve.

8.11 Wash the concrete on the 4.75 mm [No. 4] sieve so that only coarse aggregate remains on the sieve and then deposit the coarse aggregate into a clean plastic pail.

8.12 Repeat Steps 8.10 – 8.11 for the concrete retained in the bottom section of the mold.

8.13 Bring the coarse aggregate obtained from both the top and bottom sections of the column to a surface-dry condition by rolling it in a large absorbent cloth until all visible films of water are removed.

8.14 Determine the mass of coarse aggregate from the top and bottom sections of the column to the nearest 0.1 lb [50 g].

9. Calculation

9.1 Calculate the percent static segregation using the following equation:

$$S = 2\left[\frac{(CA_B - CA_T)}{(CA_B + CA_T)}\right] * 100, \quad if\ CA_B > CA_T$$

$$S = 0, \quad if\ CA_B \le CA_T$$

where:

S = static segregation, percent
CA_T = mass of coarse aggregate in the top section of the column
CA_B = mass of coarse aggregate in the bottom section of the column

10. Report

10.1 Mixture designation.

10.2 The mass of coarse aggregate obtained from the top and bottom sections of the column separately to the nearest 0.1 lb [0.05 kg].

10.3 The static segregation to the nearest 0.1 percent.

11. Precision and Bias

11.1 *Precision*—The estimate of the precision of this test method is provisional. A repeatability standard deviation of

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0.2 % was obtained from a study (1) involving five replicate batches of a concrete mixture with a mean static segregation of 3.8 %.

11.2 *Bias*—The procedure used in this test method has no bias since coarse aggregate segregation of self-consolidating concrete is defined only in terms of this method.

12. Keywords

12.1 coarse aggregate; self-consolidating concrete; stability; static segregation

REFERENCES

(1) J., Assaad, K., H., Khayat, and J., Daczko, "Evaluation of Static Stability of Self-Consolidating Concrete", *ACI Materials Journal*, Vol. 101, No. 3, May-June, 2004, pp. 207 – 215.

SUMMARY OF CHANGES

Committee C09 has identified the location of selected changes to this test method since the last issue, C 1610/C 1610M – 06, that may impact the use of this test method. (Approved December 15, 2006)

(*1*) Revised the definition of *static segregation*.
(*2*) Revised 1.2.
(*3*) Replaced reference to Practice C 172 with Test Method C 231.

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Designation: C 1611/C 1611M – 09b

Standard Test Method for Slump Flow of Self-Consolidating Concrete[1]

This standard is issued under the fixed designation C 1611/C 1611M; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope*

1.1 This test method covers the determination of slump flow of self-consolidating concrete.

1.2 The values stated in either SI units or inch-pound units are to be regarded separately as standard. The values stated in each system may not be exact equivalents; therefore, each system shall be used independently of the other. Combining values from the two systems may result in non-conformance with the standard.

1.3 The text of this standard references notes and footnotes that provide explanatory material. These notes and footnotes (excluding those in tables and figures) shall not be considered as requirements of the standard.

1.4 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.* (**WARNING**—Fresh hydraulic cementitious mixtures are caustic and may cause chemical burns to skin and tissue upon prolonged exposure.[2])

2. Referenced Documents

2.1 *ASTM Standards:*[3]

C 125 Terminology Relating to Concrete and Concrete Aggregates

C 143/C 143M Test Method for Slump of Hydraulic-Cement Concrete

C 172 Practice for Sampling Freshly Mixed Concrete

C 173/C 173M Test Method for Air Content of Freshly Mixed Concrete by the Volumetric Method

C 670 Practice for Preparing Precision and Bias Statements for Test Methods for Construction Materials

3. Terminology

3.1 For definitions of terms used in this test method, refer to Terminology C 125.

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *halo*, *n*—an observed cement paste or mortar ring that has clearly separated from the coarse aggregate, around the outside circumference of concrete after flowing from the mold.

3.2.2 *spread*, *n*—the distance of lateral flow of concrete during the slump-flow test.

3.2.3 *stability*, *n*—the ability of a concrete mixture to resist segregation of the paste from the aggregates.

3.2.4 *viscosity*, *n*—resistance of a material to flow under an applied shearing stress.

4. Summary of Test Method

4.1 A sample of freshly mixed concrete is placed in a mold either in the upright or inverted position. The concrete is placed in one lift without tamping or vibration. The mold is raised, and the concrete is allowed to spread. After spreading ceases, two diameters of the concrete mass are measured in approximately orthogonal directions. Slump flow is the average of the two diameters.

5. Significance and Use

5.1 This test method provides a procedure to determine the slump flow of self-consolidating concrete in the laboratory or the field.

5.2 This test method is used to monitor the consistency of fresh, unhardened self-consolidating concrete and its unconfined flow potential.

5.3 It is difficult to produce self-consolidating concrete that is both flowable and nonsegregating using coarse aggregates larger than 25 mm [1 in.]. Therefore, this test method is considered applicable to self-consolidating concrete having coarse aggregate up to 25 mm [1 in.] in size. Appendix X1 provides non-mandatory visual rating criteria that may be used

[1] This test method is under the jurisdiction of ASTM Committee C09 on Concrete and Concrete Aggregates and is the direct responsibility of Subcommittee C09.47 on Self-Consolidating Concrete.

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[2] Section on Safety Precautions, Manual of Aggregate and Concrete Testing, *Annual Book of ASTM Standards*, Vol. 04.02.

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to classify the ability of a self-consolidating concrete mixture to resist segregation (stability).

5.4 The rate at which the concrete spreads is related to its viscosity. Appendix X1 provides a non-mandatory procedure that may be used to provide an indication of relative viscosity of self-consolidating concrete mixtures.

6. Apparatus

6.1 *Mold*—The mold used in this test method shall conform to that described in Test Method C 143/C 143M.

6.2 *Base Plate*—A nonabsorbent, smooth, rigid plate having a minimum diameter of 915 mm [36 in.] (See Note 1).

NOTE 1—*Field experience and results from the round robin test program have shown that base plates made from sealed/laminated plywood, acrylic plastic, or steel are suitable for performing this test.*

6.3 *Strike-off Bar*—As described in Test Method C 173/C 173M.

6.4 *Measuring Device*—A ruler, metal roll-up measuring tape, or similar rigid or semi-rigid measuring instrument marked in increments of 5 mm [¼ in.] or less.

7. Sample

7.1 The sample of concrete from which test specimens are made shall be representative of the entire batch. It shall be obtained in accordance with Practice C 172.

8. Procedure

8.1 Perform the test on a flat, level, nonabsorbent surface such as a concrete floor or a base plate. Use the base plate in conditions where a flat, level surface is not available, such as on a construction site. When the base plate is used, position and shim the base plate so that it is fully supported, flat, and level. Pre-moisten the work surface or base plate with a damp towel, rag, or sponge.

8.1.1 When performing the slump flow test for a given study or project, do not change the base plate surface type for the duration of the study or project.

8.2 *Filling the Mold:* Fill the mold by following either Procedure A or Procedure B (See Note 2).

8.2.1 *Filling Procedure A (Upright Mold):* Dampen the mold and place it on the work surface, or centered on the base plate, with the larger opening facing down. Hold the mold firmly in place during filling by standing on the two foot pieces. Fill the mold in a continuous manner (See Note 3). Overfill the mold slightly above its top.

8.2.2 *Filling Procedure B (Inverted Mold):* Dampen the mold and place it on the work surface, or centered on the base plate, with the smaller opening facing down (See Note 4). Fill the mold in a continuous manner (See Note 3). Overfill the mold slightly above its top.

NOTE 2—*During the development of this test method, it was found that some of the users preferred to perform the test with the large opening of the mold facing down as is performed in Test Method C 143/C 143M. The provision of a collar to the top of the mold is useful to reduce the probability of concrete spilling over the mold and on to the base plate. Other users preferred to place the mold with the smaller opening face down, which facilitates the ease of filling. Both filling procedures have been found to be suitable when performing this test. The precision statement in Section 10 reflects the use of both procedures. Test data using the two filling procedures can be obtained in the round robin test report available from ASTM headquarters.*

NOTE 3—Filling the mold with concrete by using multiple scoops or by pouring from a bucket or similar container has been found to be acceptable.

NOTE 4—*As a precaution, when filling the mold in the inverted position, the mold may be supported to prevent accidental movement or tipping. Experienced users of this test method have found that it is not necessary to support the mold.*

8.3 Strike off the surface of the concrete level with the top of the mold by a sawing motion of the strike-off bar. Remove concrete from the area surrounding the base of the mold to preclude interference with the movement of the flowing concrete. Remove the mold from the concrete by raising it vertically. Raise the mold a distance of 225 ± 75 mm [9 ± 3 in.] in 3 ± 1 s by a steady upward lift with no lateral or torsional motion. Complete the entire test from the start of filling through removal of the mold without interruption within an elapsed time of 2 ½ min.

8.4 Wait for the concrete to stop flowing and then measure the largest diameter (d_1) of the resulting circular spread of concrete. When a halo is observed in the resulting circular spread of concrete, it shall be included as part of the diameter of the concrete. Measure a second diameter (d_2) of the circular spread at an angle approximately perpendicular to the first measured diameter (d_1). Measure the diameters to the nearest 5 mm [¼ in.]. Determine the Slump flow in accordance with Section 9.

8.5 If the measurement of the two diameters differs by more than 50 mm [2 in.], the test is invalid and shall be repeated.

9. Calculation

9.1 Calculate the slump flow using Eq 1:

$$\text{Slump flow} = (d_1 + d_2)/2 \quad (1)$$

where:

d_1 = the largest diameter of the circular spread of the concrete, and

d_2 = the circular spread of the concrete at an angle approximately perpendicular to d_1

9.2 Record the average of the two diameters to the nearest 10 mm [½ in.].

10. Report

10.1 Report the filling procedure (A or B) used.

10.2 Report the slump flow to the nearest 10 mm [½ in.].

11. Precision and Bias

11.1 The precision of this test method was determined based on the results obtained from a round robin test program conducted by members of the ASTM C09.47 subcommittee on January 9, 2003. The round robin test program consisted of using single and multiple operators performing 3 replicas of the test using the mold in both the upright and inverted positions. The tests were performed using self-consolidating concrete with high and low levels of slump flow and on stable and unstable mixes. Complete details of the round robin test program are available from ASTM headquarters in a report entitled "Report on Development of a Precision Statement for the Slump Flow Test Method for Self-Consolidating Concrete."

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11.2 *Single-Operator Precision*—The single-operator precision statement reflects the use of both procedures A and B. The single-operator standard deviation for slump flow has been found to be 27 mm [1.1 in.] (See Note 5) for mixtures having slump flow values between approximately 480 and 680 mm [19 and 27 in.]. Therefore, results of two properly conducted tests by the same operator on the same batch of concrete should not differ by more than 75 mm [3.0 in.] (See Note 5).

11.3 *Multi-Operator Precision*—The multi-operator precision statement reflects the use of both procedures A and B. The multi-operator standard deviation for slump flow has been found to be 27 mm [1.1 in.] (See Note 5) for mixtures with slump flow values between approximately 530 and 740 mm [21 and 29 in.]. Therefore, the results of properly conducted tests by two operators on the same batch of concrete should not differ by more than 75 mm [3.0 in.] (See Note 5).

NOTE 5—*These numbers represent, respectively, the (1s) and (d2s) limits as described in Practice C 670.*

11.4 *Bias*—The procedure used in this test method has no bias since slump flow is defined only in terms of this test method.

12. Keywords

12.1 halo; self-consolidating concrete; slump flow; spread; stability; viscosity; visual stability index

APPENDIX

(Nonmandatory Information)

X1. RELATIVE MEASURE OF FLOW RATE, VISCOSITY, AND STABILITY

X1.1 The flow rate of a self-consolidating concrete mixture is influenced by its viscosity. Hence, for the purpose of developing a self-consolidating concrete mixture in the laboratory, a relative measure of viscosity is useful. When performing the slump flow test, the time it takes for the outer edge of the concrete mass, to reach a diameter of 500 mm [20 in.] from the time the mold is first raised, provides a relative measure of the unconfined flow rate of the concrete mixture. For similar materials, this time period, termed T_{50}, gives an indication of the relative viscosity of the self-consolidating concrete mixture.

NOTE X1.1—The T_{50} value can provide information on the flow properties of the self-consolidating concrete mixture, whereby longer values normally correspond to increased viscosity. Special high-range water-reducing admixtures are typically used to modify the flow properties of the self-consolidating concrete mixture. In addition, viscosity-modifying admixtures and other changes in mixture proportions and materials can also influence flow properties and resistance to segregation.

X1.2 The stability of self-consolidating concrete can be observed visually by examining the concrete mass and therefore can be used for quality control of self-consolidating concrete mixtures. Table X1.1 contains Visual Stability Index (VSI) values with corresponding criteria to qualitatively assess the stability of self-consolidating concrete. However, these values do not quantify a concrete property.

X1.3 *Apparatus:*

X1.3.1 *Inscribed base plate* - a base plate as described in 6.2, with a circular mark centrally located for the placement of mold, and a further concentric circle at 500 mm [20 in.].

TABLE X1.1 Visual Stability Index Values

VSI Value	Criteria
0 = Highly Stable	No evidence of segregation or bleeding.
1 = Stable	No evidence of segregation and slight bleeding observed as a sheen on the concrete mass.
2 = Unstable	A slight mortar halo ≤ 10 mm [≤ 0.5 in.] and/or aggregate pile in the of the concrete mass.
3 = Highly Unstable	Clearly segregating by evidence of a large mortar halo > 10 mm [> 0.5 in.] and/or a large aggregate pile in the center of the concrete mass.

NOTE X1.2—The centrally located circular mark made at the 500 mm [20 in.] location on the base plate will assist the user in determining the T_{50} value.

X1.3.2 *Stop watch* – least reading of not more than 0.01 s.

X1.4 *Procedure:*

X1.4.1 To determine T_{50}, use a stopwatch to measure the time in seconds it takes any part of the outer edge of the spreading concrete to reach the inscribed mark on the base plate from the time the mold is first lifted.

X1.4.2 After spreading of the concrete has stopped, visually inspect the concrete mixture by observing the distribution of the coarse aggregate within the concrete mass the distribution of the mortar fraction particularly along the perimeter, and the bleeding characteristics. Assign a Visual Stability Index (VSI) value to the concrete spread using the criteria shown in Table X1.1 and illustrated in Figs. X1.1-X1.4.

X1.5 *Recording:*

X1.5.1 Record T_{50} to the nearest 0. 2 second.

X1.5.2 Record the VSI value.

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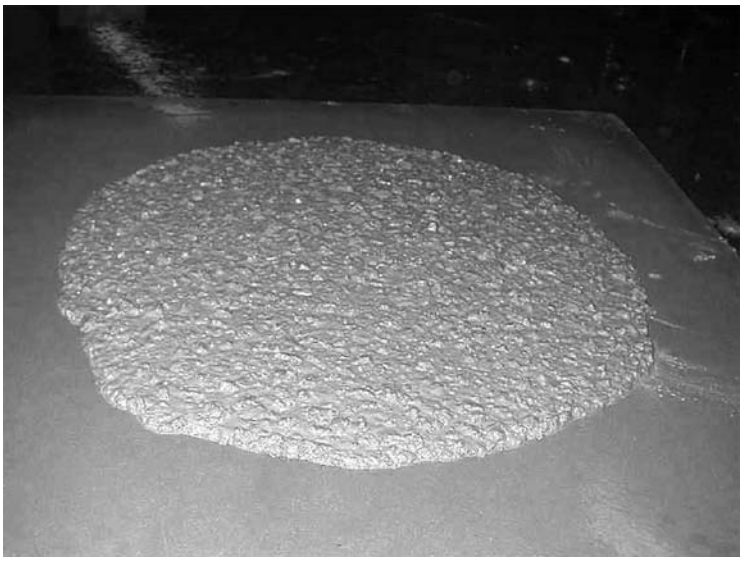

FIG. X1.1 VSI = 0 – Concrete Mass is Homogeneous and No Evidence of Bleeding.

FIG. X1.2 VSI = 1 – Concrete Shows Slight Bleeding Observed as a Sheen on the Surface.

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FIG. X1.3 VSI = 2 – Evidence of a Mortar Halo and Water Sheen.

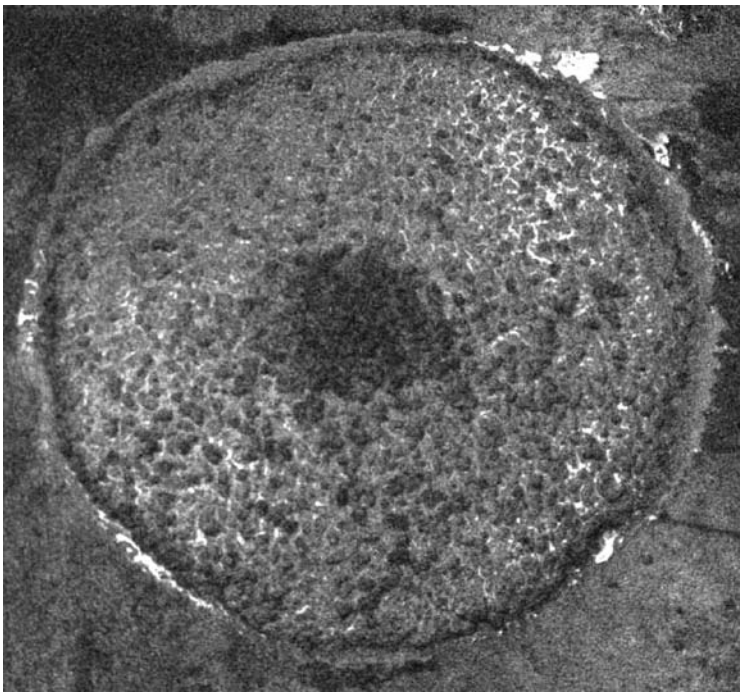

FIG. X1.4 VSI = 3 – Concentration of Coarse Aggregate at Center of Concrete Mass and Presence of a Mortar Halo.

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SUMMARY OF CHANGES

Committee C09 has identified the location of selected changes to this test method since the last issue, C 1611/C 1611M – 09a, that may impact the use of this test method. (Approved August 1, 2009)

(*1*) Revised 4.1 for harmony with Test Method C 1621/C 1621M.

(*2*) Revised 6.2 for harmony with Test Method C 1621/C 1621M. Added a "measuring device" to the list of apparatus in new 6.4.

Committee C09 has identified the location of selected changes to this test method since the last issue, C 1611/C 1611M – 09, that may impact the use of this test method. (Approved June 1, 2009)

(*1*) Revised Section 8, including the addition of Notes 3 and 4.

Committee C09 has identified the location of selected changes to this test method since the last issue, C 1611/C 1611M – 05, that may impact the use of this test method. (Approved May 1, 2009)

(*1*) Revised the Scope to harmonize the test method with Test Method C 1621/C 1621M.

(*2*) Added reference to Terminology C 125 in new 3.1 to harmonize the test method with Test Method C 1621/C 1621M and renumbered subsequent paragraphs.

(*3*) Revised 10.1 to harmonize the test method with Test Method C 1621/C 1621M.

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Designation: C 1621/C 1621M – 09b

Standard Test Method for Passing Ability of Self-Consolidating Concrete by J-Ring[1]

This standard is issued under the fixed designation C 1621/C 1621M; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope*

1.1 This test method covers determination of the passing ability of self-consolidating concrete by using the J-Ring in combination with a mold.

1.2 The values stated in either SI units or inch-pound units are to be regarded separately as standard. The values stated in each system may not be exact equivalents; therefore, each system shall be used independently of the other. Combining values from the two systems may result in non-conformance with the standard.

1.3 The text of this standard references notes and footnotes that provide explanatory material. These notes and footnotes (excluding those in tables and figures) shall not be considered as requirements of the standard.

1.4 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use. (***Warning**—Fresh hydraulic cementitious mixtures are caustic and may cause chemical burns to skin and tissue upon prolonged exposure.[2])

2. Referenced Documents

2.1 *ASTM Standards:*[3]

C 125 Terminology Relating to Concrete and Concrete Aggregates

C 143/C 143M Test Method for Slump of Hydraulic-Cement Concrete

C 172 Practice for Sampling Freshly Mixed Concrete

C 173/C 173M Test Method for Air Content of Freshly Mixed Concrete by the Volumetric Method

C 1611/C 1611M Test Method for Slump Flow of Self-Consolidating Concrete

3. Terminology

3.1 *Definitions*:

3.1.1 For definitions of terms used in this test method, refer to Terminology C 125.

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *halo*, *n*—an observed cement paste or mortar ring that has clearly separated from the coarse aggregate, around the outside circumference of concrete after flowing from the mold.

3.2.2 *J-ring*, *n*—an apparatus consisting of a rigid ring supported on sixteen 16 mm [⅝ in.] diameter rods equally spaced on a 300 mm [12 in.] diameter circle 100 mm [4 in.] above a flat surface as shown in Fig. 1.

3.2.3 *J-ring flow*, *n*—the distance of lateral flow of concrete using the J-Ring in combination with a mold.

3.2.4 *passing ability*, *n*—the ability of self-consolidating concrete to flow under its own weight (without vibration) and fill completely all spaces within intricate formwork, containing obstacles, such as reinforcement.

4. Summary of Test Method

4.1 A sample of freshly mixed concrete is placed in a mold, either in the upright or inverted position, that is concentric with the J-Ring (Fig. 2). The concrete is placed in one lift without tamping or vibration. The mold is raised, and the concrete is allowed to spread through the J-Ring (Fig. 3). After spreading ceases, two diameters of the concrete mass are measured in approximately orthogonal directions. J-Ring flow is the average of the two diameters. The test is repeated without the J-Ring to obtain the slump flow. The difference between the slump flow and J-Ring flow is an indicator of the passing ability of the concrete.

5. Significance and Use

5.1 This test method provides a procedure to determine the passing ability of self-consolidating concrete. This test method is applicable for laboratory use in comparing the passing ability

[1] This test method is under the jurisdiction of ASTM Committee C09 on Concrete and Concrete Aggregates and is the direct responsibility of Subcommittee C09.47 on Self-Consolidating Concrete.

Current edition approved July 1, 2009. Published August 2009. Originally approved in 2006. Last previous edition approved in 2009 as C 1621/C 1621M – 09a.

[2] Section on Safety Precautions, Manual of Aggregate and Concrete Testing, *Annual Book of ASTM Standards*, Vol. 04.02.

[3] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

***A Summary of Changes section appears at the end of this standard.**

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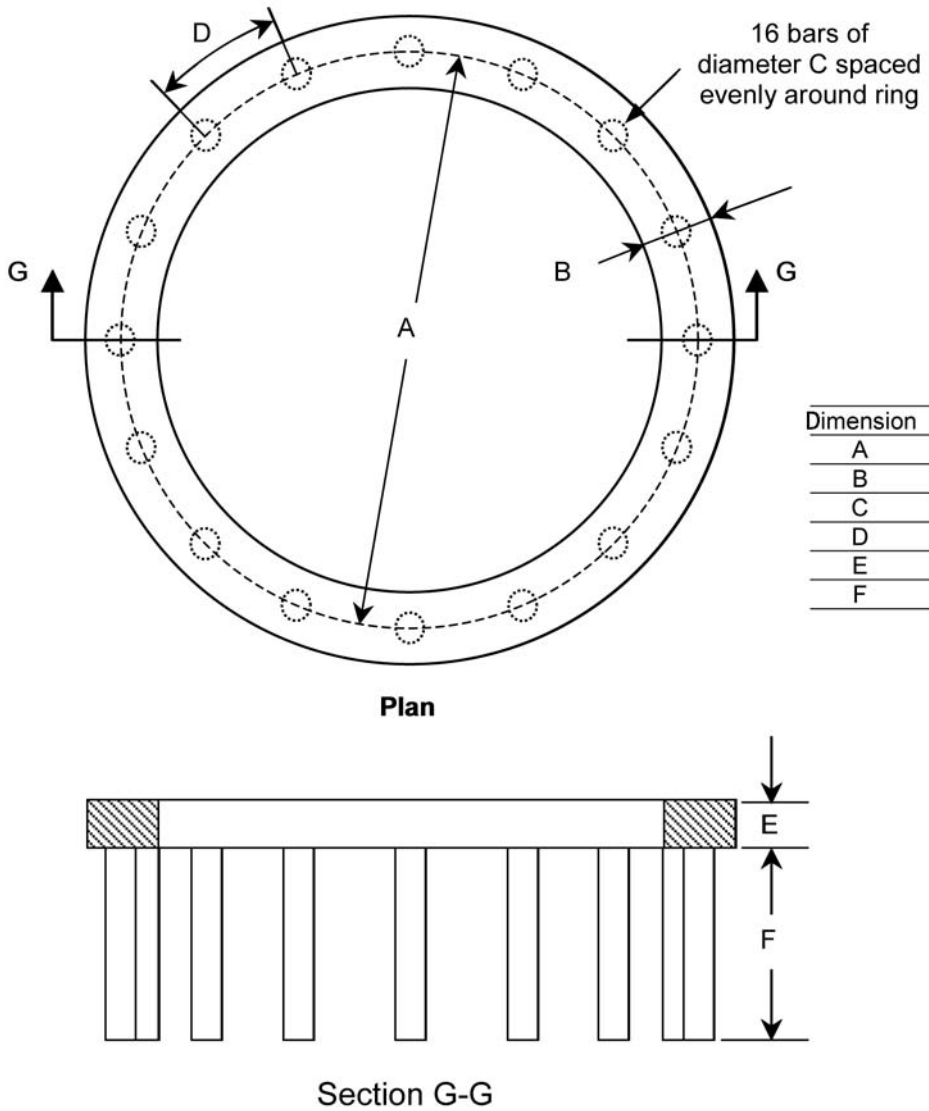

Dimension	in.	mm
A	12.0 +/- 0.13	300 +/- 3.3
B	1.5 +/- 0.06	38 +/- 1.5
C	0.625 +/- 0.13	16 +/- 3.3
D	2.36 +/- 0.06	58.9 +/- 1.5
E	1.0 +/- 0.06	25 +/- 1.5
F	4.0 +/- 0.06	100 +/- 1.5

FIG. 1 J-Ring Apparatus

of different concrete mixtures. It is also applicable in the field as a quality control test.

5.2 The difference between the slump flow and J-Ring flow is an indication of the passing ability of the concrete. A difference less than 25 mm [1 in.] indicates good passing ability and a difference greater than 50 mm [2 in.] indicates poor passing ability. The orientation of the mold for the J-Ring test and for the slump flow test without the J-Ring shall be the same.

5.3 This test method is limited to self-consolidating concrete with nominal maximum size of aggregate of up to 25 mm [1 in.].

6. Apparatus

6.1 *J-Ring*—The apparatus shall consist of a steel (or equivalent nonabsorbent, rigid material) ring measuring 300 mm [12 in.] in diameter at the center of the ring and 25 mm [1 in.] in thickness, and sixteen 16 mm [⅝ in.] diameter smooth steel rods spaced evenly around the ring measuring 100 mm [4 in.] in length (see Fig. 1).

6.2 *Mold*—The mold used in this test method shall conform to that described in Test Method C 143/C 143M, except that the foot pieces are removed when the test is performed with the mold in the upright position (Procedure A).

6.3 *Base Plate*—A nonabsorbent, smooth, rigid plate having a minimum diameter of 915 mm [36 in.].

NOTE 1—Field experience has shown that base plates made from sealed or laminated plywood, rigid plastic, or steel are suitable for performing this test.

6.4 *Strike-off Bar*—As described in Test Method C 173/C 173M.

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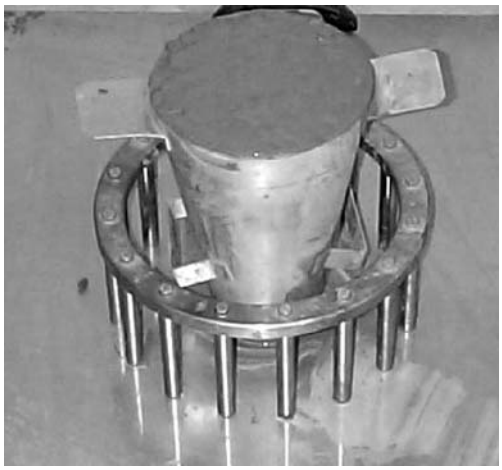

FIG. 2 J-Ring Setup with Inverted Mold Filled with Concrete

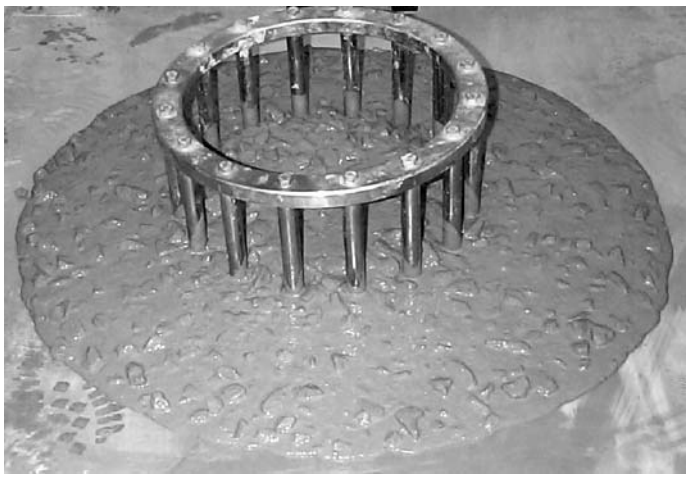

FIG. 3 J-Ring Flow

6.5 *Measuring Device*—A ruler, metal roll-up measuring tape, or similar rigid or semi-rigid measuring instrument marked in increments of 5 mm [¼ in.] or less.

7. Sample

7.1 The sample of concrete from which test specimens are made shall be representative of the entire batch. It shall be obtained in accordance with Practice C 172.

8. Procedure

8.1 Perform the test on a flat, level, nonabsorbent surface such as a concrete floor or a base plate. Use the base plate in conditions where a flat, level surface is not available, such as on a construction site. When the base plate is used, position and shim the base plate so that it is fully supported, flat, and level. Pre-moisten the work surface or base-plate with a damp towel, rag, or sponge. Rest the J-Ring on the work surface or at the center of the base plate.

8.1.1 When performing the slump flow test for a given study or project, do not change the base plate type for the duration of the study or project.

8.2 *Filling the Mold*—Fill the mold by following either Procedure A or Procedure B.

8.2.1 *Filling Procedure A (Upright Mold)*—Dampen the mold and place it on the work surface or base plate with the larger opening facing down and concentric with the JRing. Hold the mold firmly in place during filling. Fill the mold in a continuous manner. Overfill the mold slightly above its top.

8.2.2 *Filling Procedure B (Inverted Mold)*—Dampen the mold and place it on the work surface or base plate with the smaller opening facing down and concentric with the JRing. Support the mold during filling. Fill the mold in a continuous manner. Overfill the mold slightly above its top.

NOTE 2—As a precaution, when filling the mold in the inverted position, the mold may be supported to prevent accidental movement or tipping. Experienced users of this test method have found that it is not necessary to support the mold.

NOTE 3—Filling the mold with concrete by using multiple scoops or by pouring from a bucket or similar container has been found to be acceptable.

8.3 Strike off the surface of the concrete level with the top of the mold by a sawing motion of the strike-off bar. Remove concrete from the area surrounding the base of the mold to preclude interference with the movement of the flowing concrete. Remove the mold from the concrete by raising it vertically. Raise the mold a distance of 225 ± 75 mm [9 ± 3 in.] in 3 ± 1 s by a steady upward lift with no lateral or torsional motion. Complete the entire test from the start of filling through removal of the mold without interruption within an elapsed time of 2 ½ min.

8.4 Wait for the concrete to stop flowing and then measure the largest diameter (j_1) of the resulting circular spread of concrete. When a halo is observed in the resulting circular spread of concrete, it shall be included as part of the diameter of the concrete. Measure a second diameter (j_2) of the circular spread at an angle approximately perpendicular to the first measured diameter (j_1). Measure the diameters to the nearest 5 mm [¼ in.]. Determine the J-Ring flow in accordance with Section 9.

8.5 If the measurement of the two diameters differs by more than 50 mm [2 in.], the test is invalid and shall be repeated.

8.6 Conduct a slump flow test without the J-Ring in accordance with Test Method C 1611/C 1611M. Use the same filling procedure as used with the J-Ring. Complete the tests with and without the J-Ring within 6 min.

9. Calculation

9.1 Calculate J-Ring flow according to the following equation:

$$\text{J}-\text{Ring flow} = \frac{(j_1 + j_2)}{2} \quad (1)$$

where:

j_1 = the largest diameter of the circular spread of the concrete from the J-Ring test, and

j_2 = the circular spread of the concrete at an angle approximately perpendicular to j_1.

9.2 Calculate the slump flow according to the following equation:

$$\text{Slump flow} = \frac{(d_1 + d_2)}{2} \quad (2)$$

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where:

d_1 = the largest diameter of the circular spread of the concrete from the slump flow test, and

d_2 = the circular spread of the concrete at an angle approximately perpendicular to d_1.

9.3 Calculate the difference between slump flow and J-Ring flow to the nearest 10 mm [½ in.]. This number represents the passing ability of the concrete.

10. Blocking Assessment

10.1 Identify blocking assessment according to Table 1.

11. Report

11.1 Report the filling procedure (A or B) used.

11.2 Report the J-Ring flow to the nearest 10 mm [½ in.].

TABLE 1 Blocking Assessment

Difference Between Slump Flow and J-Ring Flow	Blocking Assessment
0 to 25 mm [0 to 1 in.]	No visible blocking
>25 to 50 mm [>1 to 2 in.]	Minimal to noticeable blocking
>50 mm [>2 in.]	Noticeable to extreme blocking

11.3 Report the slump flow (without the J-Ring) to the nearest 10 mm [½ in.].

11.4 Report the passing ability as the difference between the slump flow and J-Ring flow to the nearest 10 mm [½ in.]. Identify the blocking assessment.

12. Precision and Bias

12.1 *Precision*—An interlaboratory study of this test method has not been carried out. In a study involving two operators who performed three replicate tests on 30 batches of the same concrete mixture during normal production at a precast plant, the within-test standard deviation (repeatability) for passing ability was 5.8 mm [0.23 in.]. The average passing ability in these tests was 20.5 mm [0.81 in.] for slump-flow values ranging from about 480 to 740 mm [19 to 29 in.]. Measurements were done in the inch-pound system and the SI values are conversion of the inch-pound values.

12.2 *Bias*—The procedure used in this test method has no bias since passing ability based on the J-Ring flow is defined only in terms of this test method.

13. Keywords

13.1 halo; j-ring; j-ring flow; passing ability self-consolidating concrete; slump flow; spread

SUMMARY OF CHANGES

Committee C09 has identified the location of selected changes to this test method since the last issue, C 1621/C 1621M – 09a, that may impact the use of this test method. (Approved July 1, 2009)

(*1*) Reworded the Scope, Section 5, Section 6, and Section 8 to be in harmony with Test Method C 1611/C 1611M.

Committee C09 has identified the location of selected changes to this test method since the last issue, C 1621/C 1621M – 09, that may impact the use of this test method. (Approved June 1, 2009)

(*1*) Revised Section 8. Added new Notes 2 and 3 and renumbered subsequent notes.

(*2*) Revised Section 9 to be in harmony with Test Method C 1611/C 1611M and to comply with ASTM's Form and Style.

Committee C09 has identified the location of selected changes to this test method since the last issue, C 1621/C 1621M – 08, that may impact the use of this test method. (Approved May 1, 2009)

(*1*) Added a noun designation to the terms in Section 3.

(*2*) Revised 4.1 and Section 11 to be in harmony with Test Method C 1611/C 1611M.

Committee C09 has identified the location of selected changes to this test method since the last issue, C 1621/C 1621M – 06, that may impact the use of this test method. (Approved June 1, 2008)

(*1*) Revised 1.1 to clarify the scope of this test method.

(*2*) Corrected a value in the dimension table of Fig. 1.

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Designation: C1622/C1622M – 09

Standard Specification for Cold-Weather Admixture Systems[1]

This standard is issued under the fixed designation C1622/C1622M; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope*

1.1 This specification covers cold-weather admixture systems to be added to hydraulic-cement concrete when the temperature of the concrete immediately after placement will be as low as -5.0 °C [23.0 °F].

1.2 This specification stipulates tests of the cold-weather admixture system with suitable materials as described in 11.1-11.3 or with materials proposed for specific work (See 11.5). Unless otherwise requested by the purchaser, tests shall be made using suitable concreting materials as described in 11.1-11.3.

NOTE 1—Whenever practicable, tests should be made using the concreting materials, the mixture proportions, and batching sequence proposed for the specific work (See 11.5) because the time of setting, compressive strength gain, and other properties may vary.

1.3 This specification provides three levels of testing.

1.3.1 *Level 1*—During the initial approval stage, proof of compliance with the performance requirements defined in Table 1 demonstrates that the cold-weather admixture system meets the requirements of this specification. Uniformity and equivalence tests (See Section 6) shall be carried out to provide results against which later comparisons can be made.

1.3.2 *Level 2*—Limited retesting is described in 5.2, 5.2.1, and 5.2.2. Proof of compliance with the requirements of Table 1 demonstrates conformity of the admixture system with the requirements of this specification.

1.3.3 *Level 3*—For acceptance of a lot or for measuring uniformity within or between lots, when specified by the purchaser, uniformity and equivalence tests (See Section 6) shall be used.

1.4 The values stated in either SI units or inch-pound units are to be regarded separately as standard. Within the text, the inch-pound units are shown in brackets. The values stated in each system may not be exact equivalents; therefore, each system shall be used independently of the other. Combining values from the two systems may result in non-conformance with the standard.

1.5 The text of this standard references notes and footnotes, which provide explanatory material. These notes and footnotes (excluding those in tables and figures) shall not be considered as requirements of the standard.

1.6 The following precautionary caveat pertains to the test methods portion, Sections 11-18, of this specification. *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.* **WARNING**—Fresh hydraulic cementitious mixtures are caustic and may cause chemical burns to skin and tissue upon prolonged exposure.[2]

2. Referenced Documents

2.1 *ASTM Standards:*[3]

C33 Specification for Concrete Aggregates

C39/C39M Test Method for Compressive Strength of Cylindrical Concrete Specimens

C125 Terminology Relating to Concrete and Concrete Aggregates

C136 Test Method for Sieve Analysis of Fine and Coarse Aggregates

C138/C138M Test Method for Density (Unit Weight), Yield, and Air Content (Gravimetric) of Concrete

C143/C143M Test Method for Slump of Hydraulic-Cement Concrete

C150 Specification for Portland Cement

C157/C157M Test Method for Length Change of Hardened Hydraulic-Cement Mortar and Concrete

C183 Practice for Sampling and the Amount of Testing of Hydraulic Cement

C192/C192M Practice for Making and Curing Concrete Test Specimens in the Laboratory

C231 Test Method for Air Content of Freshly Mixed Concrete by the Pressure Method

C260 Specification for Air-Entraining Admixtures for Concrete

[1] This specification is under the jurisdiction of ASTM Committee C09 on Concrete and Concrete Aggregates and is the direct responsibility of Subcommittee C09.23 on Chemical Admixtures.

Current edition approved Dec. 15, 2009. Published February 2010. Originally approved in 2005. Last previous edition approved in 2006 as C1622/C1622M–06. DOI: 10.1520/C1622_C1622M-09.

[2] Section on Safety Precautions, Manual of Aggregates and Concrete Testing, Annual Book of ASTM Standards Vol. 04.02.

[3] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

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TABLE 1 Performance Requirements for Cold-Weather Admixture[A]

Time of Initial Setting, maximum % of control[B]	200
Compressive Strength. minimum % of control[C]	
7 days[D]	40
28 days	80
90 days	90
Length Change, Maximum Shrinkage (alternative requirements)[E]	
Percent of Control[B]	135
Increase over control, percentage points	0.010
Relative Durability Factor, Minimum % of control[F]	80

[A]The values in the table include allowance for normal variation in test results

[B]As an example, in the case of initial time of setting, if the control mixture has a set time of 4.0 hrs, the test specimens can have a set time up to 8.0 hrs. For length change, if the control specimen shrinks X units, the test specimen is allowed to shrink up to 1.35X.

[C]The compressive strength of the concrete containing the cold-weather admixture shall not be less than 90 % of that attained at the previous test age. The objective of this limit is to require that the compressive strength of the cold-weather admixture concrete shall not decrease with age.

[D]Because the test specimens will be cool and damp for the 7d compressive test, it will be necessary to use unbonded caps as described in Practice C1231/C1231M.

[E]Alternative requirements, see 17.1.2: Percent of control applies when shrinkage of control concrete is 0.030 % or greater; the increase over control limit applies when shrinkage of control concrete is 0.030 % or less.

[F]This requirement is applicable only when the cold-weather admixture is to be used in air-entrained concrete that may be exposed to freezing and thawing while wet.

C403/C403M Test Method for Time of Setting of Concrete Mixtures by Penetration Resistance

C494/C494M Specification for Chemical Admixtures for Concrete

C666/C666M Test Method for Resistance of Concrete to Rapid Freezing and Thawing

C1064/C1064M Test Method for Temperature of Freshly Mixed Hydraulic-Cement Concrete

C1231/C1231M Practice for Use of Unbonded Caps in Determination of Compressive Strength of Hardened Concrete Cylinders

D1193 Specification for Reagent Water

2.2 *American Concrete Institute Standard:*[4]

ACI 211.1 Practice for Selecting Proportions for Normal, Heavyweight, and Mass Concrete

3. Terminology

3.1 *Definitions of Terms:*

3.1.1 For definitions of terms used in this specification, refer to Terminology C125.

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *cold-weather admixture system*, *n*—an admixture or group of admixtures that depresses the freezing point of mixing water and increases the hydration rate of cement in concrete.

3.2.2 *control concrete mixture*, *n*—a concrete mixture without the cold-weather admixture system.

3.2.3 *dummy concrete specimen*, *n*—additional concrete specimen instrumented with a temperature sensing device to estimate the temperature of test concrete specimens.

3.2.4 *replicate concrete specimen*, *n*—additional time-of-setting specimen exposed to the same temperature regimen as the test concrete specimen.

3.2.5 *test concrete mixture*, *n*—a concrete mixture with the cold weather admixture system.

4. Apparatus

4.1 *Low Temperature Environment*—A chamber of sufficient size to subject the test specimens to the specified low temperature and that allows access for laboratory personnel to conduct appropriate tests. The chamber or chambers shall be capable of cooling numerous specimens from their initial temperature to -5.0 ± 1 °C [23.0 ± 2.0 °F] within the specified elapsed time and maintain them at that temperature for the specified time period.

4.2 *Temperature Measuring Equipment*—The temperature measuring equipment shall be capable of measuring and recording the temperature at the center of the dummy specimens to ± 1.0 °C [± 2.0 °F] at least every ½ h for 7 days.

4.3 *Tools*—Molds and tools for preparing test specimens as described in Practice C192/C192M. Molds shall have lids to provide for sealed conditions.

5. General Requirements

5.1 For initial compliance with this specification, the concrete shall be tested with the cold-weather admixture system for conformance with the requirements in Table 1.

5.2 The purchaser is permitted to require limited retesting to confirm current compliance of the admixture system to specification requirements. The limited retesting includes measurements of physical and performance properties of the admixture system as described in 5.2.1 and 5.2.2.

5.2.1 The physical properties retesting consists of uniformity and equivalence tests of the admixture system for infrared absorption spectrum and relative density.

5.2.2 The performance properties retesting consists of time of initial setting and compressive strength of concrete at 7 and 28 days. Purchasers having special requirements are permitted to require additional tests.

5.3 At the request of the purchaser, the manufacturer shall state in writing that the admixture system supplied for use in the work is equivalent in all essential respects, including concentration, to the admixture system tested under this specification.

5.4 At the request of the purchaser, the manufacturer shall state in writing the chloride content of the admixture system.

5.5 Tests for uniformity and equivalence, as indicated in Section 6, shall be made on the initial sample and the results retained for reference and comparison with the results of samples taken elsewhere within the lot or subsequent lots of admixture supplied to the work.

6. Uniformity and Equivalence Tests

6.1 When specified by the purchaser, the uniformity of a lot, or equivalence of multiple lots from the same source shall be established by the following requirements:

[4] Available from American Concrete Institute (ACI), P.O. Box 9094, Farmington Hills, MI 48333-9094, http://www.aci-int.org.

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6.1.1 *Infrared Analysis*—The absorption spectra of the initial sample and the test sample, obtained as specified in Section 18, shall exhibit the same pattern of absorption bands in terms of frequency and intensity.

6.1.2 *Relative Density (Liquid Admixture)*—When tested as specified in Section 18, the relative density (specific gravity) of subsequent test samples shall not differ from the relative density of the initial sample by more than 10 % of the difference between the relative density of the initial sample and reagent water at the same temperature. Reagent water conforming to Specification D1193, Type III or IV, and prepared by distillation, ion exchange, reverse osmosis, or a combination of these procedures, is acceptable (See Note 2).

6.2 When the nature of the admixture system or analytical capability of the purchaser make these procedures unsuitable, other requirements for uniformity and equivalence from lot to lot or within a lot shall be established by agreement between the purchaser and the manufacturer.

NOTE 2—Oven drying methods are not appropriate for measuring the oven-dried residue content for cold-weather admixture system because water, present in the form of bound water of hydration, is released slowly upon drying, and can often lead to highly variable results. Relative density is an acceptable indication of lot-to-lot uniformity.

7. Packaging and Marking

7.1 When the cold-weather admixture system is delivered in packages or containers, the proprietary name of the individual admixtures in the system, the designation of this specification, and the net mass or volume shall be plainly marked thereon. Similar information shall be provided in the shipping information accompanying packages or bulk shipments of admixture.

8. Storage

8.1 Store the cold-weather admixture system to permit easy access for proper inspection and identification of each shipment, and in a suitable building that will protect the admixture from moisture absorption if it is a dry admixture or from freezing if it is a liquid admixture.

9. Sampling and Testing

9.1 Every facility shall be provided to the purchaser for sampling and inspection, either at the point of manufacture or at the site of the work, as specified by the purchaser.

9.2 Samples shall be either “grab” or “composite” samples as specified by this specification. A grab sample is one obtained in a single operation. A composite sample is one obtained by combining three or more grab samples.

9.3 For the purpose of this specification, it is recognized that samples will be taken for two reasons:

9.3.1 *Compliance Tests*—A sample taken for evaluating compliance of a source or lot of cold-weather admixture system shall meet the applicable requirements of this specification. Samples used to determine conformance with this specification shall be composites of grab samples taken from different locations so that the composite sample will be representative of the lot.

9.3.2 *Uniformity and Equivalence Tests*—When specified by the purchaser, a sample taken for evaluating the uniformity of a single lot or equivalence of multiple lots from one source shall be tested as provided in Section 6. When uniformity of a single lot is being determined, grab samples shall be used. When uniformity of multiple lots from the same source is being determined, composite samples from individual lots shall be used.

9.4 *Liquid Admixtures*—Liquid admixtures shall be agitated immediately prior to sampling. Grab samples taken for quality or uniformity tests shall represent a unit shipment or a single production lot. Each grab sample shall be at least 1 L [1 qt]. At least three grab samples of equal portions shall be taken. Composite samples shall be prepared by mixing the grab samples and the resultant mixture shall provide at least 3 L [3 qt] for compliance tests. Grab samples shall be taken from different locations distributed throughout the quantity to be represented.

9.4.1 Admixtures in bulk storage tanks shall be sampled equally from the upper, intermediate, and lower levels by means of drain cocks in the sides of the tanks or a weighted sampling bottle fitted with a stopper that can be removed after the bottle is lowered to the desired depth.

9.4.2 Samples shall be stored in impermeable containers that are resistant to attack by the admixture.

9.5 *Nonliquid Admixtures*—Grab samples taken for compliance or uniformity tests shall be at least 1kg [2 lb]. At least four grab samples of equal portions shall be taken from not more than 2 Mg [2 tons] of admixture. Prepare composite samples by mixing the grab samples and sampling the resultant mixture to provide at least 2.5 kg [5 lb] for the composite sample. Take grab samples from different locations distributed throughout the quantity to be represented.

9.5.1 Obtain samples of packaged admixtures by means of a sampler as described in Practice C183.

9.5.2 Samples shall be stored in moisture-proof, airtight containers.

9.6 Mix samples before testing to ensure uniformity. When recommended by the manufacturer, dissolve the entire sample of non-liquid admixture in water prior to testing.

10. Rejection

10.1 For initial compliance testing, the purchaser is permitted to reject the cold-weather admixture system if it fails to meet any of the requirements of this specification.

10.2 For the initial retesting, the purchaser is permitted to reject the admixture if it fails to meet any of the requirements of Section 6 and applicable parts of Table 1, as defined in 5.2.2.

10.3 If, after completion of tests, an admixture has been stored at the point of manufacture for more than 6 months prior to shipment, or an admixture has been in local storage in the hands of a vendor for more than 6 months, it shall be retested before use when requested by the purchaser and is permitted to be rejected if it fails to conform to this specification.

10.4 Packages and containers varying more than 5 % from the specified mass or volume are permitted to be rejected. If the average mass or volume of 50 packages taken at random is less than that specified, the entire shipment is permitted to be rejected.

10.5 When the admixture is for a specific use in non-air-entrained concrete, it is permitted to be rejected if the test concrete containing it has an air content greater than 3.5 % at

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the dosage used to meet this specification. When the admixture is to be used in air-entrained concrete, it is permitted to be rejected if the test concrete containing it has an air content greater than 7.5 % at the dosage used to meet this specification.

11. Materials

11.1 *Concrete Not for Specific Use*—The materials in 11.2-11.4 are for compliance testing using a concrete mixture not for a specific use.

11.2 *Cementitious Materials*—The cementitious materials shall be a Type I or Type II portland cement conforming to Specification C150, or a blend of two or more of these cements from different sources.

11.3 *Aggregates*—Except when tests are made in accordance with 11.4 using the aggregates for a specific use, the fine and coarse aggregates used in any series of tests shall come from single lots of materials that conform to the requirement of Specification C33, except that the grading shall conform to the following requirements:

11.3.1 *Fine Aggregate Grading:*

Sieve	Percent Passing by Mass
4.75 mm (No. 4)	100
1.18 mm (No. 16)	65 to 75
300 µm (No. 50)	12 to 20
150 µm (No. 100)	2 to 5

11.3.2 *Coarse Aggregate Grading*—The coarse aggregate grading shall meet the Size 57 grading requirements of Specification C33. Take care in loading and delivery to avoid segregation.

11.3.3 Coarse aggregate used for control concrete and test concrete shall be essentially the same. Provide sufficient coarse aggregate for the control concrete, the test concrete, and for grading analysis.

11.3.3.1 Prepare required quantities of coarse aggregate (See Note 3) as follows: Fill tared containers, one for sieve analysis, one for a batch of control concrete, and one for a batch of test concrete, to the required mass from the aggregate stockpile. Accomplish this by placing equal quantities into each container, successively, and repeat the procedure until all the containers have their required mass.

NOTE 3—Refer to the section on Sampling Aggregates in the Manual of Aggregate and Concrete Testing for guidance on sampling from stockpiles.

11.3.4 Perform sieve analyses on the coarse aggregate prepared in 11.3.3.1 by Test Method C136. Discard any prepared quantity of aggregate that deviates from the specified percent passing by more than the amount shown in column 3 below.

Sieve	Specification C33, No. 57 Percent Passing by Mass	Maximum Variation from Percent Passing
37.5 mm (1 ½ in.)	100	0.0
25.0 mm (1 in.)	95 to 100	1.0
12.5 mm (½ in.)	25 to 60	4.0
4.75 mm (No. 4)	0 to 10	4.0
2.36 mm (No. 8)	0 to 5	1.0

11.4 *Air-Entraining Admixture*—Except when tests are made in accordance with 11.5 using an air-entraining admixture proposed for specific work, the air-entraining admixture used in the concrete mixtures specified in Section 12 shall be a material such that, when used to entrain the specified amount of air in the concrete mixture, will give concrete of satisfactory resistance to freezing and thawing. The air-entraining admixture shall conform to Specification C260.

11.5 *Concrete for Specific Use*—The materials in this section are for specific use, such as for testing the cold-weather admixture system in simulated job concrete mixtures. To test the cold-weather admixture system for use in specific work, the cementitious materials, aggregates (See 11.3), other chemical admixtures, and air-entraining admixture used shall be representative of those used in the work. Add the cold-weather admixture system in the same manner and at the same time during the batching and mixing sequence as it will be added on the job. Proportion the concrete mixture to be similar to that used in the work. If the maximum size of coarse aggregate in the job concrete is greater than 25.0 mm [1 in.], screen the fresh concrete over a 25.0 mm (1 in.) sieve prior to fabricating the specimens to be tested.

12. Proportioning Concrete Mixtures

12.1 *Preparation and Batching*—Prepare all materials and make all weighing as prescribed in Practice C192/C192M. Prepare all materials so that the test concrete temperature, at the time of specimen casting, shall be 14 ± 2 °C [57 ± 3 °F]. Prepare all control concrete materials according to 14.6.2.

12.2 *Proportions*—Concrete mixtures not for specific uses shall be proportioned using ACI 211.1 (See Note 4). After evaluation of trial mixtures, aggregate proportions shall be adjusted as needed to obtain workable, cohesive mixtures with the correct yield. Unless otherwise specified, the cold-weather admixture system shall be added with the second increment of mixing water added to the mixer.

12.2.1 The cementitious materials content shall be 357 ± 3 kg/m^3[600 ± 5 lb/yd^3].

12.2.2 For the first trial mixture, refer to the table on volume of coarse aggregate in ACI 211.1 for guidance on amount of coarse aggregate to use for the fineness modulus of the fine aggregate being used.

NOTE 4—Values in the referenced table of ACI 211.1 are intended to ensure workable mixtures with the least favorable combinations of aggregates used. It is suggested, therefore, that for a closer approximation of the proportions required for this test, the volume of coarse aggregate (in the dry-rodded condition) per unit volume of concrete selected from ACI 211.1 be increased by about 0.07 for the first trial mixture.

12.2.3 The target air content of air-entrained concrete shall be 6 %.

12.2.4 Adjust the water content to obtain a slump of 150 ± 15 mm [6 ± ½ in.].

The workability of the control concrete mixture shall be suitable for consolidation by hand rodding and the concrete mixture shall have the lowest water content possible. Achieve these conditions by final adjustment in the amount of fine aggregate or in the amount of total aggregate, or both, while maintaining yield and slump.

12.3 *Specimens*—Prepare concrete mixtures with and without the cold-weather admixture system. Control concrete specimens shall be cured in above-freezing conditions and test concrete specimens in below-freezing conditions as specified

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in Section 14 and Section 16. Add the cold-weather admixture system in a manner recommended by the manufacturer and in an amount necessary to comply with Table 1.

12.4 *Non-Air-Entrained Concrete*—When the cold-weather admixture system is to be tested in non-air-entrained concrete, the air content of both the control and test mixtures shall be 3.5 % or less, and the difference between the air contents of the two mixtures shall not exceed 1.0 percentage point. If necessary, air-entraining admixture shall be added to the control mixture to achieve the same air content as the test concrete. Tests for freezing and thawing are not required.

12.5 *Air-Entrained Concrete*—When the cold-weather admixture system is to be tested in air-entrained concrete, the air-entraining admixture shall be added to the control concrete and, if necessary, to the test concrete mixtures in sufficient amounts to produce air contents of 6 ± 1.5 % when measured according to Test Method C231. The difference between the air content of the control concrete mixture and that of the test concrete mixture shall not exceed 0.5 percentage point. Tests for freezing and thawing are required.

13. Mixing

13.1 Machine mix the concrete as prescribed in Practice C192/C192M.

NOTE 5—Tests in Sections 14-18 are based on arbitrary stipulations, which make possible highly standardized testing in the laboratory, and are not intended to simulate actual job conditions.

14. Test and Properties of Freshly Mixed Concrete

14.1 Samples of freshly mixed concrete from at least three separate batches for each control and test concrete mixture shall be tested according to 14.2-14.6.

14.2 *Slump*—Test Method C143/C143M.

14.3 *Density*—Test Method C138/C138M

14.4 *Air Content*—Test Method C231.

14.5 *Temperature of Freshly Mixed Concrete*—Test Method C1064/C1064M.

14.6 *Time of Initial Setting*—Test Method C403/C403M with the following exceptions:

14.6.1 Quantity of mortar used in each container for determining initial setting shall not exceed 5.7 L [350 $in.^3$].

14.6.2 *Control Concrete:* Condition concrete ingredients at 20 to 25 °C [68 to 77 °F] prior to mixing. Mix the concrete, prepare test specimens, and measure penetration resistance at this temperature. Make the initial penetration measurement 3 to 4 h after initial contact of the cement with the water.

14.6.3 *Test Concrete:* Measurements are made in a low-temperature environment. Unless otherwise specified, make the initial penetration measurement 3 to 5 h after initial contact of the cement with the water. Prepare three specimens: one for measuring setting time at low temperature; a dummy specimen for measuring temperature history; and a replicate specimen for verifying that freezing did not occur. Place the specimens into the low temperature environment within 40 min after the start of mixing. The temperature at the center of the specimen shall reach -5 ± 1 °C [23 ± 2 °F] not sooner than 6 h and not later than 8 h after placement into the cold temperature environment (See Note 6). Record the initial temperature of the dummy specimen, its temperature history every ½ h while in the low-temperature environment, and the time required to cool it from its initial temperature to the required temperature range.

NOTE 6—It may be desirable to use a series of baths, each at a different temperature, for cooling specimens to target temperature within the specified period.

14.6.3.1 To make certain that the test specimen did not freeze during the test, a replicate specimen (See Table 2) shall be removed from the low-temperature room and placed at 20 to 25 °C [68 to 77 °F] at the time the test specimen reaches initial setting. Penetration readings shall be made on the replicate specimen every 15 min for 2 h. If the penetration resistance continues to increase, the test specimen is considered not to have frozen. Conversely, if a decrease in penetration resistance is observed during the 2 h period, the test specimen is considered to have frozen and the admixture system fails to meet this specification. The results of this testing of the replicate specimen, including the thermal history of the dummy specimen recorded every ½ h, shall be included in the final report.

14.6.4 Calculate the average time of initial setting from the results of each batch of concrete. Calculate relative initial setting time by dividing the average time of initial setting of the test concrete by the average time of initial setting of the control concrete and multiplying by 100.

14.7 *Water-Cementitious Materials Ratio and Water Content*:

14.7.1 Determine the water-cementitious materials ratio of concrete as follows: Determine the amount of total water in the batch as the mass of water added to the batch, water occurring as free moisture on the aggregates, and water introduced by the admixtures. Determine the water-cementitious materials ratio as the mass of the total water divided by the mass of the

TABLE 2 Minimum Number of Specimens for each test.

Test	Tests Ages	Test Specimens		Dummy Specimens		Batches per test age		Total Specimens	
		Control	Test	Control	Test	Control	Test	Control	Test
Setting	[A]	1	2	–	1[B]	3	3	3	9[C]
Compressive Strength	3	2	2		1	3	3	18	19
Freezing and Thawing	1	2	2	–	–	3	3	6	6
Length Change	1	1	1	–	–	3	3	3	3

[A] See 14.6.
[B] For measurement of the thermal history of each batch of test concrete.
[C] Includes one replicate specimen per batch of test concrete.

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cementitious materials. Calculate the volume of concrete from the total batch quantities and density in accordance with Test Method C138/C138M. Determine the water content as the mass of total water divided by the volume of the concrete batch. Determine the cementitious materials content as mass of cementitious materials divided by the volume of the concrete batch.

14.7.2 Calculate the relative water content of the test concrete as follows: Divide the average water content of all batches of test concrete by the average water content of all batches of the control concrete and multiply the quotient by 100.

15. Preparation of Test Specimens

15.1 Make sufficient number of specimens representing each test from at least three separate batches. The minimum numbers of specimens are shown in Table 2 (See Note 7). It is permitted to complete specimen fabrication in one, two, or three days of mixing provided control concrete specimens are made each day.

NOTE 7—It is recommended that more than the minimum number of specimens be prepared so that replacements are available in case some specimens are faulty.

15.2 *Manifestly Faulty Specimens*—Visually examine each test specimen before testing and discard any specimen found to be manifestly faulty. Visually examine each test specimen after testing and discard any test result associated with a specimen found to be manifestly faulty. If there are not enough replacement specimens to provide at least two valid results for each test, the entire test shall be disregarded and repeated. The test report shall be the average of the individual test results of the specimens tested or, in the event that one specimen or one result has been discarded, it shall be the average of the remaining test specimens.

16. Test Specimens for Hardened Concrete

16.1 *Number of Specimens*—The minimum number of specimens and the number of test ages are shown in Table 2.

16.2 *Types of Specimens*—Specimens made from control concrete and test concrete shall be prepared in accordance with the following:

16.2.1 *Compressive Strength*—Make specimens in accordance with Practice C192/C192M. Specimen size shall be 100- by 200-mm [4- by 8-in.] cylinders to facilitate adequate cooling rates using readily available cooling equipment. All specimens shall be cured in a sealed condition.

NOTE 8—Typically, plastic cylindrical molds are sealed with plastic caps. Alternately, a plastic bag may be placed over the top of a mold and held snugly to the side of the mold with a rubber band.

16.2.1.1 *Control Concrete:* Specimens shall be stored in a 23 ± 2 °C [73.5 ± 3.5 °F] environment within 40 min of initial contact of cement and water until time of testing.

16.2.1.2 *Test Concrete:* Specimens shall be stored in the low-temperature curing environment within 40 min after the start of mixing. Specimens shall be exposed to the same environment as the time of setting specimens as specified in 14.6.3. Use the dummy specimen to record the maximum initial starting temperature of one batch of test specimens, their temperature history while in the low-temperature environment, and the time required to cool the test specimens to the required temperature range. Test concrete specimens shall be stored in a sealed condition so that their internal temperatures are maintained at -5 ± 1 °C [23 ± 2 °F] until an age of 7 days from initial contact of cement and water. After 7 days, cure the test concrete in accordance with Practice C192/C192M until the 28-day test. After 28 days, cure the remaining test specimens at not less than 95 % relative humidity until time of test. The thermal history of the dummy specimen shall be included in the test report.

16.2.2 *Resistance to Freezing and Thawing*—Concrete specimens shall be prisms made in accordance with Practice C192/C192M, and having dimensions in accordance with Test Method C666/C666M. Make one set of two specimens from each batch of the control concrete and one set of two specimens from each batch of the test concrete. The air content of each mixture shall be as specified in 12.4 and 12.5. The control and test concrete specimens shall be cured in accordance with Practice C192/C192M. Test the specimens in accordance with Test Method C666/C666M, Procedure A, unless specified otherwise.

16.2.3 *Length Change*—Concrete specimens shall be made in accordance with Test Method C157/C157M, except for the following curing conditions. Make one specimen from each batch of the control concrete and one specimen from each batch of the test concrete. Remove the molds at 24 h and store all specimens in lime-saturated water at 23.0 ± 1.0 °C [73.5 ± 2.0 °F] until age of 28 days. At 28 days, remove all specimens from water bath and store in accordance with the air storage procedure in Test Method C157/C157M for an additional 28 days.

17. Tests on Hardened Concrete

17.1 *Compressive Strength*—Test in accordance with Test Method C39/C39M at 7, 28 and 90 days. For the 7-day tests, the test concrete specimens shall be moved from the low-temperature environment to a 23 ± 2 °C [73.5 ± 3.5 °F] environment for no less than 2 h and no more than 4 h before testing (See Note 9). The test concrete specimens shall be spaced at least 50 mm [2 in.] apart during this warming period. Record the temperature history of the dummy specimen from the time of removal from the low-temperature environment until testing. Compute the average compressive strength from the separate batches of test concrete and control concrete. Divide the average strength of the test concrete by the average strength of the control concrete at each test age and multiply by 100 to obtain relative strength. Report the results to the nearest 1 %.

NOTE 9—The intent is to have the center of the test concrete specimens at 4 and 7 °C [40 to 45 °F] at the time of testing to avoid possible influence of ice crystals inside the specimens.

17.1.1 *Resistance to Freezing and Thawing*—Comparison of the test concrete with the control concrete shall be made in accordance with Test Method C666/C666M, Procedure A, unless specified otherwise. Calculate the relative durability factor in accordance with Specification C260, where DF is the durability factor of the control concrete.

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17.1.2 *Length Change*—Measure the initial length at 28 days within 5 min of removing the specimen from curing water. After 28 days of air drying, determine the length in accordance with Test Method C157/C157M. The drying shrinkage is the length change during the 28-day drying period, based on the initial length at the time of removal of the specimen from the curing water, expressed as a percentage of the initial length to the nearest 0.001 %. Calculate the relative shrinkage by dividing the average shrinkage of the test concrete by the average shrinkage of the control concrete and multiplying by 100. If the shrinkage of the control concrete after 28 days is 0.030 % or greater, the relative shrinkage of the test concrete shall not exceed 135 %. If the shrinkage of the control concrete at 28 days is less than 0.030 %, the test concrete shrinkage shall be not more than 0.010 percentage points greater than the control concrete.

NOTE 10—Since the specific effects produced by a cold-weather admixture system may vary with the properties of other ingredients of the concrete, results of length change tests using aggregates of such a nature that the shrinkage on drying is low may not accurately indicate relative performance to be expected with other aggregates having properties such as to produce concrete of high shrinkage on drying.

18. Uniformity and Equivalence Tests

18.1 Perform the infrared analysis and relative density (specific gravity) procedures in accordance with Specification C494/C494M Section on Uniformity and Equivalence Tests.

19. Report

19.1 Report the following:

19.1.1 Results of tests specified in Section 14 and Sections 16-18 and the relevant specification requirements, with which they are compared,

19.1.2 Brand name, manufacturer's name, lot number, and the quantity represented by the sample of cold-weather admixture system under test,

19.1.3 Brand name, manufacturer's name and specification conformance for air entraining admixture and any other admixtures used,

19.1.4 Brand name, manufacturer's name, type, and specification conformance for cementitious materials used,

19.1.5 Producer's name, description, and specification conformance for fine and coarse aggregates,

19.1.6 Data on concrete mixtures used, including amounts and dosages of admixtures, cementitious materials content, water-cementitious materials ratios, water content, ratio of fine to coarse aggregates, slumps, total air contents, initial setting times, and temperature history of the dummy specimens stored at low-temperature conditions.

19.1.7 In the event that some of the tests have been waived, the circumstances under which such action was taken shall be stated.

20. Keywords

20.1 chemical admixture; cold-weather admixture; concrete; performance requirements

SUMMARY OF CHANGES

Committee C09 has identified the location of selected changes to this specification since the last issue, C1622/C1622M–06, that may impact the use of this specification. (Approved December 15, 2009)

(*1*) Added new 14.6.1 to restrict the size of specimen used for measuring time of setting and renumbered subsequent paragraphs.
(*2*) Revised 14.6.3 by specifying a range of time for the time of setting specimens to reach the target temperature.
(*3*) Revised 16.2.1.2 by requiring compressive strength specimens to be exposed to the same environment as the time of setting specimens.
(*4*) Revised 16.2.2 by reducing the number of speciments for testing resistance to freezing and thawing from three specimens per batch to two specimens per batch.
(*5*) Revised 16.2.3 by reducing the number of speciments for testing length change from three specimens per batch to one specimen per batch.
(*6*) Revised Table 2 for consistency with changes in 16.2.2 and 16.2.3.

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Designation: C 1629/C 1629M – 06

Standard Classification for Abuse-Resistant Nondecorated Interior Gypsum Panel Products and Fiber-Reinforced Cement Panels[1]

This standard is issued under the fixed designation C 1629/C 1629M; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope*

1.1 This standard establishes classifications of abuse resistance based on minimum abuse-resistance performance of nondecorated interior gypsum panel products and fiber-reinforced cement panels (abuse resistant wall panels).

1.2 The values stated in inch-pound and SI (metric) units are to be regarded separately as standard. Within the text, the SI units are shown in brackets. The values stated in each system shall be used independent of the other. Values from the two systems shall not be combined.

1.3 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

2. Referenced Documents

2.1 *ASTM Standards:* [2]

C 11 Terminology Relating to Gypsum and Related Building Materials and Systems

C 1154 Terminology for Non-Asbestos Fiber-Reinforced Cement Products

D 4977 Test Method for Granule Adhesion to Mineral Surfaced Roofing by Abrasion

D 5420 Test Method for Impact Resistance of Flat, Rigid Plastic Specimen by Means of a Striker Impacted by a Falling Weight (Gardner Impact)

E 695 Test Method of Measuring Relative Resistance of Wall, Floor, and Roof Construction to Impact Loading

2.2 *ISO Documents:*

ISO 6707-1 Building and Civil Engineering -- Vocabulary -- Part 1: General Terms

3. Terminology

3.1 Definitions of terms shall be in accordance with Terminologies C 11 and C 1154.

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *failure (hard body impact), n*—test result constituted either by the penetration of the wall cavity by the impacting head of the impacting arm or the denting of the panel resulting in an indentation of a depth that exceeds the thickness of the test panel.

3.2.1.1 *Discussion*—Depth of the indentation on the test panel is measured from the face side.

3.2.2 *failure (soft body impact), n*—a test result constituted either by the breaking of the wall cavity by the soft body impactor or the residual deflection of any area on the test panel that exceeds the thickness of the test panel.

3.2.2.1 *Discussion*—Deformation of the test panel in the form of residual deflection is measured from the face side.

3.2.2.2 *deformation, n*—change of shape or dimension or both. **ISO 6707-1**

3.2.2.3 *surface damage, n*—pulverization of the core of the test panel at the point of impact, which is evidenced by cracking, creasing, or other visible damage short of failure as defined in 3.2.2.

3.2.3 *residual deflection, n*—permanent deformation of a building element, component, or structure after removal of applied force.

3.2.3.1 *Discussion*—Also called permanent set or residual deformation.

4. Significance and Use

4.1 Each abuse/impact property of abuse resistant wall panels is divided into three classification levels. The three levels of classification are: Level I, Level II, and Level III, with Level I representing the lowest rating for any given property. The test methods specified are utilized to establish the abuse-resistance classification of an abuse resistant wall panel. Each

[1] This classification is under the jurisdiction of ASTM Committee C11 on Gypsum and Related Building Materials and Systems and is the direct responsibility of Subcommittee C11.01 on Specifications and Test Methods for Gypsum Products.

Current edition approved Nov. 1, 2006. Published November 2006. Originally approved in 2005. Last previous edition approved in 2005 as C 1629/C 1629M – 05.

[2] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

***A Summary of Changes section appears at the end of this standard.**

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classification level requires a minimum overall specified performance. Any classified abuse resistant wall panel can be used at a classification level which is rated lower than the highest level qualified.

5. Basis of Classification

5.1 Abuse resistant wall panels are classified into one of three levels of abuse resistance based on minimum performance when tested in accordance with test methods that evaluate surface abrasion, indentation, soft body impact, and hard body impact as specified in 6.1 through 6.4.

5.2 Minimum requirements for each level are as shown in Tables 1-4.

6. Test Methods

6.1 *Surface Abrasion Test*—This test is conducted in accordance with Test Method D 4977 using a total load of 25.0 lb. The specimen is conditioned to constant weight at 70F and 50 % relative humidity and subjected to 50 abrasion cycles. The abrasive motion on the specimen creates measurable surface wear or indentation which is measured to determine the level of surface abrasion resistance.

NOTE 1—It is especially important to prepare the apparatus and condition the brush as specified in Test Method D 4977.

6.2 *Indentation Test*—This test, conducted in accordance with Test Method D 5420 (Gardner Impact), utilizes procedure GC, with a ⅝ in. hemispherical head and a 72 in.-lb. [12.6 J] impact energy. The depth of the indentation is measured to determine the level of indentation resistance.

6.3 *Soft Body Impact Test*—This test, conducted in accordance with Method E 695, is performed with the use of the standard leather bag filled with steel pellets to a weight of 60.0 lb [27.2 kg] and dropped through an angular distance until the specimen is impacted.

6.3.1 The specimen is mounted on nominal 2-by-4 wood studs 16 in. [400 mm] o.c. Point of impact is midway between studs at the mid-height of the test panel.

6.3.2 A single specimen is repeatedly impacted at a single point of impact in one cavity with the drop height being increased by 6 in. with each successive drop until structural failure as defined in 3.2.2 is achieved.

6.3.2.1 Surface damage and deformation are recorded following each impact, and the level of impact energy applied is calculated. The residual deflection shall be measured from the face side of the panel.

TABLE 1 Performance Requirements Surface Abrasion Resistance

Classification Level	Abraded Depth Maximum in. [mm]
1	0.126 [3.2]
2	0.059 [1.5]
3	0.010 [0.3]

TABLE 2 Performance Requirements Indentation Resistance

Classification Level	Indentation Maximum in. [mm]
1	0.150 [3.8]
2	0.100 [2.5]
3	0.050 [1.3]

TABLE 3 Performance Requirements Soft Body Impact Test

Classification Level	Soft Body Minimum ft-lbf [J]
1	90 [122]
2	195 [265]
3	300 [408]

TABLE 4 Performance Requirements Hard Body Impact

Classification Level	Hard Body Minimum ft-lbf [J]
1	50 [68]
2	100 [136]
3	150 [204]

NOTE 2—Surface damage and deformation, which do not constitute structural failure, may compound the results.

6.3.3 Following structural failure in the initial cavity, the procedure described in 6.3.2 is repeated on the next cavity, beginning with a drop height of 6 in. higher than the drop height causing structural failure in 6.3.2.

6.3.3.1 If structural failure in the second cavity occurs with the first drop, the test is terminated and the level of energy required to cause the single impact penetration or excessive deformation is calculated to determine the soft body impact resistance.

6.3.3.2 If structural failure in the second cavity occurs on the second or subsequent drop, repeat the procedure described in 6.3.3 in the next cavity, beginning with a drop height 6 in. higher than the drop height causing structural failure in the second cavity.

6.3.4 Repeat the procedures in 6.3.2 through 6.3.3.2 until structural failure occurs on a single drop in a fresh cavity, at which time the test is terminated and the level of energy required to cause the single impact penetration or excessive deformation is calculated to determine the soft body impact resistance.

6.4 *Hard Body Impact Test*—This test is conducted in accordance with the method described in Annex A1 or with another apparatus equipped with an equivalent impact head that is capable of delivering equivalent impact loads.

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ANNEX

(Mandatory Information)

A1. HARD BODY IMPACT TEST

A1.1 Scope

A1.1.1 The hard body impact test measures resistance to penetration of a wall panel when impacted by a rigid body. Failure in the hard body impact test is achieved when the impacting head completely penetrates through the test panel, or the depth of the indentation exceeds the thickness of the product being tested when measured from the face side following impact, or both.

A1.2 Summary of Test Method

A1.2.1 A nominal 2 by 2 ft [610 by 610 mm] specimen is mounted to the apparatus frame. A ramming arm impactor strikes the wall specimen while swinging in an arc. The impactor is dropped from a fixed height to impart specific design energy to the wall specimen. Weights are progressively added to the impactor to increase the design impact energy until specimen failure occurs. For each impact, a new test specimen is used.

A1.3 Significance and Use

A1.3.1 The test method measures relative performance of interior wall panel materials. Although the test panel is mounted on framing and tested vertically as a wall assembly, the impact damage is normally limited to a small area.

A1.4 Apparatus

A1.4.1 The apparatus consists of a rigid frame with a ramming arm pinned to swing in an arc. See Figs. A1.1 and A1.2. The frame is constructed of 14 ga, 1 5⁄8 by 1 5⁄8 in. [41.3 by 41.3 mm] B-Line B24 Regular Framing Channels.

A1.4.1.1 The dimensions and details of the ramming arm impactor are shown in Fig. A1.3. The ramming arm impactor consists of a cylindrical steel impact head (made by milling a round steel bar), a structural steel tubing with square cross-section, two square steel plates (front and rear end plates of the structural steel tubing), a steel plate pivot arm, a round steel bar (to add weights), and a rectangular steel plate attached to the bottom of the structural steel tubing. The total weight of the components of the ramming arm impactor is 20.0 lb [9.07 kg] ± 0.5 %, as shown in Table A1.1. The center of mass of the ramming arm impactor coincides with the location of the steel round bar (that is, the weight bar). Additional weights are attached to the weight bar to increase the impacting energy.

TABLE A1.1 Weight (Mass) Schedule for the Components of the Ramming Arm Impactor

Component	Weight lb, ± 0.5 %	Mass kg, ± 0.5 %
Structural Steel Tubing (square cross-section)	8.10	3.67
Steel Plate Pivot Arm	1.10	0.50
Front Square Steel Plate (end plate attached to the front of the structural steel tubing)	0.90	0.41
Rear Square Steel Plate (end plate attached to the back of the structural steel tubing)	0.90	0.41
Cylindrical Steel Impact Head	1.90	0.86
Steel Round Bar (Weight Bar)	2.60	1.18
Bottom Rectangular Steel Plate (attached to the bottom of the structural steel tubing)	4.50	2.04

A1.4.1.2 The ramming arm impactor shall have a suitable mechanism to secure it at the top of the swing. An example of such a mechanism is a small eyebolt attached to the back of the impactor. When released from the top of the swing, the drop height of the center of mass of the ramming arm impactor shall be 12.0 in. [305 mm].

A1.4.1.3 The ramming arm is located such that the face of the impactor head, when hanging free at the bottom of the arc, is in the same plane as the surface of the test specimen so that, when dropped, the impactor head strikes the surface of the specimen at the bottom of the arc.

A1.5 Test Specimen

A1.5.1 The test wall assembly shall be constructed by attaching a 2 by 2 ft [610 by 610 mm] specimen of the interior wall panel material to a frame of 3 5⁄8 in. [92 mm] deep 20 ga steel studs with Type S-12 bugle head screws spaced 8 in. [200 mm] o.c. as shown in Fig. A1.4. The length of the screws shall be 1 1⁄4 in. [32 mm] for panels up to 5⁄8 in. [15.9 mm] in thickness. For panels with thickness greater than 5⁄8 in. [15.9 mm], the length of the screws shall be at least 5⁄8 in. [16 mm] longer than the panel thickness.

A1.6 Preparation of Apparatus

A1.6.1 The apparatus shall be securely anchored to a level floor to prevent sliding or rocking of the apparatus during impact.

A1.7 Procedure

A1.7.1 The test wall assembly shall be securely clamped to the face of the apparatus so that the surface of the test specimen is in the same plane as the face of the impact head.

A1.7.1.1 A new test wall assembly shall be used for each impact.

A1.7.2 The ramming arm is raised to the top or the arc and secured with a pin.

A1.7.3 The pin is removed, allowing the arm to swing freely and strike the test specimen.

A1.7.4 A new test wall assembly is mounted to the apparatus and the weight on the impactor is increased by adding 2.50 lb [1.10 kg] to the weight bar and the test repeated.

A1.7.5 The test shall be performed by incrementally increasing the barbell free weights on the impactor until a failure impact energy is achieved.

A1.7.5.1 The failure impact energy is defined as the minimum energy required for the impactor to penetrate through the face of the panel into the stud cavity, or when the depth of the indentation exceeds the thickness of the product being tested when measured from the face side.

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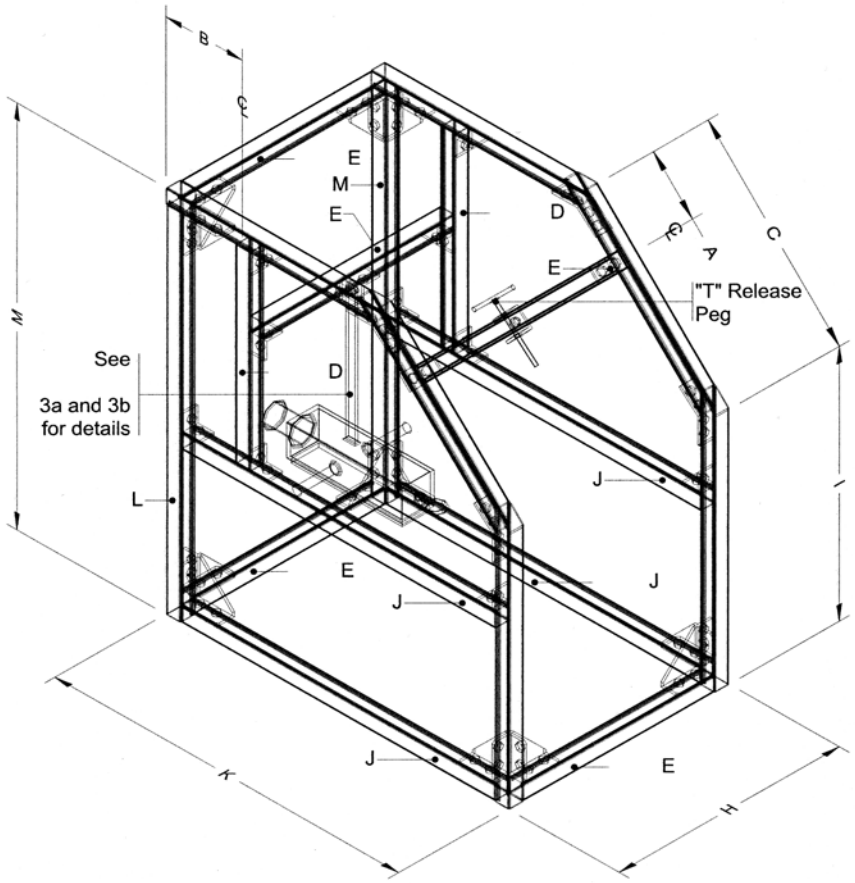

	in.	mm		in.	mm
A	6 1/16	154.0	I	26 5/16	668.3
B	8 5/16	211.1	J	34 1/4	870.0
C	20 5/16	515.9	K	37 1/2	952.5
D	20 9/16	522.3	L	39 1/16	992.2
E	20 3/4	527.1	M	40 11/16	1033.5
H	24	609.6			

NOTE—All framing members shall be B-Line B24 Regular Framing Channels cut to the specified dimensions in this sketch. These channels are 14 gauge and have an outside dimension of 1 5/8 by 1 5/8 in. (41.3 by 41.3 mm).

FIG. A1.1 Axonometric of Hard Body Apparatus Framing Members (not to scale)

A1.7.6 Testing shall continue until the failure impact energy is confirmed on three identical assemblies for each wall panel material being tested.

A1.7.7 Impact energy and damage at each test shall be recorded.

A1.8 Calculation of Energy Impact

A1.8.1 Impact energy in ft-lb units is calculated as the product of the weight of the impacting instrument and the drop height:

$$E = (w \times h) \quad \text{(A1.1)}$$

where:
E = impact energy, ft-lb,
w = weight of impactor, lb, and
h = drop height of the center of mass of the impactor, ft.

A1.8.2 Impact energy in SI units is calculated as the product of the mass of the following three quantities—the mass of the impactor, gravitational acceleration, and the drop height of the center of mass of the impactor:

$$E = (m \times g \times h) \quad \text{(A1.2)}$$

where:
E = impact energy, J,
m = mass of impactor, kg,
g = gravitational acceleration, 9.81 ms^{-2}, and
h = drop height of the center of mass of the impactor, m.

A1.9 Precision and Bias

A1.9.1 The precision and bias of this test method has not been determined.

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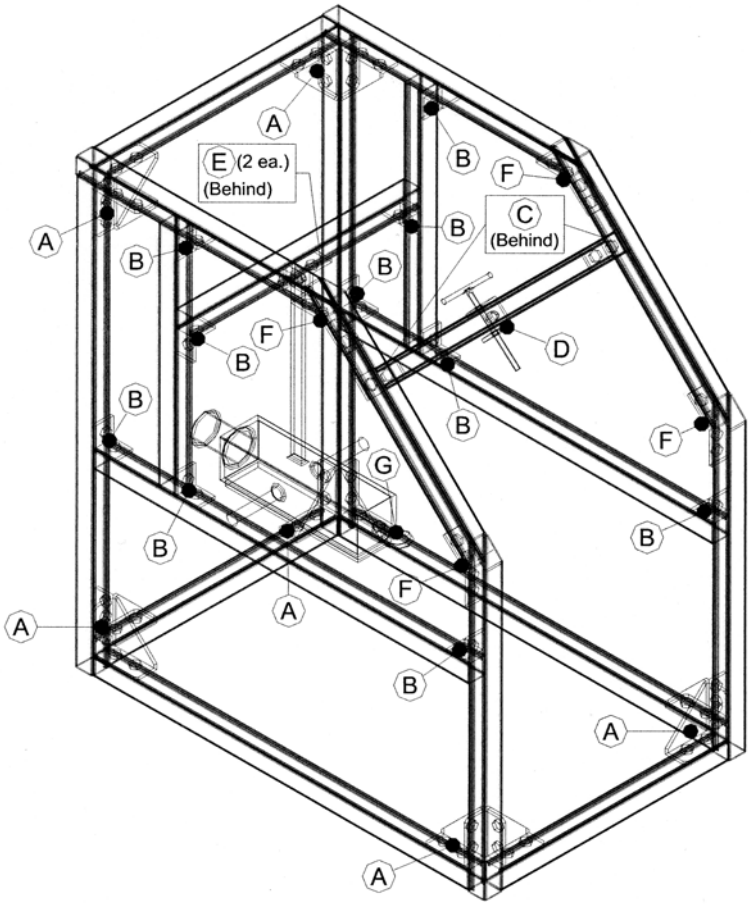

	Fastener Schedule
A	B-Line Universal 90° Shelf Bracket B844
B	B-Line Two Hole 90° Corner Angle B230
C	B-Line Two Hole Flat Splice Plate
D	B-Line Beam Clamp B593 Clevis Swivel
E	Unistrut 90° Fitting P6281
F	B-Line Four Hole Open 45° Angle Fitting B248
G	Threaded steel eyebolts with a ½ in. (12.5 mm) threaded leg 3 in. (75 mm) long, and an eye interior diameter of 3⁄16 in. (5 mm)

NOTE—Use B-Line Hex Head Cap Screws HHCS ½ by 1 ¼ in. (12.7 by 31.8 mm), B-Line Flat Washers FW ½ in., and B-Line N225 Spring Nuts to secure all fasteners to framing members.

FIG. A1.2 Axonometric of Hard Body Apparatus Fasteners (not to scale)

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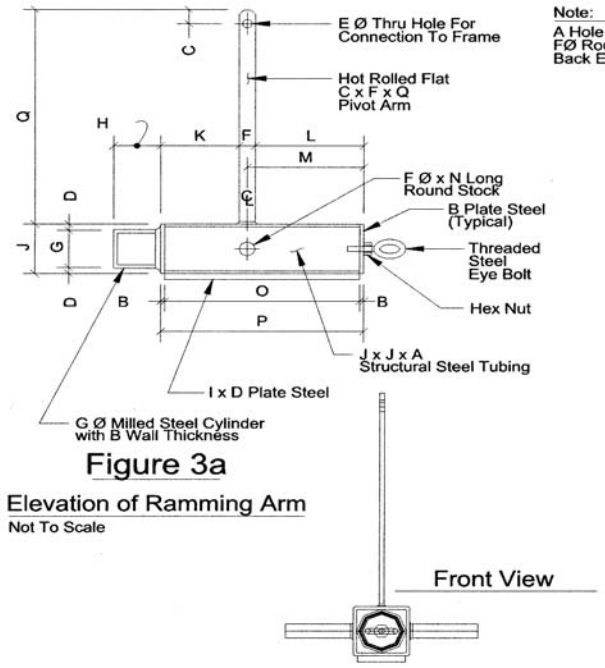

Figure 3a

Elevation of Ramming Arm

Not To Scale

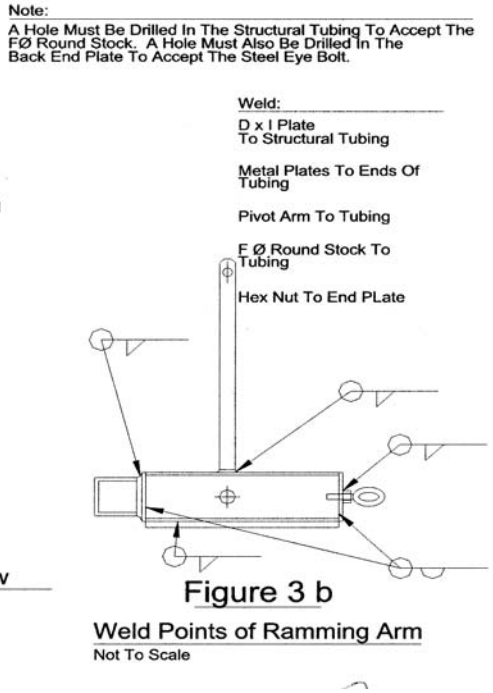

Figure 3 b

Weld Points of Ramming Arm

Not To Scale

	in.	mm		in.	mm
A	3/16	4.8	J	3 1/2	88.9
B	1/4	6.4	K	4 7/8	123.8
C	5/16	7.9	L	6 3/4	171.5
D	7/16	11.1	M	7 1/4	184.2
E	5/8	15.9	N	12	304.8
F	1	25.4	O	12 1/8	308.0
G	2 3/4	69.9	P	12 5/8	320.7
H	2 15/16	74.6	Q	15 1/4	387.4

FIG. A1.3 Ramming Arm

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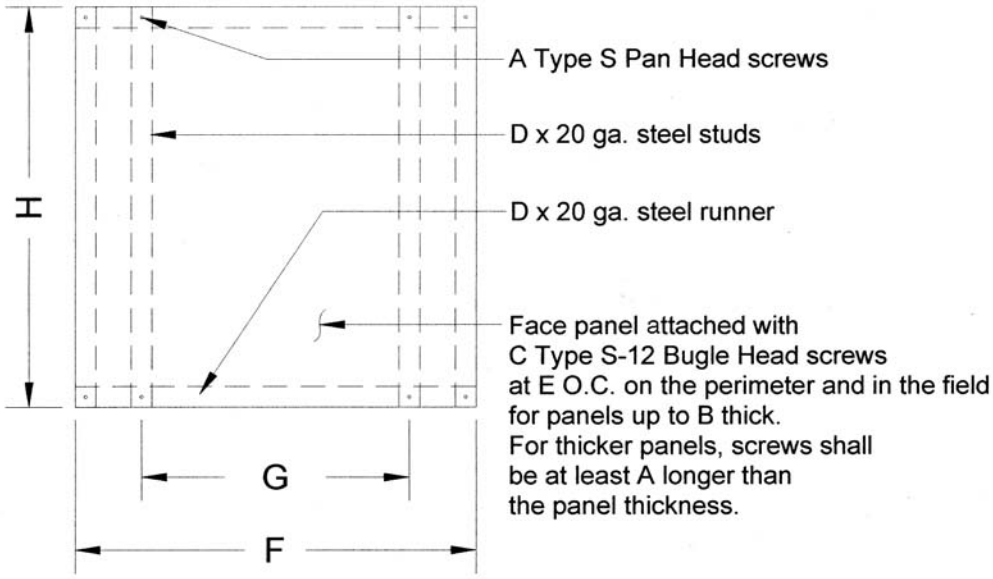

	in.	mm
A	⅜	9.5
B	⅝	15.9
C	1	25.4
D	3 ⅝	92.1
E	8	203.2
F	12	304.8
G	16	406.4
H	24	609.6

FIG. A1.4 Wall Assembly Specimen Construction Detail

SUMMARY OF CHANGES

Committee C11 has identified the location of selected changes to this classification since the last issue, C 1629/C 1629M – 05, that may impact the use of this classification. (Approved November 1, 2006)

(*1*) Revised the titles of Tables 1-4.
(*2*) Revised Section 3.
(*3*) Revised Section 6.

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Designation: C 1646/C 1646M – 08a

Standard Practice for Making and Curing Test Specimens for Evaluating Resistance of Coarse Aggregate to Freezing and Thawing in Air-Entrained Concrete[1]

This standard is issued under the fixed designation C 1646/C 1646M; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope*

1.1 This practice covers procedures for making and curing test specimens for evaluating resistance of normal-weight coarse aggregates to freezing and thawing in air-entrained concrete in accordance with Test Method C 666/C 666M, Procedure A or B.

1.2 The values stated in either SI units or inch-pound units are to be regarded separately as standard. The values stated in each system may not be exact equivalents; therefore, each system shall be used independently of the other. Combining values from the two systems may result in non-conformance with the standard.

1.3 *This practice does not purport to address all the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.* (**Warning**—Fresh hydraulic cementitious mixtures are caustic and may cause chemical burns to skin and tissue upon prolonged use.[2])

2. Referenced Documents

2.1 *ASTM Standards:*[3]

C 33 Specification for Concrete Aggregates

C 39/C 39M Test Method for Compressive Strength of Cylindrical Concrete Specimens

C 125 Terminology Relating to Concrete and Concrete Aggregates

C 143/C 143M Test Method for Slump of Hydraulic-Cement Concrete

C 150 Specification for Portland Cement

C 173/C 173M Test Method for Air Content of Freshly Mixed Concrete by the Volumetric Method

C 192/C 192M Practice for Making and Curing Concrete Test Specimens in the Laboratory

C 231 Test Method for Air Content of Freshly Mixed Concrete by the Pressure Method

C 490 Practice for Use of Apparatus for the Determination of Length Change of Hardened Cement Paste, Mortar, and Concrete

C 494/C 494M Specification for Chemical Admixtures for Concrete

C 666/C 666M Test Method for Resistance of Concrete to Rapid Freezing and Thawing

D 75 Practice for Sampling Aggregates

2.2 *ACI Standard:*[4]

211.1 Practice for Selecting Proportions for Normal, Heavyweight, and Mass Concrete

3. Terminology

3.1 *Definitions*:

3.1.1 For definitions of terms used in this specification, refer to Terminology C 125.

4. Significance and Use

4.1 This practice provides standard requirements for evaluating coarse aggregate in air-entrained concrete subjected to freezing and thawing in accordance with Test Method C 666/C 666M.

4.2 Concrete having an adequate air-void system may not be resistant to freezing and thawing if it contains coarse aggregate that becomes critically saturated. An aggregate particle is considered to be critically saturated when there is insufficient

[1] This practice is under the jurisdiction of ASTM Committee C09 on Concrete and Concrete Aggregates and is the direct responsibility of Subcommittee C09.67 on Resistance to the Environment.

Current edition approved Dec. 15, 2008. Published January 2009. Originally approved in 2007. Last previous edition approved in 2008 as C 1646/C 1646M – 08.

[2] Section on Safety Precautions, Manual of Aggregate and Concrete Testing, *Annual Book of ASTM Standards*, Volume 04.02.

[3] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

[4] Available from American Concrete Institute (ACI), P.O. Box 9094, Farmington Hills, MI 48333-9094, http://www.aci-int.org.

***A Summary of Changes section appears at the end of this standard.**

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unfilled pore space to accommodate the expansion of water that accompanies the freezing.

4.3 The potential of the coarse aggregate to cause damage due to cycles of freezing and thawing is evaluated by Test Method C 666/C 666M.

5. Apparatus

5.1 Equipment for mixing concrete and procedures for making and curing test specimens shall be in accordance with Practice C 192/C 192M.

6. Coarse Aggregate Preparation

6.1 *Sampling*—Sample in accordance with Practice D 75.

6.2 *Grading*—When coarse aggregates are to be compared using this practice, standardize the coarse aggregate gradings by recombining individual size fractions in accordance with Table 1 for the appropriate size aggregate being tested. Bring the as-received sample to a saturated-surface-dry (SSD) condition or drier prior to sieving. Do not oven-dry the coarse aggregate sample. If necessary, air drying of the sample to achieve this condition is permitted. The nominal-maximum-aggregate size shall not exceed one-third the least dimension of the test specimen to be used. Fine aggregate shall meet the requirements of Specification C 33 and the grading shall conform to Table 1.

6.3 *Conditioning*—Condition fine and coarse aggregates as follows:

6.3.1 *Fine Aggregate*—Uniformly wet the fine aggregate 24 h prior to mixing of concrete so that the moisture content exceeds the saturated-surface-dry condition but there is no tendency for loss of surface water by draining. Keep the fine aggregate covered to prevent evaporation prior to use.

6.3.2 *Coarse Aggregate*—Immerse the coarse aggregate in water 24 h prior to mixing of concrete. On the day of mixing, decant the water from the coarse aggregate.

7. Concrete Mixture

7.1 *Ingredients*—The portland cement shall meet the requirements of Specification C 150, Type I or Type II. Batches for a particular test series shall use cement, fine aggregate, and air-entraining admixture taken from the same lot.

7.2 *Air-entraining admixture*—As described in Specification C 494/C 494M, section on Air-Entraining Admixture (See Note 1).

NOTE 1—As stated in Specification C 494/C 494M, note that "neutralized Vinsol resin" is required if no material is designated by the person or agency for whom the testing is being performed.

7.3 *Proportions*—Except when tests are being made where mixture proportions are those proposed for the work, proportion all concrete using ACI 211.1 conforming to the following requirements:

7.3.1 The cement content shall be 307 ± 3 kg/m^3 [517 ± 5 lb/yd^3]

7.3.2 The air content used in the computation of mixture proportions shall be in accordance with Table 2. The amount of air-entraining admixture used shall be such as to give an air content as prescribed in Table 2, ± 1 %, when tested according to Test Method C 231 or Test Method C 173/C 173M.

7.3.3 The mixture shall contain the amount of coarse aggregate shown in the "Volume of Coarse Aggregate Per Unit of Volume of Concrete" table of ACI 211.1 for the nominal-maximum size of aggregate and for the fineness modulus of the fine aggregate being used.

7.3.4 Adjust the water content and fine aggregate content to obtain a slump of 75 ± 25 mm [3 ± 1 in.] when tested in accordance with Test Method C 143/C 143M.

7.4 *Mixing*—Machine mix the concrete as prescribed in Practice C 192/C 192M.

8. Specimen Preparation and Conditioning

8.1 *Specimen Preparation*—The type and size of the test specimen and the method for molding shall be in accordance with the Test Specimen section of Test Method C 666/C 666M, unless otherwise specified. If length change testing is to be performed as a permitted option in Test Method C 666/C 666M, fit the specimens with axially centered stainless steel gauge studs in accordance with Practice C 490.

8.2 *Number of Specimens*—Make at least three freezing-and-thawing test specimens from each batch. In addition, make at least three cylindrical specimens from each batch for strength verification. The cylindrical specimens shall be made in accordance with Practice C 192/C 192M and tested in accordance with Test Method C 39/C 39M.

8.3 *Curing*—Complete initial storage and remove from molds in accordance with Practice C 192/C 192M. After removal from the molds, inspect for defects and store in saturated limewater at 23.0 ± 2.0 °C [73.5 ± 3.5 °F] to an age of 14 days.

TABLE 1 Grading Requirements

	Amounts Finer Than Each Laboratory Sieve, Mass Percent										
Size No.	Nominal Max. Size	37.5 mm [1 ½ in.]	25.0 mm [1 in.]	19.0 mm [¾ in.]	12.5 mm [½ in.]	9.5 mm [⅜ in.]	4.75 mm [No. 4]	2.36 mm [No. 8]	1.18 mm [No. 16]	300 µm [No. 50]	150 µm [No. 100]
467	37.5 mm [1 ½ in.]	100	70	50	30	20	0				
56	25.0 mm [1 in.]		100	60	25	0					
57	25.0 mm [1 in.]		100	75	40		0				
6	19.0 mm [¾ in.]			100	35	0					
67	19.0 mm [¾ in.]			100	60	35	0				
7	12.5 mm [½ in.]				100	55	0				
8	9.5 mm [⅜ in.]					100	20	0			
89	9.5 mm [⅜ in.]					100	35	15	0		
Fine Aggregate	4.75 mm [No. 4]						100		65-75	12-20	2-5

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TABLE 2 Target Total Air Content

	Nominal Maximum Size of Aggregate, mm [in.]				
	9.5 [⅜]	12.5 [½]	19.0[¾]	25.0 [1]	37.5 [1 ½]
Total Air Content, %	7.5	7.0	6.0	6.0	5.5

9. Method of Test

9.1 After the specimens have cured, test in accordance with Procedure A or Procedure B of Test Method C 666/C 666M.

10. Keywords

10.1 aggregate; coarse aggregate; freezing and thawing

SUMMARY OF CHANGES

Committee C09 has identified the location of selected changes to this practice since the last issue, C 1646/C 1646M – 08, that may impact the use of this practice. (Approved December 15, 2008)

(*1*) Revised the title, 1.1, 4.1, 4.2, and Keywords to replace the term “frost” with “freezing and thawing.”

Committee C09 has identified the location of selected changes to this practice since the last issue, C 1646/C 1646M – 07, that may impact the use of this practice. (Approved August 1, 2008)

(*1*) Revised 1.2 and put SI units first throughout the standard to comply with C09’s policy addressing SI units.
(*2*) Added new Section 3 Terminology and renumbered subsequent sections.
(*3*) Added new Note 1 after 7.2.

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Designation: C 1658/C 1658M – 06

Standard Specification for Glass Mat Gypsum Panels[1]

This standard is issued under the fixed designation C 1658/C 1658M; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope

1.1 This specification covers the glass mat gypsum panels described in 1.1.1-1.1.3.

1.1.1 *Glass mat interior gypsum panel*, designed for use on walls, ceilings, or partitions and that affords a surface suitable to receive decoration.

1.1.2 *Glass mat coreboard gypsum panel, and glass mat shaftliner gypsum panel*, designed for use as a base in multilayer systems or as gypsum studs or cores in semisolid or solid gypsum board partitions, or in shaftwall assemblies.

1.1.3 *Glass mat water-resistant gypsum panel*, designed to be used as a base for the application of ceramic or plastic tile on walls or ceilings. This product is also suitable for decoration. (*This is distinct from a coated glass mat water-resistant gypsum panel ASTM C 1178.*)

1.2 Specifications applicable to all glass mat gypsum panels are located in Sections 1-4 and 8-10. Specifications applicable to specific glass mat gypsum panels are located in the following sections:

	Section
Glass mat interior gypsum panel	5
Glass mat coreboard gypsum panel, and glass mat shaftliner gypsum panel	6
Glass mat water-resistant gypsum panel	7

1.3 The values stated in either inch-pound units or SI (metric) are to be regarded separately as standard. Within the text, the SI units are shown in brackets. The values stated in each system shall be used independent of the other. Values from the two systems shall not be combined.

2. Referenced Documents

2.1 *ASTM Standards:* [2]

C 11 Terminology Relating to Gypsum and Related Building Materials and Systems

C 473 Test Methods for Physical Testing of Gypsum Panel Products

C 645 Specification for Nonstructural Steel Framing Members

C 1264 Specification for Sampling, Inspection, Rejection, Certification, Packaging, Marking, Shipping, Handling, and Storage of Gypsum Panel Products

E 84 Test Method for Surface Burning Characteristics of Building Materials

E 119 Test Methods for Fire Tests of Building Construction and Materials

3. Terminology

3.1 Definitions used in this specification shall be in accordance with Terminology C 11.

3.2 *Definitions of Terms Specific to This Standard:*

3.3 *glass mat*, *n*—a mat of glass fibers with or without a binder.

4. Materials and Manufacture

4.1 Glass mat gypsum panel shall consist of a noncombustible core, essentially gypsum, surfaced with glass mat partially or completely embedded in the core.

4.1.1 Glass mat interior gypsum panel shall consist of a noncombustible core, essentially gypsum, surfaced on both the face and back with glass mat partially or completely embedded into the core.

4.1.2 Glass mat coreboard gypsum panel, and glass mat shaftliner gypsum panel shall be either a single panel or composed of two factory-laminated gypsum panels to provide up to 1 in. [25.4 mm] total nominal thickness, surfaced on both face and back with glass mat partially or completely embedded into the core.

4.1.3 Glass mat gypsum water-resistant panel shall consist of a noncombustible water-resistant core, essentially gypsum, surfaced on the face with water-resistant glass mat partially or completely embedded into the core.

4.2 *Glass Mat Interior Gypsum panel, and Glass Mat Water-Resistant gypsum panel, type X (special fire-resistant)* designates glass mat gypsum panel complying with this specification that provide not less than 1 h fire resistance for panel ⅝ in. [15.9 mm] thick or ¾ h fire resistance for panel ½ in. [12.7 mm] thick, applied parallel with and on each side of load bearing 2 by 4 wood studs spaced 16 in. [406 mm] on center

[1] This test method is under the jurisdiction of ASTM Committee C11 on Gypsum and Related Building Materials and Systems and is the direct responsibility of Subcommittee C11.01 on Specifications and Test Methods for Gypsum Products.

Current edition approved Dec. 1, 2006. Published January 2007.

[2] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

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with 6d coated nails, 1⅞ in. [48 mm] long, 0.0915 in. [2.3 mm] diameter shank, ¼ in. [6.4 mm] diameter heads, spaced 7 in. [178 mm] on center with glass mat gypsum panel joints staggered 16 in. [406 mm] on each side of the partition and tested in accordance with Test Methods E 119.

NOTE 1—Consult manufacturers for independent test data on assembly details and fire resistance classifications for other types of construction. See fire test reports or listings from recognized fire testing laboratories for assembly particulars, materials, and classifications.

4.3 *Glass Mat Shaftliner gypsum panel*, type X, designates glass mat gypsum shaftliner panel complying with this specification that meets the acceptance criteria for temperature rise for not less than panels 1-in. [25.4 mm] thick, when applied in a double layer solid non-load bearing partition as described in 4.3.2 and tested in accordance with Test Methods E 119 with thermocouple locations as specified in 4.3.2.

4.3.1 Two layers of glass mat gypsum shaftliner panel applied vertically and friction fit into vertical 25-gauge steel "H" members, 2-in. [50.8 mm] deep for panels 1-in. [25.4 mm] thick, spaced 24-in. [610 mm] on centers and 25-gauge steel track at the perimeter of the partition. "H" members shall be formed with a single web or shall be two pieces of perimeter track fastened together along the web with screws spaced 24-in. [610 mm] on centers.

4.3.2 Temperature rise on the unexposed surface shall be measured using not less than five thermocouples; one shall be located at the center of the assembly and one shall be located at the center of each quadrant. Thermocouples shall be located not less than 3-in. [76 mm] from an "H" member.

4.4 Glass mat gypsum panels shall have a flame spread index of not more than 25 when tested in accordance with Test Method E 84.

4.5 *Physical Properties, Dimensions, and Tolerances of Glass Mat Gypsum Panel*:

4.5.1 Specimens shall be taken from the samples obtained in accordance with Specification C 1264.

4.5.1.1 Specimens shall be tested in accordance with Test Methods C 473.

4.5.2 *Core, End, and Edge Hardness*—The specimens shall have an average hardness of not less than 15 lbf [67 N] when tested by Method A or by Method B.

4.5.3 *Edges and Ends*—The edges and ends shall be straight.

4.5.4 *Length*—The tolerance in length shall be ± ¼ in. [± 6 mm].

4.5.5 *Tapered Edge Depth*—The average thickness of the edge of recessed or tapered edge glass mat gypsum panel shall be not less than 0.020 in. [0.51 mm] but not more than 0.090 in. [2.29 mm] less than the average thickness of the glass mat gypsum panel.

5. Glass Mat Interior Gypsum Panel

5.1 *Physical Properties of Glass Mat Interior Gypsum Panel*:

5.1.1 *Flexural Strength*—The specimens shall be tested face up and face down. The average breaking load shall be not less than the following:

Thickness, in. [mm]	Method A or B Load, lbf [N] Bearing edges perpendicular to the panel edge	Load, lbf [N] Bearing edges parallel to the panel edge
¼ [6.4]	50 [222]	40 [178]
½ [12.7]	100 [445]	80 [356]
⅝ [15.9]	140 [623]	100 [445]

5.1.2 *Humidified Deflection*—The specimens shall have an average deflection of not more than the following:

Thickness, in. [mm]	Deflection, sixteenths of an in. [mm]
¼ [6.4]	not required
½ [12.7]	5 [8]
⅝ [15.9]	4 [6]

5.1.3 *Nail Pull Resistance*—The specimens shall have an average nail-pull resistance of not less than the following:

Thickness, in. [mm]	Method A or B lbf [N]
¼ [6.4]	40 [178]
½ [12.7]	80 [356]
⅝ [15.9]	90 [400]

5.2 *Dimensions and Tolerances of Glass Mat Interior Gypsum Panel*:

5.2.1 *Thickness*—The nominal thickness shall be from ¼ to ⅝ in. [6.4 to 15.9 mm] with tolerances in the nominal thickness of ± 1/64 in. [± 0.4 mm], and with local variations of ± 1/32 in. [± 0.8 mm] from the nominal thickness.

5.2.2 *Width*—The width shall be up to 48 in. [1220 mm], or up to 54 in. [1370 mm], with a tolerance of 3/32 in. [3 mm] under the specified width.

5.2.3 *End Squareness*—Corners shall be square with a tolerance of ± ⅛ in. [± 3 mm] in the full width of the board.

5.3 *Edges*:

5.3.1 The edges of glass mat interior gypsum panel shall be either square, beveled, featured, tapered, or featured and tapered.

6. Glass Mat Coreboard Gypsum Panel, and Glass Mat Shaftliner Gypsum Panel

6.1 *Physical Properties of Glass Mat Coreboard Gypsum Panel and Glass Mat Shaftliner Gypsum Panel*:

6.1.1 *Flexural Strength*—The specimens shall be tested face up and face down. The average breaking load shall be not less than the following:

Thickness, in. [mm]	Method A or B Load, lbf [N] Bearing edges perpendicular to the panel edge	Load, lbf [N] Bearing edges parallel to the panel edge
1 [25.4]	230 [1023]	80 [356]

6.2 *Dimensions and Tolerances of Glass Mat Coreboard Gypsum Panel, and Glass Mat Shaftliner Gypsum Panel*:

6.2.1 *Thickness*—The nominal thickness shall be 1 in. [25.4 mm] with tolerances in the nominal thickness of ± 1/32 in. [± 0.8 mm], and with local variations of ± 1/16 in. [± 1.6 mm] from the nominal thickness.

6.2.2 *Width*—The width shall be from 16 to 48 in. [406 to 1220 mm] with a tolerance of ± ⅛ in. [3 mm] under the specified width.

6.2.3 *End Squareness*—Corners shall be square with a tolerance of ± ⅛ in. [± 3 mm] in the full width of the board.

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6.3 *Edges*—The edges shall be either square, beveled, round, V-tongue and groove, or featured.

7. Glass Mat Water-Resistant Gypsum Panel

7.1 *Physical Properties of Glass Mat Water-Resistant Gypsum Panel*:

7.1.1 *Flexural Strength*—The specimens shall be tested face up and face down. The average breaking load shall be not less than the following:

Thickness, in. [mm]	Load, lbf [N] Bearing edges perpendicular to the panel edge	Method A or B Load, lbf [N] Bearing edges parallel to the panel edge
½ [12.7]	100 [445]	80 [356]
⅝ [15.9]	140 [623]	100 [445]

7.1.2 *Humidified Deflection*—The specimens shall have an average deflection of not more than the following:

Thickness, in. [mm]	Deflection, sixteenths of an in. [mm]
½ [12.7]	5 [8]
⅝ [15.9]	4 [6]

7.1.3 *Nail Pull Resistance*—The specimens shall have an average nail-pull resistance of not less than the following:

Thickness, in. [mm]	Method A or B lbf [N]
½ [12.7]	80 [356]
⅝ [15.9]	90 [400]

7.1.4 *Water Resistance*—The specimens shall have an average water absorption of not more than 5 weight % after 2-h immersion.

7.1.5 *Surface Water Absorption*—The specimens shall have an average face surface water absorption of not more than 1.6 g after 2 h of elapsed time.

7.2 *Dimensions and Tolerances of Glass Mat Water-Resistant Gypsum Panel*:

7.2.1 *Thickness*—The nominal thickness shall be ½ or ⅝ in. [12.7 or 15.9 mm] with tolerances in the nominal thickness of ± 1/64 in. [± 0.4 mm], and with local variations of ± 1/32 in. [± 0.8 mm] from the nominal thickness.

7.2.2 *Width*—The width shall be up to 48 in. [1220 mm], or up to 54 in. [1370 mm], with a tolerance of 3/32 in. [3 mm] under the specified width.

7.2.3 *End Squareness*—Corners shall be square with a tolerance of ± ⅛ in. [± 3 mm] in the full width of the board.

7.3 *Edges*—The edges shall be either square, beveled, featured, tapered, or featured and tapered.

8. Finish and Appearance

8.1 The glass mat gypsum panel surface shall be true and free from imperfections that would render it unfit for use with or without decoration.

9. Sampling, Inspection, Rejection, Certification, Packaging, Marking, Shipping, Handling, and Storage

9.1 Sampling, inspection, rejection, certification, packaging, marking, shipping, handling, and storage of glass mat gypsum panel shall be in accordance with Specification C 1264.

10. Keywords

10.1 ceiling; coreboard; glass mat; glass mat gypsum panel; partitions; shaftliner; type X; wall; water-resistant

APPENDIX

(Nonmandatory Information)

This appendix gives general information and also suggestions for inclusions to be made elsewhere by the specifier. They are not part of this specification.

The definition of type X as given in 4.2 and 4.3 and the alternate definition given in this appendix, are intended only as a test to define the glass mat gypsum panel as meeting the requirements of type X products. These tests do not indicate a preferred application nor do they limit the use of the product in other fire rated assemblies.

All gypsum panel products for which type X is defined, except shaftliner gypsum panel, use the same test for type X products, therefore the type X definition indicates a consistent level of fire resistance.

X1. ALTERNATE DEFINITION FOR TYPE X

X1.1 Glass mat gypsum panel, type X (special fire-resistant) designates glass mat gypsum panel providing a greater fire-resistance than regular glass mat gypsum panel of the same thickness. Type X (special fire-resistant) glass mat gypsum panel, when tested in accordance with Test Methods E 119, shall provide the following minimum fire resistance ratings for the assemblies described:

X1.1.1 One hour for a ⅝-in. [15.9-mm] thickness applied to a partition in a single-layer application on each side of 3 ⅝-in. [92-mm] deep non-load bearing galvanized steel studs complying with Specification C 645, spaced 24 in. [610 mm] on center. The ⅝-in. [15.9-mm] thick gypsum board 48 in. [1220 mm] wide shall be attached using 1-in. [25-mm] long drywall screws spaced 8 in. [203 mm] on center along the edges and

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ends, and 12 in. [305 mm] along intermediate studs. All joints shall be oriented parallel to and located over studs and staggered on opposite sides of the assembly, and

X1.1.2 Two hours for a ½-in. [12.7-mm] thickness applied to a partition in a double-layer application on each side of 2 ⅝-in. [64-mm] deep non-load bearing galvanized steel studs complying with Specification C 645, spaced 24 in. [610 mm] on center. The 48-in. [1220-mm] wide base layer shall be attached using 1-in. [25-mm] long drywall screws spaced 12 in. [305 mm] on center along board edges, ends, and along intermediate studs. Joints shall be oriented parallel to and located over studs and staggered on opposite sides of the assembly. The 48-in. [1220-m] wide face layer shall be attached using 1 ⅝-in. [41-mm] long drywall screws spaced 12 in. [305 mm] along board edges, ends, and along intermediate studs. Joints shall be oriented parallel to and located over studs, offset 24 in. [610 mm] from the base layer joints, and staggered on opposite sides of the assembly.

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Designation: C 1679 – 08

Standard Practice for Measuring Hydration Kinetics of Hydraulic Cementitious Mixtures Using Isothermal Calorimetry[1]

This standard is issued under the fixed designation C 1679; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope*

1.1 This practice describes the apparatus and procedure for measuring relative differences in hydration kinetics of hydraulic cementitious mixtures, either in paste or mortar (See Note 1), including those containing admixtures, various supplementary cementitious materials (SCM), and other fine materials by measuring the thermal power using an isothermal calorimeter.

NOTE 1—Paste specimens are often preferred for mechanistic research when details of individual reaction peaks are important or for particular calorimetry configurations. Mortar specimens may give results that have better correlation with concrete setting and early strength development and are often preferred to evaluate different mixture proportions for concrete. Both paste and mortar studies have been found to be effective in evaluating concrete field problems due to incompatibility of materials used in concrete mixtures.

1.2 The values stated in SI units are to be regarded as standard. No other units of measurement are included in this standard.

1.3 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.* (**Warning—**Fresh hydraulic cementitious mixtures are caustic and may cause chemical burns to skin and tissue upon prolonged exposure.[2])

2. Referenced Documents

2.1 *ASTM Standards:* [3]

C 125 Terminology Relating to Concrete and Concrete Aggregates
C 172 Practice for Sampling Freshly Mixed Concrete
C 219 Terminology Relating to Hydraulic Cement
C 305 Practice for Mechanical Mixing of Hydraulic Cement Pastes and Mortars of Plastic Consistency
C 403/C 403M Test Method for Time of Setting of Concrete Mixtures by Penetration Resistance
C 511 Specification for Mixing Rooms, Moist Cabinets, Moist Rooms, and Water Storage Tanks Used in the Testing of Hydraulic Cements and Concretes
C 778 Specification for Standard Sand
C 1005 Specification for Reference Masses and Devices for Determining Mass and Volume for Use in the Physical Testing of Hydraulic Cements
C 1602/C 1602M Specification for Mixing Water Used in the Production of Hydraulic Cement Concrete

2.2 *Other Standard:*

API Specification RP 10B-2/ ISO 10426-2 Recommended Practice for Testing Well Cements[4]

3. Terminology

3.1 *Definitions*—For definitions of terms used in this practice, refer to Terminology C 125 and Terminology C 219.

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *baseline*, *n*—the signal from the calorimeter when there is an inert specimen in the instrument.

3.2.2 *calibration coefficient*, *n*—a factor that relates the value recorded by the data acquisition system to the thermal power output.

3.2.2.1 *Discussion*—Normally recorded data are in volts and the calibration coefficient has units of watts per volt (W/V). Some calorimeters may have internal automatic calibration and will give the output in watts without the user having to specify the calibration coefficient.

[1] This practice is under the jurisdiction of ASTM Committee C09 on Concrete and Concrete Aggregates and is the direct responsibility of Subcommittee C09.48 on Performance of Cementitious Materials and Admixture Combinations.

Current edition approved June 1, 2008. Published July 2008. Originally approved in 2007. Last previous edition approved in 2007 as C 1679 – 07.

[2] Section on Safety Precautions, Manual of Aggregate and Concrete Testing, *Annual Book of ASTM Standards*, Vol 04.02.

[3] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

[4] Available from American Petroleum Institute (API), 1220 L. St., NW, Washington, DC 20005-4070, http://api-ec.api.org.

***A Summary of Changes section appears at the end of this standard.**

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3.2.3 *combined mixture*, *n*—combination of all the materials that are introduced into the calorimeter for measuring hydration kinetics.

3.2.4 *hydration time*, *n*—the elapsed time from initial contact between the cementitious materials and the mix water.

3.2.5 *inert specimen*, *n*—specimen placed within the isothermal calorimeter made of a non-reactive material of similar thermal properties (mainly heat capacity) as the reacting specimen made of the cementitious test mixture.

3.2.5.1 *Discussion*—The output from the calorimeter is the difference between the heat flow from the test specimen and the inert specimen. The use of an inert specimen substantially decreases the noise and drift of the measured heat flow.

3.2.6 *isothermal calorimeter*, *n*—a calorimeter that measures heat flow from a specimen maintained at a constant temperature by intimate thermal contact with a constant temperature heat sink.

3.2.7 *isothermal calorimetry*, *n*—an experimental technique to monitor the thermal power output from a specimen kept at near isothermal conditions.

3.2.8 *isothermal hydration profile*, *n*—the thermal power plotted as a function of hydration time, which provides an indication of the rate of hydration over time at a given temperature.

3.2.9 *main hydration peak*, *n*—the broadest peak in the isothermal hydration profile that starts at the end of the dormant period and for a well-balanced mixture lasts for several hours (See Fig. 1).

3.2.10 *near isothermal conditions*, *n*—a constant temperature with a permissible variation of ± 1.0 °C.

3.2.11 *specimen holder*, *n*—container within the isothermal calorimeter that conducts the heat from the specimen in the vial to the heat flow sensor.

3.2.12 *stock solution*, *n*—a solution of admixture in water prepared to enable more precise volumetric addition of small quantities of admixture, typically made by pipetting known volumes of admixture into a volumetric flask and diluting it to the flask's fixed volume.

3.2.13 *sulfate addition*, *n*—the addition of a soluble sulfate source (such as gypsum, calcium sulfate hemihydrate, alkali sulfate) to a combined mixture to investigate whether a given combination of materials is in sulfate balance.

3.2.14 *sulfate balance of mixture*, *n*—the situation when the size of the main hydration peak is not increased by sulfate additions; in some cases where the main peak is increased in size by added sulfate, it will also be accelerated in time.

3.2.15 *sulfate depletion point*, *n*—the onset of accelerated aluminate activity that for a portland cement in absence of supplementary cementitious material (SCM) and admixture may take place after the main hydration peak.

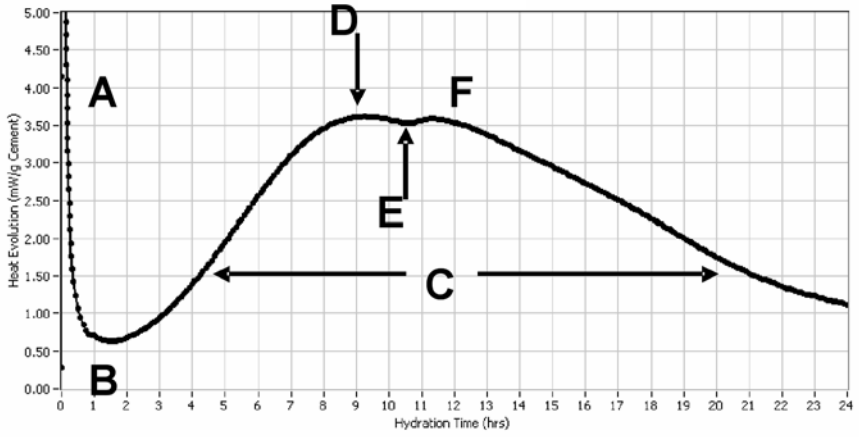
3.2.15.1 *Discussion*—The sulfate depletion point may become impossible to detect without further addition of gypsum or plaster for certain cements and more often in combined mixtures with admixtures or SCMs, or both. In some cases other sources of sulfate might be used to mimic potential conditions in the system. Among these are anhydrite, arcanite, calcium langbeinite, aphthitalite, syngenite, and others. Fig. 2 shows an example of the effect of added sulfate on the sulfate depletion point. Added sulfate may, in some combined mixtures with admixtures or SCMs, or both, accelerate the onset of the main hydration peak. When a combined mixture is at sulfate balance, further addition of soluble sulfate will not increase the size, or accelerate the onset, of the main hydration peak.

3.2.16 *thermal equilibrium time*, *n*—the elapsed hydration time when the thermal power of replicate mixtures do not differ by more than 0.2 mW/g of dry material.

3.2.17 *thermal indicator of setting time*, *n*—the hydration time to reach a thermal power of 50 % of the maximum value of the main hydration peak.

3.2.18 *thermal power*, *n*—heat production rate measured in watts (W) or joules per second (J/s), usually expressed in relation to the mass of cementitious material, as mW/g or J/s/g.

3.2.18.1 *Discussion*—The thermal power is an indicator of the rate of various chemical reactions between cementitious materials, other fine particles, mix water and admixtures.



NOTE—(A) initial thermal power by dissolution of cement and initial cement hydration; (B) dormant period associated with very low thermal power indicating slow and well-controlled hydration: (C) main hydration peak associated mainly with hydration reactions contributing to setting and early strength development, with maximum at (D); and (E) sulfate depletion point,[6] followed by (F) accelerated aluminate activity.

FIG. 1 Example of Thermal Power Curve for Isothermal Hydration of Portland Cement

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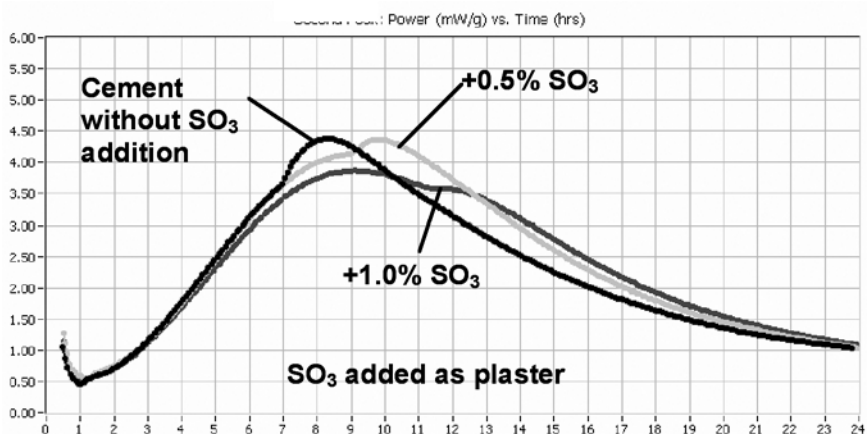

FIG. 2 Example of the Effect of Soluble Calcium Sulfate Addition on the Timing of the Sulfate Depletion Point for a Type I Portland Cement Mixed with Water Only at w/c = 0.45

3.2.19 *vial*, *n*—container into which the freshly mixed cementitious mixture is placed for a measurement.

4. Summary of Practice

4.1 An isothermal calorimeter consists of heat sink with a thermostat, two heat flow sensors and a specimen vial holder attached to each sensor. A vial containing a freshly prepared mixture is placed in contact with one of the vial holders and a thermally inert material is placed in contact with the other. The heat of hydration released by the reacting cementitious specimen is transferred and passes across a heat flow sensor. The calorimeter output is calculated from the difference between the outputs from the test specimen heat flow sensor and the inert specimen heat flow sensor. Because the heat is allowed to flow away from the specimen, the measurement will take place at essentially constant temperature (isothermal conditions).

4.2 Mixtures with cement, SCM, admixtures, water and optional fine aggregate are prepared and introduced into an isothermal calorimeter. Isothermal calorimetry tests are performed on a series of different mixtures for relative comparison of the hydration kinetics. The output of the calorimeter is evaluated by graphical and mathematical means to evaluate retarding and accelerating effects of different combinations of materials. Calcium sulfate may be added as a probe to determine if the addition of admixture, SCMs, or both have increased the mixture's demand for sulfate beyond that which is available in the cement.

5. Significance and Use

5.1 Thermal power curves are used to evaluate the isothermal hydration kinetics of the combined mixture of different materials during the early period after being mixed with water. These isothermal power curves, or hydration profiles, may provide indications relative to setting characteristics, compatibility of different materials, sulfate balance and early strength development. The isothermal hydration profiles can also be used to evaluate the effects of compositions, proportions, and time of addition of materials as well as curing temperature. Special care must be used in evaluating extended retardation with paste specimens, which have been shown to overestimate the retardation of some mixtures containing cement, SCM, and admixtures.

5.2 This procedure can be used to measure the effect of chemical admixtures on the cement hydration profile. In many cases, the addition of chemical admixture changes the kinetics of cement hydration.

5.3 Although this technique has been used historically to understand issues related to setting and slump loss, it must be emphasized that isothermal calorimetry results cannot predict concrete performance definitely, either positively or negatively. Extensive verification in concrete at planned dosages and temperatures, and at higher dosages, is needed. Isothermal calorimetry is an effective tool to identify sensitivities, so that concrete testing can be efficiently planned and performed.

5.4 This practice provides a means of assessing the relative hydration performance of various test mixtures compared with control mixtures that are prepared in a similar manner.

5.5 The procedure and apparatus can be used to monitor the thermal power from pastes and mortars alone or in combination with chemical admixtures.

5.6 The isothermal calorimeter described here can be used to measure the thermal power and heat of hydration of mortars prepared independently or obtained by wet sieving from concrete in accordance with Practice C 172.

6. Apparatus

6.1 Devices for mixing to produce a homogeneous mixture of cement, SCM, admixtures, water and optional other fine materials or aggregate and devices for charging the mixture into the specimen vial.

6.1.1 *Weights and Weighing Devices* shall conform to the requirements of Specification C 1005.

6.1.2 *Graduated Cylinders* shall conform to the requirements of Specification C 1005. The permissible variation for graduated cylinders of less than 100-mL capacity shall be ±1.0 % of the rated capacity.

6.1.3 *Graduated Syringes* of suitable capacities to contain the desired volume of liquid admixture or stock solution at 20 °C. The permissible variation of the measured volume shall not exceed 3 % of the volume to be delivered. When admixture quantities required are less than 2 mL, or are viscous in nature, optionally prepare stock solutions at appropriate dilution, to avoid problems with small volumes measured volumetrically.

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Care shall be taken to inspect stock solutions for separation and any admixture that is prone to separation in stock solution must be added in an alternative fashion, such as by analytical syringes.

6.1.4 *Mixing Apparatus*:

6.1.4.1 *Mortar Preparation*—The mixer shall comply with Practice C 305.

6.1.4.2 *Paste Preparation*—A high shear blender,[5] or similar variable speed blender capable of maintaining a no-load speed of at least 15 000 r/min, with optional cooling device. A handheld household mixer capable of mixing paste at not less than 400 r/min or other mixers for paste or mortar preparation are also permitted.

6.1.4.3 The repeatability of results for any mixing method must be measured and reported as described in 12.5.

6.1.5 *Vials* that can be sealed and fit into the specimen vial holders of the calorimeter.

6.1.6 *Pipette, Funnel or Syringe* to facilitate charging the sample to the vials. The neck of the device must be large enough to avoid sample segregation.

6.2 *Calorimeter and Data Acquisition System* of suitable capacity and calibrated to monitor the thermal power of mortar or paste in a repeatable fashion. The actual design of an individual instrument, whether commercial or custom-built, may vary, but it shall meet the following criteria, and shall be verified to do so on a yearly basis or at any time that equipment is modified.

6.2.1 The standard deviation in thermal power for six replicate specimens sampled from *one mixture* of a portland cement paste without chemical admixture at w/c 0.45 tested at 23 ± 4.0 °C shall be no greater than 0.5 mW/g of dry material measured at the maximum of the main hydration peak (See Fig. 1 for identification of the main hydration peak). For calorimeters which do not allow external mixing, prepare six replicate mixtures.

6.2.2 The baseline measured with an inert specimen of similar thermal properties (mainly heat capacity) as the test specimen shall exhibit a low random noise level and be stable against drift. The baseline measured at 23 ± 4 °C during a time period of 24 h shall have a long-term drift of less than 0.5 mW per day per gram of inert material used and a baseline random noise level of less than 0.2 mW per gram of inert material used. In practice, the baseline is measured for 24 h or longer and a straight line is fitted to the data using a linear least squares procedure. The long-term drift is the slope of the line and the baseline random noise level is the standard deviation of the data about the best-fit line.

6.2.3 The vials shall be vapor tight so that endothermic heat of evaporation does not significantly influence the measurements. This shall be verified with a 24 h measurement with water instead of the mortar or paste specimen. The difference between the measured thermal powers of an empty vial and one containing water shall be less than 0.2 mW per gram of water when calculated according to the procedure in 13.1.

[5] Mixing devices described in API Specification RP 10B-2/ ISO 10426-2 have been found suitable for this purpose.

6.2.4 The data acquisition equipment shall be capable of performing continuous logging of the calorimeter output with a time interval between the measurements that is no larger than 60 s.

7. Materials

7.1 *Sand*:

7.1.1 Unless specified otherwise, use standard graded sand as defined in Specification C 778 for preparing mortar samples.

7.1.2 When specified, use job-specific sand when performing a specific mortar test series that is related to field application.

7.2 *Water*:

7.2.1 Unless specified, use potable water as defined in Specification C 1602/C 1602M.

7.2.2 When specified, use job-specific water when performing a specific test series that is related to field application. Follow Specification C 1602/C 1602M in reporting the type of water used.

7.3 *Sulfate Source*:

7.3.1 Unless specified otherwise, use reagent grade calcium sulfate dihydrate or hemihydrate prepared from reagent grade calcium sulfate dihydrate to verify whether a mixture is in sulfate balance. See Appendix for examples.

7.3.2 When specified, use a source-specific calcium sulfate for performing a specific test series that is related to field application.

8. Temperature and Humidity

8.1 *Sample Preparation Temperature*—Unless specified otherwise, maintain the temperature of the air in the vicinity of all equipment and materials used in accordance with the requirements for cement mixing rooms in Specification C 511.

8.1.1 When specified, different temperature conditions are permitted for research purposes or to simulate field conditions.

8.1.2 To reduce the time to reach thermal equilibrium, it is permitted to cool the mixture during mixing. It is also permitted to adjust the temperature of the mix water or the starting materials, or both, in order to obtain a temperature of the prepared mixture close the temperature of the calorimeter. This is especially needed when using high shear mixing.

8.2 *Isothermal Calorimeter Test Temperature*—The temperature of the isothermal calorimeter shall be set at 23.0 ± 4.0 °C and allowed sufficient time to stabilize at that temperature.

8.2.1 When specified, a different calorimeter test temperature is permitted for research purposes or to simulate field conditions. Take precaution to prevent condensation of moisture inside the calorimeter if the calorimeter test temperature is set below the temperature of the laboratory.

NOTE 2—Condensation inside the calorimeter cells can be prevented by controlling the humidity inside the calorimeter, or by controlling the humidity or temperature of the testing environment that is in direct contact with the calorimeter. Condensation will not occur inside the calorimeter cells if the temperature of the testing environment is at or below the temperature of the thermostat.

9. Test Specimens

9.1 The number of specimens and number of test batches depend on the purpose of the test program. Replicate testing of

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specimens sampled from a single prepared batch shall be done initially to establish acceptable repeatability of the apparatus as defined in 6.2. Replicate testing of separately-prepared specimens is also required in 12.5 to establish the repeatability of results for each mixing method. The number of replicates for routine testing is addressed in 12.2.1.

NOTE 3—See the Appendix for examples of different test programs.

9.2 The specimen size placed in the calorimeter depends on the instrument used as well as the type of mixture (paste or mortar).

NOTE 4—Typical specimen sizes for paste and mortar are 5 to 10 g and 50 to 100 g, respectively. A smaller specimen will reduce the time to reach isothermal conditions if the initial specimen temperature differs from the calorimeter test temperature.

10. Composition of Paste or Mortar Mixtures

10.1 Mixture proportions depend on the purpose of the test program (See Note 4).

10.2 Record mixture proportions for each mixture that is tested, including complete description of mixing method, order and timing of admixture addition.

11. Preparation of Apparatus

11.1 *Determination of Baseline*—Baselines are determined during calibrations or before each measurement, preferably when the calorimeter contains inert specimens, as this reduces the noise. If baselines are stable over time as defined in 6.2.3, they need only be determined at calibrations. If they are not stable, they shall be determined before each measurement.

11.2 *Calibration*—Calibration shall be made according to manufacturer's recommendations at regular intervals of one year or less to determine the calibration coefficient. If the calibration coefficient differs more than 5 % from one calibration to the next, calibration intervals shall be reduced to 90 days. The length of the time intervals between calibrations depends on the instrument and the personnel. For the purpose of this practice, the calibration coefficient can be assumed to be constant independent of the level of the signal.

12. Procedure

12.1 *Mixing*:

12.1.1 Various mixing methods that have been found useful are described in the Appendix. Because mixing intensity is a variable that may influence the interaction of materials used to prepare cementitious mixtures, in many cases different mixing procedures (speeds or durations) may be needed, depending on the goal of the testing. Unless mixing intensity is a defined variable in a testing program, mixtures prepared under different mixing conditions shall not be compared. External mixing may result in a temperature increase in the sample that may lead to temporary non-isothermal conditions after loading the specimen into the calorimeter. The thermal equilibrium time shall be estimated in accordance with 12.4. The results obtained at hydration times shorter than the equilibrium time are less repeatable and shall only be used if the measured effects are larger than the variation found when estimating the thermal equilibrium time (See Note 5).

NOTE 5—The isothermal calorimeter will bring the temperatures of specimens into thermal equilibrium, but the time required to do so depends on the instrument parameters, specimen size, mixing method, and materials used. Differences in initial thermal power caused by differences in initial temperature can optionally be minimized by keeping all materials at equal temperature, including any water used in cleaning mixing equipment. If needed, the temperatures of the starting materials may be adjusted to compensate for temperature changes during mixing, so that the temperature after mixing is as close as possible to the calorimeter set point.

12.2 *Loading Specimen into Calorimeter*:

12.2.1 Two specimens shall be prepared from one batch, unless the standard deviation of the time to reach the maximum of the main hydration peak for six replicate *separately-prepared* specimens has previously been determined according to 12.5.1 to be less than 60 min, in which case one specimen is adequate (See Note 6).

NOTE 6—A sub-sample of the prepared mixture is used in this method, and it is necessary to obtain a representative sample. Normally, replicate measurements are made initially as specified in 12.5 in order to establish the error associated with variability in specimen composition, preparation, and sampling.

12.2.2 Wear insulating gloves or use tweezers to minimize warming of the vial and specimen by heat from hands.

12.2.3 Weigh and record the empty mass of the vial to be used, or tare the scale to zero with the empty vial on the scale.

12.2.4 Place a representative sample of fresh paste or mortar into the specimen vial resting on the scale. Typically a plastic disposable pipette is used for paste, with the opening cut to size to match the stiffness of the paste, or a spoon is used for mortar. Make sure that masses of all specimens that will be compared with each other do not differ by more than 20 %. Clean and dry the outside of the vials as needed.

12.2.5 Weigh and record the specimen mass to the nearest 0.1 g and seal the vial in order to be vapor tight.

12.2.6 Immediately place the vial into the calorimeter ensuring consistency between the specimens ages at the time specimens are placed in the calorimeter. Typical loading times are 1 to 2 min after the end of the mixing cycle, which for a 4-min cycle yields 5 to 6 min after the cementitious material is added to the water. Record the time the vial was introduced into the calorimeter.

12.3 *Measurement of Thermal Power*:

12.3.1 Start thermal power measurement immediately after specimen has been placed in calorimeter. In the case of internal mixing, start thermal power measurement before initial contact between the cementitious materials and the mixing water.

12.3.2 Measure the thermal power approximately every 60 s until at least two hours after the maximum of the main hydration peak (See Fig. 1). The testing duration and data sampling frequency are permitted to be modified according to the nature of the test program and the rate of change in thermal power.

NOTE 7—Paste studies are generally more repeatable than mortar, because less paste is needed to ensure known and uniform binder content in the specimen. However, certain mixtures may be sensitive to the mixing action. Paste mixtures with water reducing or retarding admixtures generally have longer retardation than the corresponding mortar mixtures. Especially when testing for the effect of admixtures with a retarding component, it is recommended to verify any results obtained in paste by testing in mortar. The larger the specimen, the longer it takes for heat

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transfer from specimen to calorimeter sensor. Also, the larger the specimen, the larger will be the temperature rise within the specimen, and the longer will be the time required to reach thermal equilibrium. Mortar studies are, on the other hand, more concrete-like and allow for parallel testing of other properties such as flow, stiffening, strength, and air content.

12.4 *Determination of Thermal Equilibrium Time*:

12.4.1 The thermal equilibrium time shall be determined for a given instrument and type of specimens (defined by specimen mass, initial temperature and type (paste or mortar) by preparing and testing a at least six replicate batches and measuring the elapsed hydration time when the range of the thermal power of replicate specimens falls to 0.2 mW/g of dry material (See Fig. 3).

12.5 *Determination of Repeatability of Results*:

12.5.1 The repeatability of the results of any mixing method must be determined by preparing and testing at least six replicate batches of a paste mixture that has a thermal indicator of setting time that is equal to or exceeds that of the most retarded mixture in the planned test program. The repeatability shall be recorded as the standard deviation of the time to reach the maximum of the main hydration peak (See Fig. 4). The repeatability must be measured annually or when the operator or mixing method has changed.

NOTE 8—It is convenient to develop a chart of repeatability versus time to reach the maximum of the main hydration peak for a particular mixing method used. This allows for estimation of repeatability for any given level of retardation in a particular experiment.

13. Calculation of Results

13.1 *Post-Processing of Data*—The aim of the evaluation is to monitor differences in the evolution of thermal power for different mixtures during the test period, typically 24 or 48 h. The data evaluation method consists of the following steps:

13.1.1 Remove the baseline:

$$V(t) = V_{raw}(t) - V_{bl} \quad (1)$$

where:

V_{raw} = signal from the calorimeter, and
V_{bl} = measured baseline signal of the calorimeter.

13.1.2 Apply the calibration coefficient (ε) and divide by the mass of cementitious materials (m_c) in the specimen to obtain the normalized thermal power P per unit mass of cementitious material (W/g) as a function of time:

$$P(t) = \frac{\varepsilon \cdot V(t)}{m_c} \quad (2)$$

13.1.3 Plot the normalized thermal power as a function of time. For example, see Fig. 1.

NOTE 9—The accumulated energy for a given mixture may serve as an indicator of potential strength development as a function of time. The accumulated energy, normalized to a unit mass of total cementitious materials (J/g), is obtained by integrating the area under the power curve.

14. Evaluation of Test Results

14.1 Calorimetry results are typically evaluated graphically by comparing differences in response from tests of different mixtures.

NOTE 10—The evaluation of calorimetry results depends on the nature of the test program. See examples in the Appendix.

14.2 If presenting results that include the initial, non-isothermal test period, present the data as two separate plots:

14.2.1 The first plot displays the initial thermal power, typically from 0 to 30 min or 0 to 60 min and, if external mixing was used, includes a statement that results were obtained while not at thermal equilibrium. Care must be taken in interpretation of these initial results.

14.2.2 The second plot displays the thermal power starting at the time of thermal equilibrium until the completion of the test.

15. Report

15.1 Report the following information:

15.1.1 Type of instrument used.

15.1.2 Date of last calibration.

15.1.3 Source and identity of all materials tested, method of conditioning them to test temperature, and temperature prior to mixing.

15.1.3.1 The specific type of sulfate source shall be included as part of the description of a sulfate addition, as well as its precise method and timing of addition. If plaster is used, evidence shall be supplied of its hydration state prior to testing.

15.1.4 Mixture proportions.

15.1.5 Temperature, date, starting time, and duration of test.

15.1.6 Mixing method and duration, including sequences and timing of mixing and scraping down, volume of container and speed of mixer.

15.1.7 Thermal equilibrium time determined for the type of mixture tested as determined in 12.4.

15.1.8 Standard deviation of time to reach maximum on the main hydration peak as determined in 12.5.

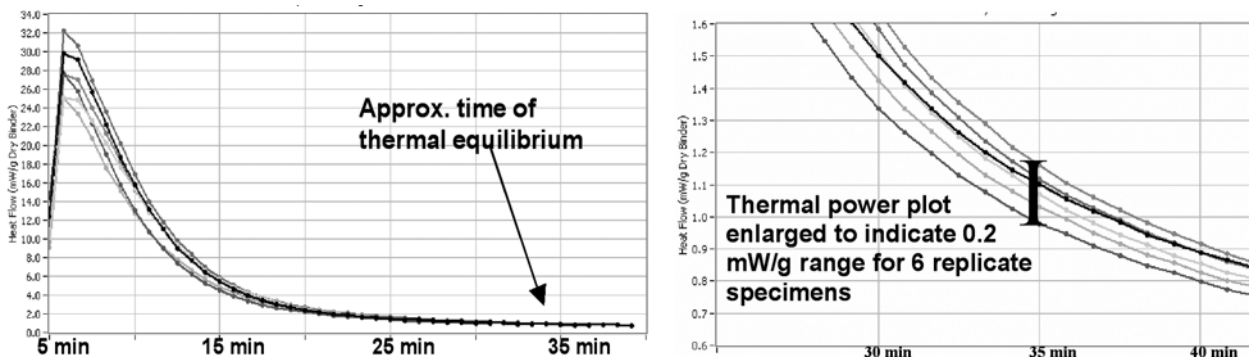

FIG. 3 Illustration of Estimated Time to Reach Thermal Equilibrium Using Six Replicate Specimens

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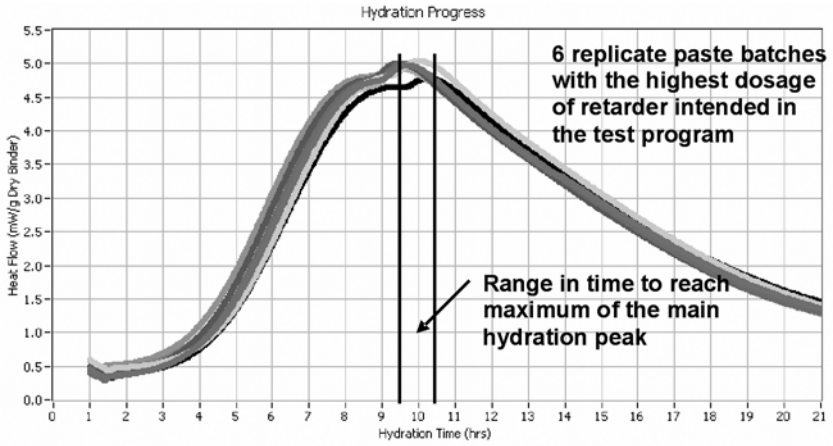

NOTE—The range of results from which the standard deviation is calculated is shown.

FIG. 4 Procedure for Measuring Repeatability of a Mixing Procedure Using Replicate Batches of a Paste Mixture with Longest Setting Time in the Test Program

15.1.9 Admixture addition sequence, if applicable, and method of addition of admixture including description of any stock solutions used.

15.1.10 Any unusual observations, such as early stiffening during sample preparation.

15.1.11 If thermal indicators of relative setting time are used, method of calculating relative setting time if different from default method.

15.1.12 Plots of thermal power per unit mass of cementitious materials. See Appendix for examples. It is important to adapt the graphs to address each technical point on separate graphs. Plotting many together may cause confusion even among the experienced users of this technique.

15.1.13 Statement that the test was carried out in accordance with this practice and notes of all deviations from the described procedure.

16. Keywords

16.1 cement-admixture interactions; hydration kinetics; hydration performance; isothermal calorimetry; sulfate depletion

APPENDIXES

(Nonmandatory Information)

X1. DEFINITIONS OF TERMS USED IN APPENDIX

X1.1 *delay time, n*—period between initial contact of mix water and cementitious materials and when an admixture is added to the mixture.

X1.2 *delayed addition of admixture, n*—addition of admixture to the mixture when the delay time exceeds 10 s after the initial contact between mix water and cementitious materials.

X1.3 *heat of hydration, n*—total energy released at a given hydration time measured in joules per unit mass of cementitious material (J/g); the time integral of normalized thermal power.

X1.4 *tail end addition of admixture, n*—addition of admixture to the mixture within 2 to 10 s after the initial contact between mix water and cementitious materials.

Discussion—The exact addition time should be defined as needed in the test program; see examples.

X1.5 *upfront addition of admixture, n*—addition of admixture to mix water prior to mixing with cementitious materials.

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X2. TYPICAL USES, EXPERIMENTAL DESIGNS AND EVALUATION

X2.1 *General*:

X2.1.1 Experimental designs are typically devised to study the effect of supplementary cementitious materials or admixture type, dosage and addition mode on the hydration kinetics of cementitious systems. Other parameters such as source of water, fine particles, mixing method, or curing temperature can be studied as well. The water content should be sufficient to produce a homogeneous mixture without excess bleeding. Tests of separate mixtures with additional source of soluble sulfate, corresponding to 0.5 % SO_3 by mass of portland cement or other amounts, added before testing, are typically performed to evaluate if additional sulfate would improve the hydration performance of mixtures with high SCM or admixture dosage. Several example experimental designs are shown in this appendix. It should be noted that each example represents a specific set of materials for the purpose of showing experimental designs. The example results cannot be extrapolated to other sets of materials.

Use of different SCMs or admixtures, or both, may result in mixtures with different workability. This can affect the amount of shear imparted to the cementitious particle by the mixing action, which may affect hydration kinetics. In cases where problems are found, it may be useful to alter the water-cementitious materials (*w/cm*) ratio in order to investigate its effect on the results.

X2.1.2 Admixture type, dosages, and addition modes can be selected based on local market conditions, experience, dosing equipment, or recommendations from the supplier. The dosage of admixtures may vary with weather conditions.

X2.1.3 It is strongly recommended to test for the effect of an admixture overdose. Mixtures that are sensitive to minor overdoses are likely to show abnormal performance in the field, given the inherent variability of typical concrete materials and production operations.

X2.1.4 It is also recommended to test for the effects of temperature change. Hot weather typically causes faster loss of workability and therefore higher dosages of water-reducing or set-retarding admixtures are often used. The combination of higher admixture dosage and higher temperature can cause abnormal performance in the field. Similarly, cold temperatures, especially with lower C_3A cements may result in extended setting time, especially when higher admixture dosages appropriate for warm weather are maintained during cold conditions.

X3. SULFATE BALANCE

X3.1 See Fig. 1 of this practice for an example of the portion of the thermal power output associated with aluminate reaction after sulfate depletion, point E, which is the small peak labeled F. This point is of concern as there is a correlation between this peak occurring before the completion of the main hydration peak, and problems with premature or severely delayed setting and slump loss of combined mixtures. In many cases, cements that have enough sulfate for proper control of their own hydration cannot supply enough sulfate when combined with various amounts of other materials, so it becomes of importance to understand the effect of the added materials on the location of the sulfate depletion point.

X3.2 The sulfate depletion point is indicated as the onset of either a sharp or shallow hump on the main hydration peak of the thermal power curve. The sulfate depletion point will move later in time relative to the maximum of the main hydration peak (point D in Fig. 1) and diminish in size when additional source of soluble sulfate is added to the system. This peak seen after the sulfate depletion point may be shallow and difficult to distinguish from the rest of the main hydration peak for some portland cements and in many combined mixtures containing SCM or admixture, or both. The peak typically is more visible with very active aluminate cement such as a high C_3A Type I, and decreases in sharpness as the C_3A content decreases, making it difficult to identify on many Type V cements. In such cases, performing additional tests with various sulfate addition levels may clarify the timing of the sulfate depletion point, (See Fig. 2 of this practice), but there are cases where no depletion point and subsequent peak can be resolved.

X3.3 The nature and position of the sulfate depletion point in most combined mixtures can be verified by monitoring the effect of incremental addition(s) of reagent grade calcium sulfate dihydrate (gypsum), Terra Alba gypsum or calcium sulfate hemihydrate (plaster) to the mixture, as shown in Fig. X3.1. Because few cements have enough sulfate to avoid any signs of sulfate depletion until after 24 h, a point of depletion is typically observed in the hydration profile. However, if the depletion occurs near the maximum of the main hydration peak it may not be discernible, and it is frequently found as merely a slight asymmetry of the peak and shown in curve #3 of Fig. X3.1. Addition of one or sometimes two levels of additional sulfate will cause the depletion point to move to later times, and therefore show up clearly as seen in curve #4 of Fig. X3.1.

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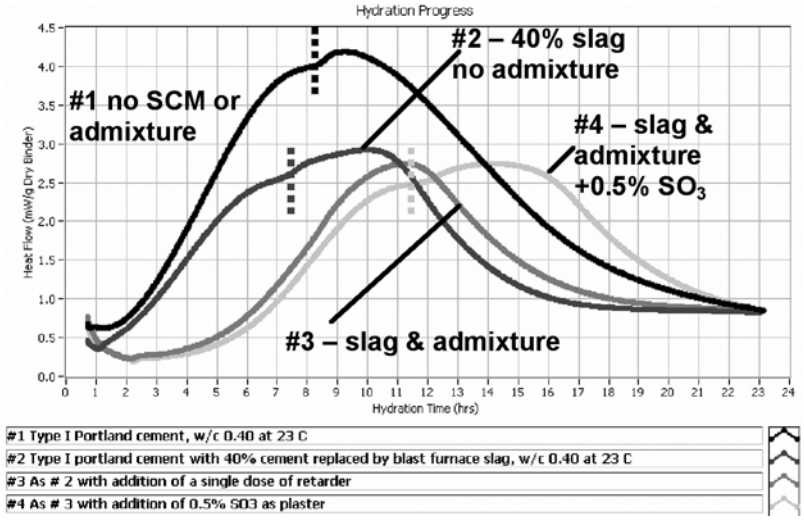

FIG. X3.1 Effect of SCM, Admixture and Sulfate Addition on the Sulfate Depletion Points, as Indicated by Vertical Dotted Lines

X4. MIXING METHODS

X4.1 Mixing intensity may significantly affect the results of isothermal calorimetry. Consistency in mixing method is vital for results to be compared, but as numerous techniques have proven useful, no one method is specified in this practice. Mixing may be either internal in the specimen vial, either by simple absorption of water or by mechanical means.

X4.2 Internal mixing has the advantage of allowing capture of the whole thermal power diagram, but the disadvantage of not being able to achieve shear rates approaching that in concrete. Delayed addition of admixture can be difficult or impossible depending on calorimeter design. Care must be taken that the full sample of paste is wetted equally; a means to verify this is to remove the hardened sample from the sample vial and crush it to see equal color. If significant variation in paste color is seen it should be so noted in the report.

X4.3 External mixing may be used for paste, mortar, or concrete. Depending on calorimeter design, concrete samples may be tested as concrete or as mortar separated according to the method in Practice C 172. Several methods that have been used successfully are outlined below.

X4.4 *Preparation of Paste Using a Hand-Held Kitchen Mixer or Similar Mixer*:

X4.4.1 Add cementitious materials into the mixing container. Add water including any dissolved admixtures, and immediately start the timer. Increase the speed of rotation of the mixing blades to 200 ± 100 r/min while avoiding splashing. Record the time of initial contact between cementitious materials and water.

X4.4.2 Mix at 200 ± 100 r/min to the 1 min 30 s mark.

X4.4.3 Stop mixing and for 30 s scrape corners of container to ensure all dry materials are mixed in, and scrape down any paste that may have collected on the sides of the container.

X4.4.4 Start the mixer at 500 ± 100 r/min and continue to mix at this speed for 2 min to the 4 min mark.

X4.4.5 Add admixtures at any time appropriate to the test program. Typical delay times are 10 s for tail end addition or 45 s for delayed addition. Unless specified otherwise, mix at 500 ± 100 r/min for at least 60 s after all admixtures have been added.

X4.5 *Preparation of Paste Using a High Speed Blender*:

X4.5.1 Add water and any admixture to be added upfront into the mixing jar. Increase the mixing speed over 10 s to 2000 ± 200 r/min while minimizing splashing. Add dry materials, and immediately start the timer. Record the time of initial contact between cementitious materials and water.

X4.5.2 Add admixtures at any time appropriate to the test program.

X4.5.3 Mix at 4000 ± 400 r/min for 10 s.

X4.5.4 Increase mixer speed to 13 000 ± 1000 r/min within 10 s and continue to mix at this speed to the 40 s mark.

X4.5.5 At the 40 s mark, decrease mixer speed to 2000 ± 200 r/min and continue to mix at this speed for 50 s (to the 1 min 30 s mark).

X4.5.6 Stop mixing and let the mixture rest for 60 s (to the 2 min 30 s mark).

X4.5.7 Start the mixer at 2000 ± 200 r/min and increase the mixer speed to 13 000 ± 1000 r/min within 10 s and continue to mix at this speed to the 4 min mark.

X4.5.8 Mix at 13 000 ± 200 r/min for at least 30 s after all admixtures have been added.

X4.6 *Preparation of Mortar (modified Practice C 305 procedure)*:

X4.6.1 Place the water and any admixtures to be added upfront into the mixing container.

X4.6.2 Add cementitious materials; then start the mixer and mix at the slow speed (140 ± 5 r/min), and immediately start the timer. Record the time of initial contact between cementitious materials and water. Mix for 30 s.

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X4.6.3 Add the entire quantity of sand slowly over a 30-s period, while mixing at slow speed.

X4.6.4 Stop the mixer, change to medium speed (285 ± 10 r/min) and mix for 30 s.

X4.6.5 Stop the mixer and let the mortar stand for 1½ min. During the first 15 s of this interval, quickly scrape down into the batch any mortar that may have collected on the side of the bowl; then for the remainder of this interval, cover the bowl with the lid.

X4.6.6 Mix for 1 min at medium speed (285 ± 10 r/min).

X4.6.7 In any case requiring a remixing interval, any mortar adhering to the side of the bowl shall be quickly scraped down into the batch before remixing.

X4.6.8 Add admixtures at the appropriate time according to the test program.

X4.6.9 Mix for at least 30 s at medium speed (285 ± 10 r/min) after all admixtures have been added.

X4.7 *Obtaining Sample of Mortar from Concrete*:

X4.7.1 Mortar test samples may be obtained from concrete following the wet-sieving procedure in Practice C 172.

X5. GRAPHICAL EVALUATION OF RESULTS

X5.1 Prepare comparative graphs including a reference mixture and other mixtures of significance, in order to evaluate hydration characteristics such as:

X5.1.1 Retardation of the main hydration as a function of admixture type and dosage. Thermal indicators of setting time may be taken as the time to reach 50 % of the average maximum power of the main hydration peaks (See example in Fig. X5.1).

X5.1.2 Relation between the time of maximum of the main hydration peak and the time of sulfate depletion. This relationship may be used as an indicator for the overall sulfate balance of each combined mixture according to Lerch.[6] Note if there is any effect of adding extra SO_3 to the combined mixture before testing.

X5.1.3 Acceleration of early aluminate hydration as a function of admixture type and dosage.

[6] Lerch, W., "The Influence of Gypsum on the Hydration and Properties of Portland Cement Pastes," *Proceedings, Vol 46, of the American Society for Testing and Materials* , 1946, pp. 1252-1292.

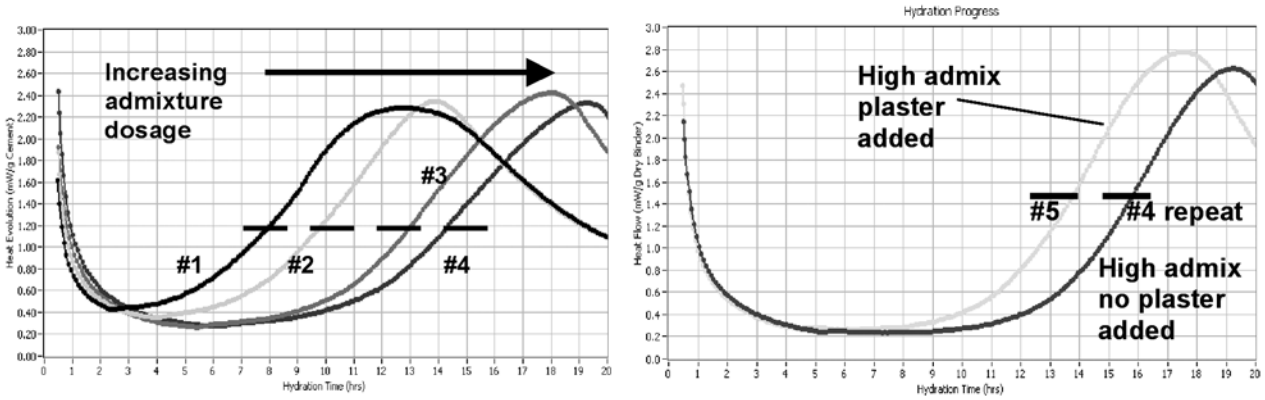

FIG. X5.1 (a) Effect of Admixture Dosage on the Thermal Indicator of Setting Time for This Given Set of Materials; (b) Effect of SO_3 Addition (as Plaster) for This Given Set of Materials

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X6. EXAMPLES

X6.1 *Study of Effect of Admixture Dosage and SCM Content on Thermal Indicator of Setting Time at Constant Temperature*:

X6.1.1 Different admixtures and SCM can have a strong effect on the setting time of a cementitious mixture. The relative effect of such changes on thermal indicators of setting time can be investigated by testing a series of mixtures. Table X6.1 shows an example of an experimental design for paste mixtures with a *w/c* of 0.40, Class C fly ash (CFA), and a water-reducing admixture. The sulfate addition test (Mixtures #5 and #8) is important for evaluation of whether a selected set of materials and dosages appears to be in sulfate balance.

X6.1.2 *Evaluation of Setting Time Study*—The thermal indicator of setting time is typically taken as the time to reach one-half the average maximum power of the main hydration peaks. Fig. X5.1(a) shows the response for mixtures 1 through 4 tested at room temperature. Fig. X5.1(b) shows the effect of SO_3 addition (as plaster) for mixture #5 with high admixture dosage. The thermal indicator of setting time is a relative value and can be correlated with a physical setting time method such as Test Method C 403/C 403M for a given mixture.

X6.1.3 *Indications*:

X6.1.3.1 The aluminate reaction peak after the sulfate depletion point appears to overlap the main hydration peak, indicating a mixture that is potentially sensitive to high admixture dosages.

X6.1.3.2 Increased admixture dosages retard the onset of the main hydration peak used to evaluate thermal indicators of setting time.

X6.1.3.3 The plaster addition (mixture #5) accelerated the onset of the hydration peak and also enlarged the height of the peak, indicating that the mixture with the high admixture dose is close to being out of sulfate balance. Note that the addition of sulfate showing in Fig. X5.1(b) did not result in a clear sulfate depletion point.

X6.1.4 Fig. X6.1(a) shows the effect of varying CFA dosage at typical dosage of admixture. Fig. X6.1(b) shows the effect of SO_3 addition (as plaster) to the mixture with high fly ash dosage.

X6.1.5 *Indications*:

X6.1.5.1 The CFA content had a strong effect on the hydration kinetics.

TABLE X6.1 Example of 8-Mixture Calorimetry Test Design

Mixture #	Dosages		Remarks
	SCM-FA	Admixture	
1	20 % CFA	None	Reference
2	20 % CFA	Low	Admixture dosage window of interest,
3	20 % CFA	Typical	(water reducing admixture WRA)
4	20 % C	High	
5	20 % C	High	0.5 % SO_3 added to cement before test
6	10 % C	Typical	Fly ash dosage window of interest
7	30 % C	Typical	
8	30 % C	Typical	0.5 % SO_3 added to cement before test

X6.1.5.2 Mixture # 7 with high amount of CFA displayed abnormal hydration with a strong premature exotherm indicated by the abnormally steep rise in thermal power at 6 to 7 h and no main hydration within 23 h. The abnormal peak may not be used for estimation of the thermal indicator of setting time. Mixture # 7 could stiffen and possibly flash set because of the abnormal exotherm at 6 to 7 h, but would not develop normal strength within 23 h.

X6.1.5.3 The plaster addition test confirmed that the premature exotherm at high dosage of CFA was caused by insufficient amount of available sulfate to control the aluminate hydration (probably as a result of aluminate in the CFA consuming some of the soluble sulfate from the cement).

X6.2 *Study of Effect of Curing Temperature on Hydration Kinetics*:

X6.2.1 Calorimetry is well suited for monitoring the effect of temperature on hydration kinetics. An example is shown in Fig. X6.2 for a portland cement mixture, with *w/c* = 0.45, with and without a water-reducing admixture, and tested at three different temperatures. One mortar mixture was prepared and tested in parallel at three different temperatures. Table X6.2 shows the experiment design.

X6.2.2 *Evaluation of Curing Temperature Study*—Fig. X6.2(a) shows the hydration kinetics for all mixtures in Table X6.2. Fig. X6.2(b) shows the effect of curing temperature on the increase in the thermal indicator of setting time caused by the admixture.

X6.2.3 *Indications*:

X6.2.3.1 The retarding effect of temperature on cement hydration was readily visible by isothermal calorimetry.

X6.2.3.2 The location of the sulfate depletion point, in relation to the main hydration peak, is affected by temperature with or without the admixture present.

X6.2.3.3 The retardation time caused by an admixture is often temperature dependent, as illustrated in this example.

X6.3 *Study of Effect of Admixture Dosage and Sequence of Addition on Setting Time*:

X6.3.1 The sequence of admixture addition can have a strong effect on setting times and early strength. The relative effect of changing the addition sequence can be investigated by a series of mixtures, preferably including a reference mixture with known setting times. Table X6.3 shows an example of an experimental design for mixtures with two different admixtures tested at two fly ash contents. The plaster addition test is important to evaluate whether a mixture appears to be in sulfate balance. In addition, temperature sensitivity can be assessed by testing each mixture at more than one temperature.

X6.3.2 *Evaluation of Admixture Addition Sequence Sensitivity Study*—Fig. X6.3(a) shows the response for mixtures with typical (20 %) CFA dosage and two admixtures at typical

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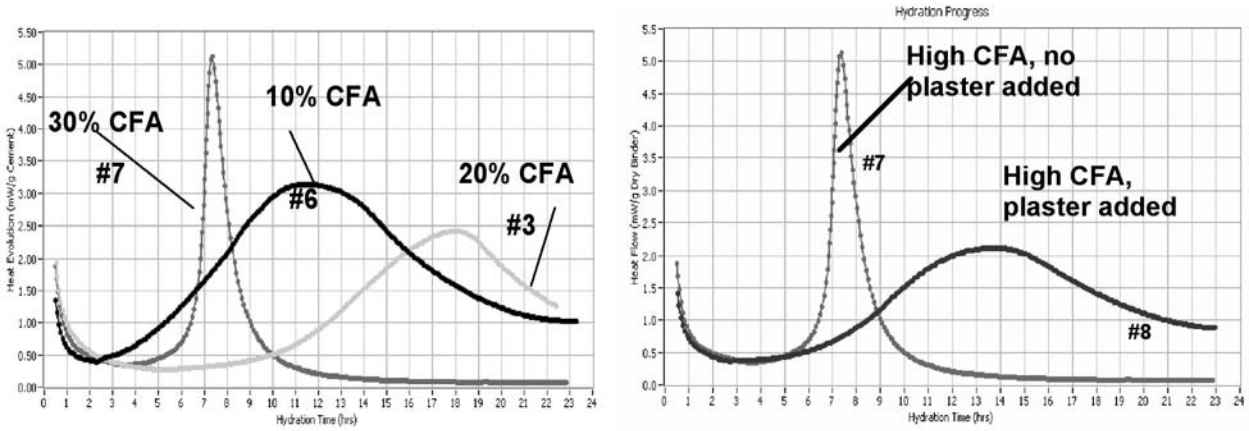

FIG. X6.1 (a) Effect of Fly Ash Dosage on Hydration Kinetics; (b) Effect of SO_3 Addition (as Plaster)

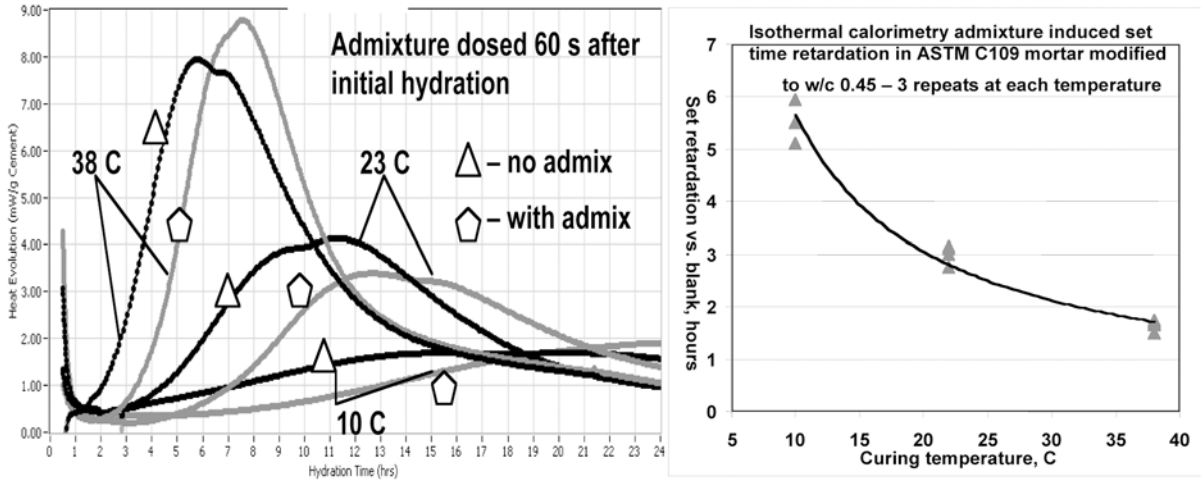

FIG. X6.2 (a) Effect of Temperature on the Hydration Kinetics; (b) Effect of Temperature on Retardation of Setting Time

TABLE X6.2 Example of Calorimetry Test Design

Mixture	Admixture	Temperature
1	No	38 °C (100 °F)
2	Yes	38 °C (100 °F)
3	No	23 °C (73 °F)
4	Yes	23 °C (73 °F)
5	No	10 °C (50 °F)
6	Yes	10 °C (50 °F)

dosages but different dosing sequence, tested at room temperature. Fig. X6.3(b) shows the effect of SO_3 addition (as plaster) to the mixture with both admixtures dosed "tail end" (10 s delayed addition).

X6.3.3 *Indications*:

X6.3.3.1 Tail end addition of both admixtures extended the thermal indicator of setting time approximately 90 min compared with mixtures with same admixture dosages but either admixture or both added upfront.

X6.3.3.2 The plaster addition (mixture #6) accelerated the onset of the hydration peak and also enlarged the height and width of the peak, indicating that the mixture with the tail addition of both admixtures is not in sulfate balance.

X6.3.4 Fig. X6.4(a) shows the effect of overdosing admixture A or B, both added upfront. Fig. X6.4(b) shows the effect of plaster addition (0.5 % SO_3) to the cement prior to testing (#13 and #14).

X6.3.5 *Indications*:

X6.3.5.1 An overdose of admixture A caused abnormal exotherms indicated by the abnormally steep rise in thermal power at 50 % and 100 % overdose (#9 and #10), with no subsequent silicate hydration. Note flatline out to 22 hours.

X6.3.5.2 No abnormal hydration was seen when overdosing admixture B (#11 and #12).

X6.3.5.3 The plaster addition test (#13 and #14) confirmed that the premature exotherms at high dosages of admixture A were caused by uncontrolled aluminate hydration. Note that silicate hydration, although still severely delayed, is seen to start within the 22 hour test period.

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TABLE X6.3 Example of Experimental Design for Screening Sensitivity to Admixture Dosage and Addition Sequence

Mixture No.	CFA Dosage	Admixture Dosages and Addition Sequence		Remarks
		A-WR	B-HRWR	
1	20 %	None	None	Reference
2	20 %	Typical upfront	Typical upfront	Actual mixture design
3	20 %	Typical tail end	Typical upfront	Effect of admixture addition sequence. Admixture typical dosages as in typical field application.
4	20 %	Typical upfront	Typical tail end	
5	20 %	Typical tail end	Typical tail end	
6	20 %	Typical upfront	Typical upfront	0.5 % SO_3 added to cement before test
7	10 %	Typical upfront	Typical upfront	Effect of fly ash dose
8	None	Typical upfront	Typical upfront	Effect of fly ash dose
9	20 %	150 % upfront	Typical upfront	Effect of admixture overdose
10	20 %	200 % upfront	Typical upfront	
11	20 %	Typical upfront	150 % upfront	
12	20 %	Typical upfront	200 % upfront	
13	20 %	150 % upfront	Typical upfront	Further tests with plaster addition are recommended for any mixture that displays signs of abnormal hydration kinetics. In this case mixtures 9 and 10 were retested with plaster addition (0.5 % SO_3).
14	20 %	200 % upfront	Typical upfront	

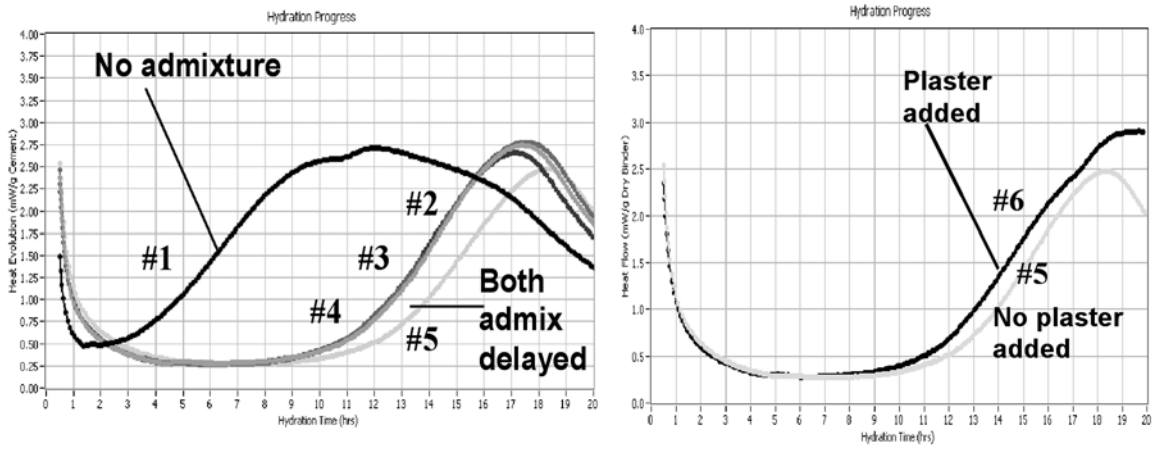

FIG. X6.3 (a) Effect of Admixture Addition Sequence on Cement Hydration Kinetics; (b) Effect of Plaster Addition with Delayed Addition of Both Admixtures

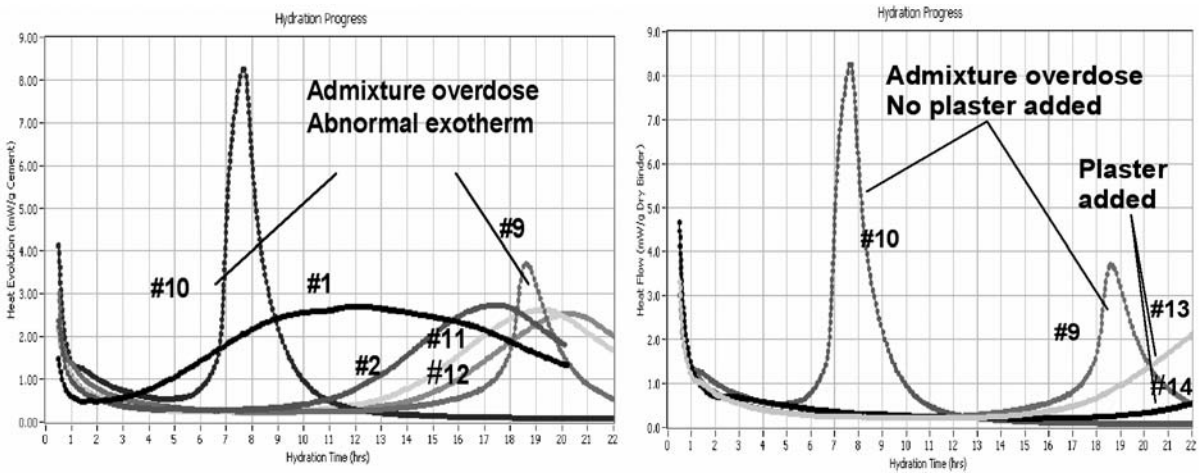

FIG. X6.4 (a) Effect of Different Admixture Dosages on Mixtures with High Fly Ash Dosage; (b) Effect of Plaster Addition to Mixtures with Overdose of Admixture A

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SUMMARY OF CHANGES

Committee C09 has identified the location of selected changes to this practice since the last issue, C 1679 – 07, that may impact the use of this practice. (Approved June 1, 2008)

(*1*) Revised Note 2 to clarify how to avoid condensation inside the calorimeter.
(*2*) Made the making of diluted solutions of the admixtures optional in 6.1.3.
(*3*) Removed explanatory test in 12.1.1and placed it in new Note 5; renumbered subsequent notes

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Designation: C 1688/C 1688M – 08

Standard Test Method for Density and Void Content of Freshly Mixed Pervious Concrete[1]

This standard is issued under the fixed designation C 1688/C 1688M; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope

1.1 This test method covers determining the density of freshly mixed pervious concrete and gives formulas for calculating the void content of pervious concrete.

1.2 The values stated in either SI units or inch-pound units are to be regarded separately as standard. The values stated in each system may not be exact equivalents; therefore, each system shall be used independently of the other. Combining values from the two systems may result in non-conformance with the standard.

1.3 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.* (**Warning**—Fresh hydraulic cementitious mixtures are caustic and may cause chemical burns to skin and tissue upon prolonged exposure.[2])

1.4 The text of this test method references notes and footnotes that provide explanatory information. These notes and footnotes (excluding those in tables) shall not be considered as requirements of this test method.

2. Referenced Documents

2.1 *ASTM Standards:*[3]

C 29/C 29M Test Method for Bulk Density ("Unit Weight") and Voids in Aggregate

C 125 Terminology Relating to Concrete and Concrete Aggregates

C 127 Test Method for Density, Relative Density (Specific Gravity), and Absorption of Coarse Aggregate

C 128 Test Method for Density, Relative Density (Specific Gravity), and Absorption of Fine Aggregate

C 150 Specification for Portland Cement

C 172 Practice for Sampling Freshly Mixed Concrete

C 188 Test Method for Density of Hydraulic Cement

C 192/C 192M Practice for Making and Curing Concrete Test Specimens in the Laboratory

C 231 Test Method for Air Content of Freshly Mixed Concrete by the Pressure Method

C 311 Test Methods for Sampling and Testing Fly Ash or Natural Pozzolans for Use in Portland-Cement Concrete

C 595 Specification for Blended Hydraulic Cements

C 989 Specification for Ground Granulated Blast-Furnace Slag for Use in Concrete and Mortars

C 1157 Performance Specification for Hydraulic Cement

C 1240 Specification for Silica Fume Used in Cementitious Mixtures

D 698 Test Methods for Laboratory Compaction Characteristics of Soil Using Standard Effort (12 400 ft-lbf/ft^3(600 kN-m/m^3))

3. Terminology

3.1 *Definitions*:

3.1.1 For definitions of terms used in this test method, refer to Terminology C 125.

3.2 *Symbols*:

D	=	density (unit weight) of concrete kg/m^3 [lb/ft^3]
M_s	=	total mass of all materials batched, kg [lb] (see Note 1)
M_c	=	mass of the measure filled with concrete, kg [lb]
M_m	=	mass of the measure, kg [lb]
T	=	theoretical density of the concrete computed on an airfree basis, kg/m^3 [lb/ft^3] (see Note 1)
U	=	percentage of voids in the fresh pervious concrete, including entrained and entrapped air voids in the cement paste.
V_s	=	sum of the absolute volumes of the component ingredients in the batch, m^3 [ft^3]
V_m	=	volume of the measure, m^3 [ft^3]

NOTE 1—The theoretical density is a laboratory determination, and is assumed to remain constant for all batches made using identical component ingredients and proportions. It is calculated from the following equation:

$$T = \frac{M_s}{V_s}$$

The total mass of all materials batched is the sum of the masses of the cement, the fine aggregate in the saturated-surface-dry condition, the

[1] This test method is under the jurisdiction of ASTM Committee C09 on Concrete and Concrete Aggregates and is the direct responsibility of Subcommittee C09.49 on Pervious Concrete.

Current edition approved Oct. 1, 2008. Published October 2008.

[2] Section on Safety Precautions, Manual of Aggregate and Concrete Testing, *Annual Book of ASTM Standards*, Vol 04.02.

[3] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

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coarse aggregate in the saturated-surface-dry condition, the mixing water in the batch (includes free water from the aggregate), and any other solid or liquid materials used.

The absolute volume of each ingredient is equal to the quotient of the mass of that ingredient divided by the product of its relative density (specific gravity) times the density of water (See Test Method C 29/C 29M). For the aggregate components, the relative density (specific gravity) should be based on the saturated-surface-dry condition (as determined by Test Method C 127 for coarse aggregate and Test Method C 128 for fine aggregate). For cements meeting Specification C 150, Specification C 595, and Specification C 1157, the relative density should be determined by Test Method C 188, and is typically available from the cement manufacturer. A value of 3.15 may be used for Portland cements manufactured to meet the requirements of Specification C 150. The relative density of supplementary cementitious materials should be determined as follows: for fly ash, use Test Methods C 311; for silica fume, use Specification C 1240; and for slag cement, use Specification C 989.

4. Summary of Test Method

4.1 A sample of fresh pervious concrete is placed and consolidated in a standard measure. The concrete is consolidated using a standard Proctor hammer. The density and void content of the pervious concrete are calculated based on the measured mass of the consolidated concrete specimen, the volume of the measure, and the total mass of materials batched.

5. Significance and Use

5.1 This test method provides a procedure for determining the density and void content of freshly mixed pervious concrete.

5.2 This test method is applicable to pervious concrete mixtures containing coarse aggregate with a nominal maximum size of 25 mm [1 in.] or smaller.

5.3 The measured fresh density may be used as verification of mixture proportions.

5.4 The fresh density and void content calculated from this test may differ from the in-place density and void content, and this test shall not be used to determine in-place yield.

6. Apparatus

6.1 *Balance*—A balance or scale accurate to 50 g [0.1 lb] or to within 0.3 % of the test load, whichever is greater, at any point within the range of use. The range of use shall be considered to extend from the mass of the empty measure to the mass of the measure filled with concrete having an assumed density of 2600 kg/m^3 [160 lb/ft^3].

6.2 *Standard Proctor Hammer*—A device used to compact a pervious concrete sample that conforms to Test Method D 698.

6.3 *Measure*—A cylindrical container made of steel or other suitable metal (See Note 2) with a capacity of 7.0 ± 0.6 L [0.25 ± 0.02 ft^3] and a diameter equal to 0.75 to 1.25 times the height. The measuring bowl of a Type B air meter conforming to Test Method C 231 meets the requirements for the measure. The volume of the measure shall be determined as described in Test Method C 29/C 29M. The top rim of the container shall be plane within 0.3 mm [0.01 in.] (See Note 3).

NOTE 2—The metal should not be attacked readily by cement paste. However, a reactive material such as aluminum alloy may be used if, as a result of an initial reaction, a surface film is formed that protects the metal against further corrosion.

NOTE 3—The top rim is satisfactorily plane if a 0.3 mm [0.01-in.] feeler gauge cannot be inserted between the rim and a piece of 6 mm [¼-in.] or thicker plate glass laid over the top of the measure.

6.4 *Strike-Off Plate*—A flat rectangular metal plate at least 6 mm [¼ in.] thick or a glass or acrylic plate at least 12 mm [½ in.] thick with length and width that are at least 50 mm [2 in.] greater than the diameter of the measure with which it is to be used. The edges of the plate shall be straight within a tolerance of 2 mm [1⁄16 in.].

6.5 *Scoop*—Of a size large enough so each amount of pervious concrete obtained from the sampling receptacle is representative and small enough so that the concrete is not spilled during placement in the measure.

7. Sampling

7.1 Obtain the sample of freshly mixed pervious concrete on field placements in accordance with Practice C 172.

7.2 Obtain the sample of freshly mixed pervious concrete in laboratory testing in accordance with Practice C 192/C 192M.

7.3 The elapsed time between obtaining the first and final portions of the composite sample shall not exceed 15 min.

7.3.1 Transport the individual samples to the place where fresh concrete tests are to be performed. Combine and remix the samples with a shovel the minimum amount necessary to ensure uniformity and compliance with the maximum time limits specified in 7.3.2. Protect the composite sample from the sun, wind, and other sources of rapid evaporation.

7.3.2 Start the test for density within 5 min after obtaining the final portion of the composite sample.

8. Procedure

8.1 Place the measure on a flat, level surface free from vibration. Moisten the inside of the measure before placing pervious concrete. Remove any standing water from the bottom of the container using a moistened sponge. Place the pervious concrete in the measure in two layers of approximately equal depth using the scoop described in 6.5. During filling of the measure, move the scoop around the perimeter of the opening to ensure an even distribution of the concrete with minimal segregation. Drop the hammer 20 times per layer at the full 305 mm [12 in.] drop height. For each layer, distribute the position of the tamper so that the entire surface area of the pervious concrete in the measure is consolidated equally. Before consolidating the final layer, fill the measure to overflowing. After completion of consolidation, the measure must contain about 3 mm [¼ in.] of excess pervious concrete protruding above the top of the measure. If after 10 hammer drops to the final layer it appears that there will be insufficient concrete, add a small quantity of concrete to correct the deficiency. If after 10 hammer drops to the final layer it appears that there will be too much concrete in the measure, remove a representative portion of excess concrete with a trowel or scoop. Complete the consolidation of the final layer.

8.2 *Strike Off*—After consolidation, strike off the top surface of the concrete and finish it flat with the strike-off plate so that the concrete surface is level with the top of the measure. Accomplish the strike-off by pressing the strike-off plate on the top surface of the measure to cover about two thirds of the surface and withdrawing the plate with a sawing motion to

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strike off the area originally covered. Then place the plate on the top of the measure to cover the same two thirds of the surface and advance it with a vertical pressure and a sawing motion to cover the whole surface of the measure; continue to advance plate until it slides completely off the measure. Several final sawing-motion strokes with the edge of the plate, which has been inclined to the top of the measure, will produce a flat finished surface.

8.3 *Cleaning and Weighing*—After strike-off, clean excess concrete from the exterior of the measure and determine the mass of the concrete and measure to an accuracy consistent with the requirements of 6.1.

9. Calculation

9.1 *Density (Unit Weight)*—Calculate the net mass of the concrete by subtracting the mass of the measure, M_m, from the mass of the measure filled with concrete, M_c. Calculate the density (unit weight), D, by dividing the net mass of concrete by the volume of the measure, V_m, as follows:

$$D = \frac{M_c - M_m}{V_m} \quad (1)$$

9.2 *Void Content*—Calculate the percentage of voids as follows:

$$U = \frac{T - D}{T} \times 100\ \% \quad (2)$$

10. Precision and Bias

10.1 Repeatability testing was performed by six laboratories using pervious concrete mixtures proportioned using local materials. Each laboratory prepared three batches and performed two replicate tests per batch. The range of density of fresh pervious concrete was from 1750 to 2000 kg/m^3[109 to 125 lb/ft^3] (See Note 4).

NOTE 4—Round robin testing was performed using the following six consolidation methods:

Proctor Hammer-2 equal layers, 20 times per layer
Marshall Hammer-2 equal layers, 5 times per layer
Marshall Hammer-2 equal layers, 10 times per layer
ASTM C29 Jigging-2 equal layers, 50 drops per layer as per Test Method C 29/C 29M
ASTM C138 Rodding Method-2 equal layers, 25 times per layer
No Consolidation-Fill the empty unit weight bucket.

Of the six consolidation methods evaluated, the method using the Proctor Hammer produced a high degree of repeatability, employed a straightforward process, and was not physically demanding due to the lower weights as compared to the Marshall Hammer.

10.1.1 The single-operator standard deviation of density of freshly mixed pervious concrete has been found to be 22 kg/m^3 [1.4 lb/ft^3].

10.1.2 The multi-operator standard deviation has not been developed.

10.2 This test method has no bias because the density of pervious concrete is defined only in terms of this test method.

11. Keywords

11.1 density; fresh concrete; pervious concrete; Proctor hammer; void content

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Designation: C1697 – 10

Standard Specification for Blended Supplementary Cementitious Materials[1]

This standard is issued under the fixed designation C1697; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope

1.1 This specification covers blended supplementary cementitious materials that result from the blending or intergrinding of two or three ASTM compliant supplementary cementitious materials, for use in concrete or mortar where hydraulic or pozzolanic action, or both, is desired. The supplementary cementitious materials include slag cement conforming to Specification C989, natural pozzolans and coal fly ash conforming to Specification C618 and silica fume conforming to Specification C1240.

1.2 The values stated in SI units are to be regarded as standard. No other units of measurement are included in this standard.

NOTE 1—The incorporation of supplementary cementitious materials as separate additions or as a manufactured blend may significantly alter the properties of fresh and hardened concrete. The user should be aware of these changes and is referred to the *ACI Manual of Concrete Practice*[2] for information and guidelines. Specific reference is made to:

ACI 232.1R	Use of Natural Pozzolans in Concrete
ACI 232.2R	Use of Fly Ash in Concrete
ACI 233R	Slag Cement in Concrete and Mortar
ACI 234R	Guide for the Use of Silica Fume in Concrete

1.3 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

2. Referenced Documents

2.1 *ASTM Standards:*[3]

C114 Test Methods for Chemical Analysis of Hydraulic Cement

C125 Terminology Relating to Concrete and Concrete Aggregates

C150 Specification for Portland Cement

C151 Test Method for Autoclave Expansion of Hydraulic Cement

C183 Practice for Sampling and the Amount of Testing of Hydraulic Cement

C311 Test Methods for Sampling and Testing Fly Ash or Natural Pozzolans for Use in Portland-Cement Concrete

C618 Specification for Coal Fly Ash and Raw or Calcined Natural Pozzolan for Use in Concrete

C989 Specification for Slag Cement for Use in Concrete and Mortars

C1240 Specification for Silica Fume Used in Cementitious Mixtures

3. Terminology

3.1 *Definitions*:

3.1.1 For definitions of other terms used in this specification, refer to Terminology C125.

3.2 *Definitions of Terms Specific to This Standard:*

3.3 *slag cement*, *n*—granulated blast furnace slag that is ground to cement fineness with or without additions and meets Specification C989.

3.4 *supplementary cementitious material*, *n*—a slag cement or pozzolan that contributes to the properties of concrete or mortar through hydraulic or pozzolanic activity, or both.

3.5 *silica fume*, *n*—as defined in Specification C1240.

4. Classification

4.1 This specification applies to a hydraulic or pozzolanic material composed of a blend of multiple supplementary cementitious materials as defined in Table 1. The supplementary cementitious materials of the blend are identified in accordance with the Type listed in the first column of Table 1. For the purpose of conformance to the requirements of this specification, the blend is classified according to the predominant supplementary cementitious material. For blended supplementary cementitious matierals that have no predominant constituent, the manufacturer selects the blend type.

4.2 The naming practice for reporting blended supplementary cementitious materials is as follows:

[1] This test method is under the jurisdiction of ASTM Committee C09 on Concrete and Concrete Aggregates and is the direct responsibility of Subcommittee C09.24 on Supplementary Cementitious Materials.

Current edition approved Feb. 1, 2010. Published March 2010.

[2] Available from American Concrete Institute (ACI), P.O. Box 9094, Farmington Hills, MI 48333-9094, http://www.concrete.org.

[3] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

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TABLE 1 Classification of Supplementary Cementitious Materials

Type	Name
N	Class N Pozzolan meeting Specification C618
F	Class F fly ash meeting Specification C618
C	Class C fly ash meeting Specification C618
SF	Silica Fume meeting Specification C1240
S	Slag cement meeting Specification C989

SCMb−*Axx*/*Byy*/*Czz*

where:

SCMb = designation of the product as a blended supplementary cementitious material,

A = targeted mass % of the predominant supplementary cementitious material in the blended supplementary cementitious material expressed by mass of the final blended supplementary cementitious material,

xx = predominant supplementary cementitious material—use Type designation in accordance with Table 1,

B = targeted mass % of the secondary supplementary cementitious material in the blended supplementary cementitious material expressed by mass of the final blended supplementary cementitious material,

yy = secondary supplementary cementitious material—use Type designation in accordance with Table 1

C = targeted mass % of the tertiary supplementary cementitious material in the blended supplementary cementitious material expressed by mass of the final blended supplementary cementitious material. This would be required only for ternary mixtures, and

zz = tertiary supplementary cementitious material—use Type designation in accordance with Table 1.

NOTE 2—Examples of the naming practice are as follows:
A binary mixture of 65 % Class C fly ash and 35 % slag cement would be:

SCMb−65*C*/35*S*

A ternary mixture of 60 % Class F fly ash, 35 % slag cement and 5 % silica fume would be:

SCMb−60*F*/35*S*/5*SF*

5. Ordering Information

5.1 Orders for material under this specification shall include the following:

5.1.1 Specification number,

5.1.2 The composition of the blend using the naming convention in 4.2.

5.1.3 Any optional requirements as delineated in Table 2.

NOTE 3—In advance of ordering, it is important to check for market availability of blended supplementary cementitious materials.

6. Materials and Manufacture

6.1 All individual constituents used in the manufacture of the blended supplementary cementitious material shall conform to their applicable specification.

6.2 All blended supplementary cementitious materials shall consist of a uniform mixture of constituents within the limits specified in Section 9.

7. Chemical Composition

7.1 The individual constituents and the blended supplementary cementitious material shall be chemically analyzed using applicable analytical methods of Test Methods C311 or Test Methods C114. Analyze for major and minor oxides present in greatest quantity that together, including loss-on-ignition constitutes at least 98 % of the total mass of the material.

7.2 There are no chemical requirements for the blended supplementary cementitious material but the chemical composition of the constituents and of the blended supplementary cementitious material are necessary to verify blend proportions.

8. Physical and Optional Properties

8.1 Blended supplementary cementitious materials shall conform to the physical requirements in Table 3, where the blend type is in accordance with Section 4.

8.2 Blended supplementary cementitious materials shall conform to the optional requirements in Table 2, only when specifically requested by the purchaser. The blend type is in accordance with Section 4.

9. Permissible Variations in Blending Accuracy

9.1 The amount of pozzolan or slag cement in the finished blended supplementary cementitious material shall not vary from the target value by more than ± 2.5 percentage points for silica fume and not more than ± 5 percentage points for other supplementary cementitious materials, with a 99 % probability of compliance.

NOTE 4—To satisfy the 99 % probability of compliance, the blending process must be capable of producing a blend containing silica fume such that the standard deviation of the measured mass percentage of silica fume in the blend is less than 1 %. For constituents other than silica fume, the standard deviations of their measured mass percentages have to be less than 1.9 %.

9.2 The chemical composition of the individual constituents and of the finished blended supplementary cementitious material shall be determined in accordance with Section 7. The composition of the blend in terms of mass percentage of the constituents shall be calculated.

NOTE 5—Appendix X1 provides an example to illustrate how the composition of the blend can be calculated from the various measured chemical compositions.

10. Sampling

10.1 The manufacturer shall sample and test the finished blended supplementary cementitious material in order to verify compliance with this specification.

10.1.1 Upon request of the purchaser, the manufacturer shall furnish the sampling procedure used to certify compliance with this specification.

10.2 If the purchaser desires to verify product compliance with this specification, appropriate sampling and testing procedures shall be used. For guidance, refer to standard Practice C183.

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TABLE 2 Optional Requirements

	Blend Type				
	N	F	C	S	SF
Increase of drying shrinkage of mortar bars at 28 days, max, difference, in %, over control[A]	0.03	0.03	0.03	...	...
Uniformity Requirements:[B]					
Density - max variation from average, %	5	5	5	...	...
% retained on 45-μm (No. 325) sieve, max variation from average, %	5	5	5	5	5
When air-entraining concrete is specified, the quantity of air-entraining agent required to produce an air content of 18.0 vol % of mortar shall not vary from the average established by the ten preceding tests or by all preceding tests if less than ten, by more than, %	20	20	20	...	20
Effectiveness in Controlling Alkali-Silica Reaction:					
Expansion of test mixture as percentage of low-alkali cement control, at 14 days, max, %[C]	100	100	100	...	...
Expansion of mortar bars at 14 days, max, %[D]	...	...	...	0.020	...
Reduction of mortar expansion at 14 days, min, %	...	...	...	75[D]	80[E]
Effectiveness in Contributing to Sulfate Resistance:					
Procedure A:[F]					
Expansion of test mixture:					
For moderate sulfate exposure after 6 months exposure, max, %	0.10[G]	0.10[G]	0.10[G]	0.10[D]	0.10[E]
For high sulfate exposure after 6 months exposure, max, %	0.05[G]	0.05[G]	0.05[G]	0.05[D]	0.05[E]
For very high sulfate exposure after 12 months exposure, max, %	...	...	...	...	0.05[D]
Procedure B:					
Expansion of test mixture as a percentage of sulfate resistance cement control after at least 6 months exposure, max,%[G]	100	100	100	...	...

[A]Determination of compliance or noncompliance with the requirement relating to increase in drying shrinkage will be made only at the request of the purchaser. Test method in accordance with Test Methods C311.

[B]Test in accordance with Test Methods C311 or Specification C1240 as appropriate.

[C]Blended supplementary cementitious materials meeting this requirement are considered as effective in controlling alkali aggregate reactions as the use of the low-alkali control cement used in the evaluation. However, the blended supplementary cementitious material shall be considered effective only when used at percentages by mass of the total cementitious material equal to or exceeding that used in the tests and when the alkali content of the cement to be used does not exceed that used in the tests by more than 0.05 %. See Appendix XI, Test Methods C311. Test method in accordance with Test Methods C311.

[D]Refer to the Appendix of Specification C989.

[E]As delineated in Specification C1240.

[F]Only one limit shall be specified.

[G]Blended supplementary cementitious materials shall be considered effective only when the blended supplementary cementitious material is used at percentages, by mass, of the total cementitious material within 2 % of those that are successful in the test mixtures or between two percentages that are successful, and when the C_3A content of the project cement is less than, or equal to, that which was used in the test mixtures. See Appendix X2 of Test Methods C311. Test method in accordance with Test Methods C311.

11. Storage and Inspection

11.1 The blended supplementary cementitious materials shall be protected from the detrimental effects of exposure to the environment and stored in such a manner as to permit easy access for proper inspection and identification.

11.2 Inspection of the material shall be made as agreed upon by the purchaser and the seller as part of the purchase contract.

12. Rejection and Rehearing

12.1 The purchaser has the right to reject material that fails to conform to the requirements of this specification. Rejection shall be reported to the manufacturer or supplier promptly and in writing. In case of dissatisfaction with the results of the tests, the manufacturer or supplier is not prohibited from making a claim for retesting.

13. 13. Certification

13.1 Upon request, the purchaser shall be furnished certification that all material has been tested as directed in this specification and the specified requirements have been met.

13.1.1 When requested by the purchaser or when specified in the purchase order or contract, a report of individual constituents including source and specification compliance shall be furnished.

13.1.2 When requested by the purchaser or when specified in the purchase order or contract, a report of the blended supplementary cementitious material test results, including chemical composition and physical properties shall be furnished.

14. Packaging and Package Marking

14.1 When blended supplementary cementitious material is delivered in packages, the composition of the blend using the naming practice in 4.2, the name and brand of the manufacturer, and the mass contained therein shall be plainly marked on each package. Similar information shall be provided in the shipping invoices accompanying the shipment of bulk blended supplementary cementitious material.

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15. Keywords

15.1 blend; fly ash; pozzolan; silica fume; slag cement; supplementary cementitious material

TABLE 3 Physical Requirements

	Blend Type				
	N	F	C	S	SF
% retained when wet sieved on 45-μm (No. 325) sieve[A]	Report only	Report only	Report only	Report only	Report only
Activity Index, min, % of control[B]					
7 day Index	75[C]	75[C]	75[C]	Report only	105
28 day Index	75[C]	75[C]	75[C]	75[D]	...
Water Requirement, % of control[E]	Report only	Report only	Report only	Report only	Report only
Autoclave, expansion or contraction, max, %[F]	0.8	0.8	0.8	...	...

[A]Refer to Test Methods C311 except compare with water meeting the applicable Activity Index method.

[B]The activity index with portland cement is not to be considered a measure of the compressive strength of concrete containing the pozzolan or slag. The tests are conducted as follows - for N, F, C refer to Specification C618; for S refer to Specification C989; for SF refer to Specification C1240.

[C]Meeting the 7 day or 28 day activity index will indicate specification compliance.

[D]Requirement is for the average of last 5 consecutive samples; no individual sample shall be more than 5 % less than the average requirement.

[E]Refer to test method in Test Methods C311.

[F]In accordance with Test Method C151, except the specimens shall be molded from a paste composed of 25 parts by mass of blended supplementary cementitious material and 100 parts by mass of a portland cement conforming to Specification C150.

APPENDIX

(Nonmandatory Information)

X1. VERIFYING BLEND PROPORTIONS

X1.1 This Appendix provides information for purchasers of blended supplementary cementitious materials about typical methods that manufacturers use to control the blend production process and verify product conformance.

X1.2 Mechanical methods, such as weighing individual constituents as each goes to the blending system are adequate to provide production control but chemical analysis as described below is required by this specification for verifying actual blend proportions:

X1.2.1 Ensure weighfeeders are maintained and calibrated before production. Weigh feeders are to provide for general control and adjustment during production.

X1.2.2 Ensure that the analysis method, X-ray fluorescence (XRF) or other qualified method is calibrated within the ranges of materials being tested.

X1.2.3 Sample and chemically analyze individual constituents before production begins and at established frequencies during production.

X1.2.4 Sample and chemically analyze finished blended supplementary cementitious materials at established frequencies during production runs for quality control purposes and verification of blend proportions.

X1.2.5 Proportion analysis, as used here, is a calculation using the chemical analysis of the individual constituents and the resultant blend.

X1.2.5.1 The individual constituents are analyzed and predominant elements are chosen as chemical identifiers.

X1.2.5.2 Those chosen identifiers are then used to calculate the mass % of constituents in the blended supplementary cementitious material.

An example of this calculation follows. This is a basic example for illustrative purposes using one element. A more detailed analysis using multiple elements can be performed using a spreadsheet program such as EXCEL Solver.

Target: A blended supplementary cementitious material with 10 % silica fume and 90 % slag cement.

Individual constituent analysis: Silica Fume with 90 % SiO_2 and Slag cement with 30 % SiO_2

Finished product analysis: 36 % SiO_2

Calculation:

$$(10\ \%\ \textit{Silica Fume} \cdot 90\ \%\ \textit{SiO}_2) + (90\ \%\ \textit{Slag cement} \cdot 30\ \%\ \textit{SiO}_2) = 36\ \%\ \textit{SiO}_2$$

Evaluation: The proportions of the constituents, mass %, are as targeted (10 % Silica fume / 90 % slag cement) because the finished product SiO_2 equals the calculated SiO_2 at the targeted blend ratio.

Additional analysis to determine if the proportions are within allowable tolerances is shown below:

Target: A blended supplementary cementitious material with 10 % silica fume and 90 % slag cement.

Allowable tolerance of silica fume = ± 1 %

Calculation using the same constituent analysis as above:

$$(9\ \%\ \textit{Silica Fume} \cdot 90\ \%\ \textit{SiO}_2) + (91\ \%\ \textit{Slag cement} \cdot 30\ \%\ \textit{SiO}_2) = 35.4\ \%\ \textit{SiO}_2$$

$$(11\ \%\ \textit{Silica Fume} \cdot 90\ \%\ \textit{SiO}_2) + (89\ \%\ \textit{Slag cement} \cdot 30\ \%\ \textit{SiO}_2) = 36.6\ \%\ \textit{SiO}_2$$

Evaluation: The blend proportions would be within allowable tolerances if the SiO_2 of the blend is between 35.4 % and 36.6 %

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X1.2.6 During manufacturing, feeder adjustments would be made as necessary to achieve the targeted proportions. However, it is normal to apply "Statistical Process Control" rules to the proportion results in order to prevent unnecessary reactions to normal process variation.

X1.2.7 Proportion analysis with other equipment such as colorimeter or induction furnace sulfur analyzers can be used for quality control during production but should not be used for "Manufacturers Certification" unless they are qualified to Test Methods C114.

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Designation: C 1698 – 09

Standard Test Method for Autogenous Strain of Cement Paste and Mortar[1]

This standard is issued under the fixed designation C 1698; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope

1.1 This test method measures the bulk strain of a sealed cement paste or mortar specimen, including those containing admixtures, various supplementary cementitious materials (SCM), and other fine materials, at constant temperature and not subjected to external forces, from the time of final setting until a specified age. This strain is known as *autogenous strain*. Autogenous strain is most significant in concrete with low water-cementitious materials ratio (*w/cm*) (See Note 1).

NOTE 1—A low water-cementitious materials ratio (*w/cm*) can be considered to be a water to cement ratio of 0.40 or lower for this test.

1.2 The values stated in SI units are to be regarded as standard. No other units of measurement are included in this standard.

1.3 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.* (**Warning**—Fresh hydraulic cementitious mixtures are caustic and may cause chemical burns to skin and tissue upon prolonged exposure.[2])

2. Referenced Documents

2.1 *ASTM Standards:*[3]

C125 Terminology Relating to Concrete and Concrete Aggregates

C157/C157M Test Method for Length Change of Hardened Hydraulic-Cement Mortar and Concrete

C191 Test Methods for Time of Setting of Hydraulic Cement by Vicat Needle

C192/C192M Practice for Making and Curing Concrete Test Specimens in the Laboratory

C219 Terminology Relating to Hydraulic Cement

C305 Practice for Mechanical Mixing of Hydraulic Cement Pastes and Mortars of Plastic Consistency

C403/C403M Test Method for Time of Setting of Concrete Mixtures by Penetration Resistance

C1005 Specification for Reference Masses and Devices for Determining Mass and Volume for Use in the Physical Testing of Hydraulic Cements

2.2 *API Specification*[4]

RP 10B-2/ISO 10426-2 Recommended Practice for Testing Well Cements

3. Terminology

3.1 *Definitions*:

3.1.1 For definitions of terms used in this test method, refer to Terminologies C125 and C219.

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *autogenous strain*, *n*—the bulk strain of a sealed specimen of a cementitious mixture, not subjected to external forces and under constant temperature, measured from the time of final setting until a specified age; negative strain corresponds to shrinkage and positive strain corresponds to expansion.

4. Summary of Test Method

4.1 A specimen of freshly mixed paste or mortar is prepared using a corrugated mold that offers little resistance to length change of the specimen. The mold is sealed to prevent moisture loss and the specimen is stored at constant temperature. Starting at the time of final setting, the length of the specimen is measured using a dilatometer. The change in length is recorded at regular time intervals until the designated age. The change in length and original length of the specimen are used to compute the autogenous strain.

5. Significance and Use

5.1 Autogenous strain is the self-created bulk strain of cement paste, mortar, or concrete during hardening at constant temperature. In conventional concrete, autogenous shrinkage strain is generally negligible, but in concrete with low water-cementitious materials ratio (*w/cm*) or with silica fume it may be considerable (**1**).[5] Restraint of the autogenous strain by

[1] This test method is under the jurisdiction of ASTM Committee C09 on Concrete and Concrete Aggregates and is the direct responsibility of Subcommittee C09.68 on Volume Change.

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[2] Section on Safety Precautions, Manual of Aggregate and Concrete Testing, *Annual Book of ASTM Standards*, Vol. 04.02.

[3] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

[4] Available from American Petroleum Institute (API), 1220 L. St., NW, Washington, DC 20005-4070, http://www.api.org.

[5] The boldface numbers in parentheses refer to a list of references at the end of this standard.

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aggregates or adjoining structural members may result in formation of micro and macro cracks that impair strength, durability and aesthetics. Cracks may also be a problem with regard to hygienic cleaning of surfaces.

5.2 An accurate measurement of the autogenous strain of cementitious mixtures with low *w/cm* is important for evaluating the risk of early-age cracking of concrete structures. Measurements of autogenous strain have been carried out using either volumetric or linear methods. Both methods may show evidence of significant artifacts (**1**); therefore, results of the two methods may disagree considerably if not carried out properly.

5.3 A sealed, flexible corrugated mold system (**2**) combines the advantages of linear and volumetric measurement of autogenous strain, while avoiding most of their disadvantages. The mold effectively prevents moisture loss and minimizes restraint to volume change during hardening. Moreover, results obtained with the corrugated mold system agree with those from the volumetric method, once some artifacts, in particular water absorption through the membrane used to contain the test specimen, have been eliminated in the latter (**3**,**4**). The corrugated mold system is easier to use and shows better repeatability than the volumetric technique (**3**,**4**). Measurements with the corrugated mold system are in good agreement with unrestrained length change measurements obtained using Test Method C157/C157M with sealed specimens (**5**); however, Test Method C157/C157M does not allow measurement of the shrinkage occurring before 24 h (**5**).

5.4 This test method can be used to evaluate the effects of cementitious materials, admixtures, and mixture proportions on autogenous shrinkage strain of paste or mortar specimens.

5.5 The autogenous shrinkage strain of mortar specimens will be less than that of paste specimens for the same *w/cm*. The autogenous shrinkage strain of concrete will be less than that of mortar for the same *w/cm*. The nominal maximum aggregate size for mortar used in this test method is 4.75 mm.

6. Apparatus

6.1 The apparatus to measure autogenous strain is composed of a corrugated mold with two end plugs, a dilatometer bench, a length measuring gauge, and a reference bar (see Fig. 1).

6.2 *Molds*—The molds consist of corrugated plastic tubes, having a length of 420 ± 5 mm and an outer diameter of 29 ± 0.5 mm (see Note 2). The plastic tubes are made of 0.5 ± 0.2-mm thick low-density polyethylene (PE) and have triangular-shaped corrugations in order to minimize restraint in the longitudinal direction (see Fig. 2). The distance between corrugations is 5.8 ± 0.2 mm. The mold is tightly closed with two tapered end plugs having a length of 19 ± 0.5 mm. The diameter of the plastic end plugs tapers from 21 ± 0.1 mm to 22.4 ± 0.1 mm (see Fig. 3).

NOTE 2—The small diameter of the molds limits the temperature differences that may arise during hydration of the cementitious materials. Typical maximum temperature increase in the center of the test specimen, due to heat of hydration of cement paste or mortar has been determined to be 2 °C. The maximum longitudinal restraint stress exerted by the molds has been determined to be 0.001 MPa (**6**).

6.3 *Dilatometer Bench*—The dilatometer bench consists of three stainless steel rods with a diameter of 20 ± 1.0 mm and two stainless steel end plates. Technical drawings of a suitable dilatometer bench are shown in Fig. 4. During measurement, the test specimen is positioned horizontally and is supported longitudinally by the two upper rods.

6.4 *Length Measuring Gauge*—A gauge measures length changes at one end of the specimen. The measuring range of the gauge shall be at least 10 mm and the resolution shall be at least 0.0025 mm, corresponding to a resolution of about 6 µm/m for the calculated strain.

6.5 *Reference Bar*—Measurements in the dilatometer are performed relative to the length of the reference bar. The bar is made of Invar with a length of 425 ± 0.5 mm and a diameter

NOTE—In the foreground a corrugated PE-mold with two specially shaped end plugs and a 425 mm reference bar. In the background the dilatometer bench with a test specimen placed for length measurement. To the right a digital length gauge with remote control.

FIG. 1 A Suitable Dilatometer Bench with Accessories

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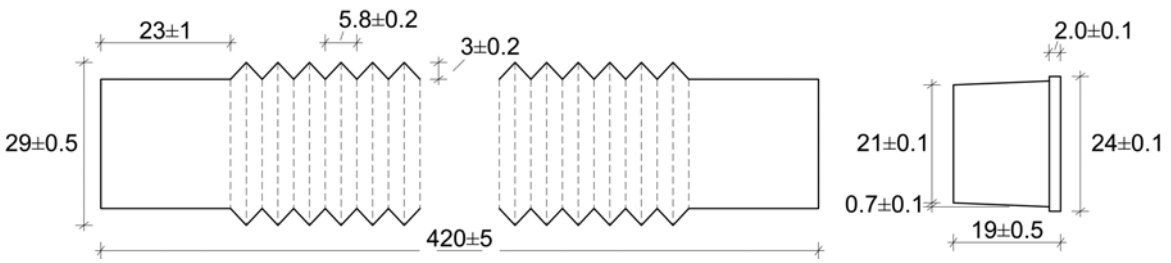
FIG. 2 Corrugated Polyethylene Mold



NOTE—Plastic Tube Wall Thickness 0.5 ± 0.2 mm.

FIG. 3 Outer Dimensions (mm) of Corrugated Low-Density Polyethylene Mold and End Plug

of 20 ± 1.0, tapering to 10 ± 1.0 mm at both ends as shown in Fig. 5. The actual length of the reference bar shall be marked permanently on the bar to the nearest 0.01 mm. Two plastic rings with an external diameter 30 ± 0.5 mm are mounted on the reference bar, as shown in Fig. 1.

6.6 *Reference Masses and Devices for Determining Mass and Volume* shall conform to the requirements of Specification C1005.

6.7 *Support Tube* used to support the corrugated mold during specimen fabrication. The support tube has a length of 400 ± 5 mm and an inside diameter of 32 ± 1 mm (see Fig. 6). The tube is attached to a base that can be fixed to a vibrating table.

6.8 *Vibrating Table* as described in Practice C192/C192M.

6.9 *Tamping Rod* for consolidation of the paste or mortar. It shall be made of a rigid, non-absorptive material that does not react with the cementitious mixture. The length of the rod shall be at least 500 mm and the diameter shall be 6 ± 1 mm. The ends may be flat or hemispherical.

7. Procedure

7.1 *Number of Specimens*—Three replicate specimens shall be tested for each cement paste or mortar (see Note 3).

7.1.1 *Mixing*—Mix cement pastes and mortars according to Practice C305. Record the time when the cementitious materials are added to the water.

7.1.2 *Mixing Apparatus*

7.1.2.1 *Mortar Preparation*—The mixer shall comply with the sequence in Practice C305.

7.1.2.2 *Paste Preparation*—A high shear blender,[6] or similar variable speed blender capable of maintaining a no-load speed of at least 15 000 r/min, with optional cooling device. A hand-held household mixer capable of mixing paste at not less than 400 r/min or other mixers for paste or mortar preparation are also permitted.

NOTE 3—About 185 mL of cement paste or mortar are needed to fill each corrugated mold. For a paste with a water-cement ratio of 0.4, this

[6] Mixing devices described in API Specification RP 10B-2/ISO 10426-2.

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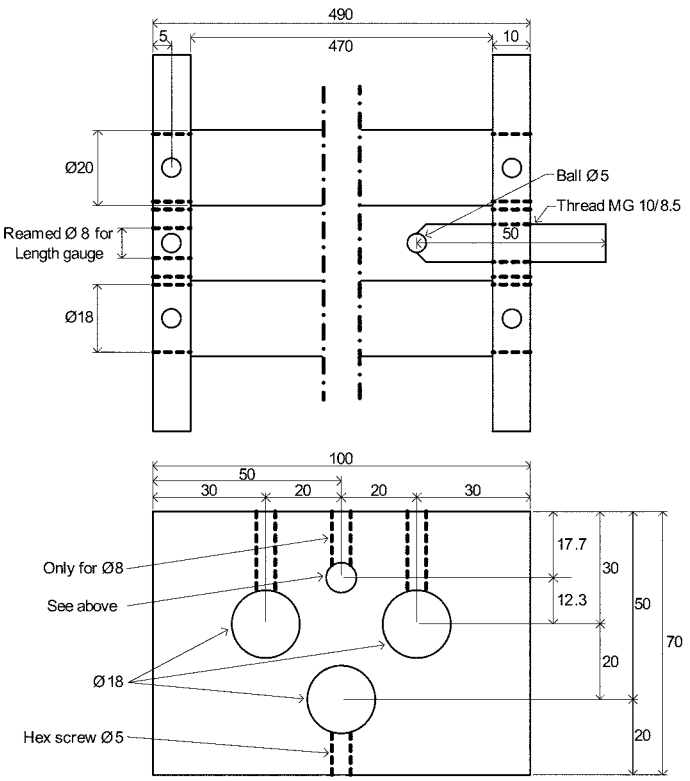
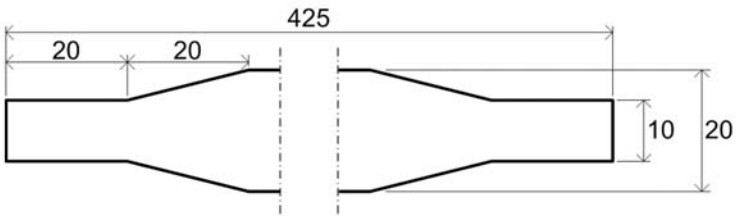


NOTE—All dimensions are in mm (tolerance ± 0.5 %).

FIG. 4 Technical Drawing of the Dilatometer Bench Shown in Fig. 1
Top: Plan View. Bottom: Elevation View of End Plate



NOTE—All dimensions are in mm and tolerances given in the text.

FIG. 5 Technical Drawing of the Reference Bar Shown in Fig. 1

corresponds to approximately 360 g of paste.

7.2 *Filling and Closing of Molds*—Clamp the mounting base of the support tube to a vibrating table. Measure the lengths of the plugs to be used for each specimen. Place a plug into one end of the mold, and position the mold, with the closed end down, inside the support tube. If the cementitious mixture is pourable, slowly pour the mixture into the corrugated mold with the vibrating table turned on (see Fig. 7). For a semi-fluid mixture, fill the mold in four equal layers and compact each layer 5 times with the tamping rod before each subsequent layer is cast. The rod shall just penetrate the underlying layer. For a stiff mixture, hand prepare rolled sections of the cementitious mixture, drop them into the mold, and consolidate with the tamping rod. To ensure that the cast specimens have approximately the same length, do not stretch or compress the corrugated mold during filling. For fluid mixtures, the corrugated mold shall be held only by the support tube during casting. For semi-fluid and stiff mixtures, manually maintain the initial length of the mold during compaction. Fill the mold to approximately 15 mm below the top end of the mold to allow room for the top end plug. Before mounting the top end plug, gently compress the corrugated mold to bring the cement paste or mortar in contact with the end plug. Mount the end plug during relief of the compression of the corrugated mold. Use a screwing motion of the end plug to ease the mounting operation. Immediately after casting, carefully wipe the surface

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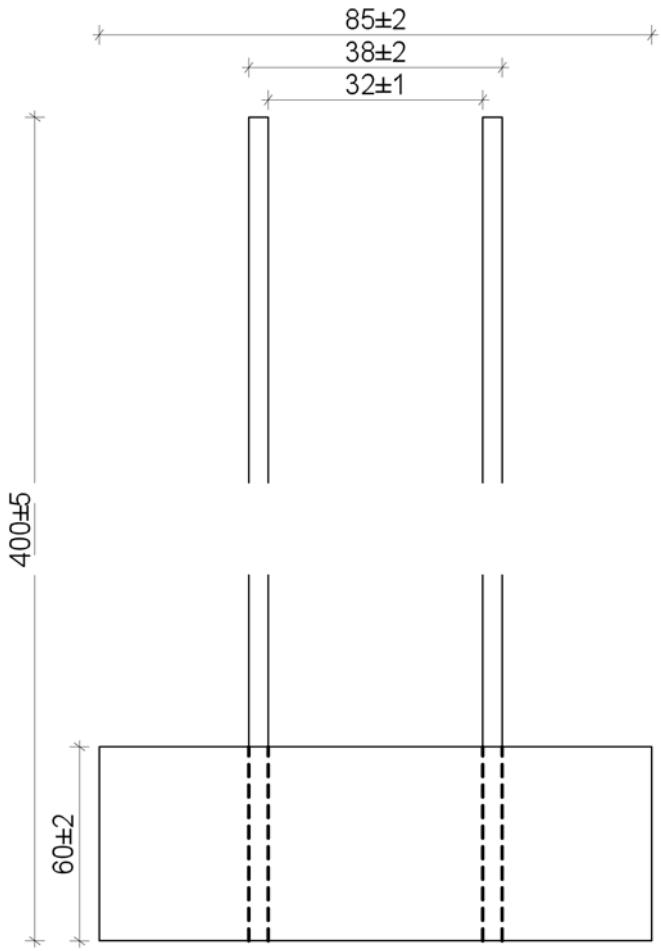

NOTE—All dimensions are in mm. The base of the support tube allows clamping to a vibration table.

FIG. 6 Suitable Dimensions of the Support Tube That is Used During Filling of the Corrugated Molds

of the corrugated mold with a dry cloth to remove any cement paste, mortar, or water.

7.3 *Measuring Room*—To minimize the influence of temperature variations, both the specimens and the dilatometer shall be kept in a thermostatically controlled room or cabinet at all times during the test. Maintain the surrounding air temperature at 23.0 ± 1.0 °C, unless otherwise specified (see Note 4). Do not store specimens in a water bath due to possible water transport through the corrugated molds.

NOTE 4—The measurement can be performed at any temperature specified by the user, provided that the temperature in the measuring room or cabinet is maintained constant during the test with a tolerance of ± 1.0 °C.

7.4 *Specimen Storage*—After filling and sealing the molds, store the specimens horizontally on a smooth surface, to avoid any restraint to length change. Support specimens along their entire length to avoid damage and to ensure they remain straight (see Note 5). Maintain a separation of at least 30 mm between specimens during the first day of measurement to allow dispersion of their heats of hydration.

NOTE 5—Corrugated plastic sheets as shown in Fig. 8 or other suitable materials can be used to support the molded specimens.

7.5 *Time of First Measurement*—Start length measurements at the time of final setting. Determine times of setting using Test Method C191 for paste or Test Method C403/C403M for mortar on specimens made with the same mixture used to mold the autogenous shrinkage specimens and cured at the same temperature as for the autogenous strain measurement. Protect the specimens used for determination of setting times from moisture loss during the measurement.

7.6 *Length Measurement*—Insert the reference bar in the dilatometer bench and bring the measuring gauge in contact with the end of the bar. Reset the measuring gauge so that it reads zero with the reference bar in position (see Note 6). Remove the reference bar and insert a specimen in the dilatometer bench. Measure the length of the specimen with the gauge (see Note 6). Remove the specimen and measure the length of the next specimen.

NOTE 6—A number of digital length measurement devices have the option of changing the sign of the length measurements. Ensure that the sign for the gauge reading is positive for elongation of the specimen (see Eq 1).

During handling of the specimens, support them at all times with both hands and use care to avoid damage. In particular at

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NOTE—An empty corrugated mold, closed at one end with an end plug, is inserted into the support tube and positioned vertically on a vibrating table. The fresh mixture is slowly poured into the corrugated mold during vibration, until the mold is filled.

FIG. 7 How to Fill the Corrugated Molds

early age the specimens must be supported along their entire length while they are moved to and from the dilatometer bench (Note 7).

NOTE 7—This can be done by moving the specimen together with a corrugated support rack and rolling the specimen into the frame gently onto the dilatometer bench.

To ensure optimal measuring accuracy, place the reference bar and the specimens in the same orientation during each measurement. Draw a line mark with permanent ink on one end of the corrugated mold after the first measurement to indicate both the upside and the measuring gauge position (see Figs. 8 and 9).

7.7 *Frequency and Duration of Measurements*—Frequency and duration of measurements depends on the cementitious mixture and on the scope of the measurements. The specifier of tests shall indicate the frequency of measurements and the duration of testing (see Note 8). In the absence of other specified ages, measure specimen length at the time of final setting and ages of 1, 3, 7, 14, and 28 d from the time of initial mixing of cementitious materials and water. For longer test durations, protect the molds from moisture loss.

NOTE 8—More frequent measurements may be performed at intervals of one to three hours during the first day, twice a day during the first week, once a day after the first week. Typical duration of the measurements varies from one week to several months. For long term measurements, the corrugated molds may be further protected from moisture loss by storing them in sealed tubes between the measurements.

7.8 *Monitoring Mass Change*—Measure specimen mass using a balance with a resolution of at least 0.01 g. Measure the mass of each specimen after the first autogenous strain measurement has been taken at the time of final setting. Measure the mass of each specimen again after each autogenous strain measurement has been performed. Support the specimens along their length while they are moved to the balance and during mass measurement (Note 9).

NOTE 9—This can be done by measuring the mass of the specimen together with a corrugated support rack (see Fig. 8). Ensure that each specimen is weighed with the same support rack during each mass measurement. The measurement of mass loss indicates if drying shrinkage may be occurring, in addition to autogenous shrinkage.

8. Interferences

8.1 *Bleeding*—Bleeding is expected to influence the measured autogenous strain because reabsorption of bleed water after setting may cause expansion. Bleeding has, however, been shown to have minimal influence on the results of the test (see Note 10). For mixtures prone to bleeding, use an apparatus to slowly rotate the filled molds in a horizontal position at a speed of 1 to 3 r/min until final setting has occurred.

NOTE 10—Bleeding should not be a problem in cement pastes or mortars made with values of *w/cm* lower than about 0.4.

8.2 *Entrapped Air*—Before setting, entrapped air inside the corrugated molds as a consequence of less than perfect filling will influence the deformation of the specimens. However, the effect of entrapped air is negligible after setting, when a solid skeleton has developed in the cement paste or mortar.

9. Calculations

9.1 *Time*—The time t is defined as the time elapsed from the first addition of the cementitious materials to the water during mixing.

9.2 *Length*—The length of the paste or mortar specimen at time t is calculated with the following formula:

$$L(t) = L_{ref} + R(t) - 2 \cdot L_{plug} \tag{1}$$

where:

L_{ref} = length of reference bar, mm
$R(t)$ = reading of length gauge with specimen in the dilatometer, mm, and
L_{plug} = average length of end plugs, mm.

9.3 *Autogenous Strain*—The autogenous strain of the specimen at time t, expressed as μm/m, is calculated with the following formula:

$$\varepsilon_{autogenous} = \frac{L(t) - L(t_{fs})}{L(t_{fs})} \cdot 10^6 = \frac{R(t) - R(t_{fs})}{L(t_{fs})} \cdot 10^6 \ \mu m/m \tag{2}$$

where:

t_{fs} = time of final setting, when the first length measurement is performed, min.

9.4 *Mass Change*—The mass change of the specimen is calculated as the difference between the mass of the specimen M_s measured at the conclusion of the test and the mass at the time of final setting:

$$\Delta M = M_s(t_e) - M_s(t_{fs}) \tag{3}$$

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NOTE—Note pen marks on the ends of the tubes to ensure proper positioning of specimens in the dilatometer bench during length measurements.

FIG. 8 Corrugated Plastic Sheets for Supporting the Specimens During the Test

NOTE—Notice the mark with permanent ink at one end of the specimen showing the upside and measuring gauge position during measurements.

FIG. 9 Placement of Specimen in the Dilatometer Bench for Length Measurement

where:

t_e = time of last mass measurement, min,

$M_s\ (t_e)$ = mass when last mass measurement is made (at the conclusion of the test), g, and

$M_s\ (t_{fs})$ = mass at time of final setting when first mass measurement is made, g.

It is assumed that all the mass change of the specimen is due to exchange of moisture between the cementitious system and the external environment. The exchange of moisture results in an error in the autogenous strain measurement for cement pastes of about 200 μm/m per gram of mass change and for mortars of about 80 μm/m per gram of mass change (7). If the calculated error in the autogenous measurement on this basis exceeds 5 % of the total autogenous strain, the test is considered invalid.

10. Report

10.1 Report the following for each mixture tested:

10.1.1 The mixture proportions in kg/m^3 of water, cement (and other cementitious materials), and aggregates; admixtures in L/m^3; and water-cementitious materials ratio (*w/cm*) to the nearest 0.01.

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10.1.2 Measuring room temperature.

10.1.3 Time of first addition of the cementitious materials to water and duration of mixing if different from the mixing time in Practice C305.

10.1.4 Indicate if specimens were rotated before final setting and report the speed of rotation. Also indicate the test method used to determine the time of final setting.

10.1.5 For each length measurement: the time of measurement, gauge reading of each measured specimen at each measuring age, time elapsed from first addition of the cementitious materials to water during mixing, and the autogenous strain value calculated with Eq 1 and 2.

10.1.6 Mass of each specimen at final setting and at end of test. Change of mass (in g) calculated with Eq 3.

11. Precision and Bias

11.1 *Precision*—Preliminary information on repeatability of this test method was derived from single-operator testing in two different laboratories. The standard deviation appears to be constant and is used as the measure of repeatability. For replicate specimens of paste with values of *w/cm* between 0.35 and 0.37, the pooled value of the single operator standard deviation was found to be 110 μm/m. For mortar specimens with values of *w/cm* between 0.30 and 0.43, the pooled value of the single operator standard deviation was found to be 28 μm/m (see Note 11).

NOTE 11—A full analysis of precision, as derived from an interlaboratory program, is expected to be completed by 2013.

11.2 *Bias*—Since there is no accepted reference material suitable for determining the bias of this procedure, no statement on bias is made.

12. Keywords

12.1 autogenous strain; cement paste; length change; mortar

REFERENCES

(1) Jensen, O.M., Hansen, P.F., Autogenous Deformation and RH-Change in Perspective, Cem. Con. Res. 31 (12) (2001) 1859-1865.

(2) Jensen, O.M., Hansen, P.F., A Dilatometer for Measuring Autogenous Deformation in Hardening Portland Cement Paste, Mater. Struct. 28 (181) (1995) 406-409.

(3) Lura, P., Jensen, O.M., Measuring Techniques for Autogenous Strain of Cement Paste, Portland Cement Association, PCA R&D Serial No. 2925 (2005) (Skokie, IL), 26 pp.

(4) Lura, P., Jensen, O.M., Measuring Techniques for Autogenous Strain of Cement Paste, Mater. Struct. 40 (4) (2007) 431-440.

(5) Sant, G., Lura, P., Weiss, W.J., Measurement of Volume Change in Cementitious Materials at Early Ages: Interpretation and Reconciliation of Testing Protocols and Results, Transportation Research Record 1979 (2006) 21-29.

(6) Jensen, O.M., Dilatometer - Calibration and Testing, PhD Thesis, Building Materials Laboratory, The Technical University of Denmark, Technical report 261/92, 1992

(7) Verbeck, G.J. and Helmuth, R.H., Structure and Physical Properties of Cement Paste, Proc. 5th Int. Symp. on the Chemistry of Cement, 1968 (Tokyo), Part III, pp. 1-32.

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Designation: C 1701/C 1701M – 09

Standard Test Method for Infiltration Rate of In Place Pervious Concrete[1]

This standard is issued under the fixed designation C 1701/C 1701M; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope

1.1 This test method covers the determination of the field water infiltration rate of in place pervious concrete.

1.2 The values stated in either SI units or inch-pound units are to be regarded separately as standard. The values stated in each system may not be exact equivalents; therefore, each system shall be used independently of the other. Combining values from the two systems may result in non-conformance with the standard.

1.3 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

1.4 The text of this standard references notes that provide explanatory material. These notes shall not be considered as requirements of the standard.

2. Referenced Documents

2.1 *ASTM Standards:*[2]

C 125 Terminology Relating to Concrete and Concrete Aggregates

C 920 Specification for Elastomeric Joint Sealants

2.2 *Other Standards*

Federal Specification A-A-3110 (TT-P-1536A) Plumbing Fixture Setting Compound[3]

3. Terminology

3.1 *Definitions:*

3.1.1 The terms used in this test method are defined in Terminology C 125.

4. Summary of Test Method

4.1 An infiltration ring is temporarily sealed to the surface of a pervious pavement. After prewetting the test location, a given mass of water is introduced into the ring and the time for the water to infiltrate the pavement is recorded. The infiltration rate is calculated in accordance with 9.1.

5. Significance and Use

5.1 Tests performed at the same location across a span of years may be used to detect a reduction of infiltration rate of the pervious concrete, thereby identifying the need for remediation.

5.2 The infiltration rate obtained by this method is valid only for the localized area of the pavement where the test is conducted. To determine the infiltration rate of the entire pervious pavement multiple locations must be tested and the results averaged.

5.3 The field infiltration rate is typically established by the design engineer of record and is a function of the design precipitation event.

5.4 This test method does not measure the influence on in-place infiltration rate due to sealing of voids near the bottom of the pervious concrete slab. Visual inspection of concrete cores is the best approach for determining sealing of voids near the bottom of the pervious concrete slab.

6. Apparatus

6.1 *Infiltration Ring*—A cylindrical ring, open at both ends (See Fig. 1). The ring shall be watertight, sufficiently rigid to retain its form when filled with water, and shall have a diameter of 300 ± 10 mm [12.0 ± 0.5 in.] with a minimum height of 50 mm [2.0 in.]. The bottom edge of the ring shall be even. The inner surface of the ring shall be marked or scored with two lines at a distance of 10 and 15 mm [0.40 and 0.60 in.] from the bottom of the ring. Measure and record the inner diameter of the ring to the nearest 1 mm [0.05 in.].

[1] This test method is under the jurisdiction of ASTM Committee C09 on Concrete and Concrete Aggregates and is the direct responsibility of Subcommittee C09.49 on Pervious Concrete.

Current edition approved Aug. 1, 2009. Published September 2009.

[2] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

[3] http://www.everyspec.com

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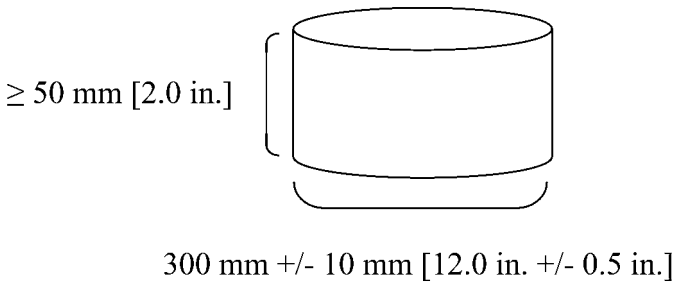

FIG. 1 Dimensions of Infiltration Ring

NOTE 1—Ring materials that have been found to be suitable include steel, aluminum, rigid plastic, and PVC.

6.2 *Balance*—A balance or scale accurate to 10 g [0.02 lb].

6.3 *Container*—A cylindrical container typically made of plastic having a volume of at least 20 L [5 gal], and from which water may be easily poured at a controlled rate into the infiltration ring.

6.4 *Stop Watch*—Accurate to 0.1 s.

6.5 *Plumbers Putty (Non-Hardening)*—Meeting Specification C 920 or Federal Specification A-A-3110.

6.6 *Water*—Potable water.

7. Test Locations

7.1 Perform tests at multiple locations at a site as requested by the purchaser of testing services. Unless otherwise specified, use the following to determine the number of tests to perform:

7.1.1 Three test locations for areas up to 2,500 m^2 [25,000 ft^2].

7.1.2 Add one test location for each additional 1,000 m^2 [10,000 ft^2] or fraction thereof.

7.2 Provide at least 1 m [3 ft] clear distance between test locations, unless at least 24 h have elapsed between tests.

7.3 Do not test if there is standing water on top of the pervious concrete. Do not test within 24 h of the last precipitation.

8. Procedure

8.1 *Infiltration Ring Installation*—Clean the pavement surface by only brooming off trash, debris, and other non-seated material. Apply plumbers putty around the bottom edge of the ring and place the ring onto the pervious concrete surface being tested. Press the putty into the surface and around the bottom edge of the ring to create a watertight seal. Place additional putty as needed

NOTE 2—In a hot environment where the surface temperature is over 38 °C [100 °F] plumbers putty may not adhere to the concrete surface easily. Therefore it is advisable to perform this test during cooler temperature.

8.2 *Prewetting*—Pour water into the ring at a rate sufficient to maintain a head between the two marked lines. Use a total of 3.60 ± 0.05 kg [8.0 ± 0.1 lb] of water. Begin timing as soon as the water impacts the pervious concrete surface. Stop timing when free water is no longer present on the pervious surface. Record the amount of elapsed time to the nearest 0.1 s.

8.3 *Test*—The test shall be started within 2 min after the completion of the prewetting. If the elapsed time in the prewetting stage is less than 30 s, then use a total of 18.00 ± 0.05 kg [40.00 ± 0.1 lb] of water. If the elapsed time in the prewetting stage is greater than or equal to 30 s, then use a total of 3.60 ± 0.05 kg [8.0 ± 0.1 lb] of water. Record the weight of water to the nearest 10 g [0.02 lb] (M). Pour the water into the ring at a rate sufficient to maintain a head between the two marked lines and until the measured amount of water has been used. Begin timing as soon as the water impacts the pervious concrete surface. Stop timing when free water is no longer present on the pervious surface. Record the testing duration (t) to the nearest 0.1 s.

NOTE 3—If a sloped pavement is being measured, maintain head between the two marked lines at the lowest point of the slope.

8.4 If a test is repeated at the same location, the repeat test does not require pre-wetting if conducted within 5 min after completion of the first test. If more than one test is conducted at a location on a given day, the infiltration rate at that location on that day shall be calculated as the average of the two tests. Do not repeat this test more than twice at the same location on a given day.

9. Calculation

9.1 Calculate the infiltration rate (I) using consistent units as follows:

$$I = \frac{KM}{(D^2 * t)}$$

where:

I = Infiltration rate, mm/h [in./h],
M = Mass of infiltrated water, kg [lb],
D = Inside diameter of infiltration ring, mm [in.],
t = time required for measured amount of water to infiltrate the concrete, s, and
K = 4 583 666 000 in SI units or 126 870 in [inch-pound] units.

NOTE 4—The factor K has units of $(mm^3 s)/(kgh)$ $[(in.^3 s)/(lbh)]$ and is needed to convert the recorded data (W, D, and t) to the infiltration rate I in mm/h [in./h].

10. Report

10.1 Report the following information:

10.1.1 Identification number,

10.1.2 Location,

10.1.3 Date of test,

10.1.4 Age and thickness of concrete (label Unknown if not known),

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10.1.5 Time elapsed during prewetting, s,
10.1.6 Amount of rain during last event, if known, mm [in.],
10.1.7 Weight of infiltrated water, kg [lb],
10.1.8 Inside diameter of infiltration ring, mm [in.],
10.1.9 Time elapsed during infiltration test, s,
10.1.10 Infiltration rate, mm/h [in./h], and
10.1.11 Number of tests performed at each location, if applicable.

11. Precision and Bias

11.1 Repeatability testing was performed by a single laboratory by making 2 replicate measurements at three locations on a newly placed pervious concrete pavement. The replicate measurements were repeated daily from day 1 to day 10. The single-operator coefficient of variation of the infiltration rate at one test location was found to be 4.7 %.

11.2 The multi-operator variability data has not been developed. The reproducibility of this test method is being determined and will be available on or before October 1, 2014.

11.3 This test method has no bias because the infiltration rate of in-place pervious concrete is defined only in terms of this test method.

12. Keywords

12.1 concrete; infiltration; pervious; water

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Designation: C 1701/C 1701M – 09

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1.2 The values stated in either SI units or inch-pound units are to be regarded separately as standard. The values stated in each system may not be exact equivalents; therefore, each system shall be used independently of the other. Combining values from the two systems may result in non-conformance with the standard.

1.3 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

1.4 The text of this standard references notes that provide explanatory material. These notes shall not be considered as requirements of the standard.

2. Referenced Documents

2.1 *ASTM Standards:*[2]

C 125 Terminology Relating to Concrete and Concrete Aggregates

C 920 Specification for Elastomeric Joint Sealants

2.2 *Other Standards*

Federal Specification A-A-3110 (TT-P-1536A) Plumbing Fixture Setting Compound[3]

3. Terminology

3.1 *Definitions:*

3.1.1 The terms used in this test method are defined in Terminology C 125.

4. Summary of Test Method

4.1 An infiltration ring is temporarily sealed to the surface of a pervious pavement. After prewetting the test location, a given mass of water is introduced into the ring and the time for the water to infiltrate the pavement is recorded. The infiltration rate is calculated in accordance with 9.1.

5. Significance and Use

5.1 Tests performed at the same location across a span of years may be used to detect a reduction of infiltration rate of the pervious concrete, thereby identifying the need for remediation.

5.2 The infiltration rate obtained by this method is valid only for the localized area of the pavement where the test is conducted. To determine the infiltration rate of the entire pervious pavement multiple locations must be tested and the results averaged.

5.3 The field infiltration rate is typically established by the design engineer of record and is a function of the design precipitation event.

5.4 This test method does not measure the influence on in-place infiltration rate due to sealing of voids near the bottom of the pervious concrete slab. Visual inspection of concrete cores is the best approach for determining sealing of voids near the bottom of the pervious concrete slab.

6. Apparatus

6.1 *Infiltration Ring*—A cylindrical ring, open at both ends (See Fig. 1). The ring shall be watertight, sufficiently rigid to retain its form when filled with water, and shall have a diameter of 300 ± 10 mm [12.0 ± 0.5 in.] with a minimum height of 50 mm [2.0 in.]. The bottom edge of the ring shall be even. The inner surface of the ring shall be marked or scored with two lines at a distance of 10 and 15 mm [0.40 and 0.60 in.] from the bottom of the ring. Measure and record the inner diameter of the ring to the nearest 1 mm [0.05 in.].

[1] This test method is under the jurisdiction of ASTM Committee C09 on Concrete and Concrete Aggregates and is the direct responsibility of Subcommittee C09.49 on Pervious Concrete.

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[2] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

[3] http://www.everyspec.com

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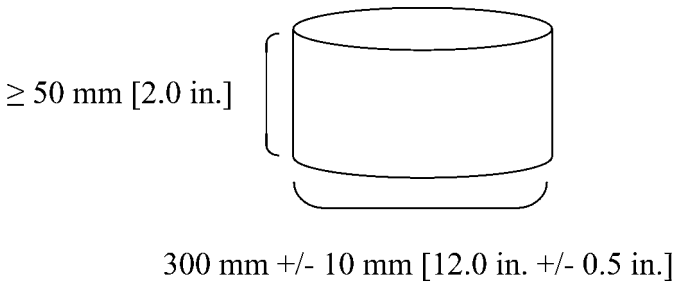

FIG. 1 Dimensions of Infiltration Ring

NOTE 1—Ring materials that have been found to be suitable include steel, aluminum, rigid plastic, and PVC.

6.2 *Balance*—A balance or scale accurate to 10 g [0.02 lb].

6.3 *Container*—A cylindrical container typically made of plastic having a volume of at least 20 L [5 gal], and from which water may be easily poured at a controlled rate into the infiltration ring.

6.4 *Stop Watch*—Accurate to 0.1 s.

6.5 *Plumbers Putty (Non-Hardening)*—Meeting Specification C 920 or Federal Specification A-A-3110.

6.6 *Water*—Potable water.

7. Test Locations

7.1 Perform tests at multiple locations at a site as requested by the purchaser of testing services. Unless otherwise specified, use the following to determine the number of tests to perform:

7.1.1 Three test locations for areas up to 2,500 m^2 [25,000 ft^2].

7.1.2 Add one test location for each additional 1,000 m^2 [10,000 ft^2] or fraction thereof.

7.2 Provide at least 1 m [3 ft] clear distance between test locations, unless at least 24 h have elapsed between tests.

7.3 Do not test if there is standing water on top of the pervious concrete. Do not test within 24 h of the last precipitation.

8. Procedure

8.1 *Infiltration Ring Installation*—Clean the pavement surface by only brooming off trash, debris, and other non-seated material. Apply plumbers putty around the bottom edge of the ring and place the ring onto the pervious concrete surface being tested. Press the putty into the surface and around the bottom edge of the ring to create a watertight seal. Place additional putty as needed

NOTE 2—In a hot environment where the surface temperature is over 38 °C [100 °F] plumbers putty may not adhere to the concrete surface easily. Therefore it is advisable to perform this test during cooler temperature.

8.2 *Prewetting*—Pour water into the ring at a rate sufficient to maintain a head between the two marked lines. Use a total of 3.60 ± 0.05 kg [8.0 ± 0.1 lb] of water. Begin timing as soon as the water impacts the pervious concrete surface. Stop timing when free water is no longer present on the pervious surface. Record the amount of elapsed time to the nearest 0.1 s.

8.3 *Test*—The test shall be started within 2 min after the completion of the prewetting. If the elapsed time in the prewetting stage is less than 30 s, then use a total of 18.00 ± 0.05 kg [40.00 ± 0.1 lb] of water. If the elapsed time in the prewetting stage is greater than or equal to 30 s, then use a total of 3.60 ± 0.05 kg [8.0 ± 0.1 lb] of water. Record the weight of water to the nearest 10 g [0.02 lb] (M). Pour the water into the ring at a rate sufficient to maintain a head between the two marked lines and until the measured amount of water has been used. Begin timing as soon as the water impacts the pervious concrete surface. Stop timing when free water is no longer present on the pervious surface. Record the testing duration (t) to the nearest 0.1 s.

NOTE 3—If a sloped pavement is being measured, maintain head between the two marked lines at the lowest point of the slope.

8.4 If a test is repeated at the same location, the repeat test does not require pre-wetting if conducted within 5 min after completion of the first test. If more than one test is conducted at a location on a given day, the infiltration rate at that location on that day shall be calculated as the average of the two tests. Do not repeat this test more than twice at the same location on a given day.

9. Calculation

9.1 Calculate the infiltration rate (I) using consistent units as follows:

$$I = \frac{KM}{(D^2 * t)}$$

where:

I = Infiltration rate, mm/h [in./h],
M = Mass of infiltrated water, kg [lb],
D = Inside diameter of infiltration ring, mm [in.],
t = time required for measured amount of water to infiltrate the concrete, s, and
K = 4 583 666 000 in SI units or 126 870 in [inch-pound] units.

NOTE 4—The factor K has units of $(mm^3 s)/(kgh)$ $[(in.^3 s)/(lbh)]$ and is needed to convert the recorded data (W, D, and t) to the infiltration rate I in mm/h [in./h].

10. Report

10.1 Report the following information:

10.1.1 Identification number,

10.1.2 Location,

10.1.3 Date of test,

10.1.4 Age and thickness of concrete (label Unknown if not known),

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10.1.5 Time elapsed during prewetting, s,
10.1.6 Amount of rain during last event, if known, mm [in.],
10.1.7 Weight of infiltrated water, kg [lb],
10.1.8 Inside diameter of infiltration ring, mm [in.],
10.1.9 Time elapsed during infiltration test, s,
10.1.10 Infiltration rate, mm/h [in./h], and
10.1.11 Number of tests performed at each location, if applicable.

11. Precision and Bias

11.1 Repeatability testing was performed by a single laboratory by making 2 replicate measurements at three locations on a newly placed pervious concrete pavement. The replicate measurements were repeated daily from day 1 to day 10. The single-operator coefficient of variation of the infiltration rate at one test location was found to be 4.7 %.

11.2 The multi-operator variability data has not been developed. The reproducibility of this test method is being determined and will be available on or before October 1, 2014.

11.3 This test method has no bias because the infiltration rate of in-place pervious concrete is defined only in terms of this test method.

12. Keywords

12.1 concrete; infiltration; pervious; water

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Designation: C1702 – 09a

Standard Test Method for Measurement of Heat of Hydration of Hydraulic Cementitious Materials Using Isothermal Conduction Calorimetry[1]

This standard is issued under the fixed designation C1702; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope*

1.1 This test method specifies the apparatus and procedure for determining total heat of hydration of hydraulic cementitious materials at test ages up to 7 days by isothermal conduction calorimetry.

1.2 This test method also outputs data on rate of heat of hydration versus time that is useful for other analytical purposes, as covered in Practice C1679.

1.3 The values stated in SI units are to be regarded as standard. No other units of measurement are included in this standard.

1.4 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

2. Referenced Documents

2.1 *ASTM Standards:*[2]

C186 Test Method for Heat of Hydration of Hydraulic Cement

C670 Practice for Preparing Precision and Bias Statements for Test Methods for Construction Materials

C1679 Practice for Measuring Hydration Kinetics of Hydraulic Cementitious Mixtures Using Isothermal Calorimetry

3. Terminology

3.1 *Definitions of Terms Specific to This Standard:*

3.1.1 *baseline*, *n*—the time-series signal from the calorimeter when measuring output from a sample of approximately the same mass and thermal properties as a cement sample, but which is not generating or consuming heat.

3.1.2 *heat*, *n*—the time integral of thermal power measured in joules (J).

3.1.3 *isothermal conduction calorimeter*, *n*—a calorimeter that measures heat flow from a sample maintained at a constant temperature by intimate thermal contact with a constant temperature heat sink.

3.1.4 *reference cell*, *n*—a heat-flow measuring cell that is dedicated to measuring power from a sample that is generating no heat.

3.1.4.1 *Discussion*—The purpose of the reference cell is to correct for baseline drift and other systematic errors that can occur in heat-flow measuring equipment.

3.1.5 *sensitivity*, *n*—the minimum change in thermal power reliably detectable by an isothermal calorimeter.

3.1.5.1 *Discussion*—For this application, sensitivity is taken as ten times the random noise (standard deviation) in the baseline signal.

3.1.6 *thermal power*, *n*—the heat production rate measured in joules per second (J/s).

3.1.6.1 *Discussion*—This is the property measured by the calorimeter. The thermal power unit of measure is J/s, which is equivalent to the watt. The watt is also a common unit of measure used to represent thermal power.

4. Summary of Test Method

4.1 *Principle*—An isothermal heat conduction calorimeter consists of a constant-temperature heat sink to which two heat-flow sensors and sample holders are attached in a manner resulting in good thermal conductivity. One heat-flow sensor and sample holder contains the sample of interest. The other heat-flow sensor is a reference cell containing a blank sample that evolves no heat. The heat of hydration released by the reacting cementitious sample flows across the sensor and into the heat sink. The output from the calorimeter is the difference in heat flow (thermal power) between the sample cell and the reference cell. The heat-flow sensor actually senses a small temperature gradient that develops across the device, however the heat is removed from the hydrating sample fast enough

[1] This test method is under the jurisdiction of ASTM Committee C01 on Cement and is the direct responsibility of Subcommittee C01.26 on Heat of Hydration.

Current edition approved Dec. 1, 2009. Published January 2010. Originally approved in 2009. Last previous edition approved in 2009 as C1702–09. DOI: 10.1520/C1702-09a.

[2] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

***A Summary of Changes section appears at the end of this standard.**

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that, for practical purposes, the sample remains at a constant temperature (isothermal).

4.2 The output from the heat-flow sensor is an electrical voltage signal that is proportional to the thermal power from the sample. This output must be calibrated to a known thermal power. In this method this is accomplished by measurements on a heat source that emits a constant and known power level. The integral of the thermal power over the time of the test is the heat of hydration.

4.3 Two methods are described. In Method A the sample and water are both temperature equilibrated and mixed inside the calorimeter. This method is the most direct way to determine heat of hydration. In Method B the sample is mixed outside of the calorimeter then put into the calorimeter. This method offers certain practicality, but depending on the materials being analyzed and procedures used for mixing and handling, this method may suffer from small errors due to periods of hydration being missed or spurious heat being introduced or taken away from the calorimeter during setup or combinations thereof. Methods of correction are offered for these potential errors.

5. Significance and Use

5.1 This method is suitable for determining the total heat of hydration of hydraulic cement at constant temperature at ages up to 7 days to confirm specification compliance. It gives test results equivalent to Test Method C186 up to 7 days of age (Poole (2007) (**4**)).

5.2 This method compliments Practice C1679 by providing details of calorimeter equipment, calibration, and operation. Practice C1679 emphasizes interpretation significant events in cement hydration by analysis of time dependent patterns of heat flow, but does not provide the level of detail necessary to give precision test results at specific test ages required for specification compliance.

6. Apparatus

6.1 *Miscellaneous Equipment*:

6.1.1 *Balance*—Accurate to 0.01 g.

6.1.2 *Volumetric Dispenser*—A device for measuring volume or mass of water, accurate to 0.1 mL. This could be a syringe, pipette, or weighing device.

6.1.3 *Sample Holder*—A device that holds the cement paste and provides intimate contact with the calorimeter heat sensing device and prevents evaporation of mixing water. If using commercially manufactured equipment, consult the recommendations of the manufacturer in choosing sample holders.

6.1.4 *Resistance Heater*—An electrical device fabricated from material with similar heat capacity and shape as the test sample, but containing a resistor connected to a constant-voltage power supply such that a stable output of 0.010 ± 0.0002 J/s can be generated (see Note 1).

NOTE 1—A simple procedure for fabricating heaters and blanks having the same approximate shape and heat capacity as a sample is to make specimen similar to one used in a determination out of plaster of Paris embedded with a small resistor. Plaster of Paris has only a transient heat of hydration and is not aggressive to electronic components. A resistance of 100-300 ohms is a convenient value when using voltages of 0.1-10 volts to drive heat production.

6.1.5 *Reference Specimen*—A sample fabricated from an inert material with similar heat capacity and shape as the test sample. This is used in the reference cell.

6.1.6 *Multimeter*—An instrument for measuring DC voltage and resistance values for the resistance heater described in 6.1.4 to an accuracy of 1 %. This instrument is only required if the calorimeter does not contain built-in calibration capability.

6.1.7 *Power Supply*—A constant voltage DC power supply with a power output range sufficient to simulate the maximum output of a hydrating cement sample (see Note 2). This equipment is only required if an instrument does not contain built-in calibration capability.

NOTE 2—A power output of at least 0.33 J/s is needed for most applications.

6.1.8 *Insulated Container*—Used in the Method B described in 8.3.5.1. This device can be fabricated using a 500 mL (approximate volume) container insulated with at least 30 mm of polystyrene on the sides and top.

6.1.9 *Temperature Measuring Device*—Used in Method B described in 8.3.5.1. The device shall be capable of measuring temperature changes to the nearest 0.1 °C and of a physical configuration that allows it to operate in the confines of the insulated container described in 6.1.8.

6.2 *Calorimeter*—The schematic design of a calorimeter is given in Fig. 1. It shall consist of a sample holder for the test and reference specimens, each thermally connected to heat flow sensors, which are thermally connected to a constant-temperature heat sink. The actual design of an individual

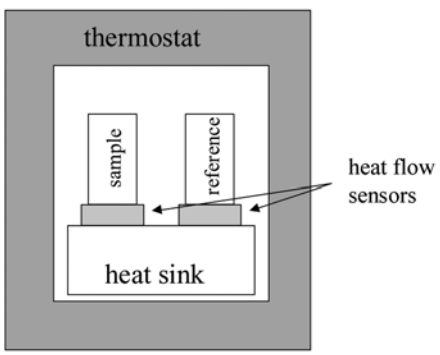

FIG. 1 Schematic Drawing of a Heat Conduction Calorimeter

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instrument, whether commercial or homemade, may vary, but it should follow the criteria given below. Any other suitable arrangement that satisfies sections 6.2.1, 6.2.2, and 6.2.3 is acceptable.

6.2.1 *Instrument Stability*—The baseline shall exhibit a low random noise level and be stable against drift. This property shall be verified on a new instrument and whenever there are questions about performance. The rate of change of the baseline measured during a time period of 3 days shall be ≤20 μJ/s per gram sample per hour of the test and a baseline random noise level of ≤10 μJ/s per gram sample (see Note 3). In practice the baseline is measured for 3 days and a straight line is fitted to the power (J/g/s) versus time (h) data using a linear regression procedure. The long term drift is then the slope in the line J/g/s/h and the baseline noise level is the standard deviation (J/g/s) around this regression line.

NOTE 3—The rationale for these limits is found in Poole (2007) (**4**).

6.2.2 *Instrument Sensitivity*—The minimum sensitivity for measuring power output shall be 100 μJ/s.

6.2.3 *Isothermal Conditions*—The instrument shall maintain the temperature of the sample to within 1 K of the thermostated temperature.

6.3 *Data Acquisition Equipment*—Data acquisition equipment may be built into the calorimeter instrument package, or it may be an off-the-shelf, stand-alone, item. The data acquisition equipment shall be capable of performing continuous logging of the calorimeter output measurement at a minimum time interval of 10 s. It is useful, for purposes of reducing amount of data, to have the flexibility to adjust the reading interval to longer times when power output from the sample is low. Some data acquisition equipment is designed to automatically adjust reading intervals in response to power output. The equipment shall have at least 4.5-digit-measuring capability, with an accuracy of 1 %, or comparable capabilities to condition the power output into the same quality as integrated signal amplifiers.

7. Instrument Calibration

7.1 *Instrument Calibration*—Commercially manufactured instruments designed for measuring heat of hydration of cementitious materials may have instrument specific calibration procedures. Conform to these procedures if they exist. In addition, the instrument shall be capable of providing data described in 7.1.1.1, 7.1.2.1, and 7.1.2.2, and calculations in 7.1.4. If there are no instrument calibration procedures, calibrate the instrument according to the following procedure. Calibration shall be at least a two-point process. This is illustrated schematically in Fig. 2.

7.1.1 Mount the resistance heater and the blank specimen in their respective measuring cells and start data collection. This step measures the baseline calorimeter output (in units of V or mV) when no heat is being generated.

7.1.1.1 Measure this baseline when it reaches a constant value (drift ≤ 20 μJ/s per gram sample per hour).

7.1.1.2 Record this output as V_0 for $P_0 = 0$ (see Note 4).

NOTE 4—V_0 may not be zero voltage, but may be a positive or negative number. The practice of using a test cell and a reference cell usually results in the V_0 being a relatively small number but, depending on the variability in properties of some hardware, it may not be zero.

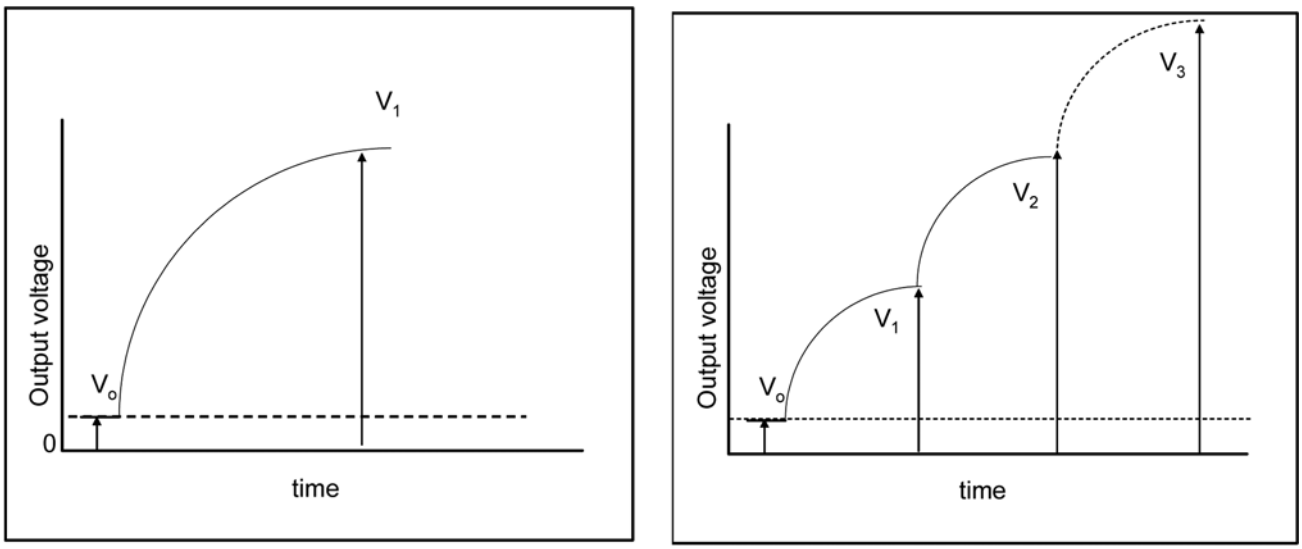

FIG. 2 (A) Schematic Steady-State Calibration Using A 2-Point Calibration Process And (B) Multi-Point Calibration Process

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7.1.2 Power in the heater circuit is related to voltage and resistance by the following equation:

$$P = I^2R \quad (1)$$

where:
P = power, J/s,
I = applied current, amperes, and
R = resistance, ohms.

Apply sufficient voltage to the heater circuit to generate a heat output of approximately 0.1 J/s, measured to an accuracy of 5 %.

7.1.2.1 Allow the output to stabilize signal at a drift of ≤0.1 % over 60 min or ≤0.05 % over 30 min.

7.1.2.2 Record this output as V_1 for a power P_1(see Note 5). This is the minimum requirement for a calibration sequence. At the users discretion any number of voltage levels may be used to characterize the operating range of the calorimeter.

NOTE 5—The early C_3A reaction of a typical portland cement evolves a maximum power of about 0.02 J/s/g. The alite phase typically evolves heat at a maximum power of about 0.002 J/s/g during the first 24 h of hydration. A5 g sample then generates power peaks in the range of 0.10 J/s/g in the first few minutes after adding water, and in the range of 0.010 J/s/g in the first 24 h.

7.1.3 *Calibration Coefficients*—Calculate calibration coefficients by fitting the power versus voltage output data to a to a mathematical relationship using standard curve fitting techniques. Power (P), in units of J/s (or watts), is the dependent variable (y) in the calibration equation, and output voltage (V), in units of mV, is the independent variable (x). This equation is then used to translate mV output to power units meaningful for calculating heat flow (see Note 6).

NOTE 6—A linear calibration equation is found to be suitable in many instruments over the operating range necessary to analyze portland cements, as in the following equation: P = A + BV. In this case, the fitted coefficients A (y-axis intercept) and B (slope) are in units of J/s and J/s/mV, respectively.

7.1.4 In a multi-channel instrument containing several calorimeters, all channels shall be calibrated individually. However, it is possible to calibrate all calorimeters simultaneously using multiple resistance heaters and having the same current passing through the heaters in all calorimeter cells.

7.1.5 Calibration shall be executed at regular intervals to determine the calibration coefficient. The length of the time intervals between calibrations is dependent on the instrument and the personnel, and must be determined empirically. If the calibration coefficient differs more than 2 % from one calibration to the next, then calibrations intervals must be reduced until this stability limit is reached.

8. Procedure

8.1 Turn on the calorimeter equipment and data acquisition unit. Determine that the calorimeter is at temperature equilibrium by verifying that the baseline is stable over a period of a few minutes. The temperature of the heat sink during the test shall be 23.0 ± 1.0 °C, unless a different temperature is required by the analysis.

8.2 *Method A*—This method is used when an instrument is configured so that cementitious materials and water can be temperature equilibrated and mixed while in place in the calorimeter cell.

8.2.1 Weigh at least 3 g of cementitious material (see Note 7), the mass recorded to the nearest 0.01 g, and place in the calorimeter cell. Weigh or determine volumetrically sufficient water to give a paste water-cementitious materials ratio of at least 0.40, but in any case sufficient water to completely wet the sample, and place the water holder in the cell. Higher water-cementitious materials ratios may be required to get thorough mixing of cement and water (see Note 8). Allow any change in the calorimeter output caused by this process to return to the baseline level.

NOTE 7—Amount of sample required varies among calorimeter designs. Since the exothermic reaction tends to slow down after the first 24 h, a sample that is too small will generate a signal late in the test period that is too weak to detect reliably. If inconsistent results are obtained, then a larger sample size may be required. Sample sizes between about 3 and 15 g have been reported to be useful for maintaining a strong signal late in the test for portland-cement based cements. Normally a signal of at least 10 μJ/s/g at the end of the test is sufficient to give good results. Tests designed to run for 1-3 days can use a sample mass at the smaller end of this range, while longer tests, such as 7 days, require a sample mass at the larger end of this range.

NOTE 8—The w/c required for good mixing will probably have to be determined empirically by examining specimens after completion of testing for evidence of poor mixing.

8.2.2 Start data collection, then mix the water with the cementitious materials to form a uniform paste. Some commercial calorimeters and data acquisition equipment are programmable to collect data at prescribed interval lengths or at intervals that vary with the rate of change of power levels. Data are collected more rapidly when power output is high than when it is low. If this flexibility is not a feature of the data acquisition component of the calorimeter, then collect readings every 30 s throughout the length of the test (see Note 9).

NOTE 9—It is only necessary to collect data every 10 s through the period of an early and short-lived heat evolution peaks. In portland cements this is over within approximately 30 min. Data collection every 10 min is adequate after this point. Adopting this practice will reduce the size of data files.

8.3 *Method B*—This method is used when cement paste is mixed outside of the calorimeter and then loaded into the calorimeter cell. In this procedure, a small amount of the early heat-of hydration data may be lost. For non-portland-based cements, the error could be more significant. Also, the baseline may also be disturbed during the early period of the test due to spurious heat gains to the sample or losses from the sample while outside of the calorimeter, e.g. during mixing and handling. Procedures for correcting these errors are included in paragraphs 8.3.5.1 and 8.3.5.2, respectively.

8.3.1 *Conditioning Materials*—All materials shall be at a temperature of 23 ± 2 °C before mixing unless a different temperature condition is required for the analysis.

8.3.2 *Mixing and Charging of Cement Paste*—The mixing of the cement paste shall be made in such a way that the time between the addition of water and the time when the sample is put into the calorimeter is less than 5 min. Mix sufficient

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cement paste at a water-cementitious materials ratio of 0.40 or higher to give a sample containing a mass of dry cement in the range described in Method A. Determine the mass of the paste sample to the nearest 0.01 g, put it into the calorimeter sample holder, and cover to prevent evaporation of mixing water.

8.3.3 Care should be taken that the incidental warming or cooling of the sample and the sample holder due to handling are minimal. Although the method provides a correction for such temperature effects, it is not designed to handle large temperature differences between the sample and the calorimeter (see Note 10).

NOTE 10—Use of insulating cotton gloves may be helpful in minimizing heating of the sample from handling.

8.3.4 Load the sample and sample container into the calorimeter. Start data collection 10 min after adding water to cement during mixing, and collect data as described in 8.2.2.

8.3.5 *Error Corrections for Method B*—Two corrections may be needed for Method B. One is a correction for early hydration data lost during the first 10 min, while mixing, handling, and equilibrating the sample in the calorimeter (8.3.5.1). The other is a correction for heat gained or lost from or to the environment during mixing and handling before the sample is put into the calorimeter (8.3.5.2).

8.3.5.1 *Correction for Early Hydration*—Equilibrate a 500 g sample of cement, 250 mL of water, and the polystyrene insulated container described in 6.1.8 to 23 ± 1 °C. Record the starting temperature. Place the cement and water in a plastic bag and mix quickly by kneading the bag. Place the bag in the polystyrene insulated container as soon as mixing is complete along with a thermocouple. Cover and measure temperature at 10 min after adding water to the cement. Record the temperature rise to the nearest 0.1 °C. The calculation of the heat-of-hydration during this 10 min period is described in 9.2.1.

8.3.5.2 *Correct for Temperature Change Due to Mixing and Handling*—A determination of the heat increase or decrease in the sample during mixing and handling of the sample is determined by mixing an inert sample with water, using the same mass of materials and the same procedure as in a heat of hydration determination, then introducing equivalent mass of paste used in a determination into a calorimeter cell that has been running at baseline. Collect data at 10 s intervals, as in a normal determination, until the signal has returned to the baseline. The calculation of the heat is described in paragraph 9.2.2.

9. Calculation

9.1 *Method A*—For Method A, the total heat of hydration, Q_t, is the integrated value of the power versus time data, collected as described in 8.2 without further correction.

9.1.1 *Remove Leading Edge Data*—For both Methods A and B, there may be data collected during instrument setup and thermal equilibration that is not pertinent to the final determination. These data shall be removed.

9.1.2 Many data acquisition units and commercial calorimeters incorporate the calibration equation into the software and present the raw output data in units of J/g of cement. If this is not the case, then the output data will be in units of mV, and must be transformed into thermal power using the calibration coefficients determined from Eq 2.

$$P_n = A + BV_n \tag{2}$$

where:

P_n = power input level used in the instrument calibration, and

V_n = voltage output level used in the instrument calibration.

9.1.3 *Calculation of Q_t*—The total heat of hydration of the sample, Q_t, is calculated by integrating the power/g versus time data over the time interval of the test (t_0 to t_e, in units of seconds) as in Eq 3:

$$Q_t = \int_{t=t_0}^{t_e} P dt \tag{3}$$

where:

t_0 = the time the cement and water are mixed, taken as zero (in Method A), and

t_e = the end of the test.

t_0 will be different for Method A and Method B.

9.1.4 Operationally, the integration is executed by averaging the power output from two consecutive readings and multiplying by the time interval of the reading, giving an output for each time increment in units of J/g. The heat so calculated in each time increment is then summed over the duration of the test, as in Eq 4.

$$Q_t = \sum_{t=t_0}^{t_e} \left(\frac{P(t_i) - P(t_{i+1})}{2} \right) \times (t_{i+1} - t_i) \tag{4}$$

where:

$P(t_i)$ = the power output at time t_i, and

$P(t_{i+1})$ = the power output at the next time interval (t_{i+1}).

In Method A, t_0 is taken as zero when water is added to the cement.

9.2 *Method B*—The total heat evolved during the calorimeter run, Q_t is calculated as in Eq 3 and 4, but t_0 is the 600 s (10 min). Q_t must be corrected for heat evolved prior to introduction of the sample into the calorimeter, denoted as Q_2, and for any heat gained or lost during sample mixing and handling, denoted as Q_3. The total heat, Q_t' is then calculated from Eq 5.

$$Q_t' = Q_t + Q_2 + Q_3 \tag{5}$$

9.2.1 *Determine Q_2*—From the temperature rise and sample composition data in 8.3.5.1, calculate the heat evolved during the first 10 min of hydration using Eq 6.

$$Q_2 = \frac{\Delta T(F_c \times C_c + (1-F_c) \times C_w)}{F_c} \tag{6}$$

where:

ΔT = the temperature rise during the test described in 8.3.4,

F_c = the mass fraction of the cement in the paste,

C_c = the heat capacity of dry cement (nominally 0.75 kJ/kg/K), and

C_w = the heat capacity of water (nominally 4.18 kJ/kg/K).

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9.2.2 *Determine* Q_3—Q_3 is calculated from the data collected according to paragraph 8.3.5.2, and using Eq 2 and 3. The initial time (t_0) will be taken as zero when the sample is first put into the calorimeter, and t_e will be the time when the signal returns to the baseline.

10. Report

10.1 *Test Report*—Report the following information:

10.1.1 Cement sample identification.

10.1.2 Date and time when the test was performed.

10.1.3 Instrument used.

10.1.4 The mass of dry cement in sample.

10.1.5 The name of the data file.

10.1.6 Date of the calibration used.

10.1.7 A figure showing the resulting thermal power curve.

10.1.8 Calculated heat of hydration and the method (A or B) used.

11. Precision and Bias

11.1 *Precision*—A complete interlaboratory study has not been completed for this test method. Therefore the precision of the method has not been determined (Note 11).

NOTE 11—Two sources of published data give indications of the potential precision of the method. Data from Wadso and Arndt (**1**,**2**,**3**) were derived using methods that appeared to most closely resemble Method B in this test method. The program included 18 laboratories, each of which analyzed 2 cements. No within-laboratory repeatability data were reported. From these data, a between-laboratory standard deviation of 10.5 kJ/kg at 3 days was calculated. Two laboratories should be expected to differ by no more than 29 kJ/kg in 95 % of such paired laboratory comparisons. This is the d2s value as described in Practice C670.

The VDZ (2006) (**5**) round robin included 20 laboratories each conducting analysis on 5 cements. Tests are believed to be 7-day results. Analogs to Methods A and B of this test method were represented, but the precision data were not separated according to this classification. A within-laboratory standard deviation of 4.6 kJ/kg was reported (d2s = 12.9 kJ/kg). A between-laboratory standard deviation of 13.6 was reported (d2s = 35.3 kJ/kg).

11.2 *Bias*—Bias cannot be determined because there is no standard material having an accepted reference value (Note 12).

NOTE 12—Bias relative to solution calorimetry, as in Test Method C186 is of interest. Poole (2007) (**4**) compared heat of hydration determinations by solution calorimetry and conduction calorimetry among laboratories and found no consistent bias between the two methods.

12. Keywords

12.1 heat of hydration; hydraulic cement; isothermal conduction calorimetry; portland cement

REFERENCES

(**1**) Wadso L, Goldberg RN, Standards in Isothermal Microcalorimetry (IUPAC Technical Report), *Pure Appl Chem 73*, pp.1625-39, 2001.

(**2**) Wadso L, Temperature Changes within Samples in Heat Conduction Calorimeters, *Thermochim. Acta 366*, pp. 121-7, 2000

(**3**) Wadso L. and Markus Arndt, "An International Round Robin Test of Isothermal Conduction Calorimetry for Measurement of 3 Days Hydration." This is an internet posting: http://epena.u-bourgogne.fr/nanocem-calorimetry-group/literature-on-isothermal-cement calorimetry/recent-round-robin-studies.

(**4**) Poole, Toy S, Revision of Test Methods and Specifications for Controlling Heat of Hydration in Hydraulic-Cement, *PCA R&D Serial No. 3007*, Portland Cement Association, Skokie, IL, 2007.

(**5**) VDZ, "Round Robin Heat of Hydration 2006," Research Institute of the German Cement Industry, Cement Chemistry Department, Dusseldorf, Germany, 2006.

SUMMARY OF CHANGES

Committee C09 has identified the location of selected changes to this test method since the last issue, C1702–09, that may impact the use of this test method. (Approved December 1, 2009)

(*1*) Revised Section 11.

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Designation: C 1707 – 09

Standard Specification for Specification for Pozzolanic Hydraulic Lime for Structural Purposes [1]

This standard is issued under the fixed designation C 1707; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope

1.1 This standard covers four types of pozzolanic hydraulic lime for structural purposes which include use in mortar, scratch, brown, and finish (stucco) coats of interior or exterior plaster.

1.1.1 *PHL*—Pozzolanic hydraulic lime for use in mortar, scratch, brown, and finish (stucco) coats of interior or exterior plaster.

1.1.2 PHL_c—PHL with a maximum 20 % binder weight of hydraulic cement.

1.1.3 *PHL-A*—Air-entrained PHL.

1.1.4 PHL_c-*A*—Air-entrained PHL_c.

1.2 This specification classifies pozzolanic hydraulic lime by minimum hydrated lime content, maximum hydraulic cement content, and specific performance requirements.

1.3 The values stated in inch-pound units are to be regarded as standard. The values given in parentheses are mathematical conversions to SI units that are provided for information only and are not considered standard. Appropriate conversion can be done using IEEE/ASTM SI 10.

1.4 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

2. Referenced Documents

2.1 *ASTM Standards:*[2]

C 25 Test Methods for Chemical Analysis of Limestone, Quicklime, and Hydrated Lime

C 50 Practice for Sampling, Sample Preparation, Packaging, and Marking of Lime and Limestone Products

C 51 Terminology Relating to Lime and Limestone (as used by the Industry)

C 109/C 109M Test Method for Compressive Strength of Hydraulic Cement Mortars (Using 2-in. or [50-mm] Cube Specimens)

C 110 Test Methods for Physical Testing of Quicklime, Hydrated Lime, and Limestone

C 114 Test Methods for Chemical Analysis of Hydraulic Cement

C 150 Specification for Portland Cement

C 207 Specification for Hydrated Lime for Masonry Purposes

C 266 Test Method for Time of Setting of Hydraulic-Cement Paste by Gillmore Needles

C 270 Specification for Mortar for Unit Masonry

C 305 Practice for Mechanical Mixing of Hydraulic Cement Pastes and Mortars of Plastic Consistency

C 511 Specification for Mixing Rooms, Moist Cabinets, Moist Rooms, and Water Storage Tanks Used in the Testing of Hydraulic Cements and Concretes

C 595 Specification for Blended Hydraulic Cements

C 778 Specification for Standard Sand

C 1157 Performance Specification for Hydraulic Cement

IEEE/ASTM SI 10 Standard for use of the International System of Units (SI): (the Modern Metric System)

3. Terminology

3.1 *Definitions:*

3.1.1 Unless otherwise specified, for definitions of terms used in this standard see Terminology C 51.

3.1.2 *air entraining pozzolanic hydraulic lime (PHL-A), n*—as PHL with the exception that Type SA hydrated lime of Specification C 207, or Type NA of Specification C 207 shall

[1] This test method is under the jurisdiction of ASTM Committee C07 on Lime and is the direct responsibility of Subcommittee C07.02 on Specifications and Guidelines.

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[2] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

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be used if shown not detrimental to the soundness of the material. If Type SA or Type NA hydrated limes are used, an additional air entraining agent shall not be used.

3.1.3 *air entraining pozzolanic hydraulic lime with hydraulic cement (PHL$_c$-A), n*—as PHL$_c$ with exception that Type SA hydrated lime of Specification C 207 shall be used, or Type NA of Specification C 207 shall be used if shown not detrimental to the soundness of the material. If Type SA or Type NA hydrated limes are used, an additional air entraining agent shall not be used.

3.1.4 *pozzolanic hydraulic lime (PHL), n*—a powder produced by the blending or intergrinding of not less than 25 % by binder weight of Specification C 207 Type S hydrated lime with one or more pozzolan and inert filler. Type N hydrated lime of Specification C 207 shall be used if shown not detrimental to the soundness of the material.

3.1.5 *pozzolanic hydraulic lime with hydraulic cement (PHL$_c$), n*—as PHL with not more than 20 % by binder weight of hydraulic cement of Specification C 150, Specification C 595, or Performance Specification C 1157 blended or interground.

4. Requirements

4.1 PHL, PHL$_c$ PHL-A and PHL$_c$-A shall conform to the requirements prescribed in Table 1.

5. Test Methods

5.1 *Water Soluble Alkali*—Water soluble alkali shall be tested according to the procedure in Test Methods C 114, Section 17.2.

5.2 *SO_3*—Sulfur trioxide content shall be tested according to the procedure of Test Methods C 25, Section 23.

5.3 *CO_2*—Carbon dioxide content shall be tested according to the procedure of Test Methods C 25, Section 22.

5.4 *Fineness*—Fineness shall be tested according to the wet sieve method of Test Methods C 110, Section 5.

5.5 *Time of Set*—Determine the time of initial and final set according to Test Method C 266, the Gilmore needle procedure, with the following changes:

5.5.1 Determine the first penetration value after 1 h of rest, and every 4 ± 2 h after that.

5.6 *Autoclave Expansion*—Autoclave Expansion shall be measured using the method described in Test Methods C 110, Section 9.3, with the following modification:

TABLE 1 Standard Requirements

Properties	PHL, PHL$_c$	PHL-A, PHL$_c$-A
water soluble alkali, max %	0.2	0.2
SO_3, max %	3.0	3.0
CO_2, max % (as produced basis)	16.0	16.0
Fineness		
retained on 30 mesh sieve, max %	<0.5	<0.5
retained on 200 mesh sieve, max %	<15	<15
Time of initial set, max h	24	24
Time of final set, max h	48	48
Autoclave expansion, max %	0.80	0.80
Air content		
max %	7.0	12.0
min %		>7.0
Water retention, min %	70	70
Compressive strength min, N/m^2(psi), 28 days	>2.4 (>350)	>2.4 (>350)

5.6.1 Weigh 25 ± 0.1 g of one of four types of PHL. Add 3.0 ± 1.0 ml water to the weighed sample and mix by hand until wetted. If the balance allows it, work directly in the specimen mold. If this is not possible, work in an intermediate container and transfer the mixture to the specimen mold in as complete a state as possible. Press to 5.0 ± 1.5 N/m^2 (725 ± 218 psi) for 10 s and demold the specimen and autoclave as described.

5.7 *Preparation of Mortar*—Mortar, plasters and grout are specified by volume proportion of the binder materials to the aggregate in a ratio of 1 volume part binder to 3 volume part aggregate or sand. Laboratory mixed mortars used for air entrainment, water retention and compressive strength testing for this specification shall be measured by weight by converting proportions by volume to proportion by weight.

NOTE 1—Appendix X4 of Specification C 270 provides examples of calculating material proportioning.

$$\textit{Batch factor} = \frac{1440}{(80 \times 3\ (\textit{sand volume proportion}))} = 6 \qquad (1)$$

Determine weight one of the four PHL as follows:

$$\textit{Weight of PHL}\ (g) = 1(\textit{PHL Volume Proportion}) \times \textit{Bulk Density}\ (\textit{Packed Density})\ \textit{of PHL} \times \textit{Batch Factor} \qquad (2)$$

Bulk density of PHL will vary and shall be provided by the manufacturer or determined according to Test Methods C 110 Section 20.

Sand will be a 50-50 blend of graded and 20-30 standard sand meeting Specification C 778.

5.8 *Air Content*—Air content shall be measured according to the procedure of:

5.8.1 Test Methods C 110, Section 8. W_1, W_2, S_1, and S_2 are dropped from the equation to be replaced by W_4 (weight of one of four PHL, g) and S_4 (specific gravity of one of four PHL). The specific gravity of the PHL shall be provided by the manufacturer as determined by the method of Test Methods C 110, Section 21, or determined by a gas pychnometer.

NOTE 2—The specific gravity of the four PHL will vary with composition and a single value cannot be recommended.

5.8.2 Test Methods C 110, Section 8.4.3, using the air pail method.

5.9 *Water Retention*—The water retention value shall be measured following Test Methods C 110, Section 7.

5.10 *Compressive Strength*—Prepare the mortar in accordance with Practice C 305 with the exception that the binder and water are initially placed in the mixing bowl together and allowed to wet for 1½ min prior to mixing. Store the mortar in the molds for 60 ± 12 h in sealed plastic bags prior to de-molding. Determine compressive strength in accordance with Test Method C 109/C 109M. A minimum of three 2-in. cubes is required.

5.11 *Specimen Storage*—Test specimens shall be stored at not less than 95 % R.H. in a moist room or cabinet following the requirements of Specification C 511. The storage surface shall be in equilibrium with the space to ensure no moisture loss.

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6. Sampling and Inspection

6.1 The sampling, rejection, retesting, packing, and marking shall be conducted in accordance with Practice C 50.

7. Special Package Marking

7.1 When delivered in packages, the name and brand of the manufacturer, the type under this specification, and the words "AIR ENTRAINING" shall be plainly indicated on the package or in the case of bulk shipments, so indicated on shipping notices.

8. Keywords

8.1 hydrated lime; mortar; plaster grout; pozzolan; pozzolanic hydraulic lime

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Designation: C 1712 – 09

Standard Test Method for Rapid Assessment of Static Segregation Resistance of Self-Consolidating Concrete Using Penetration Test[1]

This standard is issued under the fixed designation C 1712; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope

1.1 This test method covers the rapid assessment of static segregation resistance of normal-weight self-consolidating concrete (SCC). The test does not measure static segregation resistance directly, but provides an assessment of whether static segregation is likely to occur.

1.2 The test apparatus and protocol were developed based on tests with SCC mixtures containing saturated surface dry (SSD) coarse aggregates ranging in relative density from 2.67 to 2.79 and in nominal maximum size from 9.5 mm to 25 mm. For SCC mixtures outside these ranges, testing is recommended to establish a correlation between penetration depth and static segregation measured in accordance with Test Method C1610/C1610M. This test method shall not be used to assess the static segregation resistance of self-consolidating concrete containing lightweight aggregates or heavyweight aggregates without prior testing to establish a correlation.

1.3 The values stated in SI units are to be regarded as standard. No other units of measurement are included in this standard.

1.4 The text of this standard references notes and footnotes that provide explanatory material. These notes and footnotes shall not be considered as requirements of the standard.

1.5 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.* (**Warning**—Fresh hydraulic cementitious mixtures are caustic and may cause chemical burns to skin and tissue upon prolonged exposure.[2])

2. Referenced Documents

2.1 *ASTM Standards:*[3]

C125 Terminology Relating to Concrete and Concrete Aggregates

C143/C143M Test Method for Slump of Hydraulic-Cement Concrete

C172 Practice for Sampling Freshly Mixed Concrete

C173/C173M Test Method for Air Content of Freshly Mixed Concrete by the Volumetric Method

C192/C192M Practice for Making and Curing Concrete Test Specimens in the Laboratory

C1610/C1610M Test Method for Static Segregation of Self-Consolidating Concrete Using Column Technique

C1611/C1611M Test Method for Slump Flow of Self-Consolidating Concrete

3. Terminology

3.1 *Definitions*:

3.1.1 For definitions of terms used in this test method, refer to Terminology C125.

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *static segregation resistance*, *n*—resistance of a concrete mixture to segregation of the mortar component from the coarse aggregate while the concrete is at rest and before initial setting.

4. Summary of Test Method

4.1 This test method uses a penetration apparatus (shown in Figs. 1 and 2) and an inverted slump mold (Fig. 3). A sample of freshly mixed self-consolidating concrete is placed in an inverted slump mold without tamping or vibration. The hollow cylinder attached to a metal rod is aligned in the center of the inverted slump mold as shown in Fig. 3. The hollow cylinder is then lowered onto the surface of the concrete and released to freely penetrate into the fresh concrete. The penetration depth

[1] This test method is under the jurisdiction of ASTM Committee C09 on Concrete and Concrete Aggregates and is the direct responsibility of Subcommittee C09.47 on Self-Consolidating Concrete.

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[2] Section on Safety Precautions, Manual of Aggregate and Concrete Testing, *Annual Book of ASTM Standards*, Vol. 04.02.

[3] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

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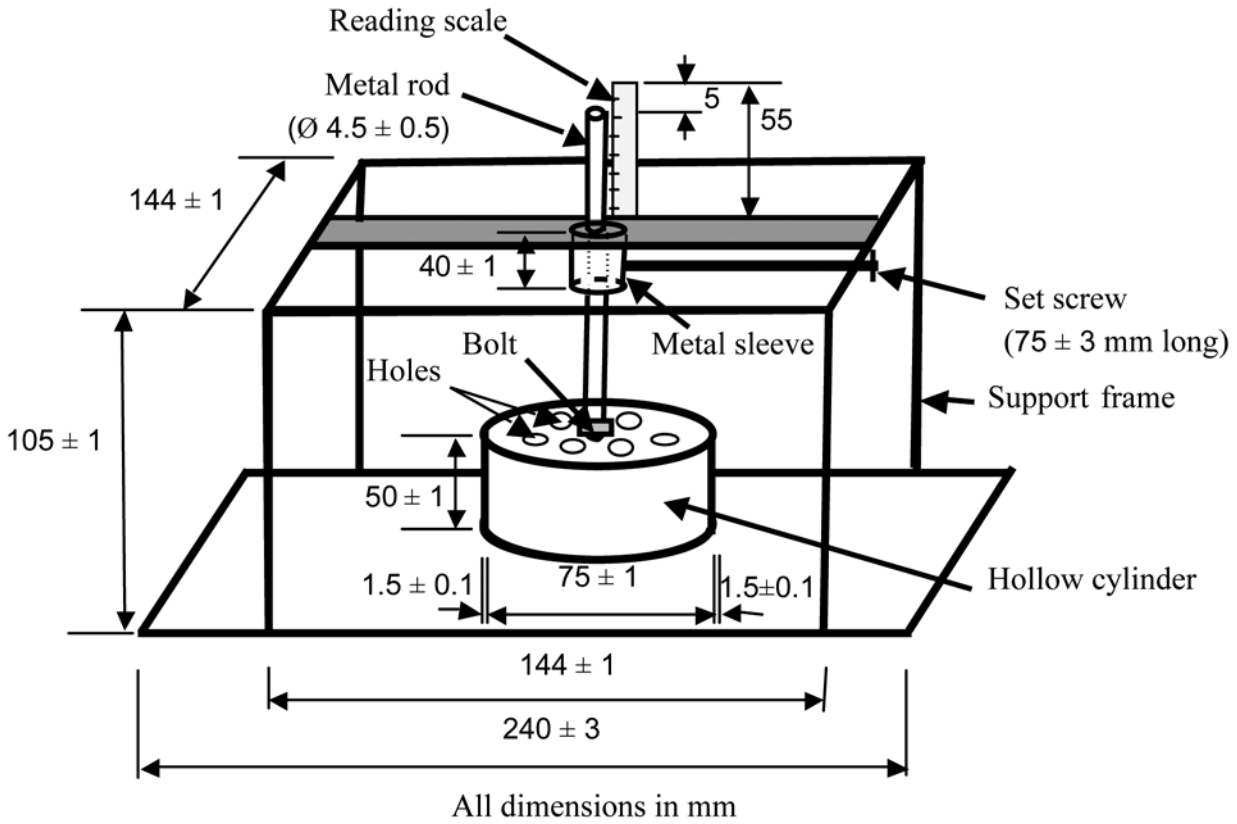

FIG. 1 Dimension of Penetration Apparatus

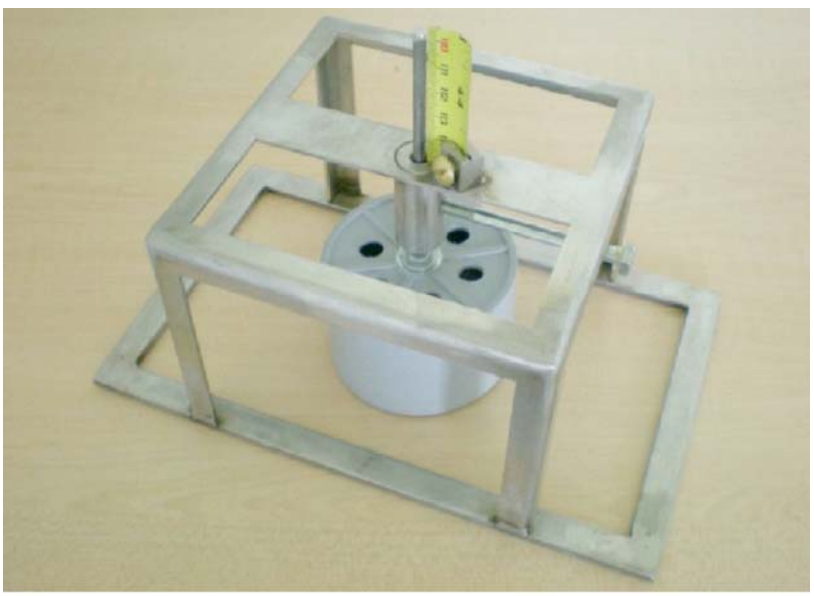

FIG. 2 Penetration Apparatus

(*Pd*) is determined and used to assess the static segregation resistance of the self-consolidating concrete mixture (**1-5**).[4]

[4] The boldface numbers in parentheses refer to a list of references at the end of this standard.

5. Significance and Use

5.1 This test method is for the rapid assessment of the static segregation resistance of self-consolidating concrete.

5.2 The method is useful for rapid assessment of the static segregation resistance of self-consolidating concrete during

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FIG. 3 Penetration Test

mixture development in the laboratory as well as prior to placement of the mixture in the field. Test Method C1610/C1610M for static segregation of SCC is not sufficiently rapid, and the non-mandatory Visual Stability Index as determined through the procedure described in Appendix X1 of Test Method C1611/C1611M is highly subjective and qualitative.

5.3 Appendix X1 provides non-mandatory criteria that may be used to indicate the degree of static segregation resistance of self-consolidating concrete mixtures.

6. Apparatus

6.1 *Mold*—The slump mold is used in this test method and shall conform to Test Method C143/C143M.

6.2 *Penetration Apparatus*—The penetration apparatus, shown in Fig. 1, consists of a support frame, a metal sleeve, a set screw, a penetration head and a reading scale. The penetration head, consisting of a non-corrosive hollow cylinder and a metal rod, has a mass of 45 ± 1 g. The rod is bolted vertically into the center of the top of the hollow cylinder and acts as a unit with the cylinder. The inner diameter, wall thickness, and height of the hollow cylinder are 75 ± 1 mm, 1.5 ± 0.1 mm, and 50 ± 1 mm, respectively. Holes are symmetrically drilled on the top surface of the hollow cylinder to allow air to escape during the penetration test. At least two holes with a minimum diameter of 6 mm must be provided (see Note 1). The reading scale shall be 55 mm long and marked in 1 mm increments. The scale is mounted on the support frame and adjacent to the metal rod, as shown in Figs. 1 and 2. With both the support frame and the hollow cylinder resting on a flat surface, the top of the metal rod shall be 5 mm below the top of the reading scale (see Note 2). The diameter of the metal rod shall be 4.5 ± 0.5 mm. The inner diameter of the metal sleeve shall be 0.7 ± 0.1 mm larger than the diameter of the metal rod to minimize friction as the rod slides.

NOTE 1—The number and size of the holes may be chosen to be greater than the minimum stated in 6.2 to achieve the required mass (45 ± 1 g) of the penetration head. The hollow cylinder shown in Fig. 2 is made of Polyvinyl Chloride (PVC) and has six holes on the top surface; each hole has a diameter of approximately 10 mm.

NOTE 2—This enables the top of the metal rod to be used as the mark for taking both the initial and final readings since it will always lie within the range of the reading scale when the surface of the concrete in the mold is properly leveled (see Section 8.5).

6.3 *Base Plate (Optional)*—As described in Test Method C1611/C1611M.

6.4 *Strike-off Bar*—As described in Test Method C173/C173M.

6.5 *Sample Receptacle*—The receptacle shall be a heavy-gauge metal pan or wheelbarrow of sufficient capacity to allow easy remixing of the entire sample with a shovel, trowel, or scoop.

6.6 *Small Tools*—Tools and items such as shovels, plastic pails, trowels, scoops, and rubber gloves shall be provided.

7. Sample

7.1 Obtain a sample of freshly mixed self-consolidating concrete in accordance with Practice C172 or Practice C192/C192M, and place it in the sample receptacle.

8. Procedure

8.1 Perform the rapid static segregation resistance test on a flat, level, nonabsorbent surface such as a pre-moistened concrete floor or base plate. Do not subject the testing surface and inverted slump mold to any vibration or disturbance.

8.2 *Conditioning the Penetration Apparatus*—Dampen the hollow cylinder, then hold the apparatus in the horizontal position and release the set screw. Spin the penetration head to

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ensure that the space between the metal sleeve and the metal rod is free of any obstruction. Tighten the screw softly to hold the rod in the sleeve.

8.3 *Setting Up the Inverted Slump Mold*—Dampen and place the slump mold, with the smaller opening facing down (inverted position), in the center of a flat base plate or moistened concrete surface.

8.4 Remixing of Sample: Remix the sample obtained in accordance with 7.1 in the sample receptacle using a shovel or scoop so that the concrete is homogeneous.

8.5 Filling the Mold: Immediately after remixing, take approximately 6 L of the concrete in a plastic pail and fill the inverted slump mold in a continuous manner. Pour the concrete mixture uniformly into the mold. Slightly overfill the concrete above the top of the inverted mold. Strike off the surface of the concrete with strike-off bar and allow the concrete to stabilize for 80 ± 5 s after finishing strike-off before measuring penetration.

8.6 *Positioning the Penetration Apparatus*—While the concrete is stabilizing, place the penetration apparatus on the top of the inverted slump mold, making sure that the hollow cylinder is aligned in the center of the inverted mold (see Fig. 3 and Note 3).

NOTE 3—Aligning the corners of the frame approximately on the circumference of the slump mold will ensure alignment of the hollow cylinder in the center of the mold.

8.7 *Measuring the Penetration Depth (Pd)*:

8.7.1 *Initial Reading*—Hold the metal rod attached to the hollow cylinder with one hand and release the set screw. Lower the hollow cylinder carefully so that it just touches the surface of the concrete. Tighten the screw and take the initial reading on the reading scale at the mark that is in line with the top of the metal rod.

8.7.2 *Final Reading*—At the end of the period over which the concrete is allowed to stabilize (80 ± 5 s after completion of strike-off), release the set screw so that the hollow cylinder freely penetrates the fresh concrete. Wait for 30 ± 2 s after releasing the set screw and take the final reading on the reading scale at the mark that is in line with the top of the metal rod. After taking the reading, remove the penetration apparatus. Between uses, wash the penetration apparatus and remove any free water on the surfaces of the hollow cylinder and the metal rod with a cloth or paper towel.

8.7.3 *Calculation*—Calculate the penetration depth, *Pd*, using Eq 1.

$$Pd = d_2 - d_1 \quad (1)$$

where:
d_1 = initial reading (mm), and
d_2 = final reading (mm).

9. Report

9.1 Concrete mixture designation.

9.2 The penetration depth (*Pd*) to the nearest 1 mm.

10. Precision and Bias

10.1 Precision – The estimation of the precision of this test method is provisional. Repeatability standard deviations were determined on five replicate batches of SCC mixtures at each of four levels of mean penetration depth (5). At a mean penetration depth of 3 mm, the repeatability standard deviation was 1 mm; at a mean penetration depth of 13 mm, the repeatability standard deviation was 2 mm; and at mean penetration depths of 23 mm and 30 mm, the repeatability standard deviation was 3 mm. The differences in repeatability standard deviation are small over the range of mean penetration depths of 3 to 30 mm. The average repeatability standard deviation over this range of mean penetration depths is 2 mm.

10.2 *Bias*—This test method has no bias because the values determined can only be defined in terms of the test method.

11. Keywords

11.1 penetration depth; penetration test; rapid test; segregation; self-consolidating concrete; stability; static segregation resistance

APPENDIX

(Nonmandatory Information)

X1. DEGREE OF STATIC SEGREGATION RESISTANCE OF CONCRETE MIXTURES

X1.1 The criteria for the different degrees of static segregation resistance are provided in Table X1.1 and are based on evaluations of SCC mixtures with nominal maximum aggregate sizes in the range of 9.5 to 25 mm. These criteria were developed through a correlation between penetration depth and static segregation measured in accordance with Test Method ASTM C1610/C1610M (**1-5**).

TABLE X1.1 Degree of Static Segregation Resistance[A]

Penetration depth (*Pd*)	Degree of static segregation resistance
$Pd \leq 10$ mm	Resistant
10 mm < Pd < 25 mm	Moderately resistant
$Pd \geq 25$ mm	Not resistant

[A] These criteria were developed based on use of the penetration apparatus with an inverted slump mold and are valid for SCC mixtures with a total aggregate volume fraction of less than 65 %. The criteria may be different if a sample container other than the inverted slump mold is used.

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REFERENCES

(1) Bui V., Attiogbe, E., Vojtko, D., Schaef S., and See H., "A Rapid Test for Segregation Resistance of Self-Consolidating Concrete," *NRMCA Concrete Technology Forum*, Dallas, Texas, USA, May 22-24, 2007.

(**2**) Bui, V., Montgomery, D., Hinczak, I., and Turner, K., "Rapid Testing Method for Segregation Resistance of Self-Compacting Concrete," *Cement and Concrete Research Journal*, Volume 32, Issue 9, 2002, pp. 1489 – 1496.

(**3**) Bui, V. and Shah, S. P., "Rapid Methods for Testing Quality of Self-Consolidating Concrete," *Proceedings of First North American Conference on the Design and Use of Self-Consolidating Concrete*, Chicago, USA, November 12-13, 2002, pp. 311- 316.

(**4**) Bui, V., Montgomery, D., Hinczak, I., and Turner, K., "Rapid Testing Methods for Segregation Resistance and Filling Ability of Self-Compacting Concrete," *Proceedings of the Fourth CANMET/ACI/JCI International Conference on Recent Advances in Concrete Technology*, Tokushima, Japan, SP 179-6, 1998, Ed. V. M. Malhotra, pp. 85-103.

(**5**) Bui, V. and Attiogbe, E., "A Rapid Evaluation of Stability of Self-Consolidating Concrete," *Proceedings of Third North American Conference on the Design and Use of Self-Consolidating Concrete*, Chicago, USA, November 10-12, 2008.

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Designation: D 1985 – 03 (Reapproved 2008)

Standard Practice for Preparing Concrete Blocks for Testing Sealants, for Joints and Cracks[1]

This standard is issued under the fixed designation D 1985; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope

1.1 This practice covers the preparation of concrete blocks used for testing of joint and crack sealants for portland cement concrete and asphaltic concrete pavements. There are numerous standard material specifications that use concrete blocks prepared according to this practice. Refer to the specific standard material specification of interest to determine which tests apply and refer to the test methods for each specific test.

1.2 The values stated in SI units are to be regarded as the standard. The values given in parentheses are provided for information purposes only.

1.3 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

2. Referenced Documents

2.1 *ASTM Standards:* [2]

C 33 Specification for Concrete Aggregates

C 150 Specification for Portland Cement

C 192/C 192M Practice for Making and Curing Concrete Test Specimens in the Laboratory

E 171 Specification for Atmospheres for Conditioning and Testing Flexible Barrier Materials

3. Significance and Use

3.1 It is intended that this practice may be used by manufacturers, users, and testing agencies. The use of this practice establishes a uniform procedure for preparing concrete blocks for the testing of sealants. It is not intended to establish test procedures or conditions of test which are associated with each of the joint sealants.

4. Standard Conditions

4.1 The laboratory atmospheric conditions, hereinafter referred to as standard conditions, shall be in accordance with Specification E 171, (23 ± 2°C (73.4 ± 3.6°F) and 50 % ± 5 % relative humidity).

5. Concrete Block Preparation[3]

5.1 *Materials*—The aggregate shall conform to Specification C 33, except as specified herein. The aggregate grading shall be as shown in Table 1. The coarse aggregate shall consist of crushed limestone (plus 95 % $CaCO_3$) having a water absorption of not more than 1.5 %. The fine aggregate shall consist of crushed limestone and shall be manufactured from the same parent rock as the coarse aggregate.[4] The portland cement shall conform to ASTM Specification C 150, Type II. The concrete shall have a water-cement ratio of 0.49, a cement factor of 335 ± 30 kg/m ^{3}(6.0 ± 0.5 bags of cement per cubic yard), and a slump of 63 ± 13 mm (2½ ± ½ in.). The ratio of fine aggregate to total aggregate shall be approximately 40 % by solid volume. The air content shall be 5.0 ± 0.5 % and shall be obtained by the addition to the batch of an air-entraining agent such as a neutralized thermoplastic resin.[5] Prepare the concrete in accordance with the procedure described in Test Method C 192/C 192M.

5.1.1 *Alternate Block Materials*—As an alternate to the materials specified in 5.1, the blocks may be prepared using a concrete mixture which meets local requirements for concrete pavements. Use the materials specified in 5.1 for all referee testing.

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[1] This practice is under the jurisdiction of ASTM Committee D04 on Road and Paving Materials and is the direct responsibility of Subcommittee D04.33 on Formed In-Place Sealants for Joints and Cracks in Pavements.

Current edition approved July 1, 2008. Published July 2008. Originally approved in 1991. Last previous edition approved in 2003 as D 1985 – 03.

[2] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

[3] The sole source of supply of blocks made to this specification are available from USAE Laboratory, Missouri River Division, 429 S18th Street, Omaha, NE 68101. If you are aware of alternative suppliers, please provide this information to ASTM International Headquarters. Your comments will receive careful consideration at a meeting of the responsible technical committee,[1] which you may attend.

[4] The sole source of supply of aggregate meeting this specification is available from Pete Lien & Sons Inc., P.O. Box 440, Rapid City, SD. If you are aware of alternative suppliers, please provide this information to ASTM International Headquarters. Your comments will receive careful consideration at a meeting of the responsible technical committee,[1] which you may attend.

[5] Vinsol resin, made by Hercules Inc., has been used satisfactorily. If you are aware of alternative suppliers, please provide this information to ASTM International Headquarters. Your comments will receive careful consideration at a meeting of the responsible technical committee,[1] which you may attend.

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TABLE 1 Aggregate Grading

Type	Sieve Size	% Passing
Coarse aggregate	19.0 mm (¾ in.)	97 to 100
	12.5 mm (½ in.)	63 to 69
	9.5 mm (⅜ in.)	30 to 36
	4.75 mm (No. 4)	0 to 3
Fine aggregate	4.75 mm (No. 4)	100
	2.36 mm (No. 8)	82 to 88
	1.18 mm (No. 16)	60 to 70
	600 mm (No. 30)	40 to 50
	300 mm (No. 50)	16 to 26
	150 mm (No. 100)	5 to 9

5.2 *Block Preparation*—Use a minimum 100 mm by 300 mm by 75 mm (4 in. wide by 12 in. long by 3 in. deep) mold, made from metal or plastic and provided with a metal or plastic base plate. Provide means for securing the base plate to the mold. Make the assembled mold and base plate water-tight and oil with mineral oil before use. Fill the mold with concrete, prepared in accordance with 5.1 or 5.1.1, to overflowing and vibrate externally for 30 s. Screed (level) the concrete to a smooth surface with a wooden float and level off with a metal straightedge drawn across the top with a sawing motion. Cure as specified in Test Method C 192/C 192M. After curing for not less than 14 days, cut the slab of concrete into individual blocks using a 40 by 60-grit diamond saw blade rotating at a peripheral speed of 3050 ± 150 m/min (10 000 ± 500 ft/min.) (see Fig. 1). Each test block should be 25 by 50 by 75-mm (1 by 2 by 3-in.), leaving 25 mm (1 in.) strips for discarding from the slab that were in contact with the vertical sides of the mold. While the blocks are still wet from the sawing operation, scrub the surfaces of the blocks lightly with a non-metallic stiff-bristle brush while holding under a stream of running water. Stocks of prepared blocks may be stored under standard conditions indefinitely, but store such blocks in a 100% humidity enviornment for not less than 7 days prior to use.

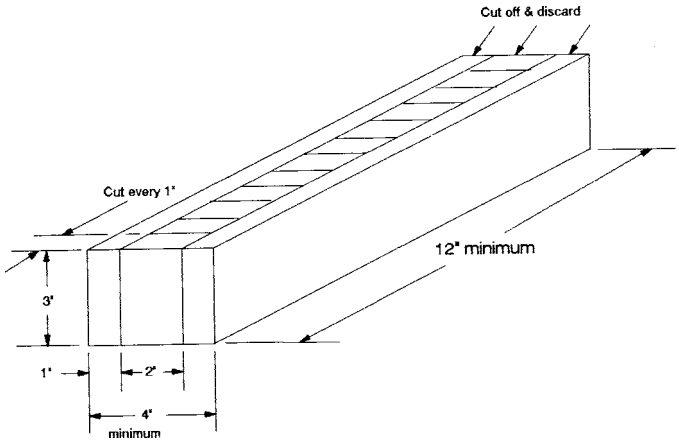

FIG. 1 Concrete Block Slab (after removal from mold)

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Designation: D 6249 – 06

Standard Guide for Alkaline Stabilization of Wastewater Treatment Plant Residuals[1]

This standard is issued under the fixed designation D 6249; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope*

1.1 This document provides guidance for use of reactive alkaline materials (quicklime, hydrated lime, high lime fly ash, or other byproducts) for treating wastewater solids (biosolids) to reduce pathogen levels and achieve compliance with regulatory requirements. Federal (40 CFR, Part 503) regulations for use or disposal of biosolids became effective on March 22, 1993; refer to USEPA regulations and guidance documents for information on other treatment processes or for specific requirements for use or disposal of biosolids.

1.2 Additional requirements may be imposed by individual states, and these are available through state regulatory agencies that issue permits for treatment and use or disposal, or both, of biosolids.

1.3 *This guide does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

2. Referenced Documents

2.1 *ASTM Standards:* [2]

C 25 Test Methods for Chemical Analysis of Limestone, Quicklime, and Hydrated Lime

C 110 Test Methods for Physical Testing of Quicklime, Hydrated Lime, and Limestone

2.2 *USEPA Publication:*

Title 40, Code of Federal Regulations (CFR), Part 503, Standards for the Use or Disposal of Sewage Sludge; Final Rules, 58 FR 9248-9404[3]

3. Terminology

3.1 *Acronyms:acronyms*—these are defined by operating parameters (for example, time, temperature) whose values must be met in order for biosolids to be used in various ways as a nutrient source/soil conditioner. Ref. 40 CFR Part 257.

3.1.1 *PFRP*—Processes to Further Reduce Pathogens (equivalent to 503 Class A).

3.1.2 *PSRP*—Processes to Significantly Reduce Pathogens (equivalent to 503 Class B).

4. Significance and Use

4.1 Operators of power and other plants producing alkaline by-products and wastewater treatment plant operators needing to treat and manage wastewater solids will find this guide helpful in dealing with their materials.

4.2 This guide provides the tests, procedures, and parameters that should be considered to significantly reduce pathogens in wastewater treatment plant solids by the addition of manufactured or by-product alkaline materials (**1**).[4]

5. Alkaline Materials Characteristics

5.1 *Chemical Composition*:

Alkaline materials may be tested for Available Lime Index (ALI) in accordance with the optional chemical test of Table 1. Other chemical components, if required, may be determined in accordance with the appropriate procedure when requested by the purchaser.

5.2 *Reactivity*:

5.2.1 Alkaline materials should be tested for pH and heat of hydration (heat rise or slaking rate) in accordance with the recommended tests of Table 2.

5.3 *Physical Characteristics*:

5.3.1 Alkaline materials should be tested to determine the particle size in accordance with the recommended physical tests of Table 3.

6. Process Performance

6.1 *PFRP (Class A) Alkaline Treatment of Biosolids*:

6.1.1 *Mixing*—Thorough mixing of the biosolids and stabilization reagent must be provided to ensure uniform pH distribution and pathogen reduction throughout the biosolids

[1] This guide is under the jurisdiction of ASTM Committee C07 on Lime and is the direct responsibility of Subcommittee C07.02 on Specifications and Guidelines.

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[2] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

[3] Available from the Superintendent of Documents, U.S. Government Printing Office, Washington, DC 20402.

[4] The boldface numbers in parentheses refer to the list of references at the end of this guide.

***A Summary of Changes section appears at the end of this standard.**

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TABLE 1 Optional Chemical Test

Test Method	Component	Specification
C 25	Available Lime Index (ALI), %	[A]

[A] To be specified only as required by purchaser.

TABLE 2 Recommended Reactivity Tests

ASTM Test Method	Component	Specification
C 25	pH	≥ 12.0[A]
C 110[B]	Heat rise, C	[C]

[A] Based on 40 CFR Part 503 for pH >12 for 2 h or more.
[B] Modify Test Method C 110 to proportion alkaline reagent in lieu of quicklime. Alkaline material and water ratio may need to be modified to obtain measurable results. Any modification of Test Method C 110 must be clearly stated on the analysis report.
[C] To be specified only as required by purchaser.

TABLE 3 Recommended Physical Test

ASTM Test Method	Component	Specification
C 110	Amount retained on 600 µm (No. 30 mesh), %	[A]
C 110	Amount retained on 75 µm (No. 200 mesh), %	[A]

[A] To be specified only as required by purchaser.

mass (**2**). Effective mixing depends upon achieving the appropriate ratio of alkaline material to biosolids cake uniformly distributed throughout the treated biosolids.

6.1.1.1 Biosolids with a high moisture content will require less mixing energy than high-solids biosolids cake.

6.1.1.2 Biosolids characteristics will determine the proper type of equipment or system required for adequate mixing. Incomplete mixing can cause odor release during product storage or application and may lead to failure to meet regulatory requirements for pathogen and vector control.

6.1.2 *Particle Size*:

6.1.2.1 Given an adequate moisture supply using alkaline agents (for example, CaO) with smaller particle sizes will facilitate rapid and efficient mixing of agents with biosolids and increase reaction rates and pH, resulting in higher temperatures and greater pathogen reduction.

6.1.2.2 Since dusts are more easily generated from finely divided particles, precautions should be taken to prevent exposure to eyes and mucous membranes, which may result in irritation.

6.1.2.3 Reactivity and particle size also affect the rate of dust and mist emissions from reactors or mixing devices, or both. Particulate release may require scrubbing, water spray, or other emission controls on reactors or mixing devices for aesthetic reasons or to meet regulatory requirements.

6.1.2.4 Very small particle size may also lead to "air slaking" or recarbonation of active lime particles if the material is exposed to high humidity. Air slaked/recarbonated materials will not achieve the pH necessary to meet regulatory requirements.

6.1.3 *Reactivity (Heat and pH Elevation)*:

6.1.3.1 Reactivity is dependent upon the interaction between the alkaline reagent and the material to be treated. Reactions occur as the alkaline material contacts the biosolids. The finer the alkaline product, the greater the potential for a more rapid pH/temperature elevation.

6.1.3.2 Reagent reactivity affects mixing time and dosage rate and must be considered in process design.

6.1.4 *Moisture Content*:

6.1.4.1 Adequate moisture must be present to react with the free CaO (as measured by Available Lime Index, ALI, as per Test Methods C 25) to generate heat and elevate pH. Generally, dry biosolids cakes (18 to 30 %) require a more intimate mix to ensure proper penetration and reaction than is required by wet biosolids (less than 18 %).

6.1.4.2 The calcium oxide in the reagent must react with the moisture in biosolids (hydration) producing calcium hydroxide and heat. The moisture content in the biosolids mass must be sufficient to allow the hydration reaction to occur between the selected reagent (CaO concentration and fineness) and biosolids mass.

6.1.4.3 Biosolids cakes with a high moisture content will tend to react faster than biosolids with a low moisture content.

6.1.5 *Biosolids Type*:

6.1.5.1 Case-by-case alkaline material demand should be determined for each biosolids type through pilot testing using the actual biosolids cake and proposed reagents for each project. Develop process guidelines for alkaline additions by biosolids type and alkaline additive characteristics.

6.1.5.2 Biosolids with a high moisture content may require a higher dose ratio than drier dewatered biosolids cake when dosage ratios are expressed on a dry weight basis.

6.1.6 *Reaction Time and Curing Time*:

6.1.6.1 Heat will be generated as hydration of calcium oxide occurs. The reaction time will vary depending on reagent composition moisture content of the biosolids mass, and mixer efficiency.

6.1.6.2 Reaction times to effect pathogen reduction are established by applicable federal and state regulations. Reaction/cure times depend upon a number of variables and should be pilot-tested using the actual biosolids cake, alkaline admixture, mix unit, cure vessel, and testing protocol and acceptance criteria to assure compliance with regulatory standards.

6.1.6.3 For alkaline treatment processes, one of the three performance criteria is required:

(1) The time-temperature relation established in 40 CFR 503.32 (a) (3) (Alternative 1). Selected time-temperature values are as follows:

Biosolids	Temp, °C	50	55	60	65	70	75	80
Moisture >7 %	Time, hours	316	63	13	2.5	0.5	0.10	0.020
Moisture <7 %	Time, hours	120	24	4.8	0.95	0.19	0.04	0.008

(2) The pH-time, temperature-time, drying procedure in 40 CFR 503.32 (a) (4) (Alternative 2). Basically, the biosolids are held at a pH above 12 for 72 hours with a 12-hour period in which the temperature exceeds 52°C, followed by air drying to a solids content exceeding 50 %.

(3) Pasteurization (40 CFR 503, App. B, Part B—PFRP Option 7) in which the biosolids are maintained at a minimum temperature of 70°C for 30 minutes.

6.1.6.4 Ammonia or other odors released may require water spray, scrubbing, gas capture, or control of emission.

6.1.7 *Reaction/Cure Vessels or Containers*:

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6.1.7.1 Consideration should be given to minimize heat losses through materials management, configuration, and materials of construction for processes that require extended curing times.

6.1.7.2 Proper temperatures can be maintained without an insulated vessel by adding adequate alkaline reagent to compensate for heat loss. However, some situations may benefit from an insulated vessel to efficiently retain the heat to meet PFRP temperature requirements.

6.1.7.3 For processes using a windrow, at a minimum, the mixture should be at least 18 inches thick at all locations in the pile to ensure heat retention throughout the entire mass for the applicable curing time. Thin areas at the pile extremities should be avoided as they will not retain adequate heat and can lead to potential regrowth and recontamination of the entire mass.

6.1.8 *Process Testing Requirements*:

6.1.8.1 Process testing requirements vary with the specific alkaline process selected.

6.1.8.2 Temperature and pH measurements for the requisite time periods should be recorded to comply with pathogen reduction (and vector attraction reduction). Daily testing may include monitoring and documenting the elevated temperature and pH for a predetermined period of time (see 6.2.6 for details). Some methods also require documentation of reduced moisture content and mixing.

6.1.8.3 Procedures to monitor or collect samples for analysis are developed for each project based upon site-specific conditions considering the process selected, equipment utilized, volumes of materials to be processed, local state and federal regulatory requirements, and local conditions (**3**).

6.1.9 *Process Testing Schedule*:

6.1.9.1 Testing must be conducted in accordance with federal, state, and local regulations. Product testing, to meet end-use requirements, will be site-specific. Under 40 CFR Part 503 regulations, pathogen (salmonella, virus, protozoan, and helminth egg) or indicator organism testing and pollutant concentration (metals) testing requirements are:

Amount of Biosolids (dry metric tons/365 days)	Frequency
> 0 and < 290	Once per year
≥ 290 and < 1500	Once per quarter
≥ 1500 and < 15 000	Once per 60 days
≥ 15 000	Once per month

6.1.9.2 In addition, at a minimum, daily operating records should be maintained documenting compliance with applicable requirements (for example, process time/temperature, pH, solids concentrations, and fecal coliform levels) (**4**).

6.1.10 *Product Solids Content*:

6.1.10.1 Product utilization may be affected by solids content to aid in control of microbial regrowth during storage to minimize odor potential at application sites and during storage or to improve end-product marketability and physical handling characteristics.

6.1.11 *On-Site Storage*:

6.1.11.1 On-site storage may be required for a land application or marketing program of the tested product. Programs that produce an end-product for sale should consider on-site storage capacity to meet the seasonal fluctuations in market demand, the scheduling needs of the consumer, and production rates of the generator.

6.1.11.2 On-site storage may require odor control for end-products with high moisture content or a low alkaline reagent dosage rate.

6.2 *PSRP (Class B) Alkaline Treatment of Biosolids*:

6.2.1 *Mixing*—Thorough mixing of the biosolids and chemical reagent must be provided to ensure uniform pH distribution and pathogen reduction (**2**). Mechanical mixing to achieve a homogeneous blend of reagent throughout the biosolids mass depends upon a number of factors, including achieving the proper ratio of alkaline reagent to biosolids, and sufficient moisture to enable the reaction to occur.

6.2.1.1 Incomplete mixing or an inadequate reagent dosage rate can cause odor generation and release during product storage or application and failure to meet regulatory pathogen or vector control requirements.

6.2.2 *Alkaline Reagent Particle Size*:

6.2.2.1 Reactions occur as the alkaline reagents contact the moist biosolids particles. The rate of reaction of the alkaline reagent tends to increase with: (1) finer reagent particle size, and (2) increased free moisture content. Reagents with a finer (smaller) particle size distribution generally are more easily and uniformly blended into the biosolids.

6.2.2.2 When using an alkaline slurry, or treating liquid biosolids, particle size may not be as critical as long as sufficient mixing and reaction time are provided.

6.2.3 *Reactivity (pH elevation)*:

6.2.3.1 Care must be taken to ensure moisture will not come into contact with the reagent prior to entering the mixer. Air slaking of the alkaline reagent can be a problem in long-term storage or pneumatic transfer systems. Guidance for proper storage of reactive alkaline materials can be found in Lime—Handling, Application and Storage, National Lime Association Bulletin 213.

6.2.3.2 Increasing the alkaline reagent oxide concentration may increase potential for reactivity.

6.2.4 *Moisture Content*:

6.2.4.1 Moisture content affects the pH by permitting the alkaline reagents to dissociate, releasing hydroxide ions, increasing the pH. As moisture increases, it is easier for the alkaline material to disperse, penetrate, react, and dissociate, thus generating hydroxide ions throughout the mixture.

6.2.4.2 Care should be exercised when working with biosolids cakes with greater than 30 % solids content to ensure a complete uniform reaction is achievable.

6.2.5 *Biosolids Type*—Biosolids characteristics will impact on the required dosage rates for specific alkaline reagents. Therefore, site-specific process guidelines should be developed through actual pilot studies for alkaline additions by biosolids type and alkaline additive characteristics. Liquid biosolids require less mixing energy to achieve a uniform distribution of alkaline reagent (and therefore uniform pH) throughout the mixture than do cake biosolids.

6.2.6 *Reaction Time*:

6.2.6.1 For dry reagents, after uniform mixing with biosolids is complete, the alkaline metal oxides must hydrate to

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hydroxides and penetrate the biosolids mass. The presence of hydroxides will increase biosolids pH.

6.2.6.2 When working with biosolids cake with low moisture content or reagents with low reactivity due to particle size or oxide content, longer curing time (contact period) may be required to allow the hydration reaction to occur.

6.2.6.3 At elevated pH values, ammonia compounds in the biosolids or water dissociate to release ammonia gas (NH_3). The biosolids may exhibit a transient pH of 12 or more due to unreleased ammonia in the form of unstable ammonium hydroxide (NH_4OH). Once the NH_4OH dissociates and the ammonia dissipates, the pH may fall. Therefore, the amounts of reagent added should take this factor into account and not be based on the short-term NH_4OH effect on pH. The strong odor of ammonia release is a signal to be alert to this process occurring.

6.2.7 *Process Testing Requirements*—pH > 12 for two hours.

6.2.7.1 When testing a liquid/solid mixture with a system designed for liquids (pH probe), care must be taken to keep flow of sample moving across the pH probe surface for accuracy. Clean the electrode frequently, paying particular attention to the reference electrode junction. Bits of adherent biosolids or alkaline agent can strongly alter the measured pH, resulting in erroneous values not representative of the entire mass of material. pH measurements should be made at 25°C, or corrected for sample temperature differences as shown in Table 4, which demonstrates the temperature/pH relationship as the measured pH approaches the regulatory limit.

NOTE 1—At high pH (above 11), temperature has a significant effect on pH readings. Therefore, at high pH levels, the reading must be corrected to 25°C, standard temperature. Table 4 and following examples may be useful for a better understanding.

NOTE 2—pH meters often have temperature correction controls. These controls correct for probe temperature and conductivity only. Changes in the concentration of the test sample due to solubility that changes with temperature are not compensated by these controls. For example, at 30°C:

$$\text{Correction Factor (CF)} = 0.03 \text{ pH units} \times (T_{meas} - 25°C)$$
$$CF = 0.03 \times (30 - 25);\ CF = 0.03 \times 5$$
$$CF = +\ 0.15$$
$$\text{Actual pH} = \text{Measured pH} \pm \text{the Correction Factor}$$
$$\text{Actual pH} = 12.304 + 0.15 = 12.454$$

6.2.7.2 pH—Calibrate routinely with laboratory-grade standards developed for high pH monitoring.

6.2.8 *On-Site Storage*:

TABLE 4 pH Temperature Correction Factors at Varying Temperatures from Standard

Temperature Measured,° C	pH Meter Reading	Correction Factor (CF), +/–		
30	12.304	+	0.15	
29	12.334	+	0.12	
28	12.364	+	0.09	
27	12.394	+	0.06	
26	12.424	+	0.03	
25	12.454		0.00	12.454[A]
24	12.484	–	0.03	
23	12.514	–	0.06	
22	12.544	–	0.09	
21	12.574	–	0.12	
20	12.604	–	0.15	

[A] pH of a saturated lime solution at 25°C.

6.2.8.1 PSRP (Class B) biosolids have regulatory restrictions preventing application of material to a site during inclement weather, standing water, ice- or snow-covered fields.

6.2.8.2 On-site storage should be considered to hold biosolids, unless backup options are available when application sites cannot be used. Storage design must address regulatory concerns for runoff or leachate and local site-specific concerns for odor. Storage capacity should be consider worst-case weather conditions.

6.2.8.3 Microbial recontamination and regrowth is possible at pH < 10, with concomitant odor potential.

7. End Use Criteria

7.1 *Matrix of Product Factors*:

7.1.1 Table 5 addresses various factors that influence specific product criteria for alkaline-treated biosolids. The relative importance of these criteria will depend on the type of product and its intended use; for example, for agricultural liming material, $CaCO_3$ equivalency and friability for handling will be important, along with metal levels, which must meet Table 3 of EPA's 503 Rule for a product to be sold or distributed.

EPA 40 CFR Part 503.13 (13 (Table 3)
Metal Concentration Limits

Metal	Pollutant Concentrations (mg/kg)
Arsenic	41
Cadmium	39
Copper	1,500
Lead	300
Mercury	17
Molybdenum	75[A]
Nickel	420
Selenium	100
Zinc	2,800

[A] This is the ceiling concentration for Molybdenum. EPA is still developing a pollutant concentration value.

8. Federal Regulations

8.1 *Introduction*:

8.1.1 *Pathogen reduction*—Alkaline materials reduce pathogens in municipal wastewater solids by creating a series of stresses on the microbial population in the solids. The addition of an alkaline material raises the pH of the mixture to levels that are toxic to some microbes, resulting in their reduction or elimination (**5**). The exothermic reaction of quicklime with water also releases heat (often intense) and the resultant temperature rise helps inactivate pathogens. Hydration of alkaline oxide materials helps dry the biosolids, further stressing the microorganisms.

8.2 *Class A Pathogen Reduction*:

8.2.1 All 40 CFR Part 503 Class A alternatives must meet the following criteria:

8.2.1.1 Either the density of fecal coliform in the biosolids must be less than 1000 most probable numbers (MPN) per gram total solids (dry-weight basis), or the density of *Salmonella* sp. bacteria in the biosolids must be less than 3 MPN per 4 g of total solids (dry-weight basis).

8.2.1.2 Either of these requirements must be met at one of the following times: *(1)* when the biosolids are used or disposed; *(2)* when the biosolids are prepared for sale or

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TABLE 5 Matrix of Product Factors

End-Use Criterion	Related Process Parameter			
	Input Biosolids	Alkaline Additive	Process Heat	Other Parameters
Percent solids	Percent solids	Percent solids	Heat of hydration and evaporative heat loss	
Friability/particle size/plasticity	Percent solids	Amount added		Percent solids of final mix; bulking agent; type and amount of mixing
Nutrient content	Nutrient content	Amount added (dilution)		Amount of ammonia driven off; amount of ″mineralization″ of nitrogen in chemical reaction; nutrient content of bulking agent
Organic matter content	Percent volatile solids	Amount added (dilution)	Loss of volatile organics	″Mineralization″ of organic content in chemical reaction; organic content of bulking agent
Metals content	Metals content	Metals content		Metals content of bulking agent
Liming potential	$CaCO_3$ equivalency	Ca content Mg content		Ca, Mg content of bulking agent
pH level and duration	pH, percent solids, ammonia and alkaline metals content, buffering capacity	CaO $Ca(OH)_2$		Final pH of product; granularity or plasticity of end-product (permeability to air and water allowing reaction to product carbonate)
Pathogen reduction		pH 12 (CaO and $Ca(OH)_2$ content)	Heat level and duration	Dryness of end-product; chemical destruction of pathogens
Odor potential	Percent ammonia, percent volatile solids, digestion process, polymer type and content	pH-driven ammonia release; neutralization of malodorous organics	Volatilization of organics	Thoroughness of mix; odor stripping during process
Bearing strength	Non-volatile solids	Material available for forming carbonates; silicates; aluminates; aluminoferrites	Vaporization of water	Time since product was made; CO_2 reaction producing carbonates; characteristics of bulk agent(s)
Permeability		Cementitious compounds		Time since product was made; CO_2 process producing carbonates; plasticity/friability of bulking agent; characteristics of bulking agents; density

give-away in a bag or other container for land application; or *(3)* when the biosolids or derived materials are prepared to meet the requirements of CFR 503 (**6**).

8.2.1.3 Vector attraction reduction must take place before or at the same time as pathogen reduction except when the pH adjustment, percent solids vector attraction, injection, or incorporation options are met for vector attraction reduction.

8.3 *Alkaline Processes for Meeting Class A Pathogen Reduction Requirements*:

8.3.1 Alternative for Meeting Class A: Biosolids Treated in a High Temperature Process (through Chemically Produced Heat).

8.3.1.1 The time-temperature relation established in 40 CFR 503.32(a)(3) (Alternative 1). (See 6.1.6 for time-temperature examples.)

8.3.2 Alternative 2 for Meeting Class A: Biosolids Treated in a High pH-High Temperature-Air Drying Process 40 CFR 503.32(a)(4).

8.3.2.1 Elevating the pH to greater than 12 (measured at 25°C) for 72 h or longer,

8.3.2.2 Maintaining the temperature above 52°C for at least 12 h during the period that the pH is greater than 12,

8.3.2.3 Air-drying to over 50 % solids after the 72-h period of elevated pH, and

8.3.2.4 Meeting all the requirements in 6.2.

8.3.3 Alternative 5 for Meeting Class A: Treated in a PFRP (Pasteurization) Process Listed in 40 CFR 503, App. B, Part B-Option 7

8.3.3.1 Combined with an Alkaline Method of Vector Attraction Reduction 40 CFR 503.33(b)(6),

raise the temperature to ≥70°C for a minimum of 30 minutes, and

8.3.3.2 Combined naturally with the vector attraction reduction, raise the pH to ≥12 for a minimum of two hours, and maintain the pH ≥11.5 for an additional 22 h.

8.4 *Alkaline Process for Meeting Class B Pathogen Reduction Requirements*:

8.4.1 Alternative 2—PSRP listed in Appendix B, 40 CFR Part 503: Alkaline stabilization—sufficient alkaline reagent is added to the biosolids to raise the pH of the biosolids to 12 after two hours of contact time.

8.4.2 Unlike the comparable Class A requirements, this alternative does not require microbiological monitoring for regrowth of fecal coliform or *Salmonella* sp. bacteria.

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8.5 *Alkaline Process for Meeting Vector Attraction Reduction*:

8.5.1 Option 6 Alkali[5], addition under specified conditions:

8.5.2 Biosolids are considered to be adequately reduced in vector attraction if sufficient alkaline material is added to achieve the following:

8.5.2.1 Raise the pH to at least 12, measured at 25°C, and without the addition of more alkaline material, maintain a pH of at least 12 for two hours, and

8.5.2.2 Maintain a pH of at least 11.5 without addition of more alkaline material for an additional 22 h.

8.5.3 The conditions required under this option are designed to ensure that the biosolids can be stored for at least several days at the treatment works, transported, and then used or disposed without the pH falling to the point where putrefaction occurs and vectors are attracted.

8.6 *Septage Treatment*:

8.6.1 *Option 12–Alkaline Treatment for Domestic Septage:*

8.6.2 This option pertains only to vector attraction reduction for domestic septage. Under this option, the pH of domestic septage must be raised to at least 12 and remain at pH 12 or above for a minimum of 30 min during which no additional alkaline material may be added.

[5] 40 CFR Part 503 uses the term "alkali" for any alkaline material. For beneficial use options, sodium (Na)-based alkaline materials are usually unsuitable due to the negative effects of sodium on soil physical properties.

9. Keywords

9.1 alkaline stabilization; biosolids; high-lime byproducts; sewage sludge; stabilization; wastewater treatment plant

REFERENCES

(1) Lime—Handling, Application and Storage, *National Lime Association Bulletin 213*, Arlington VA. 1995.

(2) Technical Support Document for Reduction of Pathogens and Vector Attraction in Sewage Sludge, *USEPA, Office of Water*, NTIS: PB93-110609.

(3) POTW Sludge Sampling and Analysis Guidance Document, *USEPA, Permits Division*, Washington, DC, First edition. August 1989, NTIS: PB93-227957.

(4) Preparing Sewage Sludge for Land Application or Surface Disposal—A Guide for Preparers of Sewage Sludge on the Monitoring, Record Keeping and Reporting Requirements of the Federal Standards for Use or Disposal of Sewage Sludge,40 CFR Part 503, *USEPA, Office of Wastewater Enforcement and Compliance*, EPA/813-B-93-002a. NTIS: PB94-102415.

(5) Environmental Regulations and Technology: Control of Pathogens and Vector Attraction in Sewage Sludge, *USEPA, Office of Research and Development*, EPA/625/R-92/013.

(6) A Plain English Guide to the EPA Part 503 Biosolids Rule,*USEPA, Office of Wastewater Management*, EPA/832/R-93/003.

SUMMARY OF CHANGES

Committee C07 has identified the location of selected changes to this guide since the last issue, D 6249 – 98(2004), that may impact the use of this guide. (Approved June 1, 2006)

(*1*) Added new 1.3.

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Designation: F1869 – 09

Standard Test Method for Measuring Moisture Vapor Emission Rate of Concrete Subfloor Using Anhydrous Calcium Chloride[1]

This standard is issued under the fixed designation F1869; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope

1.1 This test method covers the quantitative determination of the rate of moisture vapor emitted from below-grade, on-grade, and above-grade (suspended) bare concrete floors.

1.2 This quantity of moisture shall be expressed as the rate of moisture vapor emission, measured in pounds of moisture over a 1000 ft^2 area during a 24-h period.

1.3 This test shall not be used to evaluate moisture emissions over gypsum concrete.

1.4 The values stated in inch-pound units are to be regarded as the standard. The values given in parentheses are for information only.

1.5 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices, and determine the applicability of regulatory limitations prior to use.*

2. Referenced Documents

2.1 *ASTM Standards:*[2]

C670 Practice for Preparing Precision and Bias Statements for Test Methods for Construction Materials

F141 Terminology Relating to Resilient Floor Coverings

2.2 *Resilient Floor Covering Institute Standard:*

Recommended Work Practices [3]

2.3 *Military Standard:*

Mil Spec B-131H Type 1, Class III[4]

2.4 *ICRI Guide:*

Guideline No. 03732: Selecting and Specifying Concrete Preparation for Sealers, Coatings, and Polymer Overlays[5]

3. Terminology

3.1 *Definitions:* See Terminology F141 for definitions of the terms, above-grade (suspended), below-grade, concrete, on-grade, and resilient flooring.

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *moisture vapor emission rate (MVER)*—amount of water vapor in pounds emitted from a 1000 ft^2 area of concrete flooring during a 24-h period (multiply by 56.51 to convert to µg/s m^2).

4. Significance and Use

4.1 Use this test method to obtain a quantitative value indicating the rate of moisture vapor emission from a concrete floor and whether or not that floor is acceptable to receive resilient floor covering. The moisture vapor emission rate only reflects the condition of the concrete floor at the time of the test. All concrete subfloors emit some amount of moisture in vapor form. Concrete moisture emission is a natural process driven by environmental conditions. All floor coverings are susceptible to failure from excessive moisture vapor emissions. The moisture vapor emitted from a concrete slab is measured in pounds. This measurement is the equivalent weight of water evaporating from 1000 ft^2 of concrete surface in a 24–h period. The calcium chloride moisture test has been the industry standard for making this determination and is a practical, well-established and accepted test of dynamic moisture. It will produce quantified results directly applicable to flooring manufacturer's specifications. The results obtained reflect only the condition of the concrete floor at that time.

5. Apparatus

5.1 *Test Unit Contents*:

[1] This test method is under the jurisdiction of ASTM Committee F06 on Resilient Floor Coverings and is the direct responsibility of Subcommittee F06.40 on Practices.

Current edition approved Dec. 1, 2009. Published January 2010. Originally approved in 1998. Last previous edition approved in 2004 as F1869–04. DOI: 10.1520/F1869-09.

[2] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

[3] Available from Resilient Floor Covering Institute, 966 Hungerford Drive, Suite 12-B, Rockville, MD 20850.

[4] Available from Standardization Documents Order Desk, Bldg. 4 Section D, 700 Robbins Ave., Philadelphia, PA 19111-5094, Attn: NPODS.

[5] Available from International Concrete Repair Institute, International Concrete Repair Institute 3 166 S. River Road, Suite 132, Des Plaines, IL 60018;, www.icri.org

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5.1.1 *Cylindrical Plastic Dish Containing Anhydrous Calcium Chloride*, heat sealed in a heat sealable bag meeting Mil Spec B-131H Type 1, Class III, to protect from moisture intrusion.

5.1.1.1 Anhydrous calcium chloride shall be in the form of prilled beads and shall have a minimum purity of 94 %. Net weight of the anydrous calcium chloride shall be 16 ± 1 g.

5.1.1.2 Dish shall be made of a material that does not absorb moisture. Dimensions of the dish shall be 69 ± 1 mm outside diameter, 16 ± 1 mm height, wall thickness less than 1 mm. Dish shall be supplied with a tight-fitting cover. The cover shall be secured to the dish with pressure-sensitive-adhesive backed vinyl tape.

5.1.2 *Pressure Sensitive Label*, to be used to identify the container of calcium chloride and to record the date, time, and container weight when the test is started and completed.

5.1.3 *Transparent Cover*, with 0.5 in. (12 mm) flanges around the perimeter, approximately 0.5 ft^2 (460 ± 46 cm^2), as measured between the inside of the flanges, is required to seal the test area of the floor. The plastic cover shall have a depth greater than the height of the container of anhydrous calcium chloride. The height of the container shall be 1½ in. ± 0.125 (38 ± 3.2 mm).

5.1.4 *Strip of Sealant*, to secure the plastic cover to the floor in an airtight fashion.

5.1.5 *Brightly Colored Warning Label*, to be placed on the plastic cover as a protective warning while the test is being conducted.

5.1.6 *Mailing Bag*, for the return of the sample to the party responsible for calculating the test results.

5.2 *Gram Scale*, capable of measuring 0.1 g. This scale will be used to weigh the calcium chloride container at the start and end of the test. On-site measurement is preferred to mailing the container back to the supplier for results.

5.3 *Thermometer*, capable of measuring room temperature.

5.4 *Hygrometer*, capable of measuring the relative humidity of the test site.

6. Conditioning

6.1 The test site should be at the same temperature and humidity expected during normal use. If this is not possible, then the test conditions should be 75 ± 10°F (23.9 ± 5.5°C) and 50 ± 10 % relative humidity. Maintain these conditions 48 h prior to, and during testing.

6.2 Prior to placement of the anhydrous calcium chloride tests, the actual test area shall be clean and free of all foreign substances. All residual adhesives, curing compounds, sealers, paints, floor coverings, etc. shall be removed. Removal shall be accomplished using approved OSHA work practices. For removal of existing resilient floorings or residual adhesive, strictly observe the Warning that follows and Notes 1 and 2. (**Warning**—Do not sand, dry sweep, dry scrape, drill, saw, beadblast, or mechanically chip or pulverize existing resilient flooring, backing, lining felt, or asphaltic cut-back adhesives. These products may contain either asbestos fibers or crystalline silica. Avoid creating dust. Inhalation of such dust is a cancer and respiratory tract hazard. Smoking by individuals exposed to asbestos fibers greatly increases the risk of serious bodily harm. Unless positively certain that the product contains non-asbestos material, presume it contains asbestos. Regulations may require that the material be tested to determine asbestos content. RFCI's recommended work practices are a defined set of instructions addressed to the task of removing all resilient floor covering structures whether or not they contain asbestos. When RFCI's recommended work practices are followed, resilient floor covering structures that contain (or are presumed to contain) asbestos can be removed in a manner that will comply with the current occupational exposure to asbestos standard's permissible exposure limits (PEL) issued by the Occupational Safety and Health Administrations (OSHA).

NOTE 1—Various federal, state, and local government agencies have regulations covering the removal of asbestos-containing material. If considering the removal of resilient floor covering or asphaltic cut-back adhesive that contains or is presumed to contain asbestos, review and comply with the applicable regulations.

NOTE 2—Certain paints may contain lead. Exposure to excessive amounts of lead dust presents a health hazard. Refer to applicable federal, state, and local laws and "Lead-based Paint: Interim Guidelines for Hazard Identification and Abatement in Public and Indian Housing"[6] regarding: (*1*) appropriate methods for identifying lead-based paint and removing of such paint, and (*2*) any licensing, certification, and training requirements for persons performing lead abatement work. (Use only qualified of certified lead abatement contractors to remove lead-based paint.)

7. Procedure

7.1 Expose a minimum area of 20 by 20 in. (50.8 by 50.8 cm) to conditions specified in 6.1 and 6.2 for a minimum period of 24 h prior to starting each test. Weigh the container of anhydrous calcium chloride, including the tape used to seal the container, the container lid, and the label which should be affixed to the lid. Record the weight to the nearest 0.1 g on the container label along with the starting time to the nearest ± ¼ h.

7.1.1 If not provided by the $CaCl_2$ test kit manufacturer, obtain the actual area of the test site. Measure the length and width of the plastic cover between the inside of the flanges, and multiply to obtain the area. Measure the bottom of the dish containing the $CaCl_2$ to obtain the radius. To calculate the area of the dish, use the following equation:

$$A = \pi r^2 \quad (1)$$

where:

π = 3.14

Deduct the area of the dish from the area of the plastic covering. Record this as the actual test area. This will be used to make the final calculation at the end of the test.

7.2 Apply the sealant to the flanges of the plastic cover in a continuous bead. If the sealant has been preinstalled by the kit manufacturer, expose by peeling off the protective covering. The purpose of the sealant is to form an airtight seal around the perimeter of the plastic cover.

7.3 Carefully remove the sealing tape from the calcium chloride dish and attach it to the side of the plastic container. This tape will be used again to reseal the same container.

[6] Available from U.S. Department of Housing and Urban Development, Washington, DC. Use September 1990 or subsequent editions.

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Remove the container lid and invert it under the dish. Set the dish (and lid) onto the concrete surface. (**Warning**—Do not spill any of the calcium chloride from the container. If spillage occurs that test kit is to be discarded requiring test to be performed with a new test kit.

Immediately place the plastic cover over the calcium chloride dish. Firmly press down on the cover's flanges compressing the sealant providing an airtight seal around the cover.

7.4 After test has been in place for 60-72 h, remove the plastic cover. It may be best to cut the top open with a razor blade so the dish can be easily retrieved. Replace the lid on the container and immediately reseal using the original sealing tape. Immediately reweigh the sealed container. Record the new weight, the date, and time the test was stopped. Record if performed at the test site.

NOTE 3—If test container is to be return-mailed for results, immediately place in mailing bag ensuring bag is properly sealed. Follow mailing instructions provided with kit.

7.5 The formula for computing moisture vapor emission rate (MVER) is as follows:

$$\text{MVER} = \frac{24\ 000 \cdot \Delta M}{453.612 \cdot A \cdot T} = \frac{52.91 \cdot \Delta M}{A \cdot T} \quad (2)$$

where:

MVER = moisture vapor emission rate, lb/1000 ft^2/24 h,
ΔM = change in mass (weight gain) of anhydrous $CaCl_2$ in g,
A = contact area of the flanged cover on concrete in ft^2 deducting the area of the $CaCl_2$ dish, and
T = exposure time in hours.

7.6 To convert test results to SI, multiply by 56.51 to obtain results in μg/(s m^2).

7.7 Use the following guidelines to determine the number of test locations to be utilized simultaneously.

7.7.1 Three test locations for areas up to 1000 ft^2(100 m^2).

7.7.2 Add one additional test for each 1000 ft^2(100 m^2) or fraction thereof.

NOTE 4—When conducting moisture emission tests, the test units should not be concentrated but shall be located in various parts of the floor area. One unit shall be placed near the center with others being placed around perimeter. Selection of test sites shall include areas of potential moisture, that is, joints and perimeter of building.

8. Precision and Bias

8.1 Precision, characterized by repeatability *Sr*, *r* and reproducibility *SR*, *R* has been determined for the following materials to be:

Material	Average	*Sr*	*SR*	*R*	*R*
Concrete slab 6–8	5.94 lb/100 ft^2/24 h	0.24	0.32	0.68	0.90

8.1.1 This precision statement is provisional.

8.2 No information can be presented on the bias of the procedure in Test Method F1869 for measuring moisture vapor emission rates from concrete because no material having an accepted reference value is available.

9. Keywords

9.1 anhydrous calcium chloride; moisture vapor emission rate; quantitative calcium chloride; resilient flooring; RMA referee test

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