ANEXO VII

Copias de Normas ASTM empleadas por el Sistema Control Mix Express

(Acceso exclusivo para clientes a Plataforma CME)

Designation: C31/C31M – 21

Standard Practice for Making and Curing Concrete Test Specimens in the Field[1]

This standard is issued under the fixed designation C31/C31M; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

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

1. Scope*

1.1 This practice covers procedures for making and curing cylinder and beam specimens from representative samples of fresh concrete for a construction project.

1.2 The concrete used to make the molded specimens shall be sampled after all on-site adjustments have been made to the mixture proportions, including the addition of mix water and admixtures. This practice is not intended for making specimens from concrete not having measurable slump or requiring other sizes or shapes of specimens.

1.3 This practice is not applicable to lightweight insulating concrete or controlled low strength material (CLSM).

NOTE 1—Test Method C495/C495M covers the preparation of specimens and the determination of the compressive strength of lightweight insulating concrete. Test Method D4832 covers procedures for the preparation, curing, transporting and testing of cylindrical test specimens of CLSM.

1.4 The values stated in either SI units or inch-pound units are to be regarded separately as standard. The values stated in each system may not be exact equivalents; therefore, each system shall be used independently of the other. Combining values from the two systems may result in non-conformance with the standard.

1.5 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety, health, and environmental practices and determine the applicability of regulatory limitations prior to use.* (**Warning—**Fresh hydraulic cementitious mixtures are caustic and may cause chemical burns to exposed skin and tissue upon prolonged exposure.[2])

1.6 The text of this standard references notes which provide explanatory material. These notes shall not be considered as requirements of the standard.

1.7 *This international standard was developed in accordance with internationally recognized principles on standardization established in the Decision on Principles for the Development of International Standards, Guides and Recommendations issued by the World Trade Organization Technical Barriers to Trade (TBT) Committee.*

2. Referenced Documents

2.1 *ASTM Standards:*[3]

C125 Terminology Relating to Concrete and Concrete Aggregates
C138/C138M Test Method for Density (Unit Weight), Yield, and Air Content (Gravimetric) of Concrete
C143/C143M Test Method for Slump of Hydraulic-Cement Concrete
C172/C172M Practice for Sampling Freshly Mixed Concrete
C173/C173M Test Method for Air Content of Freshly Mixed Concrete by the Volumetric Method
C231/C231M Test Method for Air Content of Freshly Mixed Concrete by the Pressure Method
C330/C330M Specification for Lightweight Aggregates for Structural Concrete
C403/C403M Test Method for Time of Setting of Concrete Mixtures by Penetration Resistance
C470/C470M Specification for Molds for Forming Concrete Test Cylinders Vertically
C495/C495M Test Method for Compressive Strength of Lightweight Insulating Concrete
C511 Specification for Mixing Rooms, Moist Cabinets, Moist Rooms, and Water Storage Tanks Used in the Testing of Hydraulic Cements and Concretes
C617/C617M Practice for Capping Cylindrical Concrete Specimens
C1064/C1064M Test Method for Temperature of Freshly Mixed Hydraulic-Cement Concrete
C1077 Practice for Agencies Testing Concrete and Concrete Aggregates for Use in Construction and Criteria for

[1] This practice is under the jurisdiction of ASTM Committee C09 on Concrete and Concrete Aggregates and is the direct responsibility of Subcommittee C09.61 on Testing for Strength.

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[2] See Section on Safety Precautions, Manual of Aggregate and Concrete Testing, *Annual Book of ASTM Standards*, Vol. 04.02.

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

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

Testing Agency Evaluation

C1611/C1611M Test Method for Slump Flow of Self-Consolidating Concrete

C1758/C1758M Practice for Fabricating Test Specimens with Self-Consolidating Concrete

D4832 Test Method for Preparation and Testing of Controlled Low Strength Material (CLSM) Test Cylinders

2.2 *American Concrete Institute Publication:*[4]

309R Guide for Consolidation of Concrete

3. Terminology

3.1 For definitions of terms used in this practice, refer to Terminology C125.

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *initial curing temperature, n*—temperature of the environment surrounding the specimen during initial curing.

3.2.1.1 *Discussion*—The environment surrounding the test specimens may be air, water, or sand. The temperature of the environment surrounding the test specimen might not be the same as the concrete temperature.

4. Significance and Use

4.1 This practice provides standardized requirements for making, curing, protecting, and transporting concrete test specimens under field conditions.

4.2 If the specimens are made and standard cured, as stipulated herein, the resulting strength test data when the specimens are tested are able to be used for the following purposes:

4.2.1 Acceptance testing for specified strength,

4.2.2 Checking adequacy of mixture proportions for strength, and

4.2.3 Quality control.

4.3 If the specimens are made and field cured, as stipulated herein, the resulting strength test data when the specimens are tested are able to be used for the following purposes:

4.3.1 Determination of whether a structure is capable of being put in service,

4.3.2 Comparison with test results of standard cured specimens or with test results from various in-place test methods,

4.3.3 Adequacy of curing and protection of concrete in the structure, or

4.3.4 Form or shoring removal time requirements.

5. Apparatus

5.1 *Molds, General*—Molds for specimens or fastenings thereto in contact with the concrete shall be made of steel, cast iron, or other nonabsorbent material, nonreactive with concrete containing portland or other hydraulic cements. Molds shall hold their dimensions and shape under all conditions of use. Molds shall be watertight during use as judged by their ability to hold water poured into them. Provisions for tests of water leakage are given in the Test Methods for Elongation, Absorption, and Water Leakage section of Specification C470/C470M. A suitable sealant, such as heavy grease, modeling clay, or microcrystalline wax shall be used where necessary to prevent leakage through the joints. Positive means shall be provided to hold base plates firmly to the molds. Reusable molds shall be lightly coated with mineral oil or a suitable nonreactive form release material before use.

5.2 *Cylinder Molds*—Molds for casting concrete test specimens shall conform to the requirements of Specification C470/C470M. Cardboard cylinder molds shall not be used for standard-cured specimens.

5.3 *Beam Molds*—Beam molds shall be of the shape and dimensions required to produce the specimens stipulated in 6.2. The inside surfaces of the molds shall be smooth. The sides, bottom, and ends shall be at right angles to each other and shall be straight and true and free of warpage. Maximum variation from the nominal cross section shall not exceed 3 mm [1⁄8 in.] for molds with depth or breadth of 150 mm [6 in.] or more. Molds shall produce specimens at least as long but not more than 2 mm [1⁄16 in.] shorter than the required length in 6.2.

5.4 *Tamping Rod*—A round, smooth, straight, steel rod with a diameter conforming to the requirements in Table 1. The length of the tamping rod shall be at least 100 mm [4 in.] greater than the depth of the mold in which rodding is being performed, but not greater than 600 mm [24 in.] in overall length (see Note 2). The rod shall have the tamping end or both ends rounded to a hemispherical tip of the same diameter as the rod.

NOTE 2—A rod length of 400 mm [16 in.] to 600 mm [24 in.] meets the requirements of the following: Practice C31/C31M, Test Method C138/C138M, Test Method C143/C143M, Test Method C173/C173M, and Test Method C231/C231M.

5.5 *Vibrators*—Internal vibrators shall be used. The vibrator frequency shall be at least 150 Hz [9000 vibrations per minute] while the vibrator is operating in the concrete. The diameter of a round vibrator shall be no more than one-fourth the diameter of the cylinder mold or one-fourth the width of the beam mold. Other shaped vibrators shall have a perimeter equivalent to the circumference of an appropriate round vibrator. The combined length of the vibrator shaft and vibrating element shall exceed the depth of the section being vibrated by at least 75 mm [3 in.]. The vibrator frequency shall be checked periodically with a vibrating-reed tachometer or other suitable device.

NOTE 3—For information on size and frequency of various vibrators and a method to periodically check vibrator frequency see ACI 309R.

5.6 *Mallet*—A mallet with a rubber or rawhide head weighing 0.6 kg ± 0.2 kg [1.25 lb ± 0.50 lb] shall be used.

5.7 *Placement Tools*—of a size large enough so each amount of concrete obtained from the sampling receptacle is representative and small enough so concrete is not spilled during placement in the mold. For placing concrete in a cylinder mold,

TABLE 1 Tamping Rod Diameter Requirements

Diameter of Cylinder or Width of Beam mm [in.]	Diameter or Rod mm [in.]
<150 [6]	10 ± 2 [3⁄8 ± 1⁄16]
≥150 [6]	16 ± 2 [5⁄8 ± 1⁄16]

[4] Available from American Concrete Institute (ACI), P.O. Box 9094, Farmington Hills, MI 48333-9094, http://www.aci-int.org.

the acceptable tool is a scoop. For placing concrete in a beam mold, either a shovel or scoop is permitted.

5.8 *Finishing Tools*—a handheld float or a trowel.

5.9 *Slump Apparatus*—The apparatus for measurement of slump shall conform to the requirements of Test Method C143/C143M.

5.10 *Sampling Receptacle*—The receptacle shall be a suitable heavy gauge metal pan, wheelbarrow, or flat, clean nonabsorbent board of sufficient capacity to allow easy remixing of the entire sample with a shovel or trowel.

5.11 *Air Content Apparatus*—The apparatus for measuring air content shall conform to the requirements of Test Methods C173/C173M or C231/C231M.

5.12 *Temperature Measuring Devices*—The temperature measuring devices shall conform to the applicable requirements of Test Method C1064/C1064M.

6. Testing Requirements

6.1 *Cylindrical Specimens*—Compressive or splitting tensile strength specimens shall be cylinders cast and allowed to set in an upright position. The number and size of cylinders cast shall be as directed by the specifier of the tests. In addition, the length shall be twice the diameter and the cylinder diameter shall be at least 3 times the nominal maximum size of the coarse aggregate. When the nominal maximum size of the coarse aggregate exceeds 50 mm [2 in.], the concrete sample shall be treated by wet sieving through a 50 mm [2 in.] sieve as described in Practice C172/C172M. For acceptance testing for specified compressive strength, cylinders shall be 150 mm by 300 mm [6 in. by 12 in.] or 100 mm by 200 mm [4 in. by 8 in.] (Note 4).

NOTE 4—When molds in SI units are required and not available, equivalent inch-pound unit size mold should be permitted.

6.2 *Beam Specimens*—Flexural strength specimens shall be beams of concrete cast and hardened in the horizontal position. The length shall be at least 50 mm [2 in.] greater than three times the depth as tested. The ratio of width to depth as molded shall not exceed 1.5.

6.2.1 The minimum cross-sectional dimension of the beam shall be as stated in Table 2. Unless otherwise specified by the specifier of tests, the standard beam shall be 150 by 150 mm [6 by 6 in.] in cross section.

6.2.2 When the nominal maximum size of the coarse aggregate exceeds 50 mm [2 in.], the concrete sample shall be treated by wet sieving through a 50-mm [2-in.] sieve as described in Practice C172/C172M.

6.2.3 The specifier of tests shall specify the specimen size and the number of specimens to be tested to obtain an average test result (Note 5). The same specimen size shall be used when comparing results and for mixture qualification and acceptance testing.

NOTE 5—The modulus of rupture can be determined using different specimen sizes. However, measured modulus of rupture generally increases as specimen size decreases.[5,6] The strength ratio for beams of different sizes depends primarily on the maximum size of aggregate.[7] Experimental data obtained in two different studies have shown that for maximum aggregate size between 19.0 mm and 25.0 mm [¾ in. and 1 in.], the ratio between the modulus of rupture determined with a 150 mm by 150 mm [6 in. by 6 in.] and a 100 mm by 100 mm [4 in. by 4 in.] may vary from 0.90 to 1.07[5] and for maximum aggregate size between 9.5 mm and 37.5 mm [⅜ in. and 1½ in.], the ratio between the modulus of rupture determined with a 150 mm by 150 mm [6 in. by 6 in.] and a 115 mm by 115 mm [4.5 in. by 4.5 in.] may vary from 0.86 to 1.00.[6]

6.3 *Field Technicians*—The field technicians making and curing specimens for acceptance testing shall meet the personnel qualification requirements of Practice C1077.

TABLE 2 Minimum Cross-Sectional Dimension of Beams

Nominal Maximum Aggregate Size (NMAS)	Minimum Cross-Sectional Dimension
≤ 25 mm [1 in.]	100 mm by 100 mm [4 in. by 4 in.]
25 mm [1 in.] < NMAS ≤ 50 mm [2 in.]	150 mm by 150 mm [6 in. by 6 in.]

7. Sampling Concrete

7.1 The samples used to fabricate test specimens under this standard shall be obtained in accordance with Practice C172/C172M unless an alternative procedure has been approved.

7.2 Record the identification of the sample with respect to the location of the concrete represented and the time of casting.

8. Slump, Slump Flow, Air Content, and Temperature

8.1 Perform the following tests for each sample of concrete from which specimens are made for acceptance testing for strength:

8.1.1 *Slump or Slump Flow*—After remixing the sample in the receptacle, measure and record the slump or slump flow in accordance with Test Method C143/C143M or Test Method C1611/C1611M, respectively.

8.1.2 *Air Content*—Determine and record the air content in accordance with either Test Method C173/C173M or Test Method C231/C231M. The concrete used in performing the air content test shall not be used in fabricating test specimens.

8.1.3 *Temperature*—Determine and record the temperature in accordance with Test Method C1064/C1064M.

NOTE 6—Some specifications may require the measurement of the unit weight of concrete. The volume of concrete produced per batch may be desired on some projects. Also, additional information on the air content measurements may be desired. Test Method C138/C138M is used to measure the unit weight, yield, and gravimetric air content of freshly mixed concrete.

[5] Tanesi, J; Ardani, A. Leavitt, J. "Reducing the Specimen Size of Concrete Flexural Strength Test (AASHTO T97) for Safety and Ease of Handling," *Transportation Research Record: Journal of the Transportation Research Board,* No. 2342, Transportation Research Board of National Academies, Washington, D.C., 2013.

[6] Carrasquillo, P.M. and Carrasquillo, R. L "Improved Concrete Quality Control Procedures Using Third Point Loading", *Research Report 119-1F*, Project 3-9-87-1119, Center for Transportation Research, The University of Texas at Austin, November 1987.

[7] Bazant, Z. and Novak, D. "Proposal for Standard Test of Modulus of Rupture of Concrete with its Size Dependence," *ACI Materials Journal*, January-February 2001.

9. Molding Specimens

9.1 *Place of Molding*—Mold specimens promptly on a level, rigid surface, free of vibration and other disturbances, at a place as near as practicable to the location where they are to be stored.

9.2 *Casting Cylinders*—Select the proper tamping rod from 5.4 and Table 1 or the proper vibrator from 5.5. Determine the method of consolidation from Table 3, unless another method is specified. If the method of consolidation is rodding, determine molding requirements from Table 4. If the method of consolidation is vibration, determine molding requirements from Table 5. Select a scoop of the size described in 5.7. While placing the concrete in the mold, move the scoop around the perimeter of the mold opening to ensure an even distribution of the concrete with minimal segregation. Each layer of concrete shall be consolidated as required. In placing the final layer, add an amount of concrete that will fill the mold after consolidation.

9.2.1 *Self-Consolidating Concrete*—If casting cylinders of self-consolidating concrete, use the mold filling procedures in Practice C1758/C1758M instead of the procedure in 9.2. After filling the mold, finish the cylinders in accordance with 9.5, without further consolidation.

9.3 *Casting Beams*—Select the proper tamping rod from 5.4 and Table 1 or proper vibrator from 5.5. Determine the method of consolidation from Table 3, unless another method is specified. If the method of consolidation is rodding, determine the molding requirements from Table 4. If the method of consolidation is vibration, determine the molding requirements from Table 5. Determine the number of roddings per layer, one for each 14 cm^2 [2 $in.^2$] of the top surface area of the beam. Select a placement tool as described in 5.7. Using the scoop or shovel, place the concrete in the mold to the height required for each layer. Place the concrete so that it is uniformly distributed within each layer with minimal segregation. Each layer shall be consolidated as required. In placing the final layer, add an amount of concrete that will fill the mold after consolidation.

9.3.1 *Self-Consolidating Concrete*—If casting beams of self-consolidating concrete, use the mold filling procedures in Practice C1758/C1758M instead of the procedure in 9.3. After filling the mold, finish the beams in accordance with 9.5, without further consolidation.

9.4 *Consolidation*—The methods of consolidation for this practice are rodding or internal vibration.

9.4.1 *Rodding*—Place the concrete in the mold in the required number of layers of approximately equal volume. Rod each layer uniformly over the cross section with the rounded end of the rod using the required number of strokes. Rod the bottom layer throughout its depth. In rodding this layer, use care not to damage the bottom of the mold. For each upper layer, allow the rod to penetrate through the layer being rodded and into the layer below approximately 25 mm [1 in.]. After each layer is rodded, tap the outsides of the mold lightly 10 to 15 times with the mallet to close any holes left by rodding and to release any large air bubbles that may have been trapped. Use an open hand to tap cylinder molds that are susceptible to denting or other permanent distortion if tapped with a mallet. After tapping, spade each layer of the concrete along the sides and ends of beam molds with a trowel or other suitable tool. Underfilled molds shall be adjusted with representative concrete during consolidation of the top layer. Overfilled molds shall have excess concrete removed.

9.4.2 *Vibration*—Maintain a uniform duration of vibration for the particular kind of concrete, vibrator, and specimen mold involved. The duration of vibration required will depend upon the workability of the concrete and the effectiveness of the vibrator. Usually sufficient vibration has been applied as soon as the surface of the concrete has become relatively smooth and large air bubbles cease to break through the top surface. Continue vibration only long enough to achieve proper consolidation of the concrete (see Note 7). Fill the molds and vibrate in the required number of approximately equal layers. Place all the concrete for each layer in the mold before starting vibration of that layer. In compacting the specimen, insert the vibrator slowly and do not allow it to rest on the bottom or sides of the mold. Slowly withdraw the vibrator so that no large air pockets are left in the specimen. When placing the final layer, avoid overfilling by more than 6 mm [¼ in.].

TABLE 3 Method of Consolidation Requirements

Slump, mm [in.]	Method of Consolidation
≥25 [1]	rodding or vibration
< 25 [1]	vibration

TABLE 4 Molding Requirements by Rodding

Specimen Type and Size	Number of Layers of Approximately Equal Depth	Number of Roddings per Layer
Cylinders:		
Diameter, mm [in.]		
100 [4]	2	25
150 [6]	3	25
225 [9]	4	50
Beams:		
Width, mm [in.]		
100 [4] to 200 [8]	2	see 9.3
>200 [8]	3 or more equal depths, each not to exceed 150 mm [6 in.].	see 9.3

TABLE 5 Molding Requirements by Vibration

Specimen Type and Size	Number of Layers	Number of Vibrator Insertions per Layer	Approximate Depth of Layer, mm [in.]
Cylinders:			
Diameter, mm [in.]			
100 [4]	2	1	one-half depth of specimen
150 [6]	2	2	one-half depth of specimen
225 [9]	2	4	one-half depth of specimen
Beams:			
Width, mm [in.]			
100 [4] to 200 [8]	1	see 9.4.2	depth of specimen
over 200 [8]	2 or more	see 9.4.2	200 [8] as near as practicable

NOTE 7—Generally, no more than 5 s of vibration should be required for each insertion to adequately consolidate concrete with a slump greater than 75 mm [3 in.]. Longer times may be required for lower slump concrete, but the vibration time should rarely have to exceed 10 s per insertion.

9.4.2.1 *Cylinders*—The number of insertions of the vibrator per layer is given in Table 5. When more than one insertion per layer is required distribute the insertion uniformly within each layer. Allow the vibrator to penetrate through the layer being vibrated, and into the layer below, about 25 mm [1 in.]. After each layer is vibrated, tap the outsides of the mold at least 10 times with the mallet, to close holes that remain and to release entrapped air voids. Use an open hand to tap molds that are susceptible to denting or other permanent distortion if tapped with a mallet.

9.4.2.2 *Beams*—Insert the vibrator at intervals not exceeding 150 mm [6 in.] along the center line of the long dimension of the specimen. For specimens wider than 150 mm [6 in.], use alternating insertions along two lines. Allow the shaft of the vibrator to penetrate into the bottom layer about 25 mm [1 in.]. After each layer is vibrated, tap the outsides of the mold sharply at least 10 times with the mallet to close holes left by vibrating and to release entrapped air voids.

9.5 *Finishing*—Perform all finishing with the minimum manipulation necessary to produce a flat even surface that is level with the rim or edge of the mold and that has no depressions or projections larger than 3.3 mm [⅛ in.].

9.5.1 *Cylinders*—After consolidation, finish the top surfaces by striking them off with the tamping rod where the consistency of the concrete permits or with a handheld float or trowel. If desired, cap the top surface of freshly made cylinders with a thin layer of stiff portland cement paste which is permitted to harden and cure with the specimen. See section on Capping Materials of Practice C617/C617M.

9.5.2 *Beams*—After consolidation of the concrete, use a handheld float or trowel to strike off the top surface to the required tolerance to produce a flat, even surface.

9.6 *Identification*—Mark the specimens to positively identify them and the concrete they represent. Use a method that will not alter the top surface of the concrete. Do not mark the removable caps. Upon removal of the molds, mark the test specimens to retain their identities.

10. Curing

10.1 *Standard Curing*—Standard curing is the curing method used when the specimens are made and cured for the purposes stated in 4.2.

10.1.1 *Storage*—The supporting surface on which specimens are stored shall be level to within 20 mm/m [¼ in./ft]. If specimens are not molded in the location where they will receive initial curing, ensure that the specimens have been moved to the initial curing location no later than 15 min after molding operations have been completed. If a specimen in a single-use mold is moved, support the bottom of the mold. If the top surface of a specimen is disturbed during movement to the place of initial storage, refinish the surface.

NOTE 8—Some single-use molds, such as cylinder molds constructed of sheet metal or treated cardboard, may be permanently distorted if moved without proper support. Using a large trowel or a hand to support the bottom of these molds are acceptable means to prevent permanent deformation. It is acceptable to slightly tilt the mold to facilitate lifting and supporting the mold. If a cover is to be placed on the top of a specimen, the cover should be placed on the specimen after moving the specimen to the initial curing location to ensure the required finish of the top surface of the specimen. For example, if a specimen will be stored in water for initial curing, it would be appropriate to perform a final check of the surface finish prior to placing the cover and setting the specimen into the water.

10.1.2 *Initial Curing*—Store standard-cured specimens for a period up to 48 h after molding to maintain the specified temperature and moisture conditions described in 10.1.2.1 and 10.1.2.2.

NOTE 9—Generally, just covering the specimens is not sufficient to maintain the environment required for initial standard curing.

10.1.2.1 For concrete mixtures with a specified strength less than 40 MPa [6000 psi], maintain the initial curing temperature between 16 °C and 27 °C [60 °F and 80 °F]. For concrete mixtures with a specified strength of 40 MPa [6000 psi] or greater, maintain the initial curing temperature between 20 °C and 26 °C [68 °F and 78 °F]. Shield specimens from direct exposure to sunlight and, if used, radiant heating devices. Record the minimum temperature and maximum temperatures achieved for each set of specimens during the initial curing period.

NOTE 10—A satisfactory temperature environment can be created during the initial curing of the specimens by one or more of the following procedures: (1) use of ventilation; (2) use of ice; (3) use of cooling devices; or (4) use of heating devices such as electrical resistance heaters or light bulbs. Other suitable methods may be used provided the temperature requirements are met.

NOTE 11—Early-age strength test results may be lower if specimens are stored at temperatures lower than the specified range. At later ages, strength test results may be lower if specimens are exposed to initial curing temperatures higher than the specified range.

10.1.2.2 Store the specimens in an environment that controls the loss of moisture.

NOTE 12—A satisfactory moisture environment can be created during the initial curing of the specimens by one or more of the following procedures: (1) immerse molded specimens with plastic lids in water; (2) store specimens in a container or enclosure; (3) place specimens in damp sand pits; (4) cover specimens with plastic lids; (5) place specimens inside plastic bags; or (6) cover specimens with wet fabric.

NOTE 13—Immersion in water may be the easiest method to maintain required moisture and temperature conditions during initial curing.

10.1.3 *Final Curing:*

10.1.3.1 *Cylinders*—Upon completion of initial curing and within 30 min after removing the molds, cure specimens with free water maintained on their surfaces at all times at a temperature of 23.0 °C ± 2.0 °C [73.5 °F ± 3.5 °F] using water storage tanks or moist rooms complying with the requirements of Specification C511, except when capping with sulfur mortar capping compound and immediately prior to testing. When capping with sulfur mortar capping compound, the ends of the cylinder shall be dry enough to preclude the formation of steam or foam pockets under or in cap larger than 6 mm [¼ in.] as described in Practice C617/C617M. For a period not to exceed 3 h immediately prior to test, standard curing temperature is not required provided free moisture is maintained on the cylinders and ambient temperature is between 20 °C and 30 °C [68 °F and 86 °F].

10.1.3.2 *Beams*—Beams are to be cured the same as cylinders (see 10.1.3.1) except that they shall be stored in water saturated with calcium hydroxide at 23.0 °C ± 2.0 °C [73.5 °F ± 3.5 °F] at least 20 h prior to testing. Drying of the surfaces of the beam shall be prevented between removal from water storage and completion of testing.

NOTE 14—Relatively small amounts of surface drying of flexural specimens can induce tensile stresses in the extreme fibers that will markedly reduce the indicated flexural strength.

10.2 *Field Curing*—Field curing is the curing method used for the specimens made and cured as stated in 4.3.

10.2.1 *Cylinders*—Store cylinders in or on the structure as near to the point of deposit of the concrete represented as possible. Protect all surfaces of the cylinders from the elements in as near as possible the same way as the formed work. Provide the cylinders with the same temperature and moisture environment as the structural work. Test the specimens in the moisture condition resulting from the specified curing treatment. To meet these conditions, specimens made for the purpose of determining when a structure is capable of being put in service shall be removed from the molds at the time of removal of form work.

10.2.2 *Beams*—As nearly as practicable, cure beams in the same manner as the concrete in the structure. At the end of 48 ± 4 h after molding, take the molded specimens to the storage location and remove from the molds. Store specimens representing pavements of slabs on grade by placing them on the ground as molded, with their top surfaces up. Bank the sides and ends of the specimens with earth or sand that shall be kept damp, leaving the top surfaces exposed to the specified curing treatment. Store specimens representing structure concrete as near the point in the structure they represent as possible, and afford them the same temperature protection and moisture environment as the structure. At the end of the curing period leave the specimens in place exposed to the weather in the same manner as the structure. Remove all beam specimens from field storage and store in water saturated with calcium hydroxide at 23.0 °C ± 2.0 °C [73.5 °F ± 3.5 °F] for 24 ± 4 h immediately before time of testing to ensure uniform moisture condition from specimen to specimen. Observe the precautions given in 10.1.3.2 to guard against drying between time of removal from curing to testing.

10.3 *Lightweight Concrete Curing*—Cure lightweight concrete cylinders in accordance with Specification C330/C330M.

11. Transportation of Specimens to Laboratory

11.1 Prior to transporting, cure and protect specimens as required in Section 10. Specimens shall not be transported until at least 8 h after final set. (See Note 15). During transporting, protect the specimens with suitable cushioning material to prevent damage from jarring. During cold weather, protect the specimens from freezing with suitable insulation material. Prevent moisture loss during transportation by wrapping the specimens in plastic, wet burlap, by surrounding them with wet sand, or tight fitting plastic caps on plastic molds. Transportation time shall not exceed 4 h.

NOTE 15—Setting time may be measured by Test Method C403/C403M.

12. Report

12.1 Report the following information to the laboratory that will test the specimens:

12.1.1 Specimen identification,

12.1.2 Serial number of delivery ticket, if available,

12.1.3 Location of concrete represented by the samples,

12.1.4 Date, time and name of individual molding specimens,

12.1.5 Slump or slump flow, air content, and concrete temperature, test results and results of any other tests on the fresh concrete, and any deviations from referenced standard test methods, and

12.1.6 Curing method. For standard curing method, report the initial curing method with maximum and minimum temperatures and final curing method. For field curing method, report the location where stored, manner of protection from the elements, temperature and moisture environment, and time of removal from molds.

13. Keywords

13.1 beams; casting samples; concrete; curing; cylinders; testing

SUMMARY OF CHANGES

Committee C09 has identified the location of selected changes to this practice since the last issue, C31/C31M–19a, that may impact the use of this practice. (Approved March 1, 2021.)

(1) 12.1.1 was modified.
(2) 12.1.2 was added.

Committee C09 has identified the location of selected changes to this practice since the last issue, C31/C31M–19, that may impact the use of this practice. (Approved December 15, 2019.)

(1) Added 8.1
(2) Added Test Method C495/C495M and Test Method D4832 to Referenced Documents.
(3) Revised 1.2 and 10.3.
(4) Added Note 1.

Designation: C39/C39M – 21

Standard Test Method for Compressive Strength of Cylindrical Concrete Specimens[1]

This standard is issued under the fixed designation C39/C39M; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

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

1. Scope*

1.1 This test method covers determination of compressive strength of cylindrical concrete specimens such as molded cylinders and drilled cores. It is limited to concrete having a density in excess of 800 kg/m^3 [50 lb/ft^3].

1.2 The values stated in either SI units or inch-pound units are to be regarded separately as standard. The inch-pound units are shown in brackets. The values stated in each system may not be exact equivalents; therefore, each system shall be used independently of the other. Combining values from the two systems may result in non-conformance with the standard.

1.3 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety, health, and environmental practices and determine the applicability of regulatory limitations prior to use.*(**Warning—**Means should be provided to contain concrete fragments during sudden rupture of specimens. Tendency for sudden rupture increases with increasing concrete strength and it is more likely when the testing machine is relatively flexible. The safety precautions given in R0030 are recommended.*)*

1.4 The text of this standard references notes which provide explanatory material. These notes shall not be considered as requirements of the standard.

1.5 *This international standard was developed in accordance with internationally recognized principles on standardization established in the Decision on Principles for the Development of International Standards, Guides and Recommendations issued by the World Trade Organization Technical Barriers to Trade (TBT) Committee.*

2. Referenced Documents

2.1 *ASTM Standards:*[2]

C31/C31M Practice for Making and Curing Concrete Test Specimens in the Field
C42/C42M Test Method for Obtaining and Testing Drilled Cores and Sawed Beams of Concrete
C125 Terminology Relating to Concrete and Concrete Aggregates
C192/C192M Practice for Making and Curing Concrete Test Specimens in the Laboratory
C617/C617M Practice for Capping Cylindrical Concrete Specimens
C670 Practice for Preparing Precision and Bias Statements for Test Methods for Construction Materials
C873/C873M Test Method for Compressive Strength of Concrete Cylinders Cast in Place in Cylindrical Molds
C943 Practice for Making Test Cylinders and Prisms for Determining Strength and Density of Preplaced-Aggregate Concrete in the Laboratory
C1077 Practice for Agencies Testing Concrete and Concrete Aggregates for Use in Construction and Criteria for Testing Agency Evaluation
C1176/C1176M Practice for Making Roller-Compacted Concrete in Cylinder Molds Using a Vibrating Table
C1231/C1231M Practice for Use of Unbonded Caps in Determination of Compressive Strength of Hardened Cylindrical Concrete Specimens
C1435/C1435M Practice for Molding Roller-Compacted Concrete in Cylinder Molds Using a Vibrating Hammer
C1604/C1604M Test Method for Obtaining and Testing Drilled Cores of Shotcrete
E4 Practices for Force Verification of Testing Machines
E18 Test Methods for Rockwell Hardness of Metallic Materials

[1] This test method is under the jurisdiction of ASTM Committee C09 on Concrete and Concrete Aggregates and is the direct responsibility of Subcommittee C09.61 on Testing for Strength.

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

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

E74 Practices for Calibration and Verification for Force-Measuring Instruments
R0030 Manual of Aggregate and Concrete Testing

3. Terminology

3.1 *Definitions*—For definitions of terms used in this practice, refer to Terminology C125.

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *bearing block, n*—steel piece to distribute the load from the testing machine to the specimen.

3.2.2 *lower bearing block, n*—steel piece placed under the specimen to distribute the load from the testing machine to the specimen.

3.2.2.1 *Discussion*—The lower bearing block provides a readily machinable surface for maintaining the specified bearing surface. The lower bearing block may also be used to adapt the testing machine to various specimen heights. The lower bearing block is also referred to as *bottom block*, *plain block*, and *false platen*.

3.2.3 *platen, n*—primary bearing surface of the testing machine.

3.2.3.1 *Discussion*—The platen is also referred to as the testing machine *table*.

3.2.4 *spacer, n*—steel piece used to elevate the lower bearing block to accommodate test specimens of various heights.

3.2.4.1 *Discussion*—Spacers are not required to have hardened bearing faces because spacers are not in direct contact with the specimen or the retainers of unbonded caps.

3.2.5 *upper bearing block, n*—steel assembly suspended above the specimen that is capable of tilting to bear uniformly on the top of the specimen.

3.2.5.1 *Discussion*—The upper bearing block is also referred to as the *spherically seated block* and the *suspended block*.

4. Summary of Test Method

4.1 This test method consists of applying a compressive axial load to molded cylinders or cores at a rate which is within a prescribed range until failure occurs. The compressive strength of the specimen is calculated by dividing the maximum load attained during the test by the cross-sectional area of the specimen.

5. Significance and Use

5.1 Care must be exercised in the interpretation of the significance of compressive strength determinations by this test method since strength is not a fundamental or intrinsic property of concrete made from given materials. Values obtained will depend on the size and shape of the specimen, batching, mixing procedures, the methods of sampling, molding, and fabrication and the age, temperature, and moisture conditions during curing.

5.2 This test method is used to determine compressive strength of cylindrical specimens prepared and cured in accordance with Practices C31/C31M, C192/C192M, C617/C617M, C943, C1176/C1176M, C1231/C1231M, and C1435/C1435M, and Test Methods C42/C42M, C873/C873M, and C1604/C1604M.

5.3 The results of this test method are used as a basis for quality control of concrete proportioning, mixing, and placing operations; determination of compliance with specifications; control for evaluating effectiveness of admixtures; and similar uses.

5.4 The individual who tests concrete cylinders for acceptance testing shall meet the concrete laboratory technician requirements of Practice C1077, including an examination requiring performance demonstration that is evaluated by an independent examiner.

NOTE 1—Certification equivalent to the minimum guidelines for ACI Concrete Laboratory Technician, Level I or ACI Concrete Strength Testing Technician will satisfy this requirement.

6. Apparatus

6.1 *Testing Machine*—The testing machine shall be of a type having sufficient capacity and capable of providing the rates of loading prescribed in 8.5.

6.1.1 Verify the accuracy of the testing machine in accordance with Practices E4, except that the verified loading range shall be as required in 6.4. Verification is required:

6.1.1.1 Within 13 months of the last calibration,

6.1.1.2 On original installation or immediately after relocation,

6.1.1.3 Immediately after making repairs or adjustments that affect the operation of the force applying system or the values displayed on the load indicating system, except for zero adjustments that compensate for the mass of bearing blocks or specimen, or both, or

6.1.1.4 Whenever there is reason to suspect the accuracy of the indicated loads.

6.1.2 *Design*—The design of the machine must include the following features:

6.1.2.1 The machine must be power operated and must apply the load continuously rather than intermittently, and without shock. If it has only one loading rate (meeting the requirements of 8.5), it must be provided with a supplemental means for loading at a rate suitable for verification. This supplemental means of loading may be power or hand operated.

6.1.2.2 The space provided for test specimens shall be large enough to accommodate, in a readable position, an elastic calibration device which is of sufficient capacity to cover the potential loading range of the testing machine and which complies with the requirements of Practice E74.

NOTE 2—The types of elastic calibration devices most generally available and most commonly used for this purpose are the circular proving ring or load cell.

6.1.3 *Accuracy*—The accuracy of the testing machine shall be in accordance with the following provisions:

6.1.3.1 The percentage of error for the loads within the proposed range of use of the testing machine shall not exceed ±1.0 % of the indicated load.

6.1.3.2 The accuracy of the testing machine shall be verified by applying five test loads in four approximately equal increments in ascending order. The difference between any two successive test loads shall not exceed one third of the difference between the maximum and minimum test loads.

6.1.3.3 The test load as indicated by the testing machine and the applied load computed from the readings of the verification device shall be recorded at each test point. Calculate the error, *E,* and the percentage of error, E_p, for each point from these data as follows:

$$E = A - B \tag{1}$$

$$E_p = 100(A - B)/B$$

where:

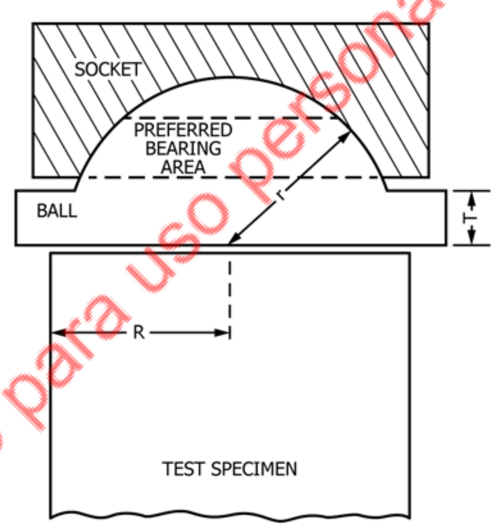
A = load, kN [lbf] indicated by the machine being verified, and

B = applied load, kN [lbf] as determined by the calibrating device.

6.1.3.4 The report on the verification of a testing machine shall state within what loading range it was found to conform to specification requirements rather than reporting a blanket acceptance or rejection. In no case shall the loading range be stated as including loads below the value which is 100 times the smallest change of load estimable on the load-indicating mechanism of the testing machine or loads within that portion of the range below 10 % of the maximum range capacity.

6.1.3.5 In no case shall the loading range be stated as including loads outside the range of loads applied during the verification test.

6.1.3.6 The indicated load of a testing machine shall not be corrected either by calculation or by the use of a calibration diagram to obtain values within the required permissible variation.



$T \geq R - r$

r = radius of spherical portion of upper bearing block

R = nominal radius of specimen

T = thickness of upper bearing block extending beyond the sphere

FIG. 1 Schematic Sketch of Typical Upper Bearing Block

6.2 *Bearing Blocks*—The upper and lower bearing blocks shall conform to the following requirements:

6.2.1 Bearing blocks shall be steel with hardened bearing faces (Note 3).

6.2.2 Bearing faces shall have dimensions at least 3 % greater than the nominal diameter of the specimen.

6.2.3 Except for the inscribed concentric circles described in 6.2.4.7, the bearing faces shall not depart from a plane by more than 0.02 mm [0.001 in.] along any 150 mm [6 in.] length for bearing blocks with a diameter of 150 mm [6 in.] or larger, or by more than 0.02 mm [0.001 in.] in any direction of smaller bearing blocks. New bearing blocks shall be manufactured within one half of this tolerance.

NOTE 3—It is desirable that the bearing faces of bearing blocks have a Rockwell hardness at least 55 HRC as determined by Test Methods E18.

NOTE 4—Square bearing faces are permissible for the bearing blocks.

6.2.4 *Upper Bearing Block*—The upper bearing block shall conform to the following requirements:

6.2.4.1 The upper bearing block shall be spherically seated and the center of the sphere shall coincide with the center of the bearing face within ±5 % of the radius of the sphere.

6.2.4.2 The ball and the socket shall be designed so that the steel in the contact area does not permanently deform when loaded to the capacity of the testing machine.

NOTE 5—The preferred contact area is in the form of a ring (described as *preferred bearing area*) as shown in Fig. 1.

6.2.4.3 Provision shall be made for holding the upper bearing block in the socket. The design shall be such that the bearing face can be rotated and tilted at least 4° in any direction.

6.2.4.4 If the upper bearing block is a two-piece design composed of a spherical portion and a bearing plate, a mechanical means shall be provided to ensure that the spherical portion is fixed and centered on the bearing plate.

6.2.4.5 The diameter of the sphere shall be at least 75 % of the nominal diameter of the specimen. If the diameter of the sphere is smaller than the diameter of the specimen, the portion of the bearing face extending beyond the sphere shall have a thickness not less than the difference between the radius of the sphere and radius of the specimen (see Fig. 1). The least dimension of the bearing face shall be at least as great as the diameter of the sphere.

6.2.4.6 The dimensions of the bearing face of the upper bearing block shall not exceed the following values:

Nominal Diameter of Specimen, mm [in.]	Maximum Diameter of Round Bearing Face, mm [in.]	Maximum Dimensions of Square Bearing Face, mm [in.]
50 [2]	105 [4]	105 by 105 [4 by 4]
75 [3]	130 [5]	130 by 130 [5 by 5]
100 [4]	165 [6.5]	165 by 165 [6.5 by 6.5]
150 [6]	255 [10]	255 by 255 [10 by 10]
200 [8]	280 [11]	280 by 280 [11 by 11]

6.2.4.7 If the diameter of the bearing face of the upper bearing block exceeds the nominal diameter of the specimen by more than 13 mm [0.5 in.], concentric circles not more than 0.8 mm [0.03 in.] deep and not more than 1 mm [0.04 in.] wide shall be inscribed on the face of upper bearing block to facilitate proper centering.

6.2.4.8 At least every six months, or as specified by the manufacturer of the testing machine, clean and lubricate the curved surfaces of the socket and of the spherical portion of the upper bearing block. The lubricant shall be a petroleum-type oil such as conventional motor oil or as specified by the manufacturer of the testing machine.

NOTE 6—To ensure uniform seating, the upper bearing block is designed to tilt freely as it comes into contact with the top of the specimen. After contact, further rotation is undesirable. Friction between the socket and the spherical portion of the head provides restraint against further rotation during loading. Pressure-type greases can reduce the desired friction and permit undesired rotation of the spherical head and should not be used unless recommended by the manufacturer of the testing machine. Petroleum-type oil such as conventional motor oil has been shown to permit the necessary friction to develop.

6.2.5 *Lower Bearing Block*—The lower bearing block shall conform to the following requirements:

6.2.5.1 The lower bearing block shall be solid.

6.2.5.2 The top and bottom surfaces of the lower bearing block shall be parallel to each other.

6.2.5.3 The lower bearing block shall be at least 25 mm [1.0 in.] thick when new, and at least 22.5 mm [0.9 in.] thick after resurfacing.

6.2.5.4 The lower bearing block shall be fully supported by the platen of the testing machine or by any spacers used.

6.2.5.5 If the testing machine is designed that the platen itself is readily maintained in the specified surface condition, a lower bearing block is not required.

NOTE 7—The lower bearing block may be fastened to the platen of the testing machine.

NOTE 8—Inscribed concentric circles as described in 6.2.4.7 are optional on the lower bearing block.

6.3 *Spacers*—If spacers are used, the spacers shall be placed under the lower bearing block and shall conform to the following requirements:

6.3.1 Spacers shall be solid steel. One vertical opening located in the center of the spacer is permissible. The maximum diameter of the vertical opening is 19 mm [0.75 in.].

6.3.2 The top and bottom surfaces of the spacer shall be parallel to each other.

6.3.3 Spacers shall be fully supported by the platen of the test machine.

6.3.4 Spacers shall fully support the lower bearing block and any spacers above.

6.3.5 Spacers shall not be in direct contact with the specimen or the retainers of unbonded caps.

6.4 *Load Indication*—The testing machine shall be equipped with either a dial or digital load indicator.

6.4.1 The verified loading range shall not include loads less than 100 times the smallest change of load that can be read.

6.4.2 A means shall be provided that will record, or indicate until reset, the maximum load to an accuracy within 1.0 % of the load.

6.4.3 If the load is displayed on a dial, the graduated scale shall be readable to at least the nearest 0.1 % of the full scale load (Note 9). The dial shall be readable within 1.0 % of the indicated load at any given load level within the loading range. The dial pointer shall be of sufficient length to reach the graduation marks. The width of the end of the pointer shall not exceed the clear distance between the smallest graduations. The scale shall be provided with a labeled graduation line load corresponding to zero load. Each dial shall be equipped with a zero adjustment located outside the dial case and accessible from the front of the machine while observing the zero mark and dial pointer.

NOTE 9—Readability is considered to be 0.5 mm [0.02 in.] along the arc described by the end of the pointer. If the spacing is between 1 and 2 mm [0.04 and 0.08 in.], one half of a scale interval is considered readable. If the spacing is between 2 and 3 mm [0.08 and 0.12 in.], one third of a scale interval is considered readable. If the spacing is 3 mm [0.12 in.] or more, one fourth of a scale interval is considered readable.

6.4.4 If the load is displayed in digital form, the numbers must be large enough to be read. The numerical increment shall not exceed 0.1 % of the full scale load of a given loading range. Provision shall be made for adjusting the display to indicate a value of zero when no load is applied to the specimen.

6.5 Documentation of the calibration and maintenance of the testing machine shall be in accordance with Practice C1077.

7. Specimens

7.1 Specimens shall not be tested if any individual diameter of a cylinder differs from any other diameter of the same cylinder by more than 2 %.

NOTE 10—This may occur when single use molds are damaged or deformed during shipment, when flexible single use molds are deformed during molding, or when a core drill deflects or shifts during drilling.

7.2 Prior to testing, neither end of test specimens shall depart from perpendicularity to the axis by more than 0.5° (approximately equivalent to 1 mm in 100 mm [0.12 in. in 12 in.]). The ends of compression test specimens that are not plane within 0.050 mm [0.002 in.] shall be sawed or ground to meet that tolerance, or capped in accordance with either Practice C617/C617M or, when permitted, Practice C1231/C1231M. The diameter used for calculating the cross-sectional area of the test specimen shall be determined to the nearest 0.25 mm [0.01 in.] by averaging two diameters measured at right angles to each other at about midheight of the specimen.

7.3 The number of individual cylinders measured for determination of average diameter is not prohibited from being reduced to one for each ten specimens or three specimens per day, whichever is greater, if all cylinders are known to have been made from a single lot of reusable or single-use molds which consistently produce specimens with average diameters within a range of 0.5 mm [0.02 in.]. When the average diameters do not fall within the range of 0.5 mm [0.02 in.] or when the cylinders are not made from a single lot of molds, each cylinder tested must be measured and the value used in calculation of the unit compressive strength of that specimen. When the diameters are measured at the reduced frequency, the cross-sectional areas of all cylinders tested on that day shall be computed from the average of the diameters of the three or more cylinders representing the group tested that day.

7.4 If the purchaser of the testing services or the specifier of the tests requests measurement of the specimen density, determine the specimen density before capping by either 7.4.1

(specimen dimension method) or 7.4.2 (submerged weighing method). For either method, use a balance or scale that is accurate to within 0.3 % of the mass being measured.

7.4.1 Remove any surface moisture with a towel and measure the mass of the specimen. Measure the length of the specimen to the nearest 1 mm [0.05 in.] at three locations spaced evenly around the circumference. Compute the average length and record to the nearest 1 mm [0.05 in.].

7.4.2 Remove any surface moisture with a towel and determine the mass of the specimen in air. Submerge the specimen in water at a temperature of 23.0 °C ± 2.0 °C [73.5 °F ± 3.5 °F] for 15 ± 5 sec. Then, determine the apparent mass of the specimen while submerged under water.

7.5 When density determination is not required and the length to diameter ratio is less than 1.8 or more than 2.2, measure the length of the specimen to the nearest 0.05 D.

8. Procedure

8.1 Compression tests of moist-cured specimens shall be made as soon as practicable after removal from moist storage.

8.2 Test specimens shall be kept moist by any convenient method during the period between removal from moist storage and testing. They shall be tested in the moist condition.

8.3 Tolerances for specimen ages are as follows:

Test Age[A]	Permissible Tolerance
24 h	±0.5 h
3 days	±2 h
7 days	±6 h
28 days	±20 h
90 days	±2 days

[A]For test ages not listed, the test age tolerance is ±2.0% of the specified age.

8.3.1 Unless otherwise specified by the specifier of tests, for this test method the test age shall start at the beginning of casting specimens.

8.4 *Placing the Specimen*—Place the lower bearing block, with the hardened face up, on the table or platen of the testing machine. Wipe clean the bearing faces of the upper and lower bearing blocks, spacers if used, and of the specimen. If using unbonded caps, wipe clean the bearing surfaces of the retainers and center the unbonded caps on the specimen. Place the specimen on the lower bearing block and align the axis of the specimen with the center of thrust of the upper bearing block.

NOTE 11—Although the lower bearing block may have inscribed concentric circles to assist with centering the specimen, final alignment is made with reference to the upper bearing block.

8.4.1 *Zero Verification and Block Seating*—Prior to testing the specimen, verify that the load indicator is set to zero. In cases where the indicator is not properly set to zero, adjust the indicator (Note 12). After placing the specimen in the machine but prior to applying the load on the specimen, tilt the movable portion of the spherically seated block gently by hand so that the bearing face appears to be parallel to the top of the test specimen.

NOTE 12—The technique used to verify and adjust load indicator to zero will vary depending on the machine manufacturer. Consult your owner's manual or compression machine calibrator for the proper technique.

8.4.2 *Verification of Alignment When Using Unbonded Caps*—If using unbonded caps, verify the alignment of the specimen after application of load, but before reaching 10 % of the anticipated specimen strength. Check to see that the axis of the cylinder does not depart from vertical by more than 0.5° (Note 13) and that the ends of the cylinder are centered within the retaining rings. If the cylinder alignment does not meet these requirements, release the load, and carefully recenter the specimen. Reapply load and recheck specimen centering and alignment. A pause in load application to check cylinder alignment is permissible.

NOTE 13—An angle of 0.5° is equal to a slope of approximately 1 mm in 100 mm [1⁄8 inches in 12 inches]

8.5 *Rate of Loading*—Apply the load continuously and without shock.

8.5.1 The load shall be applied at a rate of movement (platen to crosshead measurement) corresponding to a stress rate on the specimen of 0.25 MPa/s ± 0.05 MPa/s [35 psi/s ± 7 psi/s] (see Note 14). The designated rate of movement shall be maintained at least during the latter half of the anticipated loading phase.

NOTE 14—For a screw-driven or displacement-controlled testing machine, preliminary testing will be necessary to establish the required rate of movement to achieve the specified stress rate. The required rate of movement will depend on the size of the test specimen, the elastic modulus of the concrete, and the stiffness of the testing machine.

8.5.2 During application of the first half of the anticipated loading phase, a higher rate of loading shall be permitted. The higher loading rate shall be applied in a controlled manner so that the specimen is not subjected to shock loading.

8.5.3 Make no adjustment in the rate of movement (platen to crosshead) as the ultimate load is being approached and the stress rate decreases due to cracking in the specimen.

8.6 Apply the compressive load until the load indicator shows that the load is decreasing steadily and the specimen displays a well-defined fracture pattern (Types 1 to 4 in Fig. 2). For a testing machine equipped with a specimen break detector, automatic shut-off of the testing machine is prohibited until the load has dropped to a value that is less than 95 % of the peak load. When testing with unbonded caps, a corner fracture similar to a Type 5 or 6 pattern shown in Fig. 2 may occur before the ultimate capacity of the specimen has been attained. Continue compressing the specimen until the user is certain that the ultimate capacity has been attained. Record the maximum load carried by the specimen during the test, and note the type of fracture pattern according to Fig. 2. If the fracture pattern is not one of the typical patterns shown in Fig. 2, sketch and describe briefly the fracture pattern. If the measured strength is lower than expected, examine the fractured concrete and note the presence of large air voids, evidence of segregation, whether fractures pass predominantly around or through the coarse aggregate particles, and verify end preparations were in accordance with Practice C617/C617M or Practice C1231/C1231M.

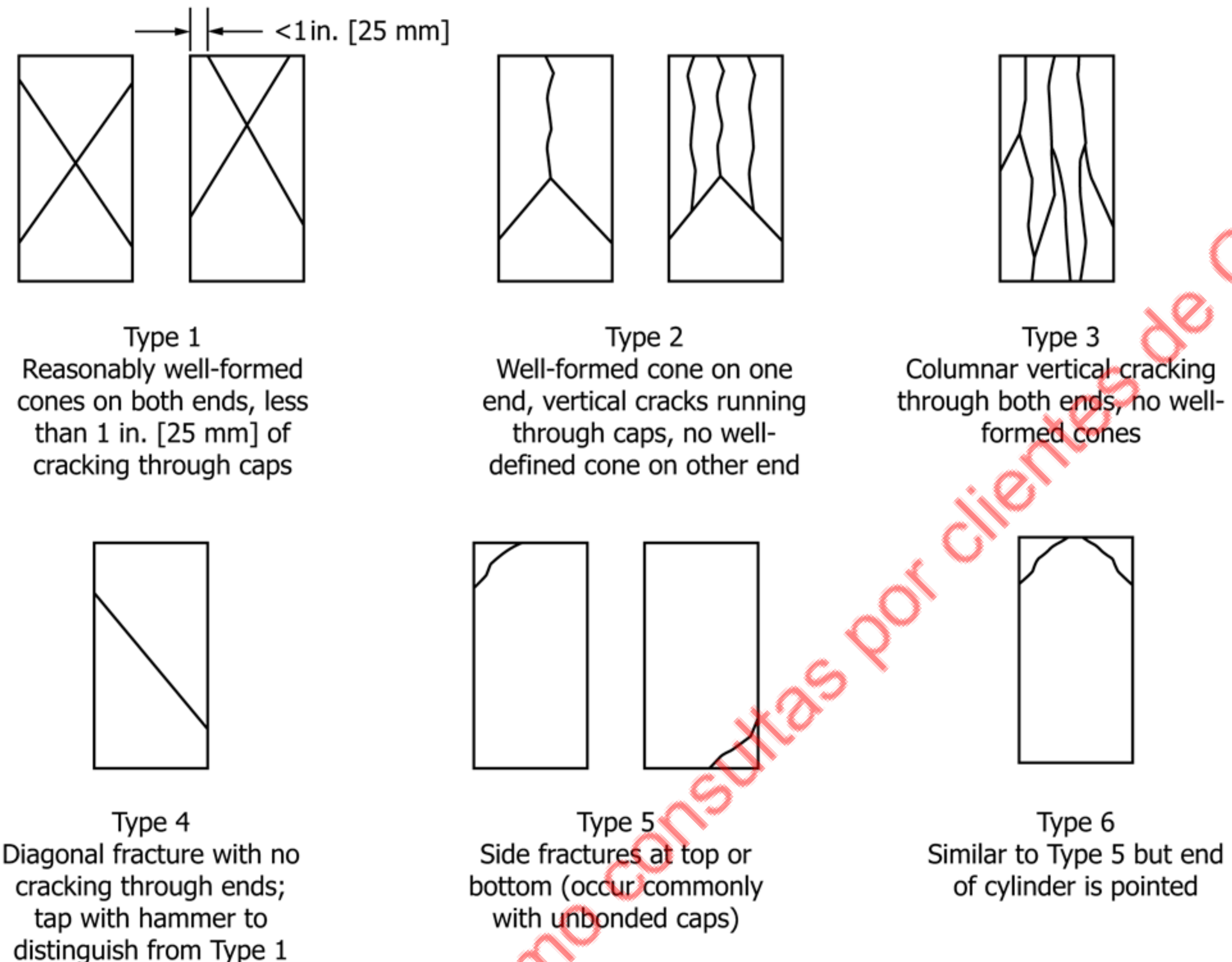


FIG. 2 Schematic of Typical Fracture Patterns

9. Calculation

9.1 Calculate the compressive strength of the specimen as follows:

SI units:

$$f_{cm} = \frac{4000\,P_{max}}{\pi D^2} \quad (2)$$

Inch-pound units:

$$f_{cm} = \frac{4\,P_{max}}{\pi\,D^2} \quad (3)$$

where:

f_{cm} = compressive strength, MPa [psi],
P_{max} = maximum load, kN [lbf], and
D = average measured diameter, mm [in.].

Use at least five digits for the value of π, that is, use 3.1416 or a more precise value.

9.2 If the specimen length to diameter ratio is 1.75 or less, correct the result obtained in 9.1 by multiplying by the appropriate correction factor shown in the following table:

L/D:	1.75	1.50	1.25	1.00
Factor:	0.98	0.96	0.93	0.87

Use interpolation to determine correction factors for L/D values between those given in the table.

NOTE 15—Correction factors depend on various conditions such as moisture condition, strength level, and elastic modulus. Average values are given in the table. These correction factors apply to low-density concrete weighing between 1600 and 1920 kg/m³ [100 and 120 lb/ft³] and to normal-density concrete. They are applicable to concrete dry or soaked at the time of loading and for nominal concrete strengths from 14 to 42 MPa [2000 to 6000 psi]. For strengths higher than 42 MPa [6000 psi] correction factors may be larger than the values listed above[3].

9.3 If required, calculate the specimen density to the nearest 10 kg/m³ [1 lb/ft³] using the applicable method.

9.3.1 If specimen density is determined based on specimen dimensions, calculate specimen density as follows:

SI units:

$$\rho_s = \frac{4 \times 10^9 \times W}{L \times D^2 \times \pi} \quad (4)$$

Inch-pound units:

$$\left[\rho_s = \frac{6912 \times W}{L \times D^2 \times \pi}\right] \quad (5)$$

where:

ρ_s = specimen density, kg/m³ [lb/ft³],

[3] Bartlett, F.M. and MacGregor, J.G., "Effect of Core Length-to-Diameter Ratio on Concrete Core Strength," *ACI Materials Journal*, Vol 91, No. 4, July-August, 1994, pp. 339–348.

W = mass of specimen in air, kg [lb],
L = average measured length, mm [in.], and
D = average measured diameter, mm [in.].

9.3.2 If the specimen density is based on submerged weighing, calculate the specimen density as follows:

$$\rho_s = \frac{W \times \gamma_w}{W - W_s} \quad (6)$$

where:

ρ_s = specimen density, kg/m^3 [lb/ft^3],
W = mass of specimen in air, kg [lb],
W_s = apparent mass of submerged specimen, kg [lb], and
γ_w = density of water at 23 °C [73.5 °F] = 997.5 kg/m^3 [62.27 lb/ft^3].

10. Report

10.1 Report the following information:

10.1.1 Specimen identification,

10.1.2 Serial number of delivery ticket, if available,

10.1.3 Average measured diameter (and measured length, if outside the range of 1.8 *D* to 2.2 *D*), in millimetres [inches],

10.1.4 Cross-sectional area, in square millimetres [square inches],

10.1.5 Maximum load, in kilonewtons [pounds-force],

10.1.6 Compressive strength rounded to the nearest 0.1 MPa [10 psi],

10.1.7 If the average of two or more companion cylinders tested at the same age is reported, calculate the average compressive strength using the unrounded individual compressive strength values. Report the average compressive-strength rounded to the nearest 0.1 MPa [10 psi].

10.1.8 Type of fracture (see Fig. 2),

10.1.9 Defects in either specimen or caps,

10.1.10 Age of specimen at time of testing. Report age in days for ages three days or greater, report age in hours if the age is less than three days,

NOTE 16—If software limitations prevent reporting the specimen age in hours, the age of the specimen in hours may be included in a note in the report.

10.1.11 If determined, the density to the nearest 10 kg/m^3 [1 lb/ft^3].

11. Precision and Bias

11.1 *Precision*

11.1.1 *Single-Operator Precision*—The following table provides the single-operator precision of tests of 150 mm by 300 mm [6 in. by 12 in.] and 100 mm by 200 mm [4 in. by 8 in.] cylinders made from a well-mixed sample of concrete under laboratory conditions and under field conditions (see 11.1.2).

	Coefficient of Variation[4]	Acceptable Range[4] of Individual Cylinder Strengths	
		2 cylinders	3 cylinders
150 by 300 mm [6 by 12 in.]			
Laboratory conditions	2.4 %	6.6 %	7.8 %
Field conditions	2.9 %	8.0 %	9.5 %
100 by 200 mm [4 by 8 in.]			
Laboratory conditions	3.2 %	9.0 %	10.6 %

11.1.2 The single-operator coefficient of variation represents the expected variation of measured strength of companion cylinders prepared from the same sample of concrete and tested by one laboratory at the same age. The values given for the single-operator coefficient of variation of 150 by 300 mm [6 by 12 in.] cylinders are applicable for compressive strengths between 15 to 55 MPa [2000 to 8000 psi] and those for 100 mm by 200 mm [4 in. by 8 in.] cylinders are applicable for compressive strengths between 17 to 32 MPa [2500 and 4700 psi]. The single-operator coefficients of variation for 150 by 300 mm [6 by 12 in.] cylinders are derived from CCRL concrete proficiency sample data for laboratory conditions and a collection of 1265 test reports from 225 commercial testing laboratories in 1978.[5] The single-operator coefficient of variation of 100 by 200 mm [4 by 8 in.] cylinders are derived from CCRL concrete proficiency sample data for laboratory conditions.

11.1.3 *Multilaboratory Precision*—The multi-laboratory coefficient of variation for compressive strength test results of 150 by 300 mm [6 by 12 in.] cylinders has been found to be 5.0 %[4]; therefore, the results of properly conducted tests by two laboratories on specimens prepared from the same sample of concrete are not expected to differ by more than 14 %[4] of the average (see Note 17). A strength test result is the average of two cylinders tested at the same age.

NOTE 17—The multilaboratory precision does not include variations associated with different operators preparing test specimens from split or independent samples of concrete. These variations are expected to increase the multilaboratory coefficient of variation.

11.1.4 The multilaboratory data were obtained from six separate organized strength testing round robin programs where 150 by 300 mm [6 by 12 in.] cylindrical specimens were prepared at a single location and tested by different laboratories. The range of average strength from these programs was 17.0 to 90 MPa [2500 to 13 000 psi].

NOTE 18—Subcommittee C09.61 will continue to examine recent concrete proficiency sample data and field test data and make revisions to precisions statements when data indicate that they can be extended to cover a wider range of strengths and specimen sizes.

11.2 *Bias*—Since there is no accepted reference material, no statement on bias is being made.

[4] These numbers represent respectively the (1s %) and (d2s %) limits as described in Practice C670.

[5] Supporting data have been filed at ASTM International Headquarters and may be obtained by requesting Research Report RR:C09-1006. Contact ASTM Customer Service at service@astm.org.

12. Keywords

12.1 concrete core; concrete cylinder; concrete specimen; concrete strength; compressive strength; core; cylinder; drilled core; strength

SUMMARY OF CHANGES

Committee C09 has identified the location of selected changes to this standard since the last issue (C39/C39M–20) that may impact the use of this standard. (Approved March 1, 2021)

(1) 10.1.1 was revised.

(2) 10.1.2 was added.

Committee C09 has identified the location of selected changes to this standard since the last issue (C39/C39M–18) that may impact the use of this standard. (Approved Feb. 1, 2020)

(1) Revised 9.1 to specify the minimum precision of π.

Designation: C172/C172M − 17

Standard Practice for Sampling Freshly Mixed Concrete[1]

This standard is issued under the fixed designation C172/C172M; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope*

1.1 This practice covers procedures for obtaining representative samples of fresh concrete as delivered to the project site on which tests are to be performed to determine compliance with quality requirements of the specifications under which the concrete is furnished (Note 1). The practice includes sampling from stationary, paving and truck mixers, and from agitating and nonagitating equipment used to transport central-mixed concrete and from continuous mixing equipment as described in Specification C685/C685M.

1.2 The values stated in either SI units or inch-pound units are to be regarded separately as standard. The values stated in each system may not be exact equivalents; therefore, each system shall be used independently of the other. Combining values from the two systems may result in non-conformance with the standard.

NOTE 1—Composite samples are required by this practice, unless specifically excepted by procedures governing the tests to be performed such as tests to determine uniformity of consistency and mixer efficiency. Procedures used to select the specific test batches are not described in this practice, but it is recommended that random sampling be used to determine overall specification compliance.

1.3 This practice also covers the procedures to be used for preparing a sample of concrete for further testing where it is desirable or necessary to remove the aggregate larger than a designated size. This removal of larger aggregate particles is preferably accomplished by wet-sieving.

1.4 The text of this standard references notes and footnotes which provide explanatory material and shall not be considered as requirements of the practice.

1.5 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety, health, and environmental practices and determine the applicability of regulatory limitations prior to use.* (**Warning**—Fresh hydraulic cementitious mixtures are caustic and may cause chemical burns to skin and tissue upon prolonged exposure.[2])

1.6 *This international standard was developed in accordance with internationally recognized principles on standardization established in the Decision on Principles for the Development of International Standards, Guides and Recommendations issued by the World Trade Organization Technical Barriers to Trade (TBT) Committee.*

2. Referenced Documents

2.1 *ASTM Standards:*[3]

C685/C685M Specification for Concrete Made by Volumetric Batching and Continuous Mixing

E11 Specification for Woven Wire Test Sieve Cloth and Test Sieves

3. Significance and Use

3.1 This practice is intended to provide standard requirements and procedures for sampling freshly mixed concrete from different containers used in the production or transportation of concrete. The detailed requirements as to materials, mixtures, air content, temperature, number of specimens, slump, interpretation of results, and precision and bias are in specific test methods.

4. Sampling

4.1 The elapsed time shall not exceed 15 min. between obtaining the first and final portions of the composite sample.

4.1.1 Transport the individual samples to the place where fresh concrete tests are to be performed or where test specimens are to be molded. They shall be combined and remixed with a shovel the minimum amount necessary to ensure uniformity and compliance with the maximum time limits specified in 4.1.2.

4.1.2 Start tests for slump, temperature, and air content within 5 min after obtaining the final portion of the composite sample. Complete these tests expeditiously. Start molding

[1] This practice is under the jurisdiction of ASTM Committee C09 on Concrete and Concrete Aggregates and is the direct responsibility of Subcommittee C09.60 on Testing Fresh Concrete.

Current edition approved Oct. 1, 2017. Published October 2017. Originally approved in 1942. Last previous edition approved in 2014 as C172/C172M–14a. DOI: 10.1520/C0172_C0172M-17.

[2] Section on Safety Precautions, Manual of Aggregate and Concrete Testing, *Annual Book of ASTM Standards*, Vol 04.02.

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

*A Summary of Changes section appears at the end of this standard specimens for strength tests within 15 min after fabricating the composite sample. Expeditiously obtain and use the sample and protect the sample from the sun, wind, and other sources of rapid evaporation, and from contamination.

5. Procedure

5.1 *Size of Sample*—Make the samples to be used for strength tests a minimum of 28 L [1 ft^3]. Smaller samples are not prohibited for routine air content, temperature, and slump tests. The size of the samples shall be dictated by the maximum aggregate size.

5.2 The procedures used in sampling shall include the use of every precaution that will assist in obtaining samples that are truly representative of the nature and condition of concrete sampled as follows:

NOTE 2—Sampling should normally be performed as the concrete is delivered from the mixer to the conveying vehicle used to transport the concrete to the forms; however, specifications may require other points of sampling, such as the discharge of a concrete pump.

5.2.1 *Sampling from Stationary Mixers, Except Paving Mixers*—Sample the concrete by collecting two or more portions taken at regularly spaced intervals during discharge of the middle portion of the batch. Obtain these portions within the time limit specified in Section 4. Combine into one composite sample for testing purposes. Do not obtain portions of the composite sample from the very first or last part of the batch discharge (Note 3). Perform sampling by passing a receptacle completely through the discharge stream, or by completely diverting the discharge into a sample container. If discharge of the concrete is too rapid to divert the complete discharge stream, discharge the concrete into a container or transportation unit sufficiently large to accommodate the entire batch and then accomplish the sampling in the same manner as given above. Take care not to restrict the flow of concrete from the mixer, container, or transportation unit so as to cause segregation. These requirements apply to both tilting and nontilting mixers.

NOTE 3—No samples should be taken before 10 % or after 90 % of the batch has been discharged. Due to the difficulty of determining the actual quantity of concrete discharged, the intent is to provide samples that are representative of widely separated portions, but not the beginning and the end of the load.

5.2.2 *Sampling from Paving Mixers*—Sample the concrete after the contents of the paving mixer have been discharged. Obtain samples from at least five different portions of the pile and combine them into one composite sample for test purposes. Avoid contamination with subgrade material or prolonged contact with and absorptive subgrade.

NOTE 4—Discharging concrete across shallow containers placed on the subgrade, or supported above the subgrade, may be effective in precluding contamination or absorption by the subgrade. If used, the concrete from the shallow containers should provide a composite sample that is in agreement with the maximum aggregate size.

5.2.3 *Sampling from Revolving Drum Truck Mixers or Agitators*—Sample the concrete by collecting two or more portions taken at regularly spaced intervals during discharge of the middle portion of the batch. Take the samples so obtained within the time limit specified in Section 4 and combine them into one composite sample for test purposes. In any case do not obtain samples until after all of the water and any admixtures have been added to the mixer; also do not obtain samples from the very first or last portions of the batch discharge (Note 3). Sample by repeatedly passing a receptacle through the entire discharge stream or by completely diverting the discharge into a sample container. Regulate the rate of discharge of the batch by the rate of revolution of the drum and not by the size of the gate opening.

5.2.4 *Sampling from Continuous Mixers*—Sample the concrete after the discharge of at least 140 L [5 ft^3] of concrete, following all mixture proportioning adjustments. Sample the concrete at the frequency specified by collecting two or more portions taken at regularly spaced intervals during discharge of the concrete. Take the portions so obtained within the time limit specified in Section 4, and combine them into one composite sample for test purposes. Do not obtain samples from the very first or last portions of a mixer's continuous discharge (Note 3). Sample by repeatedly passing a receptacle through the entire discharge stream or by completely diverting the discharge into a sample container. After obtaining the composite sample, wait a minimum of 2 minutes and a maximum of 5 minutes before beginning tests (Note 5).

NOTE 5—The waiting period prior to commencing the testing is needed because the mix water is input only seconds before discharge from the continuous mixer.

5.2.5 *Sampling from Open-Top Truck Mixers, Agitators, Nonagitating Equipment, or Other Types of Open-Top Containers*—Take samples by whichever of the procedures described in 5.2.1, 5.2.2, or 5.2.3 is most applicable under the given conditions.

6. Additional Procedure for Large Maximum Size Aggregate Concrete

6.1 When the concrete contains aggregate larger than that appropriate for the size of the molds or equipment to be used, wet-sieve the sample as described below except perform density (unit weight) tests for use in yield computations on the full mix.

NOTE 6—The effect of wet-sieving on the test results should be considered. For example, wet-sieving concrete causes the loss of a small amount of air due to additional handling. The air content of the wet-sieved fraction of concrete is greater than that of the total concrete because the larger size aggregate which is removed does not contain air. The apparent strength of wet-sieved concrete in smaller specimens is usually greater than that of the total concrete in larger appropriate size specimens. The effect of these differences may need to be considered or determined by supplementary testing for quality control or test result evaluation purposes.

6.2 *Definition:*

6.2.1 *wet-sieving concrete*—the process of removing aggregate larger than a designated size from the fresh concrete by sieving it on a sieve of the designated size.

6.3 *Apparatus:*

6.3.1 *Sieves,* as designated, conforming to Specification E11.

6.3.2 *Receptacle*—A container of suitable size having a nonabsorbent surface.

6.3.3 *Wet-Sieving Equipment*—Equipment for wet-sieving concrete shall be a sieve as noted in 6.3.1 of suitable size and conveniently arranged and supported so that one can shake it rapidly by either hand or mechanical means. Generally, a horizontal back and forth motion is preferred. The equipment shall be capable of rapidly and effectively removing the designated size of aggregate.

6.3.4 *Hand Tools*—Shovels, hand scoops, plastering trowels, and rubber gloves as required.

6.4 *Procedure:*

6.4.1 *Wet-Sieving*—After sampling the concrete, pass the concrete over the designated sieve and remove and discard the aggregate retained. This shall be done before remixing. Shake or vibrate the sieve by hand or mechanical means until no undersize material remains on the sieve. Mortar adhering to the aggregate retained on the sieve shall not be wiped from it before it is discarded. Place only enough concrete on the sieve at any one time so that after sieving, the thickness of the layer of retained aggregate is not more than one particle thick. The concrete which passes the sieve shall fall into a batch pan of suitable size which has been dampened before use or onto a clean, moist, nonabsorbent surface. Scrape any mortar adhering to the sides of the wet-sieving equipment into the batch. After removing the larger aggregate particles by wet-sieving remix the batch with a shovel the minimum amount necessary to ensure uniformity and proceed testing immediately.

7. Keywords

7.1 air content; batch; composite sample; concrete; slump; temperature; wet-sieving

SUMMARY OF CHANGES

Committee C09 has identified the location of selected changes to this practice since the last issue, C172/C172M–14a, that may impact the use of this practice. (Approved October 1, 2017)

(1) Revised 5.2.2.

(2) Revised Note 4.

Designation: C470/C470M − 15

Standard Specification for Molds for Forming Concrete Test Cylinders Vertically[1]

This standard is issued under the fixed designation C470/C470M; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

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

1. Scope*

1.1 This specification covers molds for use in forming cylindrical concrete specimens. The provisions of this specification include the requirements for both reusable and single-use molds.

NOTE 1—Sizes included are molds having diameters from 50 mm [2 in.] to 900 mm [36 in.].

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

1.3 The values stated in either SI units or inch-pound units are to be regarded separately as standard. The values stated in each system may not be exact equivalents; therefore, each system shall be used independently of the other. Combining values from the two systems may result in non-conformance with the standard. The inch-pound units are shown in brackets.

1.4 The following safety hazards caveat pertains only to the test method described in this specification: *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

2. Referenced Documents

2.1 *ASTM Standards:*[2]

C31/C31M Practice for Making and Curing Concrete Test Specimens in the Field

C33 Specification for Concrete Aggregates

C192/C192M Practice for Making and Curing Concrete Test Specimens in the Laboratory

C1077 Practice for Agencies Testing Concrete and Concrete Aggregates for Use in Construction and Criteria for Testing Agency Evaluation

D256 Test Methods for Determining the Izod Pendulum Impact Resistance of Plastics

D570 Test Method for Water Absorption of Plastics

3. General Requirements

3.1 The following provisions apply to both reusable and single-use molds:

3.1.1 Molds shall be constructed in the form of right circular cylinders which stand with the cylindrical axis vertical and the top open to receive the concrete. They shall be made of materials that do not react with concrete containing portland or other hydraulic cements. They shall be watertight and sufficiently strong and tough to permit their use without tearing, crushing, or deforming.

NOTE 2—Reusable lids may be used on molds to reduce moisture loss.

3.1.2 Molds shall have a nominal inside height equal to twice the nominal inside diameter. The diameter of a mold, consisting of the average of two measurements taken at right angles to each other at the top of the mold, shall not differ from the nominal diameter by more than 1 %. The height, determined by averaging two measurements taken 180° apart, shall not differ from the nominal height by more than 2 %. The planes of the top rim of the mold and the bottom shall be perpendicular to the axis of the mold within 0.5 degrees—approximately equivalent to 3 mm in 300 mm [⅛ in. in 12 in.]. No diameter of a mold shall differ from any other diameter of the same mold by more than 2 % except that molds that fail to meet this requirement may be used when the user is able to demonstrate that no diameter of hardened concrete specimen produced in a similar mold differs from any other diameter on the same specimen by more than 2 % (see Note 3).

NOTE 3—Certain single-use molds may require the use of a special device such as a tube of heavy-gage metal around the mold during molding to maintain the dimensional tolerances specified in 3.1.2.

3.1.3 The bottom inside surface of the mold shall not depart from a plane by more than 2 mm in 150 mm [1⁄16 in. in 6 in.] (1 % of the diameter of the mold).

[1] This specification is under the jurisdiction of ASTM Committee C09 on Concrete and Concrete Aggregates and is the direct responsibility of Subcommittee C09.61 on Testing for Strength.

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

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

4. Reusable Molds

4.1 Reusable molds are those which are designed to be used more than a single time. Reusable molds shall be made of nonabsorptive materials, and constructed as either one piece or several pieces (see Note 4).

4.2 Reusable molds shall be provided with a closure or base on the lower end at right angles to the axis of the cylinder. Molds may be single piece molds or made from castings with a separate detachable base plate or a base that is an integral part of the sidewall. The mold shall be either coated or made of a material that will prevent adherence to the concrete. At the time of use, molds shall not leak water. An inside fillet, if any, at the bottom of the side wall shall have an indentation around the circumference no more than 3 mm [1⁄8 in.] in the vertical direction or no more than 5 mm [3⁄16 in.] in the horizontal direction.

4.3 Reusable molds shall be tested for water leakage as described in 6.4, for resistance to damage as described in 6.3.1, and for dimensional stability in accordance with 3.1.2 and 3.1.3 initially and after every 50 uses or every six months, whichever comes first.

NOTE 4—Satisfactory molds can be made from lengths of steel tubing or pipe that is slit on one side parallel to the axis and fitted with a means of closing the vertical slit as well as a means of attaching a base plate. The required dimensional tolerances must be maintained after slitting, clamping, and attaching the base plate. Other nonabsorptive materials which have been used include iron, brass, steel, and various plastics. Although aluminum and magnesium alloys have been used, some of these alloys may be reactive with cement constituents and are therefore unacceptable.

5. Single-Use Molds

5.1 Single-use molds are molds designed to be used once and discarded. They are permitted to be made of sheet metal, plastic, suitably treated paper products, or other materials and shall conform to the requirements of this specification.

5.2 *Physical Requirements*—The molds as prepared for use shall comply with the following:

5.2.1 *Water Leakage*—When tested as described in Section 6, there shall be no visible leakage.

5.2.2 *Absorptivity*—When tested as described in Section 6, the absorption shall not exceed the values given in Table 1. Intermediate values are proportional to the square of the height.

5.2.3 *Elongation*—When tested as described in Section 6, the elongation after test shall not exceed 0.2 % of height.

TABLE 1 Limits for Absorption and Elongation

Nominal Mold Height, mm [in.]	Absorption, max g	Elongation, max mm [in.]
100 [4]	2.7	0.2 [0.008]
150 [6]	6.0	0.3 [0.012]
200 [8]	11	0.4 [0.016]
300 [12]	24	0.6 [0.024]
450 [18]	54	0.9 [0.036]
600 [24]	96	1.2 [0.048]
900 [36]	216	1.8 [0.072]

5.3 *Single-use Plastic Molds*—Molds shall conform to the following additional requirements when plastic is the predominant material used in construction:

5.3.1 *Wall Thickness*—The side walls shall be of sufficient stiffness to meet the requirements of 3.1 (See Note 5).

NOTE 5—This can be achieved through sufficient side wall thickness alone, or in combination with a stiffened top.

5.3.2 *Bottom Design*—The bottom shall be designed so that it will be flush with the bottom of the sidewall within a tolerance of 2 mm [1⁄16 in.]. An inside fillet, if any, at the bottom of the sidewall shall have an indentation around the circumference no more than 4 mm [1⁄8 in.] in the vertical direction or no more than 5 mm [3⁄16 in.] in the radial direction. The bottom shall be of adequate rigidity to prevent permanent deformation when specimens are molded in accordance with the applicable provisions of Practice C31/C31M or C192/C192M.

5.3.3 *Material*—The mold manufacturer shall certify that: (*1*) the plastic material used in molds has a maximum water absorption of less than 0.5 % in 24 h when tested in accordance with Test Method D570; (*2*) the plastic has an Izod impact toughness of at least 117 J/m [2.2 ft lb/in.] of notch for a 4 mm [1⁄8 in.] thick specimen tested in accordance with Test Methods D256; and (*3*) after being held at 12 °C [10 °F] for 24 h, the plastic shall not fracture when subject to tapping and jarring that is judged to be typical of what occurs when specimens are molded in accordance with the applicable provisions of Practice C31/C31M or C192/C192M.

5.4 *Paper Molds*—When paper or other potentially absorptive fiber material is used as the primary structural material in the construction of the side walls or bottom of the mold, the mold shall conform to the following additional requirements:

5.4.1 *Side Walls*—The side walls of paper molds shall be made with a minimum of three plies having a combined thickness of not less than 2 mm [0.070 in.]. Seams on the inside of the mold shall not be open by more than 2 mm [1⁄16 in.].

NOTE 6—The minimum thickness of material used in side walls and bottoms is considered adequate for cylinders up to 150 mm [6 in.] in diameter. For larger cylinders thicker material may be required to meet requirements of 3.1.

5.4.2 *Bottom Caps*—The bottom cap of the mold shall be made of either metal or paper. If metal, it shall not be less than 0.23 mm [0.009 in.] in thickness and coated to prevent corrosion (Note 6). It shall be designed so that it will be flush with the bottom edge of the side wall within a tolerance of 2 mm [1⁄16 in.] and the inside crimp, if any, shall produce an indentation around the circumference of the cylinder no more than 5 mm [3⁄16 in.] in the radial, and no more than 4 mm [1⁄8 in.] in the vertical direction. If made of paper, the bottom cap of the mold shall be of parchment-lined cap stock not less than 0.7 mm [0.028 in.] thick (Note 6). It shall be glued to the outside of the walls by means of a flange not less than 19 mm [3⁄4 in.] high. The glue shall be water-insoluble adhesive of the resin type that will not react with fresh concrete. Only the practicable minimum amount of adhesive shall be exposed on the inner side of the bottom of the mold.

5.4.3 *Waterproofing*—The mold made from paper or fiber shall be completely coated on inside and outside, side walls, and bottom with a suitable waterproofing medium (Note 7). The top edge shall be waterproofed, or coated, to limit absorption. The surfaces of metal bottoms, which must comply with 5.4.2, need not be coated. Any waterproofing coating used in this application shall have a melting point not less than 49 °C [120 °F] (Note 8). The coating shall provide a film over the inside that will minimize adherence of the concrete to the side walls and the bottom.

NOTE 7—Paraffin coating for this use may be of the grade known to the trade as crude scale wax or of any superior grade. In general, a film of paraffin of sufficient thickness to accomplish the intended purposes will permit one to raise a curl of paraffin with the thumbnail.

NOTE 8—Such coatings may be unsuitable for molds that are subjected to temperatures above 49 °C [120 °F], either before or after filling with concrete.

5.5 *Single-Use Sheet Metal Molds*—Molds shall conform to the following additional requirements when light-gage sheet metal is the predominant material used in their construction:

5.5.1 *Metal Thickness*—The side wall of steel sheet metal molds shall be manufactured from sheet metal not thinner than can-making quality blackplate and shall have a minimum metal thickness corresponding to that of 48.5-kg [107-lb] blackplate, which is approximately 0.300 mm [0.0118 in.] thick or 30½ gage. The metal for the bottom of the mold shall have a minimum thickness of 0.23 mm [0.009 in.] (Note 6).

5.5.2 *Bottom Design*—The bottom shall be so designed that it will be flush with the bottom of the side wall within a tolerance of 2 mm [1⁄16 in.]. An inside crimp, if used, shall produce an indentation around the circumference of the cylinder no more than 4 mm [1⁄8 in.] in the vertical or 5 mm [3⁄16 in.] in the radial direction.

5.5.3 *Top Edge*—The top edge of the side wall shall be curled or beaded to strengthen the mold and protect the user from sharp edges. If such bead protrudes to the inside of the mold, the indentation produced in the concrete cylinder shall not exceed 4 mm [1⁄8 in.] in either a radial or vertical direction.

5.5.4 *Coating*—If the mold is made of material which will rust, corrode, react, or adhere to the freshly mixed or hardened concrete, it must be coated with a protective coating of lacquer or other suitable material.

5.6 *Packaging:*

5.6.1 The manufacturer shall state on containers of single-use molds that molds are intended to be used a single time.

5.6.2 Containers of single-use molds shall be marked with the manufacturer's lot number or date of manufacture.

5.6.3 Containers of single-use molds shall be marked with a directional arrow indicating orientation of the vertical axis of the molds.

NOTE 9—Shipping and storing single-use molds with their axis in the vertical position reduces the incidence of distortion.

6. Test Methods for Elongation, Absorption, and Water Leakage

6.1 *Apparatus*—The assembly used for the absorption-elongation test shall follow the principles illustrated in Fig. 1.

6.2 *Specimens*—Molds shall be selected as described in Section 2. Single-use molds shall not be reused nor the same mold retested.

6.3 *Test Procedure for Molds:*

6.3.1 Samples of all types of single-use molds and reusable plastic molds shall be subjected to the dry rodded coarse aggregate test as described in 6.3.2 to evaluate their resistance to damage under use and to the water leakage test described in 6.3.3 and 6.3.4. Paper or other potentially absorptive molds shall additionally be tested for absorptivity and elongation described in 6.3.5. Plastic and sheet metal molds need not be

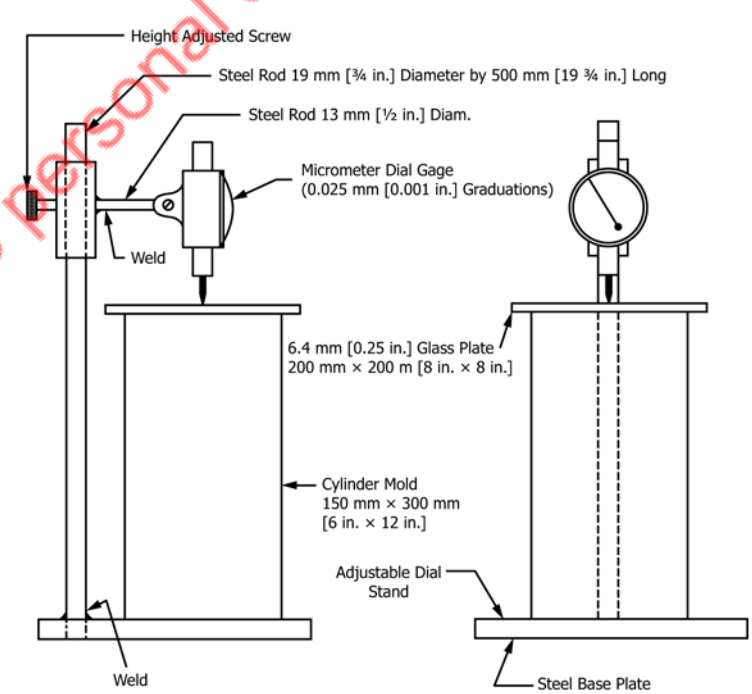


FIG. 1 Apparatus for Absorption-Elongation Test of Paper Molds

tested for elongation and absorption, but should be tested for water leakage. Dimensional requirements for all molds shall be verified.

6.3.2 Prepare the mold for test by filling with dry crushed stone coarse aggregate meeting the grading requirements of Specification C33 size No. 57, 25.0 to 4.75 mm [1 in. to No. 4] or No. 67, 19.0 to 4.75 mm [¾ in. to No. 4]. Fill and compact the mold by the rodding procedure specified in Practice C192/C192M for compression test specimens using the tamping rod, number of layers and number of strokes per layer specified. It will generally not be possible to obtain the penetration of the tamping rod specified in Practice C192/C192M. After rodding the final layer, empty the coarse aggregate, wipe lightly with a dry cloth and examine the mold for physical damage.

6.3.3 After completion of 6.3.2, determine the mass of the mold and record to the nearest 0.004 g/mm [0.1 g/in.] of mold height. Place the mold on a firm, flat surface and fill with water at room temperature to a depth of 90 to 95 % of the mold height. Then place the mold on the dial stand, cover with the glass or metal plate and record the initial length by dial micrometer to the nearest 0.025 mm [0.001 in.].

6.3.4 Allow the mold to stand for 3 h and take a final reading of the micrometer. Examine and record any visible leakage. Empty water from the mold, dry lightly with a towel and record the final mass to the nearest 0.04 g/cm [0.1 g/in.] of mold height.

6.3.5 Calculate the elongation as the difference between the final length and initial length. Calculate the absorption as the difference between the final mass and initial mass of the mold.

6.3.6 Verify all dimensional requirements.

6.4 *Water Leakage Test for Reusable Molds:*

6.4.1 Prepare reusable molds with the sealant to be used, if required. Fill molds with water to a depth of 90 to 95 % of the nominal height. Subject the mold to tapping and jarring which is judged to be typical of what occurs when specimens are molded in accordance with the applicable provisions of Practice C31/C31M or C192/C192M.

6.4.2 One hour after tapping, examine for visible leakage.

7. Sampling and Rejection

7.1 At least three single-use and reusable molds shall be selected at random from each shipment by the purchaser to ensure that the molds are in compliance with this specification.

7.2 Failure of any one of the three molds to comply with this specification shall be basis for rejection of the shipment.

8. Record to be Prepared by the Purchaser

8.1 Where applicable for the type of mold tested, record and retain in accordance with Practice C1077 the following information for each mold tested:

8.1.1 Brand or source of molds,

8.1.2 Shipment or lot from which the mold was taken,

8.1.3 Date sampled and date tested,

8.1.4 Brief general description of the mold including nominal dimensions, type of mold, and materials of which it is made,

8.1.5 Total absorption, g, if specified,

8.1.6 Total expansion, mm [in.], if specified, and

8.1.7 Water leakage reported in terms of compliance, or failure by leakage.

8.2 Where applicable for the type of mold tested, record and retain the following information for samples which do not meet the requirements of the specification:

8.2.1 Average diameter or height, mm [in.],

8.2.2 Maximum and minimum diameters or heights, mm [in.],

8.2.3 Nonconformance with required perpendicularity of rim or base to the axis of the mold,

8.2.4 Apparent reaction between mold materials and concrete or mortar or corrosion of metal in contact with concrete,

8.2.5 Melting point less than 49 °C [120 °F],

8.2.6 Minimum thickness of materials in side walls or bottom, and

8.2.7 Dimension of crimp in bottom, top edge or construction of paper bottom.

9. Keywords

9.1 concrete; molds; test cylinders

SUMMARY OF CHANGES

Committee C09 has identified the location of selected changes to this specification since the last issue, C470/C470M – 09, that may impact the use of this specification. (Approved Feb. 1, 2015.)

(1) Added 5.6 and Note 9.

Designation: C511 – 19

Standard Specification for Mixing Rooms, Moist Cabinets, Moist Rooms, and Water Storage Tanks Used in the Testing of Hydraulic Cements and Concretes[1]

This standard is issued under the fixed designation C511; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope*

1.1 This specification includes requirements for mixing rooms where paste and mortar specimens are prepared; and for moist cabinets, moist rooms, and water storage tanks where paste, mortar, and concrete specimens are stored.

1.2 The values stated in SI units are to be regarded as standard. No other units of measurement are included in this standard. Values in SI units shall be obtained by measurement in SI units or by appropriate conversion, using the Rules for Conversion and rounding given in Standard IEEE/ASTM SI 10, of measurements made in other units.

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

1.4 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety, health, and environmental practices and determine the applicability of regulatory limitations prior to use.*

1.5 *This international standard was developed in accordance with internationally recognized principles on standardization established in the Decision on Principles for the Development of International Standards, Guides and Recommendations issued by the World Trade Organization Technical Barriers to Trade (TBT) Committee.*

2. Referenced Documents

2.1 *ASTM Standards:*[2]

C51 Terminology Relating to Lime and Limestone (as used by the Industry)

E77 Test Method for Inspection and Verification of Thermometers

C125 Terminology Relating to Concrete and Concrete Aggregates

C219 Terminology Relating to Hydraulic Cement

IEEE/ASTM SI 10 Standard for Use of the International System of Units (SI): The Modern Metric System

3. Terminology

3.1 *Definitions:*

3.1.1 Refer to Terminology C125 and Terminology C219 for definitions of terms used in this test method.

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *mixing room, n*—a room with controlled temperature and relative humidity where cement paste and mortar specimens are prepared.

3.2.2 *moist cabinet, n*—a compartmented storage facility of moderate dimensions with controlled temperature and relative humidity.

3.2.3 *moist room, n*—a "walk-in" storage facility with controlled temperature and relative humidity, commonly called a fog room when the prescribed relative humidity is achieved by the atomization of water.

4. Requirements for Cement Mixing Rooms

4.1 The temperature of the air in the vicinity of the mixing slab, molds, and base plates shall be maintained at 23.0 ± 4.0 °C and at a relative humidity of not less than 50 %.

4.2 The temperature of the mixing water used to prepare cement paste and mortar specimens shall be 23.0 ± 2.0 °C.

5. Temperature Measuring Devices

5.1 *Reference Temperature Measuring Device*—used to verify the temperature recorder, must be accurate and readable to 0.5 ºC. A copy of the certificate or report which verifies the accuracy shall be available in the laboratory.

NOTE 1—The ice-point method described in Test Method E77 may be used to ensure that no damage to the reference thermometer has occurred during shipping.

[1] This specification is under the jurisdiction of ASTM Committee C01 on Cement and is the direct responsibility of Subcommittee C01.95 on Coordination of Standards.

Current edition approved June 15, 2019. Published June 2019. Originally approved in 1968. Last previous edition approved in 2013 as C511 – 13. DOI: 10.1520/C0511-19.

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

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

5.2 *Temperature Recorder*—shall record temperatures every 15 min or less and shall be accurate and readable to 1 ºC. The data from the recorder shall be evaluated at a minimum of once each week. A record of this evaluation documenting the date checked, a confirmation that the data is within the required temperature range, and the name of the individual performing this evaluation shall be maintained in the laboratory. (Note 2)

NOTE 2—This requirement may be satisfied by an initialed and dated temperature recorder chart. Brief changes in the temperature due to door openings should be ignored.

5.2.1 The temperature recorder shall be verified at least every six months or whenever there is a question of accuracy.

5.2.1.1 For moist cabinets and rooms, position the reference temperature measuring device in a readable position in air as near as practical to the temperature recorder probe. Keep the door closed for at least 5 min prior to taking readings. Record the temperature readings of both the temperature recorder and the reference temperature measuring device. When taking these readings, the reference temperature measuring device shall remain in the moist cabinet or room and read immediately upon opening the door.

5.2.1.2 For water storage tanks, position the reference temperature measuring device in a readable position in water as near as practical to the temperature recorder probe. Without removing the reference temperature measuring device from the water, record the temperature readings of both the temperature recorder and the reference temperature measuring device after the temperatures have stabilized.

5.2.1.3 Verify the accuracy of the temperature recorder by comparing the reading of the temperature recorder with that of the reference temperature measuring device during the normal operation of the moist cabinet, moist room or water storage tanks. If the difference between the temperature readings is greater than 1 ºC, the temperature recorder shall be adjusted to within 0.5 ºC of the reference temperature measuring device.

6. Requirements for Moist Cabinets and Moist Rooms

6.1 *General*—Except during those times when specimens are being placed into or removed from storage, maintain the atmosphere in a moist cabinet or moist room at a temperature of 23.0 ± 2.0 °C and a relative humidity of not less than 95 %. Maintain atmospheric conditions within a moist cabinet or moist room such that test specimens in storage are saturated with moisture to the degree needed to ensure that the exposed surfaces of all specimens in storage both look moist and feel moist (see Note 5). Equip all moist cabinets and moist rooms with a temperature recorder. The use of humidity recording devices is optional. Keep shelves on which fresh specimens are placed level.

6.1.1 The air temperature inside the moist cabinet or moist room shall be controlled with provisions made for heating or cooling, or both, as may be necessary. This shall be accomplished in one of two ways:

6.1.1.1 Thermostatically control the air temperature within the moist cabinet or moist room when surrounding space is not conditioned. In this case the sensing element for the controls shall be located inside the moist cabinet or moist room.

6.1.1.2 Thermostatically control the space surrounding the moist cabinet or moist room and manually control the temperature within the moist cabinet or moist room.

6.1.2 In either of the preceding cases, the laboratory shall demonstrate the ability of the controls to maintain the required temperature in the moist cabinet or moist room over an extended period of time. Data from the temperature recorder that indicates that the temperatures are within the temperature limits specified in 6.1 shall be required as evidence of this ability.

6.2 *Moist Cabinets*—A moist cabinet shall be constructed of durable materials and the doors shall be tight-fitting. The specified relative humidity shall be maintained by the use of one or more fog sprays, water sprays, or curtains of water on the inner walls that are so directed that the discharge will collect in a pool at or near the bottom of the moist storage section.

6.3 *Moist Rooms:*

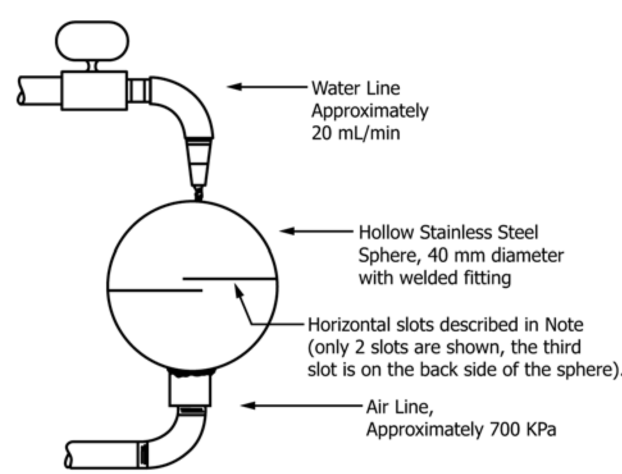
6.3.1 *General*—The walls of a moist room shall be constructed of durable materials, and all openings shall be provided with tight-fitting doors or windows (Note 3). Maintain the specified relative humidity by any convenient and suitable manner (Note 4).

NOTE 3—Well insulated walls will substantially help maintain necessary conditions.

NOTE 4—A fog spray found suitable for this purpose is shown in Fig. 1.

6.3.2 *Moist Rooms Used in Cement Testing*—Durable shelving that is properly shielded to prevent droplets of water from falling on the surfaces of freshly molded specimens shall be available within each moist room.

6.3.3 *Moist Rooms Used in Concrete Testing*—Maintain atmospheric conditions within each moist room such that test specimens in storage both look moist and feel moist (see Note 5). Do not expose specimens to dripping or running water.



NOTE 1—Cut three horizontal air slots around circumference of hollow sphere using a 0.20 mm thick diamond lapidary saw covering 120° to 150° each and spaced approximately 5 mm apart. Air passing through these slots strikes the water (which is flowing over the outer surface of the sphere) to produce a spray.

FIG. 1 Example of a Fog Spray for Maintaining Relative Humidity in Moist Rooms (Full Scale)

NOTE 5—Maintenance of adequate water spray(s) and adequate spray distribution in the moist room will result in stored specimens looking and feeling moist and will maintain the required humidity. Inadequate numbers of spray nozzles, partially obstructed spray nozzles, or disturbances in the moist air system such as open doors, air-conditioning or heating drafts, or overly crowded shelf space may result in relative dry spots. Specimen surface texture and age can influence the surface appearance and should be considered when specimens in localized areas do not look and feel moist.

7. Requirements for Water Storage Tanks

7.1 *General*—Tanks shall be constructed of non-corroding materials. Maintain storage water temperature at 23.0 ± 2.0 °C, except for those times when specimens are being placed into or removed from storage, or tank maintenance is being performed.

7.1.1 *Tank Temperature Controls*—Provision for automatic control of water temperature at 23.0 ± 2.0 °C shall be made where a tank is located in a room not having temperature controlled within the specified range and in any other instance where difficulty in maintaining temperatures within the specified range is encountered. With the exception of water storage tanks located in a moist room or moist cabinet, all water storage tanks shall be equipped with a temperature recorder with its sensing element in the storage water. For the purpose of temperature recording, a group of water storage tanks may be considered one tank if the following three conditions are met: (*1*) all the tanks are interconnected with tubing that allows the water to flow between the tanks, (*2*) some means of circulation is provided between tanks, and (*3*) temperature variation between the tanks must not exceed 1.0 °C when checked and recorded weekly.

7.2 *Tank Storage Water*—The water in a storage tank shall be saturated with calcium hydroxide to prevent leaching of calcium hydroxide from the specimens (Note 6). Water not saturated with calcium hydroxide (high-calcium hydrated lime) may affect test results due to leaching of lime from the test specimens and shall not be used in storage tanks. To maintain saturation with calcium hydroxide, excess calcium hydroxide shall be present. For the purposes of lime saturation to prevent leaching, lime means high-calcium hydrated lime, not calcium carbonate (limestone)—see Terminology C51. The water in the storage tank shall be thoroughly stirred at intervals not to exceed one month to help replace calcium ions that have depleted. Tanks shall be cleaned and refilled with water containing 3 g/L of calcium hydroxide at intervals not to exceed 24 months (Note 7).

NOTE 6—pH is not a reliable indicator of lime saturation in storage tank water since severe reductions in dissolved calcium ions can occur before pH values are significantly reduced.

NOTE 7—The 3 g/L level is intended to provide a quantity of calcium hydroxide approximately two times that required for initial saturation.

7.2.1 Do not use continuously running fresh water or demineralized water in storage tanks because it may affect test results due to excessive leaching. The use of a closed system, circulating the saturated lime water between or among storage tanks, is permitted.

8. Keywords

8.1 cement paste; concrete; mixing room; moist cabinets; moist rooms; mortar; water storage tanks

SUMMARY OF CHANGES

Committee C01 has identified the location of selected changes to this standard since the last issue (C511 – 13) that may impact the use of this standard. (Approved June 15, 2019.)

(*1*) Added 1.3.
(*2*) Added Terminology C125 and Terminology C219 to referenced documents.
(*3*) Added 3.1.1and renumbered subsequent sections accordingly.
(*4*) Revised 6.3.1 and 7.2.1.

Designation: C1077 − 17

Standard Practice for Agencies Testing Concrete and Concrete Aggregates for Use in Construction and Criteria for Testing Agency Evaluation[1]

This standard is issued under the fixed designation C1077; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

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

1. Scope*

1.1 This practice identifies and defines the duties, responsibilities, and minimum technical requirements of testing agency personnel and the minimum technical requirements for equipment utilized in testing concrete and concrete aggregates for use in construction.

1.2 This practice provides criteria for the evaluation of the capability of a testing agency to perform designated ASTM test methods on concrete and concrete aggregates. It can be used by an evaluation authority in the inspection or accreditation of a testing agency or by other parties to determine if the agency is qualified to conduct the specified tests.

NOTE 1—Specification E329 provides criteria for the evaluation of agencies that perform the inspection of concrete during placement.

1.3 This practice provides criteria for Inspection Bodies and Accreditation Bodies that provide services for evaluation of testing agencies in accordance with this practice.

1.4 The text of this standard references notes and footnotes, which provide explanatory material and shall not be considered as requirements of this standard.

1.5 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety, health, and environmental practices and determine the applicability of regulatory limitations prior to use.*

1.6 *This international standard was developed in accordance with internationally recognized principles on standardization established in the Decision on Principles for the Development of International Standards, Guides and Recommendations issued by the World Trade Organization Technical Barriers to Trade (TBT) Committee.*

2. Referenced Documents

2.1 *ASTM Standards:*[2]

C31/C31M Practice for Making and Curing Concrete Test Specimens in the Field
C39/C39M Test Method for Compressive Strength of Cylindrical Concrete Specimens
C78/C78M Test Method for Flexural Strength of Concrete (Using Simple Beam with Third-Point Loading)
C117 Test Method for Materials Finer than 75-μm (No. 200) Sieve in Mineral Aggregates by Washing
C125 Terminology Relating to Concrete and Concrete Aggregates
C127 Test Method for Relative Density (Specific Gravity) and Absorption of Coarse Aggregate
C128 Test Method for Relative Density (Specific Gravity) and Absorption of Fine Aggregate
C136/C136M Test Method for Sieve Analysis of Fine and Coarse Aggregates
C138/C138M Test Method for Density (Unit Weight), Yield, and Air Content (Gravimetric) of Concrete
C143/C143M Test Method for Slump of Hydraulic-Cement Concrete
C172/C172M Practice for Sampling Freshly Mixed Concrete
C173/C173M Test Method for Air Content of Freshly Mixed Concrete by the Volumetric Method
C231/C231M Test Method for Air Content of Freshly Mixed Concrete by the Pressure Method
C617/C617M Practice for Capping Cylindrical Concrete Specimens
C802 Practice for Conducting an Interlaboratory Test Program to Determine the Precision of Test Methods for Construction Materials
C1064/C1064M Test Method for Temperature of Freshly Mixed Hydraulic-Cement Concrete

[1] This practice is under the jurisdiction of ASTM Committee C09 on Concrete and Concrete Aggregates and is the direct responsibility of Subcommittee C09.98 on Evaluation of Laboratories.

Current edition approved Oct. 1, 2017. Published October 2017. Originally approved in 1987. Last previous edition approved in 2016 as C1077-16a. DOI: 10.1520/C1077-17.

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

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

C1231/C1231M Practice for Use of Unbonded Caps in Determination of Compressive Strength of Hardened Cylindrical Concrete Specimens
D75/D75M Practice for Sampling Aggregates
D2419 Test Method for Sand Equivalent Value of Soils and Fine Aggregate
E4 Practices for Force Verification of Testing Machines
E11 Specification for Woven Wire Test Sieve Cloth and Test Sieves
E329 Specification for Agencies Engaged in Construction Inspection, Testing, or Special Inspection
E1301 Guide for Proficiency Testing by Interlaboratory Comparisons (Withdrawn 2012)[3]

2.2 *ACI Standards:*
ACI 214-77 Recommended Practice for Evaluation of Strength Test Results of Concrete[4]

2.3 *ISO Standards:*
ISO 17011 Conformity Assessment—General Requirements For Accreditation Bodies Accrediting Conformity Assessment Bodies[5]

3. Terminology

3.1 *Definitions:*

3.1.1 For definitions of terms used in this practice, refer to Terminology C125.

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *evaluation authority, n*—an independent entity, apart from the testing agency being evaluated, that has the capability to provide an unbiased evaluation of the technical activities of concrete and concrete aggregates testing agencies in accordance with Annex A1 or Annex A2.

3.2.1.1 *Discussion*—Two acceptable methods of evaluation are inspection and accreditation, and these evaluations are offered by many evaluation authorities. An inspection is an evaluation of equipment and procedures based on the Test Methods and Procedures section, along with a review of the quality system. An inspection report is the final step in the process for an inspection agency. The testing agency being evaluated performs corrective actions for any deficiencies noted, and these corrections are to be placed with the other inspection documentation as part of the permanent record of the inspection. An accreditation agency uses the results of the inspection report or the results of their own onsite assessment as one phase of the accreditation process. As a separate phase, the accreditation agency also reviews the testing agency's corrective actions for the deficiencies noted and issues a certificate of accreditation once all of the deficiencies have been corrected. There is no universally accepted evaluation authority in the construction materials testing field; therefore, testing agencies should give careful consideration when selecting an evaluation authority to gain the most benefit from the evaluation. In most cases, a testing agency will select an evaluation authority as a result of requirements in a project specification, or contract, or in response to local codes, or other industry requirements. In those circumstances, the requirements will stipulate the acceptable evaluation authorities. If there are no specific requirements and the evaluation is in anticipation of future work or to compete with other local testing agencies, then the agency should contact the organization(s) most likely to use their services for a list of acceptable evaluation authorities. A list of evaluation authorities is provided in the Qualification of Personnel and Laboratory Evaluation section of the Manual of Aggregate and Concrete Testing.[6] The list is merely a collection of organizations willing to provide this service and is not an endorsement of any particular organization. Other organizations may also be available to provide this service.

3.2.2 *external technical services, n*—those services required by a testing agency that are provided by another organization.

3.2.3 *quality systems, n*—those internal procedures and practices that an agency utilizes to ensure continued compliance with applicable testing standards for concrete and concrete aggregates.

3.2.4 *testing agency, n*—organization that measures, examines, performs tests, or otherwise determines the characteristics or performance of materials or products. This includes organizations that offer commercial testing services, an inhouse quality control function, an academic institution, or any other organization providing the required testing services, whether performed in the laboratory or in the field.

4. Significance and Use

4.1 The testing and inspection of concrete and concrete aggregates are important elements in obtaining quality construction. A testing agency providing these services shall be selected with care.

4.2 A testing agency shall be deemed qualified to perform and report the results of its tests if the agency meets the requirements of this practice. The testing agency services shall be provided under the technical direction of a registered professional engineer.

4.3 This practice establishes essential characteristics pertaining to the organization, personnel, facilities, and quality systems of the testing agency. This practice may be supplemented by more specific criteria and requirements for particular projects.

5. Organization

5.1 The following information shall be readily available for review:

5.1.1 Description of the organization, including:

5.1.1.1 Complete legal name and address of the main office and each testing agency location,

5.1.1.2 Names and positions of the principal officers and the responsible, registered professional engineer in charge, and

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

[4] Available from American Concrete Institute (ACI), P.O. Box 9094, Farmington Hills, MI 48333-9094, http://www.aci-int.org.

[5] Available from International Organization for Standardization (ISO), 1, ch. de la Voie-Creuse, Case postale 56, CH-1211, Geneva 20, Switzerland, http://www.iso.ch.

[6] Manual of Aggregate and Concrete Testing, *Annual Book of ASTM Standards*, Vol 04.02.

5.1.1.3 Description of the testing agency management structure.

5.1.2 Listing of the relevant technical services offered, and

5.1.3 All external technical services normally utilized.

5.2 The testing agency shall designate an individual with access to management who has the responsibility of seeing that procedures required in this document are being carried out.

6. Personnel Qualifications

6.1 Information shall be made available to substantiate personnel qualifications as follows:

6.1.1 All relevant testing services shall be provided under the full-time technical direction of a licensed professional engineer with at least 5 years experience in construction materials testing.

6.1.2 Laboratory and field supervisors shall meet the following requirements:

6.1.2.1 Possess at least 3 years relevant experience.

6.1.2.2 Shall be certified in the relevant tests required of the personnel they are supervising, as outlined in 6.1.3.

6.1.3 Personnel performing laboratory and field testing shall possess current certification(s) that includes a written and performance examination for each relevant standard identified in 6.1.3.1, 6.1.3.2, and 6.1.3.3 and shall conform to the requirements identified in 6.1.4.

6.1.3.1 Concrete laboratory testing certification(s) shall include the following standards: Test Method C39/C39M and Practice C617/C617M or C1231/C1231M. Test Method C78/C78M is also considered a relevant test if it is included on the agency's list of technical services.

6.1.3.2 Aggregate laboratory testing certification(s) shall include the following standards: Test Methods C117, C127, C128, and C136/C136M.

6.1.3.3 Concrete field testing certification(s) shall include the following standards: Practices C31/C31M and C172/C172M, and Test Methods C138/C138M, C143/C143M, C173/C173M, C231/C231M, and C1064/C1064M.

6.1.4 The certification program shall meet the following criteria:

6.1.4.1 The written examination shall be of sufficient length and detail to cover the test method or practice, including, as applicable: the significance of the test or practice, sampling, specimen preparation, procedure, calculations, and reporting of results,

6.1.4.2 The performance examination shall include a demonstration of the test method or practice, to document the individual's ability to correctly perform the procedure in accordance with the standard, and

6.1.4.3 The written and performance examinations shall include all relevant test methods that are listed in the section above for the type of individual being certified.

NOTE 2—A list of certification programs is provided in the Qualification of Personnel and Laboratory Evaluation section of the Manual of Aggregate and Concrete Testing.[6] The list is merely a collection of certification programs and is not an endorsement of any particular program. Other programs may also be available.

6.1.4.4 The certification body shall establish the period of certification but not to exceed five years.

6.1.4.5 The period for which the certification is valid shall be clearly and prominently stated on any documents that attest to the certification(s) held by the individual.

7. Test Methods and Procedures

7.1 The testing agency shall be capable of performing the required ASTM test methods, guides, or practices in 7.2 and may request additional evaluation for the optional methods in 7.3 to the extent that those services are provided by the agency.

7.2 *Required Test Methods and Practices:*

7.2.1 *For Agencies Testing Concrete:*

7.2.1.1 *Sampling,* Practice C172/C172M,

7.2.1.2 *Slump,* Test Method C143/C143M,

7.2.1.3 *Unit Weight, Yield, and Air Content,* Test Method C138/C138M,

7.2.1.4 *Air Content,* Test Method C173/C173M (volumetric method), or Test Method C231/C231M (pressure method), or both.

7.2.1.5 *Temperature,* Test Method C1064/C1064M,

7.2.1.6 *Making and Curing Test Specimens,* Practice C31/C31M,

7.2.1.7 *Compressive Strength,* Test Method C39/C39M,

7.2.1.8 *Capping Cylinders,* Practice C617/C617M or Practice C1231/C1231M.

7.2.2 *For Agencies Testing Concrete Aggregates:*

7.2.2.1 *Sieve Analysis,* Test Method C136/C136M,

7.2.2.2 *Material Finer Than 75-µm (No. 200) Sieve,* Test Method C117, and

7.2.2.3 *Specific Gravity and Absorption,* Test Method C127 (Coarse Aggregate) and Test Method C128 (Fine Aggregate).

7.3 *Optional Test Methods or Practices:*

7.3.1 Some testing agencies conduct other tests on concrete and concrete aggregates in addition to those listed in The *Required Test Methods and Practices* Section. These optional test methods and practices could include any of the test methods or practices developed by Committee C09 and contained in volume 04.02, as well as other related standards such as Practice D75/D75M and Test Method D2419. The agency shall have evidence of proper facilities, equipment, and trained personnel to comply with the applicable test method or practice, if it is included in the scope of services as defined by the agency. The agency and the evaluation authority will mutually agree upon which optional test methods or practices will be included in the agency's evaluation. The evaluation authority shall then select which of the optional test methods or practices offered by the agency need to be demonstrated by the personnel.

7.4 The testing agency shall use the latest version of each referenced method within one year of its publication unless an earlier version of the standard is required by the client.

7.5 Testing agency personnel shall have convenient access to applicable standards.

8. Facilities, Equipment, and Supplemental Procedures

8.1 *General*—The testing agency shall have facilities and equipment conforming to the requirements of the applicable test method. This section contains equipment requirements and procedures that clarify certain provisions of the test methods.

8.2 *Procedures Related to Required Test Methods*—In addition to standard test method requirements, the conditions listed in 8.3 and 8.4 shall be met.

8.3 *For Agencies Testing Concrete:*

8.3.1 *Compressive Strength Testing Machines,* shall conform to the applicable requirements of Test Method C39/C39M.

8.4 *For Agencies Testing Concrete Aggregates:*

8.4.1 *Sieve Accuracy*—Verification of sieve accuracy shall be performed at least annually on each sieve used in the test for sieve analysis (Test Methods C117 and C136/C136M). Any one of the following three methods of verification is acceptable. Each method of sieve verification shall include an inspection of the sieve cloth for punctures or obvious defects.

8.4.1.1 Verification of each sieve used according to the procedures prescribed in the Annex of Specification E11.

8.4.1.2 A comparison of the results of a split sample sieved on different sieve sets. Results shall be verified for single operator precision to be within the acceptable range of two results stated in the test method.

8.4.1.3 Participation in the sieve analysis test in an aggregate proficiency sample program, as described in the Quality Systems section. Results shall be verified for multilaboratory precision to be within the acceptable range of two results stated in the test method.

8.4.2 *Mechanical Sieve Shaker*—When mechanical sieving devices are used, the period of mechanical agitation shall be checked at least annually for adequacy of sieving as described in Test Method C136/C136M. Mechanical agitation periods shall be established for each different type of aggregate tested.

NOTE 3—Different types of aggregate refer to shape and composition, not supplier. For example, agitation periods for elongated materials may need to be extended, while softer materials that break down easily may require a shorter period to minimize alteration of the particle size distribution.

8.4.3 *Relative Density (Specific Gravity) and Absorption Tests*—When performing the procedures of Test Methods C127 and C128, duplicate tests shall be made at least once every 6 months. Results shall be verified for single operator precision within the tolerance stated in the respective test method. Participation in a proficiency sample program with relative density (specific gravity) and absorption testing is an acceptable alternative.

8.4.4 Balances or scales for all concrete and aggregate tests shall be calibrated annually.

8.5 *Procedures Related to Optional Test Methods:*

8.5.1 If the applicable test method requires equipment calibration and does not specify a frequency, then the testing agency shall establish a frequency in its quality assurance program and conform thereto.

8.5.2 In the event that the testing agency borrows or rents equipment to perform an optional test method, the agency shall be able to document that it obtained the appropriate equipment and that the equipment was calibrated, standardized, or verified.

8.6 All equipment listed in this section shall be calibrated or verified before being placed in service. Equipment not in operating condition or out of tolerance shall be marked as such and taken out of service until corrected.

9. Testing Agency Records and Reports

9.1 The testing agency shall maintain a system of records that permits verification of any issued report.

9.2 The records of the testing agency shall contain the following information:

9.2.1 Standard operating procedures for the following:

9.2.1.1 Identification of the test sample,

9.2.1.2 Transfer of the sample from the field to the testing facility, and

9.2.1.3 Recording of test results.

9.2.2 Calibrations or verifications of equipment required by the test method for all of the tests offered in the scope of the testing agency's services. The records shall include:

9.2.2.1 The identification of the specific piece of equipment,

9.2.2.2 The identification of the equipment used to perform the calibration or verification,

9.2.2.3 The name of the individual who performed the calibration or verification,

9.2.2.4 The date the calibration or verification was performed,

9.2.2.5 The quantity measured by the equipment (such as length, force, or mass), and

9.2.2.6 The associated accuracy of the measurement or a comparison of the measured quantity with the associated allowable tolerances, as necessary to verify that the equipment complies with the requirements in the relevant standards. Where additional calibration or verification requirements have been listed in the *Facilities, Equipment, and Supplemental Procedures* Section, this information shall also be included in the records.

9.2.3 Records on testing agency personnel that document work experience, education, on-the-job training, and methods used to ensure continued competence in performing the required test methods,

9.2.4 Audits and inspections by outside agencies and all reports or certifications, with applicable dates, of any evaluation or accreditations issued by any evaluating authorities,

9.2.5 The testing agency shall retain results of participation in proficiency sample programs, including data sheets, summary reports and, if low proficiency sample ratings are received, a record of the agency's investigation into the reason for the low ratings and corrective action taken.

9.2.6 Current standard test methods and other pertinent reference material in a library,

9.2.7 Identification of the person performing the field and laboratory tests, and

9.2.8 Documents that establish the traceability to an acceptable reference standard or a national standard for load cells, proving rings, thermometers, test weights, and test equipment used for verification or calibration of testing equipment.

9.3 Agency test reports shall accurately and clearly present the specified test results and all pertinent data.

9.4 Test reports shall include the following information:

9.4.1 Name and address of the testing agency,

9.4.2 Identification of the report and the date issued,

9.4.3 Name of the client,

9.4.4 Project identification,

9.4.5 Sample identification,

9.4.6 Identification of the standard test method used, a notation of all known deviations from the test method, and all requirements of the test method that were not performed by the testing agency (Note 5),

9.4.7 Test results and other pertinent data required by the standard,

9.4.8 Name of the registered professional engineer or his designee, and

9.4.9 Identification of results obtained from tests performed by other testing agencies.

9.5 Corrections or additions to reports shall clearly reference the report being amended.

9.6 All records required by this standard shall be stored safely for at least 3 years, unless otherwise required by law or governing specifications. Those records that are confidential in nature, including test reports and other records generated as required by contract with the client, shall be stored safely in confidence to the client, unless otherwise required by law, governing specification, or client requirements.

NOTE 4—There are circumstances when a longer retention period may be advantageous to the testing agency. Records concerning the calibration, verification, and standardization of equipment are an example. Records of this type are often held throughout the useful life of the equipment.

NOTE 5—Deviation from standard test methods may adversely affect results.

10. Quality Systems

10.1 The testing agency shall maintain a quality manual of written procedures for ensuring the quality of the services offered (Note 8). In addition to the following information, each page in the manual shall contain a preparation or revision date to ensure the latest procedure is being followed.

10.1.1 Internal quality assurance program, including:

10.1.1.1 Personnel training and evaluation including a description of the training program, the method of evaluation, the frequency of the review, the criteria used, and the title or name of the individual responsible for administering the evaluations,

10.1.1.2 Equipment calibration and maintenance,

10.1.1.3 A current library including all relevant test methods, and

10.1.1.4 Inventory of all test equipment requiring both an initial and a subsequent periodic calibration or verification that is used by the agency to perform the test methods covered by this standard and within the agency's scope of services. The inventory shall include the equipment description, identification number, and next date of calibration or verification.

NOTE 6—The inventory should include equipment such as scales, compression machines, and slump cones. Equipment such as tamping rods and expendable supplies such as single-use cylinder molds need not be included on the inventory.

10.1.1.5 Participation in proficiency sample programs (PSP). The agency shall participate in concrete or aggregate proficiency sample programs or both if the agency performs testing in both areas. The PSP used shall meet the following criteria: (*1*) include a minimum of 10 participants, (*2*) issue a report that includes the agency's results, the average of all results, the standard deviation of the results, and rating(s) based on the number of standard deviations that the agency's results vary from the grand average for the test method(s) covered, (*3a*) include at least one of the following methods if the agency tests concrete: C39/C39M, C138/C138M, C143/C143M, C173/C173M, or C231/C231M; and, (*3b*) include at least one of the following methods if the agency tests concrete aggregates: C136/C136M, C127, or C128, (*4*) be independent of the participating agencies, (*5*) distribute samples at least once annually, and (*6*) maintain a record of all sample test results from participants for at least 3 years.

NOTE 7—For additional guidance in selecting a proficiency sample program the testing agency may wish to consult Guide E1301.

10.1.2 The testing agency shall establish procedures for responding to low proficiency sample program ratings. Ratings are considered to be low if the agency's result is beyond two standard deviations from the grand average on the final report.

10.1.3 The testing agency shall establish procedures for handling technical complaints from clients that includes the title or name of the individual responsible for handling the complaint, the review system in the agency and the type of reply to be issued.

10.1.4 The laboratory shall have a procedure in its quality system that shall be implemented when it is determined that equipment is out of calibration or testing procedures are found to be deficient. The laboratory shall halt any work affected by any deficiency until corrective actions have been completed and documented. The laboratory shall review all affected work performed between the time when the equipment or testing procedure was last verified and when the deficiency was discovered. The laboratory shall evaluate the significance of any deficiency on reported results and, if necessary, notify clients of the possibility of nonconforming test results.

10.1.5 The testing agency shall establish procedures for ensuring the quality of external technical services, such as: calibration services used by the agency, equipment and materials procured by the agency from vendors, and subcontractors (that is, an agency contracted to perform a standard test method or part of a test method). The agency should be able to demonstrate that the subcontractor is competent and is in compliance with the requirements of the test methods. The agency should maintain records of the subcontractor and vendor evaluations. The selection and evaluation criteria for the subcontractor should include a review of external audits, inspections, certifications, and accreditations held by the agency.

NOTE 8—Other recommended quality programs for a testing agency include: (*1*) Conducting within-laboratory statistical computations on concrete tests. Randomly selecting 10 tests per month and determining the within-test standard deviation (see ACI 214-77 and Practice C802 for statistical methods); (*2*) Participation in an interlaboratory proficiency program on concrete tests. A quarterly exchange of samples between agencies in accordance with Practice C802 will provide excellent quality assurance data.

11. Testing Agency Evaluation

11.1 The testing agency shall have its facilities, equipment, personnel, and procedures evaluated at intervals of approximately 2 years by an evaluation authority to confirm its ability to perform the required tests.

11.2 Two methods of evaluation, either inspection or accreditation, are acceptable.

11.2.1 Responsibilities and duties of evaluation authorities conducting assessments (identified as Inspection Bodies) shall be in accordance with Annex A1.

11.2.2 Responsibilities and duties of evaluation authorities conducting assessments as part of an accreditation process (identified as Accreditation Bodies) shall be in accordance with Annex A2.

11.3 The personnel and equipment used by the agency during the evaluation shall be representative of the personnel and equipment available during the period between evaluations. Temporary acquisition of personnel or equipment to enhance the results of the evaluation shall not be permitted.

11.4 The testing agency shall provide an initial written corrective action response within 30 days of receipt of deficiencies noted in the final report. The agency then will complete all corrections within 60 days of receipt of the final report.

11.4.1 If an inspection service is used, the agency shall supplement the final report with a statement of corrective actions taken, which is signed by the agency's professional engineer.

11.4.2 If an accreditation service is used, the agency shall report deficiency corrections to the Accreditation Body who will issue a certificate of accreditation when its requirements are satisfied.

12. Keywords

12.1 aggregates; concrete; criteria; evaluation; quality assurance (QA); testing ; testing agency

ANNEXES

(Mandatory Information)

A1. EVALUATION AUTHORITIES CONDUCTING ASSESSMENTS—INSPECTION BODIES

A1.1 Organization and Management

A1.1.1 The Inspection Body shall clearly disclose on the inspection report any potential conflicts of interest it or its inspection personnel may have with the testing agency being inspected. This shall include any potential conflicts that could be reasonably construed or perceived to impair the impartiality of their evaluation.

A1.1.2 The Inspection Body shall be under the direction of a manager who is knowledgeable of the applicable standards and inspection processes used.

A1.1.3 The Inspection Body shall implement a quality system appropriate to the type of inspections performed. The Inspection Body shall maintain a quality system manual documenting the procedures and techniques used to accomplish the objectives of its inspection.

A1.1.3.1 The Inspection Body shall maintain documentation of instructions and procedures for conducting inspections and inspection planning. These current written procedures shall be available to inspection personnel. Deviations from written procedures shall be documented during the conduct of an inspection.

A1.1.4 The Inspection Body shall maintain a training program for its personnel that includes the following:

A1.1.4.1 A review of each test method or practice as listed in the "Required Test Methods and Practices" section;

A1.1.4.2 Demonstrations by the trainer of the procedures used in each of these test methods or practices;

A1.1.4.3 Demonstrations by the trainer of the proper use of measurement tools (inspection equipment) needed to evaluate testing agency equipment;

A1.1.4.4 An evaluation by the trainer of the trainee's ability to properly execute the procedures of each test method or practice and to correctly use the measurement tools;

A1.1.4.5 At least one month of supervision by the trainer of onsite testing agency inspection work by the trainee; and

A1.1.4.6 A final evaluation by the trainer of the trainee's competence to conduct an inspection based on performance during the training period.

A1.1.5 The Inspection Body shall maintain an evaluation program for its inspectors that includes the following:

A1.1.5.1 An annual review of inspection techniques; and

A1.1.5.2 An annual review of performance based on customer feedback, including the inspector's knowledge and communication during inspections.

A1.2 Facilities and Equipment

A1.2.1 The Inspection Body shall have the facilities and equipment necessary to provide effective inspection services to its customers.

A1.2.1.1 All equipment used for training and inspections shall be identified and documented.

A1.2.1.2 All measuring equipment shall be maintained in accordance with documented procedures and verified for accuracy before being put into service and at time intervals defined in the quality system manual. When results from the measurement equipment are questionable, such equipment shall not be used until its accuracy has been verified.

A1.2.1.3 Verification or standardization of measuring equipment shall be traceable to applicable national standards. The frequency of verifications or standardizations shall be in accordance with the governing standard or the Inspection Body's quality system manual. Records of such verifications or standardizations shall be maintained.

A1.2.1.4 Reference measurement standards shall be used only for verification or standardization of measuring equipment. The reference measurement standards shall be standardized by a competent body traceable to nationally recognized standards.

A1.3 Inspection Methods and Procedures

A1.3.1 The Inspection Body shall offer inspection services for testing agencies at the frequency required in the standard or as otherwise requested by the testing agency.

A1.3.2 The inspection services shall include either the required concrete or concrete aggregate test methods and practices, or both, listed in 7.2.

A1.3.3 The Inspection Body shall provide inspection services for any optional method requested by the testing agency within the scope of its services, provided the agency's equipment and procedures can be assessed in a laboratory setting.

NOTE A1.1—There are some test methods and practices that involve observation and assessment techniques of uniquely qualified personnel that may not be possible to be evaluated by inspection personnel.

A1.3.4 The Inspection Body shall evaluate equipment and procedures for each test method or practice presented by the testing agency,

A1.3.4.1 The Inspection Body shall use its equipment to evaluate the testing agency's test equipment and verify the capability of the agency's equipment to measure to the tolerances specified in the relevant standards. Alternatively, review of accuracy verification or standardization records is permitted.

A1.3.4.2 The inspector shall observe demonstration of techniques and procedures by testing agency personnel for each test method or practice presented. At the discretion of the inspector, it is permitted for some procedural aspects of test methods or practices to be described by agency personnel in lieu of demonstration.

A1.3.5 The Inspection Body shall review the qualifications and proficiencies of testing personnel of the agency being inspected. It is permitted to use a representative sampling to evaluate proficiency of testing personnel.

A1.3.6 The Inspection Body shall interview selected testing personnel to evaluate their awareness of test methods and practices and their proficiency in performing them.

A1.3.7 The Inspection Body shall review at least the three previous years of records of testing agency participation in proficiency sample programs as required by this practice.

A1.3.8 The Inspection Body shall review typical data recording procedures and reports generated by the testing agency.

A1.4 Inspection Reports

A1.4.1 The Inspection Body shall issue a final inspection report of findings that lists the test methods and practices covered. The inspection report shall note any deficiencies of testing agency equipment, procedures relative to the pertinent standards, qualification of testing personnel, and other requirements of this standard.

A1.4.1.1 Corrections or additions to an inspection report or the testing agency's documentation of correction of deficiencies shall be retained with the original inspection report.

A1.4.1.2 The complete inspection report, including documentation of actions to correct deficiencies, shall be provided to an Accreditation Body, when the report of the Inspection Body is used as part of the process for accreditation of a testing agency.

A1.5 Statement of Conformance

A1.5.1 Upon request, the Inspection Body shall provide a statement indicating that inspection services were conducted in accordance with this Annex.

A2. EVALUATION AUTHORITIES CONDUCTING ASSESSMENTS—ACCREDITATION BODIES

A2.1 Organization and Management

A2.1.1 The Accreditation Body shall clearly disclose any potential conflicts of interest it or its assessors may have with the testing agency being accredited. This shall include any potential conflicts that could be reasonably construed or perceived to impair the impartiality of their assessment.

A2.1.2 The Accreditation Body shall be under the direction of one or more managers who are knowledgeable on the applicable standards and accreditation processes used.

A2.1.3 The Accreditation Body shall maintain a management system documenting the processes it uses to accomplish the objectives of its assessment for accreditation of testing agencies.

A2.1.3.1 The management system shall document the duties, responsibilities, and authorities of management and assessors. The qualifications of assessors relative to education, training, work and assessment experience, and scope of expertise shall be defined. The system should define what constitutes conflict of interest for assessors.

A2.1.3.2 The management system shall document information about the assessment and accreditation processes for review by users of its accreditation service. The information shall include procedures used for surveillance of accredited facilities, if any, and the process to be used by testing agencies for complaints or appeals.

A2.1.3.3 The management system shall document the procedures used for extending, suspending, withdrawing, or reducing accreditation of testing agencies. The written procedures shall be available to assessors. Deviations from written procedures during the conduct of an assessment shall be documented.

A2.1.3.4 The management system shall document the policies for retention of records for assessor personnel and for assessments.

A2.1.3.5 The management system shall define the process used to inform the public about the status and scope of accredited testing agency facilities.

A2.1.4 The Accreditation Body shall include the results of an on-site inspection of testing agency facilities and testing personnel as part of the assessment for the accreditation of a testing agency facility.

A2.1.5 If the Accreditation Body provides services for on-site inspections of testing agencies, a training program for its inspection personnel shall be maintained in accordance with A1.1.4 and its facilities and equipment shall comply with A1.2.

A2.1.6 The Accreditation Body shall maintain a management review and audit process of its assessors that includes the following:

A2.1.6.1 A periodic monitoring of assessors by peers or other means;

A2.1.6.2 An annual review of assessments; and

A2.1.6.3 An annual review of assessor performance based on customer feedback during the conduct of assessments.

A2.2 Assessment Methods and Procedures

A2.2.1 The Accreditation Body is permitted to use inspection reports from separate Inspection Bodies that comply with Annex A1, for the on-site assessment portion of the evaluation.

A2.2.2 If the Accreditation Body performs on-site assessment of facilities and personnel as part of the evaluation, those methods and procedures shall comply with the requirements of A1.3.

A2.2.3 The Accreditation Body shall assign an evaluation team with a leader for its evaluation services. The members of the evaluation team shall be qualified and trained for the services to be performed in accordance with the quality system manual of the Accreditation Body.

A2.2.4 The evaluation team shall review the testing agency's quality manual and conduct an evaluation for conformance with the procedures indicated in the quality manual. The agency's quality manual shall conform to the requirements of this practice.

A2.3 Assessment Reports

A2.3.1 The evaluation report of the Accreditation Body shall include:

A2.3.1.1 An evaluation, including notes on deficiencies requiring corrective action, of the testing agency's quality manual. This shall include an evaluation of the qualifications and testing proficiency of personnel.

A2.3.1.2 An evaluation, including notes of deficiencies requiring corrective action, of conformance to the standard test methods and practices performed by the testing agency, including the adequacy of equipment and facilities.

A2.3.1.3 An evaluation, including notes on deficiencies requiring corrective action, of participation in proficiency sample testing programs.

A2.3.2 The Accreditation Body shall require the testing agency to respond with documentation of investigations made and corrective actions taken to any deficiencies noted in the evaluation report.

A2.3.3 The Accreditation Body shall provide the testing agency a statement on the acceptability of the agency's response and actions taken to address any noted deficiencies. This statement shall be incorporated into the agency's record prior to notification of accreditation.

A2.3.4 The Accreditation Body shall provide a certificate or other means recognizing the accredited status of the testing agency. The materials and standards for which the agency has been evaluated and the duration of the accreditation shall be indicated on the certificate or on other means used to recognize accreditation.

A2.4 Statement of Conformance

A2.4.1 Upon request from the user, the Accreditation Body shall provide a statement indicating conformance with the provisions of this Annex to perform accreditation of testing agencies.

NOTE A2.1—Accreditation Bodies that have documented compliance with ISO 17011 are acceptable provided they comply with the provisions of this Annex.

SUMMARY OF CHANGES

Committee C09 has identified the location of selected changes to this practice since the last issue, C1077–16a, that may impact the use of this practice. (Approved Oct. 1, 2017.)

(1) Added new 1.4 and current 1.4 was re-numbered.

Committee C09 has identified the location of selected changes to this practice since the last issue, C1077–16, that may impact the use of this practice. (Approved October 15, 2016.)

(1) Revised Section 6.

(2) Revised 6.1.1.

Designation: C1231/C1231M – 15

Standard Practice for Use of Unbonded Caps in Determination of Compressive Strength of Hardened Cylindrical Concrete Specimens[1]

This standard is issued under the fixed designation C1231/C1231M; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope*

1.1 This practice covers requirements for a capping system using unbonded caps for testing concrete cylinders molded in accordance with Practice C31/C31M or C192/C192M, or cores obtained in accordance with Test Method C42/C42M. *Unbonded neoprene caps of a defined hardness are permitted to be used for testing for a specified maximum number of reuses without qualification testing up to a certain concrete compressive strength level. Above that strength, level neoprene caps will require qualification testing. Qualification testing is required for all elastomeric materials other than neoprene regardless of the concrete strength.*

1.2 Unbonded caps are not to be used for acceptance testing of concrete with compressive strength below 10 MPa [1500 psi] or above 80 MPa [12 000 psi].

1.3 The values stated in either SI units or inch-pound units are to be regarded separately as standard. The values stated in each system may not be exact equivalents; therefore, each system shall be used independently of the other. Combining values from the two systems may result in non-conformance with the standard.

1.4 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.* (**Warning—** Concrete specimens tested with unbonded caps rupture more violently than comparable specimens tested with bonded caps. The safety precautions given in the Manual of Aggregate and Concrete Testing are recommended.[2])

[1] This practice is under the jurisdiction of ASTM Committee C09 on Concrete and Concrete Aggregates and is the direct responsibility of Subcommittee C09.61 on Testing for Strength.

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[2] Section on Safety Precautions, Manual of Aggregate and Concrete Testing, *Annual Book of ASTM Standards*, Vol 04.02.

2. Referenced Documents

2.1 *ASTM Standards:*[3]

C31/C31M Practice for Making and Curing Concrete Test Specimens in the Field

C39/C39M Test Method for Compressive Strength of Cylindrical Concrete Specimens

C42/C42M Test Method for Obtaining and Testing Drilled Cores and Sawed Beams of Concrete

C192/C192M Practice for Making and Curing Concrete Test Specimens in the Laboratory

C617 Practice for Capping Cylindrical Concrete Specimens

D2000 Classification System for Rubber Products in Automotive Applications

3. Terminology

3.1 *Definitions of Terms Specific to This Standard:*

3.1.1 *pad, n*—an unbonded elastomeric pad.

3.1.2 *unbonded cap, n*—a metal retainer and an elastomeric pad.

4. Significance and Use

4.1 This practice provides for using an unbonded capping system in testing hardened concrete cylinders made in accordance with Practices C31/C31M or C192/C192M, or cores obtained in accordance with Test Method C42/C42M in lieu of the capping systems described in Practice C617.

4.2 The elastomeric pads deform in initial loading to conform to the contour of the ends of the test specimens and are restrained from excessive lateral spreading by plates and metal rings to provide a uniform distribution of load from the bearing blocks of the testing machine to the ends of the concrete or mortar specimens.

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

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

5. Materials and Apparatus

5.1 Materials and equipment necessary to produce ends of the reference specimens that conform to planeness requirements of Test Method C39/C39M and the requirements of Practice C617. This may include grinding equipment or capping materials and equipment to produce neat cement paste, high strength gypsum plaster, or sulfur mortar caps.

5.2 *Elastomeric Pads:*

5.2.1 Pads shall be 13 ± 2 mm [½ ± 1⁄16 in.] thick and the diameter shall not be more than 2 mm [1⁄16 in.] smaller than the inside diameter of the retaining ring.

5.2.2 Pads shall be made from polychloroprene (neoprene) meeting the requirements of Classification D2000 as follows:

Shore A Durometer	Classification D2000 Line Call-Out
50	M2BC514
60	M2BC614
70	M2BC714

The tolerance on Shore A durometer hardness is ±5. Table 1 provides requirements for use of caps made from material meeting the requirements of Classification D2000, above.

5.2.3 Other elastomeric materials that meet the performance requirements of qualification tests in Section 8 are permitted.

5.2.4 Elastomeric pads shall be supplied with the following information:

5.2.4.1 The manufacturer's or supplier's name,

5.2.4.2 The Shore A hardness, and

5.2.4.3 The applicable range of concrete compressive strength from Table 1 or from qualification testing.

5.2.5 The user shall maintain a record indicating the date the pads are placed in service, the pad durometer, and the number of uses to which they have been subjected.

5.3 *Retainers* are a pair of metal fixtures used to provide support for and alignment of the neoprene pads and the test specimen ends (Note 1 and Fig. 1). Each retainer (upper and lower) includes a (retaining) ring that is welded to or manufactured integrally with a base plate. The height of the retaining ring shall be 25 ± 3 mm [1.0 ± 0.1 in.]. The inside diameter of the retaining ring shall not be less than 102% or greater than 107% of the diameter of the specimen. For test specimens having nominal diameters of 100 mm [4 in.] or less, the thickness of the retaining ring shall be at least 9 mm [0.35 in.] and the thickness of the baseplate shall be at least 8 mm [0.30 in.]. For test specimens having nominal diameters greater than 100 mm [4 in.], the thickness of the retaining ring and baseplate shall be at least 12 mm [0.47 in.]. The surface of the baseplate that contacts the bearing block of the testing machine shall be plane to within 0.05 mm [0.002 in.]. The bearing surfaces of the retainers shall not have gouges, grooves, protrusions, or indentations greater than 0.25 mm [0.010 in.] deep or greater than 32 mm^2 [0.05 in.^{2}] in surface area.

NOTE 1—Retainers made from steel and some aluminum alloys have been found acceptable.

TABLE 1 Requirements for Use of Polychloroprene(Neoprene) Pads

Compressive Strength,[A] MPa [psi]	Shore A Durometer Hardness	Qualification Tests Required	Maximum Reuses
Less than 10 [1 500]		Not permitted	
10 to 40 [1 500 to 6 000]	50	None	100
17 to 50 [2 500 to 7 000]	60	None	100
28 to 50 [4 000 to 7 000]	70	None	100
50 to 80 [7 000 to 12 000]	70	Required	50
Greater than 80 [12 000]		Not permitted	

[A] Compressive strength of concrete at age of testing as specified in Contract Documents. For acceptance testing, it is the specified compressive strength f_c' .

6. Test Specimens

6.1 Specimens shall be cylinders made in accordance with Practices C31/C31M or C192/C192M, or cores obtained in accordance with Test Method C42/C42M.

6.2 Depressions under a straight edge measured with a round wire gage across any diameter shall not exceed 5 mm [0.20 in.]. If the specimen ends do not meet this tolerance, the specimen shall not be tested unless irregularities are corrected by sawing or grinding.

7. Procedure

7.1 Unbonded caps are permitted to be used on one or both ends of a test specimen in lieu of a cap or caps meeting Practice C617, provided the caps meet the requirements of Section 5. Pad hardness shall be in accordance with Table 1.

NOTE 2—The specified strength in the contract documents is for various stages of construction. This may include strength test requirements for formwork removal or release of prestress in addition to the test requirements for verification of specified compressive strength. Therefore, pad selection is based on the strength requirement for the designated stage of construction.

7.2 Replace pads that do not meet the dimensional requirements of 5.2 or that exceed the maximum reuse limits of Table 1. Insert pad in the retainer before it is placed on the specimen.

NOTE 3—Some manufacturers recommend dusting the pads and the ends of the specimens with corn starch or talcum powder prior to testing.

7.3 Complete the load application, testing, calculation, and reporting of results in accordance with Test Method C39/C39M.

NOTE 4—Some users have reported damage to testing machines from the sudden release of energy stored in the elastomeric pads.

NOTE 5—Occasionally, specimens tested with unbonded caps may develop early cracking, but continue to carry increasing load. For this reason Test Method C39/C39M requires test specimens to be loaded until it is certain that they have been compressed beyond their ultimate capacity.

8. Qualification of Unbonded Capping Systems and Verification of Reuse of Pads

8.1 Table 1 specifies the conditions under which polychloroprene (neoprene) unbonded pads must be qualified under this section depending on the concrete strength and the Shore A hardness. Unbonded pads made of other elastomeric materials must be qualified using the procedures in this section.

8.2 When qualification tests are required they must be made by either the supplier or user of the unbonded pads. The user of the pads must retain a copy of the current qualification test report to demonstrate compliance with this practice. See X1.1.

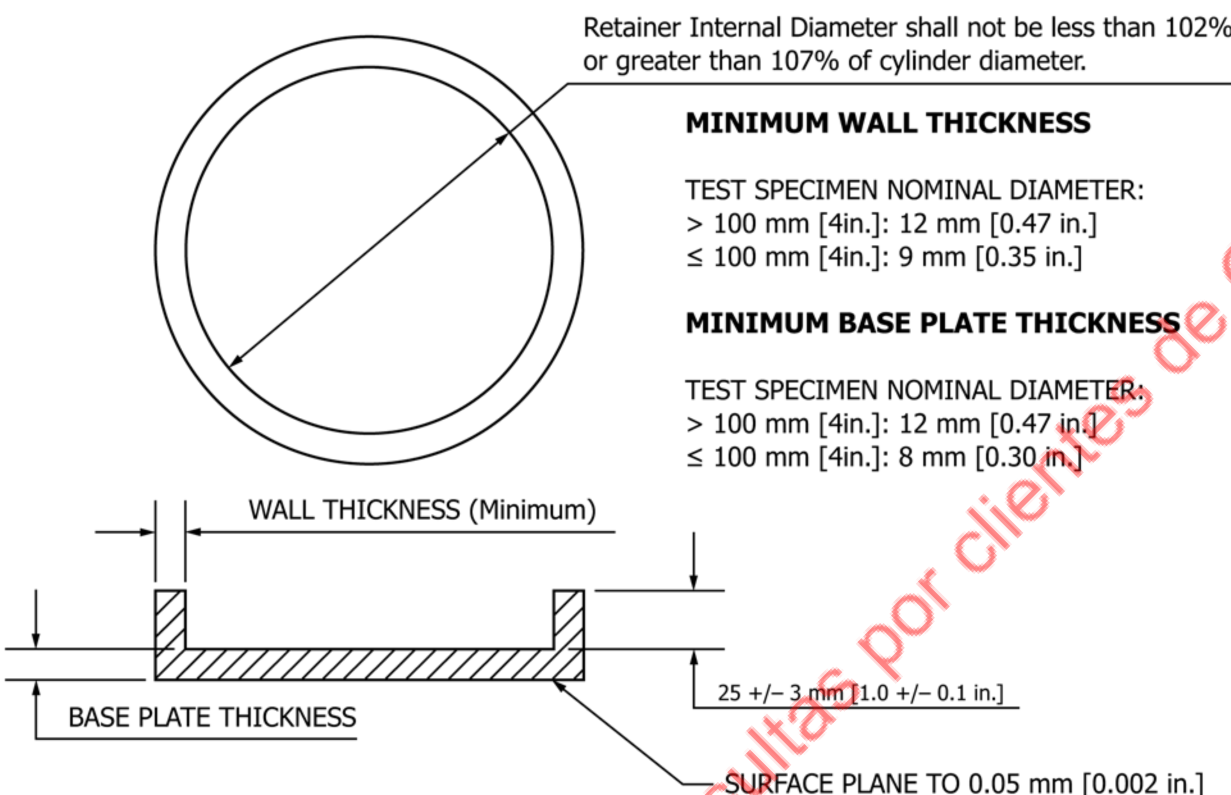

FIG. 1 Example of Retaining Ring and Base Plate

8.3 The compressive strength of molded cylinders tested with unbonded caps shall be compared with that of companion cylinders tested with ends ground or capped to meet requirements of Test Method C39/C39M and Practice C617.

8.4 To be acceptable, tests must demonstrate that at a 95 % confidence level ($\alpha = 0.05$), the average strength obtained using unbonded caps is not less than 98 % of the average strength of companion cylinders capped or ground in accordance with 8.3.

8.4.1 When required, qualification tests in accordance with 8.5 shall be made on initial use of an unbonded cap at both the highest and lowest strength levels anticipated to establish an acceptable range of cylinder strength for use. In practice individual cylinders shall not have strengths more than 10 % greater than the high strength level or more than 10 % less than the low strength level qualified or specified in Table 1. Qualification tests shall be repeated whenever there is a change in the design or dimensions of the retaining rings, or when there is a change in pad composition or thickness, or the Shore A hardness changes by more than five units. Initial qualification tests shall include verification that after the specified maximum number of reuses the pads meet the requirements of 8.4.

8.4.2 When tests are made to establish a permissible number of reuses exceeding those in Table 1, only those tests or reuses which are within 14 MPa [2000 psi] of the highest strength level to be qualified will be included in the reuse count. Laboratories must maintain records of the number of times pads are reused.

NOTE 6—Pad life depends on the hardness and type of pad material, the strength of the concrete, the difference between the outside diameter of the cylinder and the inside diameter of the retaining ring, the unevenness and roughness of the ends of the cylinder, and other factors. Based on available information, scuffing or abrasion of the perimeter of the pad is normal, provided it does not reduce the thickness of the pad around the perimeter.

8.5 *Specimen Preparation for Qualification and Pad Reuse Testing:*

8.5.1 Pairs of individual cylinders shall be made from a sample of concrete and cured as nearly alike as possible: one cylinder per pair is to be tested after grinding or capping in accordance with 8.3 and the other is to be tested using the unbonded cap system.

8.5.2 A minimum of 10 pairs of cylinders shall be made at both the highest and lowest strength levels desired or anticipated (Note 7). The "strength level" is the average of the strengths of the 20 or more cylinders whose strengths are within a range of 7 MPa [1000 psi] (Note 8). More than one pair of cylinders can be made from a single concrete sample, but cylinders must come from a minimum of two samples made on different days for each concrete strength level (Note 9).

NOTE 7—If the Practice C617 capped and unbonded capped specimens produce equal strengths, the number of pairs of cylinders that will be needed to demonstrate compliance will range from 9 to more than 60 depending on the variability of test results. If the two capping systems produce equal strengths, about 10 % of laboratories will require more than 60 tests and 10 % of the laboratories will require 9 tests to demonstrate statistical compliance.

NOTE 8—Note that the range of strengths permitted in qualification testing to define the strength level is 7 MPa [1000 psi], but that in counting number of reuses only cylinders within a range of 14 MPa [2000 psi] are included in the reuse count.

NOTE 9—Cylinders for qualification tests can be from pairs of cylinders tested in routine laboratory operations and, in most instances, special trial batches should not be required for qualification tests.

9. Calculation

9.1 For each strength level, compute the difference in strength for each pair of cylinders, and compute the average strength of the cylinders with reference caps and the average strength of the cylinders with unbonded caps, as follows:

$$d_i = x_{pi} - x_{si} \quad (1)$$

$$\bar{x}_s = (x_{s1} + x_{s2} + x_{s3} \ldots + x_{sn})/n$$

$$\bar{x}_p = (x_{p1} + x_{p2} + x_{p3} \ldots + x_{pn})/n$$

where:

d_i = difference in strength of a pair of cylinders computed as the strength of unbonded capped cylinder minus the strength of the cylinder prepared according to Practice C617 (may be positive or negative),
x_{pi} = cylinder strength using unbonded cap,
x_{si} = cylinder strength using Practice C617,
n = number of pairs of cylinders tested for the strength level,
$\bar{x}_s$ = average strength of Practice C617 capped cylinders for a strength level, and
$\bar{x}_p$ = average strength of unbonded cap cylinders for a strength level.

9.2 Compute the average difference, $\bar{d}$, and standard deviation of the difference, s_d, for each strength level, as follows:

$$\bar{d} = (d_1 + d_2 \ldots + d_n)/n \quad (2)$$

$$s_d = \left[\sum (d_i - \bar{d})^2/(n-1)\right]^{1/2}$$

9.3 To comply with this practice the following relationship must be satisfied:

$$\bar{x}_p \geq 0.98\,\bar{x}_s + (ts_d)/(n)^{1/2} \quad (3)$$

where t is the value of "students t" for $(n - 1)$ pairs at $\alpha = 0.05$ from the following table:

$(n - 1)$	$t(\alpha = 0.05)$[A]
9	1.833
14	1.761
19	1.729
100	1.662

[A] Use linear interpolation for other values of $(n - 1)$ or refer to appropriate statistical tables.

10. Keywords

10.1 cap; compressive strength; concrete; concrete test; elastomeric; neoprene; pad cap; rubber; unbonded cap

APPENDIX

(Nonmandatory Information)

X1. SAMPLE REPORT AND CALCULATION

X1.1 Sample Report

X1.1.1 *Pad Material*—Lot 3742, Shore A = 52, Thickness 13 mm [0.51 in.].

X1.1.2 *Retaining Ring*—Set A manufactured 1–87.

X1.1.3 Concrete Cylinders: Job 1207, Nos. 1–10, January 2 to 5, 1987.

X1.1.4 *Sulfur Mortar*—Lot 3420. Compressive Strength of 48.2 MPa [6985 psi].

X1.1.5 All Tests 28 days age.

X1.2 Summary

xs = 25.35 MPa [3679 psi],
xp = 25.26 MPa [3663 psi],
sd = 0.328 MPa [46.06 psi],
n = 10, and
t = 1.833.

Cylinder Pair		Neoprene Pad			Sulfur Cap			Difference, d	
		MPa	psi		MPa	psi		MPa	psi
1		24.9	3605		24.7	3580		0.20	25
2		24.9	3605		25.4	3690		-0.50	-85
3		24.7	3585		24.7	3595		0.00	-10
4		24.6	3570		25.0	3625		-0.40	-55
5		25.0	3625		25.1	3640		-0.10	-15
6		25.2	3660		25.8	3740		-0.60	-80
7		25.9	3750		25.6	3720		0.30	30
8		25.7	3725		25.6	3720		0.10	5
9		25.5	3700		25.7	3725		-020	-25
10		26.2	3805		25.9	3755		0.30	50
Average	xp	25.26	3663	xs	25.35	3679	d	-0.090	-16
Std. Dev.							sd	0.328	46.06

X1.3 Calculation

X1.3.1 Using Eq 3 in 9.3:
SI Units:

$$25.26 \geq = (0.98)(25.35) + (1.833)(0.328)/(10)^{1/2}$$
$$25.26 > 25.03 \ (\textit{System Qualifies})$$

Inch-Pound Units:

$$3663 \geq = (0.98)(3679) + (1.833)(46.06)/(10)^{1/2}$$
$$3663 > 3632 \text{ (system qualifies at 3670 psi)}$$

X1.4 Keywords

X1.4.1 caps; capping cylinders; compressive strength; pads; strength; unbonded capping system

SUMMARY OF CHANGES

Committee C09 has identified the location of selected changes to this standard since the last issue (C1231/C1231M – 14) that may impact the use of this standard. (Approved Dec. 1, 2015.)

(1) Deleted Note 2 and renumbered subsequent notes.
(2) Revised the following sections to reflect testing of cores in addition to concrete cylinders: Title, 1.1, 1.4, 4.1, 4.2, 5.1, 5.3, 6.1, 6.2, 7.1, 7.2, Note 3, and Note 5.
(3) Added Test Method C42/C42M as a referenced document in 2.1.
(4) Revised retainer requirements in 5.3 and Fig. 1.
(5) Removed perpendicularity and diameter check from 6.1.