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ASTM Standards for ACI CP-1, 38th edition: Concrete Field Testing Technician

C29/C29M-17a

C31/C31M-19

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Stock #: CP1ACICMP

INTERNATIONAL

Designation: C29/C29M − 17a

American Association of State
Highway and Transportation Officials Standard
AASHTO No.: T19/T19M

Standard Test Method for Bulk Density ("Unit Weight") and Voids in Aggregate[1]

This standard is issued under the fixed designation C29/C29M; 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 the determination of bulk density ("unit weight") of aggregate in a compacted or loose condition, and calculated voids between particles in fine, coarse, or mixed aggregates based on the same determination. This test method is applicable to aggregates not exceeding 125 mm [5 in.] in nominal maximum size.

NOTE 1—Unit weight is the traditional terminology used to describe the property determined by this test method, which is weight per unit volume (more correctly, mass per unit volume or density).

1.2 The values stated in either SI units or inch-pound units are to be regarded separately as standard, as appropriate for a specification with which this test method is used. An exception is with regard to sieve sizes and nominal size of aggregate, in which the SI values are the standard as stated in Specification E11. Within the text, 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 and health practices and determine the applicability of regulatory limitations prior to use.*

1.4 *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]

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
C670 Practice for Preparing Precision and Bias Statements for Test Methods for Construction Materials
C702/C702M Practice for Reducing Samples of Aggregate to Testing Size
C1077 Practice for Agencies Testing Concrete and Concrete Aggregates for Use in Construction and Criteria for Testing Agency Evaluation
D75/D75M Practice for Sampling Aggregates
E11 Specification for Woven Wire Test Sieve Cloth and Test Sieves

2.2 *AASHTO Standard:*

T19/T19M Method of Test for Unit Weight and Voids in Aggregate[3]

3. Terminology

3.1 *Definitions*—The terms used in this test method are defined in Terminology C125.

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *voids, n—in unit volume of aggregate*, the space between particles in an aggregate mass not occupied by solid mineral matter.

[1] This test method is under the jurisdiction of ASTM Committee C09 on Concrete and Concrete Aggregatesand is the direct responsibility of Subcommittee C09.20 on Normal Weight Aggregates.

Current edition approved April 1, 2017. Published June 2017. Originally approved in 1920. Last previous edition approved in 2017 as C29/C29M – 17. DOI: 10.1520/C0029_C0029M-17a.

[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.

[3] Available from American Association of State Highway and Transportation Officials (AASHTO), 444 N. Capitol St., NW, Suite 249, Washington, DC 20001, http://www.transportation.org.

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

3.2.1.1 *Discussion*—Voids within particles, either permeable or impermeable, are not included in voids as determined by this test method.

4. Significance and Use

4.1 This test method is often used to determine bulk density values that are necessary for use for many methods of selecting proportions for concrete mixtures.

4.2 The bulk density also may be used for determining mass/volume relationships for conversions in purchase agreements. However, the relationship between degree of compaction of aggregates in a hauling unit or stockpile and that achieved in this test method is unknown. Further, aggregates in hauling units and stockpiles usually contain absorbed and surface moisture (the latter affecting bulking), while this test method determines the bulk density on a dry basis.

4.3 A procedure is included for computing the percentage of voids between the aggregate particles based on the bulk density determined by this test method.

5. Apparatus

5.1 *Balance*—A balance or scale accurate to within 0.05 kg [0.1 lb] or to within 0.1% of the test load, whichever is greater, at any point within the range of use. The range of use shall be considered to extend from the mass of the measure empty to the mass of the measure plus its contents at 1920 kg/m^3 [120 lb/ft^3].

5.2 *Tamping Rod*—A round, plain steel rod with a diameter of 16 ± 2 mm [5⁄8 ± 1⁄16 in.]. The length of the tamping rod shall be at least 100 mm [4 in.] greater than the depth of the measure or mold in which rodding is being performed, but not greater than 750 mm [30 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. The rod shall be straight over its length to a tolerance of 0.5 % of its length.

5.3 *Measure*—A cylindrical container made of steel or other suitable metal that complies with the requirements of this section, preferably provided with handles. The measure shall be watertight and sufficiently rigid to retain its form under rough usage. The measure shall have a height at least 80 % and not more than 150 % of the diameter. The capacity of the measure shall conform to the limits in Table 1 for the aggregate size to be tested. The thickness of metal in the measure shall be as described in Table 2. The top rim shall be smooth and plane within 0.3 mm [0.01 in.] and shall be parallel to the bottom within 0.5° (see Note 2). The interior wall of the measure shall be a smooth and continuous surface.

TABLE 1 Capacity of Measures

Nominal Maximum Size of Aggregate		Capacity of Measure[A]	
mm	in.	m^3 [L]	ft^3
12.5	½	0.0028[2.8]	1⁄10
25.0	1	0.0093 [9.3]	⅓
37.5	1½	0.014 [14]	½
75	3	0.028 [28]	1
100	4	0.070 [70]	2½
125	5	0.100 [100]	3½

[A] The indicated size of measure shall be used to test aggregates of a nominal maximum size equal to or smaller than that listed. The actual volume of the measure shall be at least 95 % of the nominal volume listed.

TABLE 2 Requirements for Measures

Units	Capacity of Measure	Thickness of Metal, min		
		Bottom	Upper 38 mm or 1½ in. of wall[A]	Remainder of wall
SI	Less than 11 L	5.0 mm	2.5 mm	2.5 mm
	11 to 42 L, incl	5.0 mm	5.0 mm	3.0 mm
	over 42 to 80 L, incl	10.0 mm	6.4 mm	3.8 mm
	over 80 to 133 L, incl	13.0 mm	7.6 mm	5.0 mm
Inch-pound	Less than 0.4 ft^3	0.20 in.	0.10 in.	0.10 in.
	0.4 ft^3 to 1.5 ft^3, incl	0.20 in.	0.20 in.	0.12 in.
	over 1.5 to 2.8 ft^3, incl	0.40 in.	0.25 in.	0.15 in.
	over 2.8 to 4.0 ft^3, incl	0.50 in.	0.30 in.	0.20 in.

[A] The added thickness in the upper portion of the wall may be obtained by placing a reinforcing band around the top of the measure.

NOTE 2—The top rim is satisfactorily plane if a 0.3-mm [0.01-in.] feeler gage cannot be inserted between the rim and a piece of 6-mm [¼-in.] or thicker plate glass laid over the measure. The top and bottom are satisfactorily parallel if the slope between pieces of plate glass in contact with the top and bottom does not exceed 0.87 % in any direction.

5.3.1 Measures larger than nominal 28 L [1 ft^3] capacity shall be made of steel.

5.4 *Shovel or Scoop*—A shovel or scoop of convenient size for filling the measure with aggregate.

5.5 *Equipment for Measuring Volume of Measure:*

5.5.1 *Plate Glass*—A piece of plate glass, at least 6 mm [¼ in.] thick and at least 25 mm [1 in.] larger than the diameter of the measure to be calibrated.

5.5.2 *Grease*—A supply of water-pump, chassis, or similar grease.

5.5.3 *Thermometer*—A thermometer having a range of at least 10 to 32 °C [50 to 90 °F] and that is readable to at least 0.5 °C [1 °F].

5.5.4 *Balance*—A balance as described in 5.1.

6. Sampling

6.1 Obtain the sample in accordance with Practice D75/D75M, and reduce to test sample size in accordance with Practice C702/C702M.

7. Test Sample

7.1 The size of the test sample shall be between 125 and 200 % of the quantity required to fill the measure, and shall be handled in a manner to avoid segregation.

7.2 Dry the aggregate sample to constant mass in an oven at 110 ± 5 °C [230 ± 10 °F]. The sample is considered to be at constant mass when the difference in mass between two consecutive weighings taken one hour apart is less than 0.1% of the last weighing.

NOTE 3—Alternative means of drying are sometimes chosen for quick determinations where rapid results are desired or if an oven is not available. Alternative drying methods should not cause fracturing of particles or chemical breakdown of the aggregate. Use of alternative drying methods does not conform with this test method.

8. Determination of Volume of Measure

8.1 Determine the volume of the measure upon initial use and subsequently at a frequency not to exceed twelve months, or whenever there is reason to question the accuracy of the volumetric capacity of the measure. If required, retain a record of volume determination in accordance with Practice C1077.

8.2 Determine the mass of the plate glass and measure the nearest 0.05 kg [0.1 lb].

8.3 Place a thin layer of grease on the rim of the measure to prevent leakage of water from the measure.

8.4 Fill the measure with water that is at room temperature and cover with the plate glass in such a way as to eliminate bubbles and excess water. Remove any water that may have overflowed onto the measure or plate glass.

8.5 Determine the mass of the water, plate glass, and measure to the nearest 0.05 kg [0.1 lb].

8.6 Measure the temperature of the water to the nearest 0.5 °C [1 °F] and determine its density from Table 3, interpolating if necessary.

TABLE 3 Density of Water

Temperature °C	Temperature °F	kg/m³	lb/ft³
15.6	60	999.01	62.366
18.3	65	998.54	62.336
21.1	70	997.97	62.301
23.0	73.4	997.54	62.274
23.9	75	997.32	62.261
26.7	80	996.59	62.216
29.4	85	995.83	62.166

8.7 Calculate the volume, *V*, of the measure. Alternatively, calculate the factor, F, for the measure.

NOTE 4—For the calculation of bulk density, the volume of the measure in SI units should be expressed in cubic metres, or the factor as $1/m^3$. However, for convenience the size of the measure may be expressed in litres.

9. Procedure

9.1 Determine and record the mass of the empty measure to the nearest 0.05 kg [0.1 lb].

9.2 To determine the compacted bulk density of aggregates having a nominal maximum size of 37.5 mm [1½ in.] or less, consolidate the sample in the measure using *Method A—Rodding*; use *Method B—Jigging* for aggregates having a nominal maximum size greater than 37.5 mm [1½ in.] and not exceeding 125 mm [5 in.]. To determine the loose bulk density of the aggregate, when stipulated, fill the measure by *Method C—Shoveling*.

9.2.1 *Method A—Rodding:*

9.2.1.1 Fill the measure one-third full and level the surface with the fingers. Rod the layer of aggregate with 25 strokes of the tamping rod evenly distributed over the surface. Fill the measure two-thirds full and again level and rod as above. Finally, fill the measure to overflowing and rod again in the manner previously mentioned. Level the surface of the aggregate with the fingers or a straightedge in such a way that any slight projections of the larger pieces of the coarse aggregate approximately balance the larger voids in the surface below the top of the measure.

9.2.1.2 In rodding the first layer, do not allow the rod to strike the bottom of the measure forcibly. In rodding the second and third layers, use vigorous effort, but not more force than to cause the tamping rod to penetrate to the previous layer of aggregate.

NOTE 5—In rodding the larger sizes of coarse aggregate, it may not be possible to penetrate the layer being consolidated, especially with angular aggregates. The intent of the procedure will be accomplished if vigorous effort is used.

9.2.2 *Method B—Jigging:*

9.2.2.1 Fill the measure in three approximately equal layers as described in 9.2.1.1, compacting each layer by placing the measure on a firm base, such as a cement-concrete floor, raising the opposite sides alternately about 50 mm [2 in.], and allowing the measure to drop in such a manner as to hit with a sharp, slapping blow. The aggregate particles, by this procedure, will arrange themselves in a densely compacted condition. Compact each layer by dropping the measure 50 times in the manner described, 25 times on each side. Level the surface of the aggregate with the fingers or a straightedge in such a way that any slight projections of the larger pieces of the coarse aggregate approximately balance the larger voids in the surface below the top of the measure.

9.2.3 *Method C—Shoveling:*

9.2.3.1 Fill the measure to overflowing by means of a shovel or scoop, discharging the aggregate from a height not to exceed 50 mm [2 in.] above the top of the measure. Exercise care to prevent, so far as possible, segregation of the particle sizes of which the sample is composed. Level the surface of the aggregate with the fingers or a straightedge in such a way that any slight projections of the larger pieces of the coarse aggregate approximately balance the larger voids in the surface below the top of the measure.

9.3 Determine and record the mass of the measure plus its contents to the nearest 0.05 kg [0.1 lb].

10. Calculation

10.1 *Bulk Density*—Calculate the bulk density as follows:

$$M = (G - T)/V \quad (1)$$

or

$$M = (G - T) \times F \quad (2)$$

where:

M = bulk density of the aggregate, kg/m^3 [lb/ft^3],
G = mass of the aggregate plus the measure, kg [lb],
T = mass of the measure, kg [lb],
V = volume of the measure, m^3 [ft^3], and
F = factor for measure, m^{-3} [ft^{-3}].

10.1.1 The bulk density determined by this test method is for aggregate in an oven-dry condition. If the bulk density in terms of saturated-surface-dry (SSD) condition is desired, use the exact procedure in this test method, and then calculate the SSD bulk density using the following formula:

$$Mssd = M[1+(A/100)] \quad (3)$$

where:

M_{SSD} = bulk density in SSD condition, kg/m^3 [lb/ft^3], and
A = % absorption, determined in accordance with Test Method C127 or Test Method C128.

10.2 *Void Content*—Calculate the void content in the aggregate using the bulk density determined by either the rodding, jigging, or shoveling procedure, as follows:

$$\% \text{ Voids} = 100[(S \times W) - M]/(S \times W) \quad (4)$$

where:

M = bulk density of the aggregate, kg/m^3 [lb/ft^3],
S = bulk specific gravity (dry basis) as determined in accordance with Test Method C127 or Test Method C128, and
W = density of water, 998 kg/m^3 [62.3 lb/ft^3].

10.3 *Volume of Measure*—Calculate the volume of a measure as follows:

$$V = (W - M)/D \quad (5)$$

$$F = D/(W - M) \quad (6)$$

where:

V = volume of the measure, m^3 [ft^3]
W = mass of the water, plate glass, and measure, kg [lb]
M = mass of the plate glass and measure, kg [lb]
D = density of the water for the measured temperature, kg/m^3 [lb/ft^3], and
F = factor for the measure, 1/m^3 [1/ft^3]

11. Report

11.1 Report the results for the bulk density to the nearest 10 kg/m^3 [1 lb/ft^3] as follows:

11.1.1 Bulk density consolidated by *Method A—Rodding*, or

11.1.2 Bulk density consolidated by *Method B—Jigging*, or

11.1.3 Loose bulk density by *Method C—Shoveling*.

11.2 Report the results for the void content to the nearest 1 % as follows:

11.2.1 Voids in aggregate consolidated by *Method A—Rodding*, %, or

11.2.2 Voids in aggregate consolidated by *Method B—Jigging*, %, or

11.2.3 Voids in loose aggregate by *Method C—Shoveling*, %.

12. Precision and Bias

12.1 The following estimates of precision for this test method are based on results from the AASHTO Materials Reference Laboratory (AMRL) Proficiency Sample Program, with testing conducted using this test method and AASHTO Method T 19/T19M. There are no significant differences between the two test methods. The data are based on the analyses of more than 100 paired test results from 40 to 100 laboratories.

12.2 *Coarse Aggregate (bulk density):*

12.2.1 *Single-Operator Precision*—The single-operator standard deviation has been found to be 14 kg/m^3 [0.88 lb/ft^3] (1s). Therefore, results of two properly conducted tests by the same operator on similar material should not differ by more than 40 kg/m^3 [2.5 lb/ft^3] (d2s).

12.2.2 *Multilaboratory Precision*—The multilaboratory standard deviation has been found to be 30 kg/m^3 [1.87 lb/ft^3] (1s). Therefore, results of two properly conducted tests from two different laboratories on similar material should not differ by more than 85 kg/m^3 [5.3 lb/ft^3] (d2s).

12.2.3 These numbers represent, respectively, the (1s) and (d2s) limits as described in Practice C670. The precision estimates were obtained from the analysis of AMRL proficiency sample data for bulk density by rodding of normal weight aggregates having a nominal maximum aggregate size of 25.0 mm [1 in.], and using a 14-L [½-ft^3] measure.

12.3 *Fine Aggregate (bulk density):*

12.3.1 *Single-Operator Precision*—The single-operator standard deviation has been found to be 14 kg/m^3 [0.88 lb/ft^3] (1s). Therefore, results of two properly conducted tests by the same operator on similar material should not differ by more than 40 kg/m^3 [2.5 lb/ft^3] (d2s).

12.3.2 *Multilaboratory Precision*—The multilaboratory standard deviation has been found to be 44 kg/m^3 [2.76 lb/ft^3] (1s). Therefore, results of two properly conducted tests from two different laboratories on similar material should not differ by more than 125 kg/m^3 [7.8 lb/ft^3] (d2s).

12.3.3 These numbers represent, respectively, the (1s) and (d2s) limits as described in Practice C670. The precision estimates were obtained from the analysis of AMRL proficiency sample data for loose bulk density from laboratories using a 2.8-L [1⁄10-ft^3] measure.

12.4 No precision data on void content are available. However, as the void content in aggregate is calculated from bulk density and bulk specific gravity, the precision of the voids content reflects the precision of these measured parameters given in 12.2 and 12.3 of this test method and in Test Methods C127 and C128.

12.5 *Bias*—The procedure in this test method for measuring bulk density and void content has no bias because the values for bulk density and void content can be defined only in terms of a test method.

13. Keywords

13.1 aggregates; bulk density; coarse aggregate; density; fine aggregate; unit weight; voids in aggregates

SUMMARY OF CHANGES

Committee C09 has identified the location of selected changes to this test method since the last issue, C29/C29M – 17, that may impact the use of this test method. (Approved April 1, 2017.)

(1) Revised 7.1.
(2) Added 7.2 and Note 3 (renumbered subsequent Notes accordingly).
(3) Consolidated previous Sections 9, 10, 11, and 12. Revised 9, 10, and 11.

Committee C09 has identified the location of selected changes to this test method since the last issue, C29/C29M – 16, that may impact the use of this test method. (Approved Jan. 1, 2017.)

(1) Revised 5.1 – 5.3.
(2) Deleted 5.3.1 and renumbered subsequent section.
(3) Revised 8.1.

Designation: C31/C31M – 19

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 satisfactory for making specimens from concrete not having measurable slump or requiring other sizes or shapes of specimens.

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, 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])

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

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]

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
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 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

2.2 *American Concrete Institute Publication:*[4]

309R Guide for Consolidation of Concrete

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

Current edition approved Jan. 1, 2019. Published January 2019. Originally approved in 1920. Last previous edition approved in 2018 as C31/C31M–18b. DOI: 10.1520/C0031_C0031M-19.

[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.

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

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

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 1). The rod shall have the tamping end or both ends rounded to a hemispherical tip of the same diameter as the rod.

NOTE 1—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 2—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 ± 0.2 kg [1.25 ± 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, 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.

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]

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 by 300 mm [6 by 12 in.] or 100 by 200 mm [4 by 8 in.] (Note 3).

NOTE 3—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 4). The same specimen size shall be used when comparing results and for mixture qualification and acceptance testing.

NOTE 4—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 and 25.0 mm [¾ and 1 in.], the ratio between the modulus of rupture determined with a 150 by 150 mm [6 by 6 in.] and a 100 by 100 mm [4 by 4 in.] may vary from 0.90 to 1.07[5] and for maximum aggregate size between 9.5 and 37.5 mm [⅜ and 1½ in.], the ratio between the modulus of rupture determined with a 150 by 150 mm [6 by 6 in.] and a 115 by 115 mm [4.5 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.

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 *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, for each sample of concrete from which specimens are made.

8.2 *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.

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

NOTE 5—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.

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

[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.

TABLE 2 Minimum Cross-Sectional Dimension of Beams

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

TABLE 3 Method of Consolidation Requirements

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

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 6). 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.].

NOTE 6—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.

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

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 7—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 8—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 and 27°C [60 and 80°F]. For concrete mixtures with a specified strength of 40 MPa [6000 psi] or greater, maintain the initial curing temperature between 20 and 26°C [68 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 9—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 10—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 11—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 12—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 ± 2.0°C [73.5 ± 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 and 30°C [68 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 ± 2.0°C [73.5 ± 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 13—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 ± 2.0°C [73.5 ± 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 *Structural Lightweight Concrete Curing*—Cure structural 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 14). 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 14—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 Identification number,

12.1.2 Location of concrete represented by the samples,

12.1.3 Date, time and name of individual molding specimens,

12.1.4 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

12.1.5 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–18b, that may impact the use of this practice. (Approved January 1, 2019)

(1) Revised 5.2 to prohibit the use of cardboard mold for standard-cured specimens.
(2) Revised 10.1.2 through 10.1.2.2.
(3) Added 3.2, 3.2.1, and Notes 8-12.

Designation: C94/C94M – 20

Standard Specification for Ready-Mixed Concrete[1]

This standard is issued under the fixed designation C94/C94M; 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 ready-mixed concrete as defined in 3.2.2 (Note 1). Requirements for quality of ready-mixed concrete shall be either as stated in this specification or as ordered by the purchaser. When the purchaser's requirements, as stated in the order, differ from those in this specification, the purchaser's requirements shall govern. This specification does not cover the placement, consolidation, curing, or protection of the concrete after delivery to the purchaser.

NOTE 1—Concrete produced by volumetric batching and continuous mixing is covered in Specification C685/C685M. Fiber-reinforced concrete is covered in Specification C1116/C1116M.

1.2 As used throughout this specification the manufacturer produces ready-mixed concrete. The purchaser buys ready-mixed concrete.

1.3 The values stated in either SI units, shown in brackets, 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 nonconformance with the standard.

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

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 use.[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]

C31/C31M Practice for Making and Curing Concrete Test Specimens in the Field
C33/C33M Specification for Concrete Aggregates
C39/C39M Test Method for Compressive Strength of Cylindrical Concrete Specimens
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
C150/C150M Specification for Portland Cement
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
C260/C260M Specification for Air-Entraining Admixtures for Concrete
C330/C330M Specification for Lightweight Aggregates for Structural Concrete

[1] This specification is under the jurisdiction of ASTM Committee C09 on Concrete and Concrete Aggregates and is the direct responsibility of Subcommittee C09.40 on Ready-Mixed Concrete.

Current edition approved Feb. 1, 2020. Published March 2020. Originally approved in 1933. Last previous edition approved in 2019 as C94/C94M–19a. DOI: 10.1520/C0094_C0094M-20.

[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**

C494/C494M Specification for Chemical Admixtures for Concrete
C567/C567M Test Method for Determining Density of Structural Lightweight Concrete
C595/C595M Specification for Blended Hydraulic Cements
C618 Specification for Coal Fly Ash and Raw or Calcined Natural Pozzolan for Use in Concrete
C637 Specification for Aggregates for Radiation-Shielding Concrete
C685/C685M Specification for Concrete Made by Volumetric Batching and Continuous Mixing
C989/C989M Specification for Slag Cement for Use in Concrete and Mortars
C1017/C1017M Specification for Chemical Admixtures for Use in Producing Flowing Concrete
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 Testing Agency Evaluation
C1116/C1116M Specification for Fiber-Reinforced Concrete
C1157/C1157M Performance Specification for Hydraulic Cement
C1240 Specification for Silica Fume Used in Cementitious Mixtures
C1602/C1602M Specification for Mixing Water Used in the Production of Hydraulic Cement Concrete
C1611/C1611M Test Method for Slump Flow of Self-Consolidating Concrete
C1798/C1798M Specification for Returned Fresh Concrete for Use in a New Batch of Ready-Mixed Concrete

2.2 *ACI Documents:*[4]

ACI 211.1 Standard Practice for Selecting Proportions for Normal, Heavyweight, and Mass Concrete
ACI 211.2 Standard Practice for Selecting Proportions for Structural Lightweight Concrete
ACI 301 Standard Specifications for Structural Concrete
ACI 305R Guide to Hot Weather Concreting
ACI 306R Guide to Cold Weather Concreting
ACI 318 Building Code Requirements for Structural Concrete and Commentary

2.3 *Other Documents:*[5]

NIST 105-1 National Institute of Standards and Technology Handbook

3. Terminology

3.1 *Definitions*—The terms used in this specification are defined in Terminology C125.

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *concrete, central-mixed, n*—ready-mixed concrete mixed completely in a stationary mixer.

3.2.2 *concrete, ready-mixed, n*—concrete manufactured and delivered to a purchaser in a fresh state.

3.2.3 *concrete, shrink-mixed, n*—ready-mixed concrete partially mixed in a stationary mixer with mixing completed in a truck mixer.

3.2.4 *concrete, truck-mixed, n*—ready-mixed concrete completely mixed in a truck mixer.

3.2.5 *water, target batch, n*—quantity of water to be added to the batch through the water measuring system after compensating for the quantity of ice, if used, surface moisture on the aggregates and water in the admixtures, when applicable, and by subtracting a quantity of water that is anticipated to be added at the job site or in transit to adjust slump or slump flow of the concrete batch.

4. Basis of Purchase

4.1 The basis of purchase shall be a cubic yard or cubic metre of fresh concrete as discharged from the transportation unit.

4.2 The volume of fresh concrete in a given batch shall be determined from the total mass of the batch divided by the density of the concrete. The total mass of the batch shall be determined as the net mass of the concrete in the batch as delivered, including the total mixing water as defined in 9.3. The density shall be determined in accordance with Test Method C138/C138M. The yield shall be determined as the average of at least three measurements, one from each of three different transportation units sampled in accordance with Practice C172/C172M.

NOTE 2—It should be understood that the volume of hardened concrete may be, or appear to be, less than expected due to waste and spillage, over-excavation, spreading forms, some loss of entrained air, or settlement of wet mixtures, none of which is the responsibility of the producer.

5. Materials

5.1 In the absence of designated applicable material specifications, the following material specifications shall be used:

5.2 *Cementitious Materials:*

5.2.1 *Hydraulic Cement*—Hydraulic cement shall conform to Specification C150/C150M, Specification C595/C595M, or Specification C1157/C1157M.

5.2.2 *Supplementary Cementitious Materials*—Coal fly ash or natural pozzolans shall conform to Specification C618. Slag cement shall conform to Specification C989/C989M. Silica fume shall conform to Specification C1240.

5.3 *Aggregates*—Normal weight aggregates shall conform to Specification C33/C33M. Lightweight aggregates shall conform to Specification C330/C330M and heavyweight aggregates shall conform to Specification C637.

5.4 *Water*—Water shall conform to Specification C1602/C1602M.

5.5 *Air-Entraining Admixtures*—Air-entraining admixtures shall conform to Specification C260/C260M (Note 3).

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

[5] NIST Handbook 105-1 (revised 1990), "Specifications and Tolerances for Reference Standards and Field Standard Weights and Measures-1. Specifications and Tolerances for Field Standard Weights (NIST Class F)," National Institute of Standards and Technology., U.S. Dept. of Commerce, http://www.nist.gov/pml/wmd/upload/105-1.pdf.

5.6 *Chemical Admixtures*—Chemical admixtures shall conform to Specification C494/C494M or C1017/C1017M as applicable (Note 3).

NOTE 3—In any given instance, the required dosage of air-entraining, accelerating, and retarding admixtures may vary. Therefore, a range of dosages should be allowed, which will permit obtaining the desired effect.

NOTE 4—Interchanging kinds, characteristics, types, classes, or grades of the materials permitted in ready-mixed concrete may produce concrete of different properties.

5.7 *Returned Fresh Concrete*—Returned fresh concrete, when permitted by the purchaser, shall conform to Specification C1798/C1798M.

NOTE 5—Specification C1798/C1798M provides requirements for using, measuring, and reporting returned fresh concrete. These requirements are in addition to those stated herein. The purchaser may further clarify which concrete within an order, such as specific mixtures or applications, may incorporate returned fresh concrete.

6. Ordering Information

6.1 In the absence of designated applicable general specifications, the purchaser's order shall include the following:

6.1.1 Designated size, or sizes, of coarse aggregate,

6.1.2 Slump, or slumps, desired at the point of delivery (see Section 7 for acceptable tolerances),

6.1.3 Slump flow, or flows, desired at the point of delivery (see Section 7 for acceptable tolerances),

6.1.4 Total air content at the point of delivery for concrete that will be exposed to cycles of freezing and thawing or anticipated exposure of the concrete (see Section 8 for sampling for air content tests and tolerances).

NOTE 6—Table 1 provides total air contents for concrete that vary by exposure condition and aggregate size. Total air contents less than those shown in Table 1 may be specified or used for concrete that is not subject to freezing and thawing. This may be done to improve workability and cohesiveness, reduce the rate of bleeding, reduce the water content for a given consistency, or achieve required lightweight concrete density. Specified total air contents higher than those shown in Table 1 may reduce strength without any further improvement of durability.

Exposure conditions for freezing and thawing environments in Table 1 correspond to the following:

Moderate Exposure—Concrete exposed to freeze-thaw cycles but not in contact with the ground or with limited exposure to water, limiting the ability to cause saturation of a portion of the concrete prior to freezing. The concrete shall not receive deicing salts or other aggressive chemicals. Examples include: exterior beams, columns, walls, girders, footings below the frost line, or elevated slabs where application of deicing salt is not anticipated. The air content requirements for this exposure are consistent with those for Exposure Class F1 of ACI 318.

Severe Exposure—Concrete exposed to freeze-thaw cycles while in contact with the ground or with frequent exposure to water, potentially causing saturation of a portion of the concrete prior to freezing. The concrete may receive deicing chemicals or other aggressive chemicals. Examples include: pavements, bridge decks, curbs, gutters, sidewalks, canal linings, or exterior water tanks or sumps. The air content requirements for this exposure are consistent with those for Exposure Classes F2 and F3 of ACI 318.

6.1.5 Which of Options A, B, or C shall be used as a basis for determining the proportions of the concrete to produce the required quality,

6.1.6 When lightweight concrete is specified, the equilibrium density,

NOTE 7—The density of fresh concrete is the only measurable density of lightweight concrete at the time of delivery. The density of fresh concrete is always higher than the equilibrium or oven-dry density. Therefore, for acceptance of lightweight concrete based on density at the time of delivery, a relationship between the equilibrium density and density of fresh concrete needs to be established. Definitions of, and methods for determining or calculating equilibrium and oven-dry density, are covered by Test Method C567/C567M.

6.1.7 When high-density or heavyweight concrete is specified, the density of fresh concrete, and

NOTE 8—High-density or heavyweight concrete typically contains aggregate with a relative density of 3.3 or greater conforming to Specification C637. This concrete is used for radiation shielding or other applications where higher density is required by design. For acceptance of density at the time of delivery, a relationship between the fresh density and the density of hardened concrete required by design should be established.

6.1.8 If desired, any of the optional requirements of Table 2 in Specification C1602/C1602M.

6.1.9 Purchaser shall state any drum revolution limit as to when the concrete discharge must begin. If no drum revolution limit is stated by purchaser, the manufacturer shall determine and communicate the limit to the purchaser prior to delivery.

6.2 If a project specification applies, the order shall include applicable requirements for the concrete to be produced in compliance with the specification.

6.3 If the type, kind, or class of cementitious materials in 5.2.1 and 5.2.2 are not designated by the purchaser, it is permitted to use cementitious materials in concrete mixtures that will satisfy the concrete properties and other requirements of the purchaser as ordered.

6.4 *Option A:*

6.4.1 When the purchaser requires the manufacturer to assume full responsibility for the selection of the proportions for the concrete mixture (Note 9), the purchaser shall also specify the following:

6.4.1.1 Requirements for compressive strength as determined on samples taken from the transportation unit at the point of discharge evaluated in accordance with Section 18. The purchaser shall specify the requirements in terms of the compressive strength of standard specimens cured under standard laboratory conditions for moist curing (see Section 18). Unless otherwise specified the age at test shall be 28 days.

TABLE 1 Total Air Content for Air-Entrained Concrete Exposed to Cycles of Freezing and Thawing

Exposure Condition (See Note 6)	Total Air Content, % — Nominal Maximum Sizes of Aggregate, mm [in.]						
	9.5 [3⁄8]	12.5 [1⁄2]	19.0 [3⁄4]	25.0 [1]	37.5 [11⁄2]	50.0 [2]	75.0 [3]
Moderate	6.0	5.5	5.0	4.5	4.5	4.0	3.5
Severe	7.5	7.0	6.0	6.0	5.5	5.0	4.5

NOTE 9—The purchaser, in selecting requirements for which he assumes responsibility should give consideration to requirements for workability, placeability, durability, surface texture, and density, in addition to those for structural design. The purchaser is referred to Standard Practice ACI 211.1 and Standard Practice ACI 211.2 for the selection of proportions that will result in concrete suitable for various types of structures and conditions of exposure. The water-cement ratio of most structural lightweight concretes cannot be determined with sufficient accuracy for use as a specification basis.

6.4.2 At the request of the purchaser, the manufacturer shall, prior to the actual delivery of the concrete, furnish a statement to the purchaser, giving the dry masses of cement and saturated surface-dry-masses of fine and coarse aggregate and quantities, type, and name of admixtures (if any) and of water per cubic yard or cubic metre of concrete that will be used in the manufacture of each class of concrete ordered by the purchaser. The manufacturer shall also furnish evidence satisfactory to the purchaser that the materials to be used and proportions selected will produce concrete of the quality specified.

6.5 *Option B:*

6.5.1 When the purchaser assumes responsibility for the proportioning of the concrete mixture, he shall also specify the following:

6.5.1.1 Cement content in kilograms per cubic metre [pounds per cubic yard] of concrete,

6.5.1.2 Maximum allowable water content in litres per cubic metre [gallons per cubic yard] of concrete, including surface moisture on the aggregates, but excluding water of absorption (Note 9), and

6.5.1.3 If admixtures are required, the type, name, and dosage to be used. The cement content shall not be reduced when admixtures are used under this option without the written approval of the purchaser.

6.5.2 At the request of the purchaser, the manufacturer shall, prior to the actual delivery of the concrete, furnish a statement to the purchaser giving the sources, densities, and sieve analyses of the aggregates and the dry masses of cement and saturated-surface-dry masses of fine and coarse aggregate and quantities, type and name of admixture (if any) and of water per cubic yard or cubic metre of concrete that will be used in the manufacture of each class of concrete ordered by the purchaser.

6.6 *Option C:*

6.6.1 When the purchaser requires the manufacturer to assume responsibility for the selection of the proportions for the concrete mixture with the minimum allowable cement content specified (Note 10), the purchaser shall also specify the following:

6.6.1.1 Required compressive strength as determined on samples taken from the transportation unit at the point of discharge evaluated in accordance with Section 18. The purchaser shall specify the requirements for strength in terms of tests of standard specimens cured under standard laboratory conditions for moist curing (see Section 18). Unless otherwise specified the age at test shall be 28 days.

6.6.1.2 Minimum cement content in kilograms per cubic metre [pounds per cubic yard] of concrete.

6.6.1.3 If admixtures are required, the type, name, and dosage to be used. The cement content shall not be reduced when admixtures are used.

NOTE 10—Option C can be distinctive and useful only if the designated minimum cement content is at about the same level that would ordinarily be required for the strength, aggregate size, and slump or slump flow specified. At the same time, it must be an amount that will be sufficient to ensure durability under expected service conditions, as well as satisfactory surface texture and density, in the event specified strength is attained with it. For additional information refer to Standard Practice ACI 211.1 and Standard Practice 211.2 referred to in Note 9.

6.6.2 At the request of the purchaser, the manufacturer shall, prior to the actual delivery of the concrete, furnish a statement to the purchaser, giving the dry masses of cement and saturated surface-dry masses of fine and coarse aggregate and quantities, type, and name of admixture (if any) and of water per cubic yard or cubic metre of concrete that will be used in the manufacture of each class of concrete ordered by the purchaser. He shall also furnish evidence satisfactory to the purchaser that the materials to be used and proportions selected will produce concrete of the quality specified. Whatever strengths are attained the quantity of cement used shall not be less than the minimum specified.

6.7 The proportions arrived at by Options A, B, or C for each class of concrete and approved for use in a project shall be assigned a designation to facilitate identification of each concrete mixture delivered to the project. This is the designation required in 14.1.7 and supplies information on concrete proportions when they are not given separately on each delivery ticket as outlined in 14.2. A certified copy of all proportions as established in Options A, B, or C shall be on file at the batch plant.

6.8 The purchaser shall ensure that the manufacturer is provided copies of all reports of tests performed on concrete samples taken to determine compliance with specification requirements. Reports shall be provided on a timely basis.

6.9 The manufacturer shall obtain the purchaser's permission to incorporate returned fresh concrete.

7. Slump or Slump Flow

7.1 Unless other tolerances are indicated by the purchaser, the following shall apply.

7.1.1 When slump is stated as a "maximum" or "not to exceed" requirement:

Tolerances for "Maximum" or "Not to Exceed" Slumps

For Slump of:	Tolerance
75 mm [3 in.] or less	+0 and –40 mm [1½ in.]
More than 75 mm [3 in.]	+0 and –65 mm [2½ in.]

7.1.1.1 The maximum or not to exceed slump provision shall be used only if a job site water addition is permitted by the specification in accordance with 12.7.

7.1.2 When slump is stated as a target or nominal slump:

Tolerances for Target or Nominal Slumps

For Slump of:	Tolerance
50 mm [2 in.] and less	±15 mm [½ in.]
More than 50 to 100 mm [2 through 4 in.]	±25 mm [1 in.]
More than 100 mm [4 in.]	±40 mm [1½ in.]

7.1.3 When the purchaser states a slump flow requirement for self-consolidating concrete:

Tolerances for Slump Flow

For Slump Flow	Tolerance
Less than or equal to 550 mm [22 in.]	±40 mm [1 ½ in.]
More than 550 mm [22 in.]	±65 mm [2 ½ in.]

7.1.4 The tolerances for slump or slump flow apply to the values stated in the order when adjustments in accordance with 12.7 and 12.8 are permitted.

7.2 Concrete shall be available within the permissible range of slump or slump flow for a period of 30 min starting either on arrival at the job site or after the initial slump adjustment permitted in 12.7, whichever is later. The first and last ¼ m^3 [¼ yd^3] discharged are exempt from this requirement. If the user is unprepared for discharge of the concrete from the vehicle, the producer shall not be responsible for the limitation of minimum slump or slump flow after 30 min have elapsed starting either on arrival of the vehicle at the prescribed destination or at the requested delivery time, whichever is later.

8. Air-Entrained Concrete

8.1 Unless otherwise specified, for air-entrained concrete the total air contents in Table 1 shall apply based on the exposure condition stated in the purchase order. It is permitted to reduce the total air content values in Table 1 by one percentage point for concretes with a specified compressive strength greater than or equal to 35 MPa [5000 psi]. Total air content that differs from the values in Table 1 is permitted for concrete not exposed to cycles of freezing and thawing (Note 6).

8.2 The air content of air-entrained concrete when sampled from the transportation unit at the point of discharge shall be within a tolerance of ±1.5 of the specified value.

8.3 When a preliminary sample taken within the time limits of 12.7 and prior to discharge for placement shows an air content below the specified level by more than the allowable tolerance in accordance with 8.2, the manufacturer may use additional air entraining admixture to achieve the desired air content level, followed by a minimum of 30 revolutions at mixing speed, so long as the revolution limit of 6.1.9 is not exceeded (see Note 11).

NOTE 11—Acceptance sampling and testing in accordance with Practice C172/C172M is not obviated by this provision. Increasing the air content may increase the slump or slump flow.

9. Measuring Materials

9.1 Except as otherwise specifically permitted, cementitious materials shall be measured by mass. When supplementary cementitious materials are used in the concrete mixtures, the cumulative mass is permitted to be measured with hydraulic cement, but in a batch hopper and on a scale which is separate and distinct from those used for other materials. The mass of the hydraulic cement shall be measured before supplementary cementitious materials. When the quantity of cementitious material exceeds 30 % of the full capacity of the scale, the measured quantity of the hydraulic cement shall be within ±1 % of the required mass, and the cumulative measured quantity of hydraulic cement plus supplementary cementitious materials shall also be within ±1 % of the required cumulative mass at each intermediate weighing. For smaller batches to a minimum of 1 m^3 [1 yd^3], the measured quantity of the hydraulic cement and the measured cumulative quantity of hydraulic cement plus supplementary cementitious materials used shall be not less than the required amount nor more than 4 % in excess. When the purchaser requires alternate methods of measuring cementitious materials, measurement methods and reporting shall be stated in the order (see Note 12).

NOTE 12—Cementitious materials in bags may be used when requested or permitted by the purchaser.

9.2 Aggregate shall be measured by mass. The quantity of aggregate weighed shall be the required dry mass plus the total moisture content (absorbed and surface) of the aggregate.

9.2.1 For individual weigh batchers, the quantity of aggregate weighed shall be within ±2 % of the required mass; except if the required quantity of aggregate is less than 15 % of scale capacity, the quantity of aggregate weighed shall be within ±0.3 % of scale capacity.

9.2.2 For cumulative weigh batchers, if the required quantity of aggregate is equal to or greater than 30 % of the scale capacity, the quantity of aggregate weighed shall be within ±1 % of the required mass at each successive weighing. If the required quantity of aggregate is less than 30 % of the scale capacity, the quantity of aggregate weighed shall be within ±0.3 % of scale capacity at each successive weighing.

NOTE 13—The batching accuracy limit of 0.3 % of scale capacity establishes a reasonable minimum weighing tolerance that is independent of the quantity of material being weighed.

9.3 Mixing water shall consist of batch water (water weighed or metered at the plant), ice, free moisture on the aggregates, wash water retained in the mixer before batching, water added at the job site in accordance with 12.7 or by an automated truck mixer system in accordance with 12.8, and water introduced from admixtures if the quantity added increases the water-cementitious materials ratio by more than 0.01 (Note 14). The batch water shall be measured by mass or volume to an accuracy of ±1 % of the mixing water established by the designed mixture proportions. Ice shall be measured by mass. In the case of truck mixers, any wash water retained in the drum for use in the next batch of concrete shall be measured; if this proves impractical or impossible the wash water shall be discharged before loading the next batch of concrete. Quantity of mixing water shall be accurate to within ±3 % of the amount established by the designed mixture proportions.

NOTE 14—Mixing water is the total amount of water in a batch less the water absorbed by the aggregates. Mixing water is used to calculate the water-cementitious materials ratio (w/cm).

9.4 Chemical admixtures in powdered form shall be measured by mass. Liquid chemical admixtures shall be batched by mass or volume. Admixtures measured by either mass or volume shall be batched with an accuracy of ±3 % of the total amount required or plus or minus the amount or dosage required for 50 kg [100 lb] of hydraulic cement, whichever is greater.

NOTE 15—Admixture dispensers of the mechanical type capable of adjustment for variation of dosage, and of simple calibration, are recommended.

10. Batching Plant

10.1 Bins with adequate separate compartments shall be provided in the batching plant for fine and for each required size of coarse aggregate. Each bin compartment shall be designed and operated so as to discharge efficiently and freely, with minimum segregation, into the weighing hopper. Means of control shall be provided so that, as the quantity desired in the weighing hopper is approached, the material shall be shut off with precision. Weighing hoppers shall be constructed so as to eliminate accumulations of tare materials and to discharge fully.

10.2 Indicating devices shall be in full view and near enough to be read accurately by the operator while charging the hopper. The operator shall have convenient access to all controls.

10.3 Scales shall be considered accurate if their accuracy is verified through the normally used capacity in accordance with Table 2 and load indicated relative to applied test load is within ±0.15 % of the total capacity of the scale or 0.4 % of the net applied load, whichever is greater. The minimum quantity and sequence of applied test loads used to verify material scales shall conform to Table 2 and its notes.

10.4 All exposed fulcrums, clevises, and similar working parts of scales shall be kept clean. Beam scales shall be equipped with a balance indicator sensitive enough to show movement when a weight equal to 0.1 % of the nominal capacity of the scale is placed in the batch hopper. Pointer travel shall be a minimum of 5 % of the net-rated capacity of the largest weigh beam for underweight and 4 % for overweight.

10.5 The device for the measurement of the added water shall be capable of delivering to the batch the quantity required within the accuracy required in 9.3. The device shall be so arranged that the measurements will not be affected by variable pressures in the water supply line. Measuring tanks shall be equipped with outside taps and valves to provide for checking their calibration unless other means are provided for readily and accurately determining the amount of water in the tank.

NOTE 16—The scale accuracy limitations of the National Ready Mixed Concrete Association Plant Certification meet the requirements of this specification.

11. Mixers and Agitators

11.1 Mixers include stationary mixers or truck mixers. Agitators include truck mixers or truck agitators.

11.1.1 Stationary mixers shall be equipped with a metal plate or plates on which are plainly marked the mixing speed of the drum or paddles, and the maximum capacity in terms of the volume of mixed concrete. If used for the complete mixing of concrete, stationary mixers shall be equipped with an acceptable timing device that will not permit the batch to be discharged until the specified mixing time has elapsed.

11.1.2 Each truck mixer or agitator shall have attached thereto in a prominent place a metal plate or plates on which are plainly marked the gross volume of the drum, the capacity of the drum or container in terms of the volume of mixed concrete, and the minimum and maximum mixing speeds of rotation of the drum, blades, or paddles. If the concrete is truck mixed as described in 12.5, or shrink mixed as described in 12.4, the volume of mixed concrete shall not exceed 63 % of the total volume of the drum or container. If the concrete is central mixed as described in 12.3, the volume of concrete in the truck mixer or agitator shall not exceed 80 % of the total volume of the drum or container. Truck mixers and agitators shall be equipped with means to readily verify the number of revolutions of the drum, blades, or paddles.

11.2 Stationary and truck mixers shall be capable of producing uniformly mixed concrete within the specified time in 12.3 or the specified number of revolutions in 12.5. The capability to produce and discharge uniformly mixed concrete shall be determined in accordance with Annex A1, if required.

TABLE 2 Minimum Field Standard Weights and Test Loads[A]

Device Capacity	Minimum (in terms of device capacity): Field Standard Weights	Minimum (in terms of device capacity): Test Loads[C]	Minimum Loads for Verification of Scale Accuracy
0 to 2000 kg [0 to 4000 lb]	100 %	100 %	
2001 to 20 000 kg [4001 to 40 000 lb]	Greater of[B] 10 % or 500 kg [1000 lb]	50 %[D]	Field standard weights or test load to used capacity, if greater than minimum specified. Strain-load tests[E] are permitted to be used above test load minimums. During initial verification, a scale shall be tested to full capacity.

[A] If the configuration and set up of the scale system prevents access or application of adequate field standard weights or if an unsafe condition is created by the verification process then the use of the scale above the verified position shall be discontinued until corrective measures have been completed.
[B] Field standard weights used in verifying accuracy of weighing devices shall comply with requirements of NIST Handbook 105-1.
[C] The term "test load" means the sum of the combination of field standard weights and any other applied load used in the conduct of a test using substitution test methods. Substitution Test—In the substitution test procedure, material or objects are substituted for field standard weights, or a combination of field standard weights and previously quantified material or objects, using the scale under test as a comparator. Additional test weights or other known test loads may be added to the known test load to verify the accuracy of higher weight ranges on the scale.
[D] The scale shall be tested from zero to at least 10 % of scale capacity using field standard weights, and then to at least 50 % of scale capacity using a series of substitution load tests that utilize field standard weights equaling at least 10 % of scale capacity.
[E] A strain-load test shall be conducted to verify the accuracy from 50 % of scale capacity to the used capacity of the scale. At least one load test shall be performed in each quarter of scale capacity. Strain-Load Test—In the strain-load test procedure, an unknown quantity of material or objects are used to establish a reference load or tare to which field standard weights or substitution test loads are added.

NOTE 17—The sequence or method of charging the mixer will have an important effect on the uniformity of the concrete.

11.3 The agitator shall be capable of maintaining the mixed concrete in a uniformly mixed condition. The capability to maintain and discharge uniformly mixed concrete shall be determined in accordance with Annex A1, if required.

11.4 Slump tests of individual samples can be used to provide a quick check of the probable degree of uniformity. Sampling and testing shall be in accordance with Annex A1. If the difference in slump exceeds the limits in Annex A1, the mixer or agitator shall not be used unless the condition is corrected, except as provided in 11.5.

11.5 Use of the equipment not conforming to 11.2 is permitted if operated with a longer mixing time, a smaller load, or a more efficient charging sequence. If required, the uniformity of concrete shall be evaluated in accordance with Annex A1.

11.6 Mixers and agitators shall be examined or their mass determined as frequently as necessary to detect changes in condition due to accumulations of hardened concrete or mortar and examined to detect wear of blades. If these conditions are considered extensive enough to affect the mixer performance, Annex A1 establishes the basis to determine whether correction of deficiencies is required or if the correction of the deficiencies is adequate.

12. Mixing and Delivery

12.1 Ready-mixed concrete shall be mixed and delivered to the point designated by the purchaser by means of one of the following combinations of operations:

12.1.1 *Central-Mixed Concrete.*

12.1.2 *Shrink-Mixed Concrete.*

12.1.3 *Truck-Mixed Concrete.*

12.2 Mixers and agitators shall be operated within the limits of capacity and speed of rotation designated by the manufacturer of the equipment.

12.3 *Central-Mixed Concrete*—Concrete that is mixed completely in a stationary mixer and transported to the point of delivery either in a truck agitator, or a truck mixer operating at agitating speed, or in non-agitating equipment approved by the purchaser and meeting the requirements of Section 13, shall conform to the following: The mixing time shall be counted from the time all the solid materials are in the drum. The batch shall be so charged into the mixer that some water will enter in advance of the cement and aggregate and the target batch water shall be in the drum by the end of the first one fourth of the specified mixing time; or in accordance with the central concrete mixer manufacturer's recommended charging sequence.

12.3.1 If no mixer performance tests are made, the acceptable mixing time for mixers having capacities of 0.76 m^3 [1 yd^3] or less shall be not less than 1 min. For mixers of greater capacity, this minimum shall be increased 15 s for each cubic metre [cubic yard] or fraction thereof of additional capacity (see Note 18).

NOTE 18—Stationary mixers of similar design bearing a Performance Rating plate of the Concrete Plant Manufacturers Bureau have been tested for their ability to produce uniformly mixed concrete in accordance with Annex A1 for low slump (<50 mm [2 in.]) and normal slump (100–150 mm [4–6 in.]) concrete in a mixing time between 30 and 90 s.

12.3.2 If mixer performance tests have been made in accordance with Annex A1, the acceptable mixing time is permitted to be reduced to the time equal to or greater than that used in the qualification testing. If the mixing time is so reduced the maximum time of mixing shall not exceed this reduced time by more than 60 s for air-entrained concrete. Mixer performance tests shall be repeated whenever the appearance of the concrete or a comparison of coarse aggregate content of separate samples as described in Annex A1 indicates that adequate mixing has not been accomplished.

12.4 *Shrink-Mixed Concrete*—Concrete that is first partially mixed in a stationary mixer, and then mixed completely in a truck mixer, shall conform to the following: The time of partial mixing shall be the minimum time required to intermingle the ingredients. After transfer to a truck mixer the amount of mixing at the designated mixing speed shall be that necessary to meet the requirements for uniformity of concrete as indicated in Annex A1. Additional turning of the mixer, if any, shall be at a designated agitating speed.

12.5 *Truck-Mixed Concrete*—Concrete that is completely mixed in a truck mixer for 70 to 100 revolutions at the mixing speed designated by the manufacturer shall produce uniformly mixed concrete as defined in Annex A1. The start of mixing shall be when all the materials have been loaded in the mixer. If requirements for uniformity of concrete indicated in Annex A1 are not met with 100 revolutions of mixing that mixer shall not be used until the condition is corrected, except as provided in 11.5. If satisfactory performance is found in one truck mixer, the performance of mixers of substantially the same design and condition of blades are permitted to be regarded as satisfactory. Additional revolutions of the mixer beyond the number found to produce the required uniformity of concrete shall be at a designated agitating speed.

NOTE 19—Truck mixers of similar design bearing a Performance Rating plate of the Truck Mixer Manufacturers Bureau have been tested for their ability to produce uniformly mixed concrete in accordance with Annex A1.

12.6 When a truck mixer or truck agitator is used for transporting concrete that has been completely mixed in a stationary mixer, any turning during transportation shall be at the speed designated by the manufacturer of the equipment as agitating speed.

12.7 For concrete delivered in truck mixers, no water from the truck water system or elsewhere shall be added after the initial introduction of water during batching, except as permitted in 12.8, and if on arrival at the job site the slump or slump flow needs to be increased to comply with the requirement stated in the purchase order. Unless otherwise stated, obtain the required slump or slump flow within the tolerances stated in 7.1.1, 7.1.2, or 7.1.3 with the addition of water, or water-reducing admixture, or both. The maximum quantity of water or water-reducing admixture that can be added at the job site shall be determined by the manufacturer and shall not exceed the maximum water content for the batch as established by the designed mixture proportions. Adjusting the concrete mixture with water or water-reducing admixture shall be done before discharge of concrete, except when obtaining a preliminary sample in accordance with 17.6. Additional water shall be injected into the mixer under pressure and direction of flow to allow for proper distribution within the mixer. After the additions, the drum shall be turned at least 30 revolutions at mixing speed. The quantity of water or water-reducing admixture added shall be recorded.

12.8 For truck mixers with automated water or water-reducing admixture measurement and slump or slump flow monitoring equipment defined in 12.8.1 and if permitted by the purchaser, water, or water-reducing admixture, or both, may be added during transportation to the job site. Such additional water shall be injected into the mixer under such pressure and direction of flow to allow for proper distribution within the mixer. The water content of the batch shall not exceed that established by the designed mixture proportions. If water or water-reducing admixture is added, the mixer shall be turned at least 30 drum revolutions at mixing speed. Said mixing shall take place after the last water or water-reducing admixture addition but before the start of discharge. The acceptance or rejection of concrete based on slump or slump flow shall be in accordance with Section 17.

12.8.1 The automated slump or slump flow monitoring equipment shall be capable of obtaining one or more physical measurements on the truck mixer related to concrete slump or slump flow and providing an indication of slump or slump flow based on pre-established correlations. The slump or slump flow measurement equipment shall report in terms of slump or slump flow. The device for the measurement of water shall be accurate to ±3 % of the amount added with said device. The device for the measurement of water-reducing admixture shall be accurate to the greater of ±3 % of the amount added or ±30 mL [±1 fl oz]. Upon request by the purchaser, the manufacturer shall submit data no older than 6 months substantiating the accuracy of the devices used for the measurement of water or water-reducing admixture. The equipment shall have controls to prevent discharge of water at pre-set limits to avoid exceeding the maximum water content for the batch as established by the designed mixture proportions.

12.9 Discharge of the concrete shall be completed within 1 ½ h after the introduction of the mixing water to the cement and aggregates or the introduction of the cement to the aggregates. This limitation may be waived by the purchaser if the concrete is of such slump or slump flow after the 1½-h time has been reached that it can be placed, without the addition of water to the batch. In hot weather, or under conditions contributing to rapid stiffening of the concrete, a time less than 1 ½ h is permitted to be specified by the purchaser.

12.10 If a drum revolution limit (6.1.9) for start of discharge is specified by the purchaser, this limit shall govern.

NOTE 20—Depending on the project requirements, the technology is available to the manufacturer to alter fresh concrete properties (such as setting time, slump or slump flow, and air content). On some projects, the manufacturer may request changes to certain fresh concrete properties due to the distance or projected transportation time between the batch plant and the point of delivery.

12.11 Concrete delivered in cold weather shall have the applicable minimum temperature indicated in the following table. (The purchaser shall inform the producer as to the type of construction for which the concrete is intended.)

Minimum Concrete Temperature as Placed

Section Size, mm [in.]	Temperature, min, °C [°F]
<300 [<12]	13 [55]
300–900 [12–36]	10 [50]
900–1800 [36–72]	7 [45]
>1800 [>72]	5 [40]

The maximum temperature of concrete produced with heated aggregates, heated water, or both, shall at no time during its production or transportation exceed 32 °C [90 °F].

NOTE 21—When hot water is used rapid stiffening may occur if hot water is brought in direct contact with the cement. Additional information on cold weather concreting is contained in ACI 306R.

12.12 The producer shall deliver the ready-mixed concrete during hot weather at concrete temperatures as low as practicable, subject to the approval of the purchaser.

NOTE 22—In some situations difficulty may be encountered when concrete temperatures approach 32 °C [90 °F]. Additional information may be found in ACI 305R.

13. Use of Nonagitating Equipment

13.1 If the use of non-agitating transportation equipment is approved by the purchaser, the concrete shall be manufactured in a central mix plant. The following limitations shall apply:

13.2 Bodies of nonagitating equipment shall be smooth, watertight, metal containers equipped with gates that will permit control of the discharge of the concrete. Covers shall be provided for protection from the weather if required by the purchaser.

13.3 The concrete shall be delivered to the site of the work with a satisfactory degree of uniformity. Satisfactory degree of uniformity is defined in Annex A1.

13.4 Slump tests of individual samples obtained and tested in accordance with Annex A1 can be used for a quick check of the probable degree of uniformity. If these slumps differ by more than the limits in Table A1.1, the nonagitating equipment shall not be used unless the conditions are corrected as provided in 13.5.

13.5 If the requirements of Annex A1 are not met when the nonagitating equipment is operated for the maximum time of haul, and with the concrete mixed the minimum time, the equipment shall only be used when operated using shorter hauls, or longer mixing times, or combinations thereof that will result in the requirements of Annex A1 being met.

14. Delivery Ticket Information

14.1 The manufacturer of the concrete shall furnish to the purchaser with each batch of concrete before unloading at the site, a delivery ticket containing information concerning said concrete as follows:

14.1.1 Name of ready-mix company and batch plant, or batch plant number,

14.1.2 Serial number of ticket,

14.1.3 Date,

14.1.4 Truck number,

14.1.5 Name of purchaser,

14.1.6 Specific designation of job (name and location),

14.1.7 Specific class or designation of the concrete in conformance with that employed in job specifications,

14.1.8 Amount of concrete in cubic yards (or cubic metres),

14.1.9 Time loaded or of first mixing of cement and aggregates, and

14.1.10 Amount of water added at the request of the purchaser or the purchaser's designated representative and their initials.

14.1.11 Type and quantity of admixture or other adjustments made to the batch after batching.

14.1.12 For trucks equipped with automated water or water-reducing admixture measurement and slump or slump flow monitoring equipment as defined in 12.8.1, the total amount of water or water-reducing admixture added by said equipment.

14.1.13 Revolution limit as determined by the manufacturer in accordance with 6.1.9.

14.2 Additional information for certification purposes as designated by the purchaser and required by the job specifications shall be furnished when requested; such information as:

14.2.1 Reading of revolution counter at the first addition of water,

14.2.2 Type, brand, and amount of cement,

14.2.3 Class, brand, and amount of coal fly ash, or raw or calcined natural pozzolans,

14.2.4 Grade, brand, and amount of slag cement,

14.2.5 Type, brand, and amount of silica fume,

14.2.6 Type, brand, and amount of admixtures,

14.2.7 Type, brand, and amount of fiber reinforcement,

14.2.8 Source and amount of each metered or weighed water,

14.2.9 Information necessary to calculate the mixing water, as listed in 9.3,

14.2.10 Maximum size of aggregate,

14.2.11 Mass (amount) of fine and coarse aggregate,

14.2.12 Ingredients certified as being previously approved, and

14.2.13 Signature or initials of producer's representative.

15. Plant Inspection

15.1 The manufacturer shall afford the inspector all reasonable access, without charge, for making necessary checks of the production facilities and for securing necessary samples to determine if the concrete is being produced in accordance with this specification. All tests and inspection shall be so conducted as not to interfere unnecessarily with the manufacture and delivery of concrete.

16. Practices, Test Methods, and Reporting

16.1 Test ready-mixed concrete in accordance with the following methods:

16.1.1 *Making and Curing Concrete Test Specimens in the Field*—Practice C31/C31M, using standard moist curing in accordance with the applicable provisions of Practice C31/C31M.

16.1.2 *Compressive Strength Tests of Cylindrical Concrete Specimens*—Test Method C39/C39M.

16.1.3 *Density (Unit Weight) and Yield of Concrete*—Test Method C138/C138M.

16.1.4 *Air Content*—Test Method C173/C173M or Test Method C231/C231M.

16.1.5 *Slump*—Test Method C143/C143M.

16.1.6 *Slump Flow*—Test Method C1611/C1611M.

16.1.7 *Sampling Fresh Concrete*—Practice C172/C172M.

16.1.8 *Temperature*—Test Method C1064/C1064M.

16.2 The testing agency performing acceptance tests of concrete shall meet the requirements of Practice C1077.

16.3 Testing agency reports of concrete test results used to determine compliance with this specification shall include a statement that all tests performed by the testing agency or its agents were in accordance with the applicable test methods or shall note all known deviations from the prescribed procedures (Note 23). The reports shall also list any part of the test methods not performed by the testing agency.

NOTE 23—Deviation from standard test methods may adversely affect test results.

NOTE 24—Deviation from standard moisture and temperature curing requirements of Practice C31/C31M is often a reason for low strength test results. Such deviations may invalidate the use of such test results as a basis for rejection of the concrete.

17. Sampling and Testing Fresh Concrete

17.1 The contractor shall afford the inspector all reasonable access and assistance, without charge, for the procurement of samples of fresh concrete at time of placement to determine conformance of it to this specification.

17.2 Tests of concrete required to determine compliance with this specification shall be made by a certified technician in accordance with Practice C1077.

17.3 Samples of concrete shall be obtained in accordance with Practice C172/C172M, except when taken to determine uniformity of slump within any one batch or load of concrete (11.4, 13.4, and Annex A1).

17.4 Slump or slump flow, air-content, density, and temperature tests shall be made at the time of discharge at the option of the inspector as often as is necessary for control checks. In addition, these tests shall be made when specified and always when each set of strength specimens are made.

17.5 Strength tests as well as slump or slump flow, temperature, density, and air content tests shall generally be made with a frequency of not less than one test for each 115 m^3 [150 yd^3]. Each test shall be made from a separate batch. On each day concrete is delivered, at least one strength test shall be made for each class of concrete.

17.6 If preliminary checks of slump, slump flow, or air content are made, a single sample shall be taken after the discharge of not less than ¼ m^3 or ¼ yd^3. All other requirements of Practice C172/C172M shall be retained. If the preliminary measurement of slump (12.7) or air content (8.3) falls outside the specified limits, address as indicated in 17.6.1 or 17.6.2 as appropriate.

17.6.1 If the measured slump or slump flow, or air content, or both is greater than the specified upper limit, a check test shall be made immediately on a new test sample. In the event the check test fails, the concrete shall be considered to have failed the requirements of the specification.

17.6.2 If the measured slump or slump flow, or air content, or both is less than the lower limit, permit adjustments in accordance with 12.7 or 8.3 or both, as appropriate, and obtain a new sample. If the sample of the adjusted concrete fails, a check test shall be made immediately on a new sample of the adjusted concrete. In the event the check test fails, the concrete shall be considered to have failed the requirements of the specification.

18. Strength

18.1 When strength is used as a basis for acceptance of concrete, standard specimens shall be made in accordance with Practice C31/C31M. The specimens shall be cured under standard moisture and temperature conditions in accordance with the applicable provisions of Practice C31/C31M. The specimens shall be tested for compressive strength in accordance with Test Method C39/C39M.

18.2 *Laboratory Personnel*—The laboratory personnel performing compressive strength testing of specimens used for acceptance testing shall meet the personnel qualification requirements of Practice C1077, including an examination requiring performance demonstration that is evaluated by an independent examiner.

18.3 For a strength test, at least two standard test specimens shall be made from a composite sample secured as required in Section 17. A test shall be the average of the strengths of the specimens tested at the age specified in 6.4.1.1 or 6.6.1.1 (Note 25). If a specimen shows definite evidence other than low strength, of improper sampling, molding, handling, curing, or testing, it shall be discarded and the strength of the remaining cylinder shall then be considered the test result.

NOTE 25—Additional tests may be made at other ages to obtain information for determining form removal time or when a structure may be put in service. Specimens for such tests are cured according to the section on Field Curing in Practice C31/C31M.

18.4 The representative of the purchaser shall ascertain and record the delivery-ticket number for the concrete and the exact location in the work at which each load represented by a strength test is deposited.

18.5 To conform to the requirements of this specification, strength tests representing each class of concrete must meet the following two requirements (Note 26):

18.5.1 The average of any three consecutive strength tests shall be equal to, or greater than, the specified strength, f'_c, and

18.5.2 When the specified strength is 35 MPa [5000 psi] or less, no individual strength test (average of two cylinder tests) shall be more than 3.5 MPa [500 psi] below the specified strength, f'_c.

NOTE 26—Due to variations in materials, operations, and testing, the average strength necessary to meet these requirements will be substantially higher than the specified strength. The amount higher depends upon the standard deviation of the test results and the accuracy with which that value can be estimated from prior data as explained in ACI 214R[6] and ACI 301. Pertinent data are given in Appendix X1.

18.5.3 When the specified strength is greater than 35 MPa [5000 psi], no individual strength test (average of two cylinder tests) shall be less than 0.90 f'_c.

19. Failure to Meet Strength Requirements

19.1 In the event that concrete tested in accordance with the requirements of Section 18 fails to meet the strength requirements of this specification, the manufacturer of the ready-mixed concrete and the purchaser shall confer to determine whether agreement can be reached as to what adjustment or adjustments, if any, shall be made to the mixture proportions, production process, or testing procedures.

NOTE 27—ACI 318-14, Sections 26.12.4 and R26.12.4 (commentary) address when and how low strength test results can be investigated.

20. Keywords

20.1 accuracy; blended hydraulic cement; certification; ready-mixed concrete; scales; testing

[6] ACI 214R-11, "Guide to Evaluation of Strength Test Results of Concrete," available from American Concrete Institute, Farmington Hills, MI, www.concrete.org, 2011, 16 pp.

ANNEX

(Mandatory Information)

A1. CONCRETE UNIFORMITY REQUIREMENTS

A1.1 Significance and Use

A1.1.1 This annex provides procedures to evaluate the ability of stationary and truck mixers to produce uniformly mixed concrete. The procedures described herein can also be used to determine the required minimum mixing revolutions in truck mixers for shrink-mixed concrete and for evaluating the uniformity of concrete mixtures delivered in nonagitating equipment.

A1.1.2 The sequence and method of charging mixers has a significant effect on the ability to produce uniformly mixed concrete. The procedures in this annex can also be used to evaluate the effect of batching sequence for charging or loading mixers of acceptable condition.

A1.1.3 It is not the intent that this complete evaluation be performed on mixers at an established frequency. For equipment in operation, a visual inspection of the condition of the mixer for blade wear and hardened concrete buildup can be conducted as an alternative. If one mixer of a specific design has been evaluated by procedures in this annex, it can be assumed that mixers of essentially the same design and of different sizes will also produce uniformly mixed concrete. A selected portion of this evaluation, such as comparison of slump or coarse aggregate content, can also be performed as a quick indication of the uniformity of concrete mixtures.

A1.2 Concrete Mixture, Load Size, and Mixing

A1.2.1 Unless the intent is to evaluate special project situations or concrete mixtures, the concrete mixture used for this evaluation should be typical of that produced in the production facility. Recommended mixture characteristics include the following:

A1.2.1.1 Cementitious materials content of 300 to 350 kg/m^3 [500 to 600 lb/yd^3],

A1.2.1.2 Coarse aggregate size No. 57 or No. 67 from Specification C33/C33M,

A1.2.1.3 Fine aggregate fineness modulus 2.5 to 3.0,

A1.2.1.4 Target slump of 100 to 150 mm [4 to 6 in.] or for paving operations at 25 to 50 mm [1 to 2 in.], and

A1.2.1.5 Air content of 4 to 6 %.

A1.2.2 The load size used for this evaluation shall be within –20 % and +10 % of the rated mixing capacity of the mixer.

A1.2.3 Use a batching sequence of concrete materials that has been used previously with success or in accordance with the recommendation of the mixer manufacturer. Use alternative procedures if the purpose is to evaluate the effect of batching sequence.

NOTE A1.1—The standards of the Truck Mixer Manufacturers Bureau, TMMB 100 and of the Concrete Plant Manufacturers Bureau, CPMB 100, provide recommendations for batching sequence.

A1.2.4 For stationary mixers, mix concrete at the mixing speed and minimum duration recommended by the mixer manufacturer. The start of mixing time shall be from the time all solid materials are in the mixer. Mixing time is taken as the earlier of when the mixer is stopped or when the first material is discharged. Use a suitable timing device, accurate to 1 s, to measure and record the time duration of mixing.

A1.2.5 For truck mixers, mix concrete at a mixing speed exceeding 12 r/min or at the speed recommended by the manufacturer. Complete mixing using between 70 and 100 revolutions of the drum at mixing speed. To determine the mixer drum revolutions, the start of mixing shall be when all the materials have been loaded in the mixer. Record the number of revolutions at mixing speed.

A1.3 Sampling

A1.3.1 Separate samples, each consisting of approximately 0.1 m^3 [2 ft^3] shall be taken after discharge of approximately 15 % and 85 % of the load (Note A1.2). These samples shall be obtained within an elapsed time of not more than 15 min. The samples shall be secured in accordance with Practice C172/C172M, but shall be kept separate to represent specific points in the batch rather than combined to form a composite sample. Sufficient personnel must be available to perform the required tests promptly. Segregation during sampling and handling must be avoided. Each sample shall be covered to prevent moisture loss or contamination. Remix the minimum necessary before performing the tests.

A1.3.2 *Sampling From Stationary Mixers*—Samples of concrete shall be obtained immediately after mixing duration is completed, in accordance with one of the following procedures:

A1.3.2.1 *Alternative Procedure 1*—The mixer shall be stopped, and the required samples removed by any suitable means from the mixer at approximately equal distances from the front and back of the drum, or

A1.3.2.2 *Alternative Procedure 2*—As the mixer is being emptied, individual samples shall be taken after discharge of approximately 15 % and 85 % of the load. The method of sampling shall provide samples that are obtained from widely separated portions, but not from the very ends of the batch (Note A1.2).

A1.3.3 *Sampling From Truck Mixers*—The concrete shall be discharged at the normal operating rate for the mixer being tested, with care being exercised not to obstruct or retard the discharge. For the duration between obtaining samples, the mixer shall be turned in the mixing direction at agitating speed. Obtain samples by intercepting the full discharge stream from the chute without stopping and starting the discharge during the collection of the sample.

A1.3.4 *Sampling From Nonagitating Equipment*—Obtain the two samples from approximately 15 % and 85 % of the discharge from the nonagitating equipment in accordance with Practice C172/C172M. Mix the portions obtained from each location into uniformly mixed samples.

NOTE A1.2—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 end of the load.

A1.4 Slump

A1.4.1 Perform the slump test on each sample in accordance with Test Method C143/C143M. Start the slump test within 5 min after the sample was obtained.

A1.5 Density (Unit Weight) and Yield

A1.5.1 Determine the density of each sample in accordance with Test Method C138/C138M. Use the measure for measurement of air content by Test Method C231/C231M unless the concrete contains a larger nominal maximum size coarse aggregate than is appropriate for this measure.

A1.5.2 Calculate the density (unit weight) of each sample as follows:

$$D = \frac{M}{V} \quad \text{(A1.1)}$$

where:

D = measured density (unit weight), kg/m^3 [lb/ft^3],
M = net mass of concrete in the measure, kg [lb], and
V = volume of the measure, m^3 [ft^3].

A1.5.3 From the average density (unit weight) of the two samples, calculate the yield of the batch in accordance with Test Method C138/C138M.

A1.6 Air Content

A1.6.1 Measure the air content of each sample in accordance with Test Method C231/C231M. Use Test Method C173/C173M if the concrete is made with lightweight aggregate or if the coarse aggregate in the concrete has an aggregate correction factor larger than 0.5 % when determined in accordance with Test Method C231/C231M.

A1.7 Air-Free Density (Unit Weight)

A1.7.1 Calculate the air-free density (unit weight) of each sample as follows:

$$\text{air-free density} = \frac{D}{100 - A} \times 100 \quad \text{(A1.2)}$$

where:

D = measured density, kg/m^3 [lb/ft^3], and
A = measured air content on that sample, %.

A1.8 Coarse Aggregate Content

A1.8.1 Use the concrete in the measure used to measure density (unit weight) to determine the coarse aggregate content. If a separate portion of the sample is used, the concrete sample shall be at least 15 kg [35 lb]. Place the concrete in an adequately sized container and determine the net mass of the fresh concrete.

A1.8.2 Wash each sample over a 4.75 mm (No. 4) sieve sufficiently to remove the cement and most of the fine aggregate. Determine the mass of the wet coarse aggregate, store in a plastic bag, and transport it to a laboratory facility. Dry the coarse aggregate in an oven at 230 °C [110 °F] for 16 ± 2 h. Sieve the coarse aggregate over a 4.75 mm (No. 4) sieve to remove any fine aggregate particles. Determine the mass of dry coarse aggregate in each sample.

A1.8.3 Express the mass of dry coarse aggregate as a percentage of the mass of the original concrete sample:

$$\text{coarse aggregate content, \%} = \frac{c}{M} \times 100 \quad \text{(A1.3)}$$

where:

c = mass of dry coarse aggregate, kg [lb], and
M = net mass of same fresh concrete sample, kg [lb].

A1.9 Compressive Strength

A1.9.1 Make at least three 150 × 300 mm [6 × 12 in.] or 100 × 200 mm [4 × 8 in.] cylinders from each concrete sample. Cure the specimens in accordance with Practice C31/C31M, except that the cylinders shall be immersed in water immediately after molding with the temperature maintained between the required temperature limits for initial curing of the standard curing procedures in Practice C31/C31M for the first 24 h. Transport the cylinders to the laboratory facilities after 24 h and cure in accordance with the standard curing procedures of Practice C31/C31M.

A1.9.2 Test the cylinders in accordance with Test Method C39/C39M at an age of seven days. If the strength of an individual cylinder differs from the average strength of either sample by more than 9.5 %, this value can be disregarded for determining the average strength for the sample.

A1.9.3 Average the strength of the cylinders from each sample and express that value as a percentage of the average of all cylinders made from that batch. Calculate the difference in strength between each sample as a percentage of the overall average.

A1.10 Report

A1.10.1 Report the following information:

A1.10.1.1 Purpose of the evaluation.

A1.10.1.2 Type and description of mixer and rated mixing capacity.

A1.10.1.3 Concrete mixture proportions, batch quantities, density (unit weight), and yield of the batch.

A1.10.1.4 Mixing duration for stationary mixers or number of revolutions at mixing speed for truck mixers.

A1.10.1.5 Slump of each sample and the difference between samples, mm [in.].

A1.10.1.6 Air content of each sample and the difference between samples, %.

TABLE A1.1 Requirements for Uniformity of Concrete

Test	Maximum Permissible Difference
Air-free density (unit weight), kg/m^3 [lb/ft^3]	16 [1.0]
Air content, %	1.0
Slump, mm [in.]:	
If average slump is less than 100 mm [4 in.]	25 [1.0]
If average slump is 100 to 150 mm [4 to 6 in.]	40 [1.5]
Coarse aggregate content, %	6.0
Average compressive strength at 7 days for each sample,[A] %	7.5[A]

[A] Approval of the mixer shall be tentative, pending results of the 7-day compressive strength tests.

A1.10.1.7 Air-free density (unit weight) of each sample and the difference between samples, kg/m^3 [lb/ft^3].

A1.10.1.8 Coarse aggregate content of each sample and the difference between samples, %.

A1.10.1.9 Average strength in MPa [psi] and percent of overall average for each sample and the percent difference between samples.

A1.11 Requirements for Uniformity of Concrete

A1.11.1 The maximum permitted difference for each property obtained from the two different samples of the same batch are as provided in Table A1.1. Test results conforming to the limits of all five properties listed in Table A1.1 shall indicate uniform concrete within the limits of this specification.

APPENDIX

(Nonmandatory Information)

X1. CALCULATION OF THE AVERAGE COMPRESSIVE STRENGTH (f'_{cr}) NECESSARY TO MEET THE STRENGTH REQUIREMENTS OF 18.5

X1.1 Section 18.5 of this specification contains the same strength requirements as those contained in ACI 318 and ACI 301, except it does not require the submittal of the data and calculation of the average strength, f'_{cr} necessary to meet those requirements. This appendix does not include all of the detailed requirements of the ACI Code and Specification that will govern a submittal for their respective purposes. The following material is intended to guide users of this specification when no formal submittal is required.

X1.1.1 Table X1.1 provides the statistically based formulas to calculate the required average strength f'_{cr} when strength test records from previous projects are available. The strength test results are used to establish the standard deviation, s. At least 30 consecutive test results are required to obtain a robust estimate of the standard deviation. If the number of tests is between 15 and 30, the calculated standard deviation is multiplied by a factor to allow for the uncertainty of the estimated standard deviation. The factor is a linear interpolation between 1.16 for 15 tests and 1.00 for 30 tests. The test record should be obtained from a similar mixture with a specified strength within 7 MPa [1000 psi] of the specified strength for the new project for which the average compressive strength is being determined. The equations are related to the strength acceptance criteria in 18.5 and establish less than a 1 % chance of failing these criteria if concrete is produced to achieve the required average strength at the same degree of variability implied by the standard deviation used. Because the average strength, f'_{cr}, must be high enough to conform to both averages of three consecutive test results and the requirements on minimum strength of an individual test result, the highest average strength (f'_{cr}) determined from these two equations governs. More detailed guidance on this subject matter is available in ACI 214R.[6]

TABLE X1.1 Required Average Compressive Strength when Data are Available to Establish a Standard Deviation

Specified Strength, f'_c	Required Average Strength, f'_{cr}	
≤35 MPa [5000 psi]	Use the larger from Eq X1.1 and X1.2 [X1.2M]:	
	$f'_{cr} = f'_c + 1.34s$	(X1.1)
	$f'_{cr} = f'_c + 2.33s - 500$	(X1.2)
	[$f'_{cr} = f'_c + 2.33s - 3.5$]	[X1.2M]
>35 MPa [5000 psi]	Use the larger from Eq X1.1 and X1.3:	
	$f'_{cr} = f'_c + 1.34s$	(X1.1)
	$f'_{cr} = 0.90\,f'_c + 2.33s$	(X1.3)

where:
f'_c = specified compressive strength,
f'_{cr} = required average compressive strength, and
s = standard deviation.

TABLE X1.2 Required Average Compressive Strength When Data Are Not Available to Establish Standard Deviation

Specified Strength, f'_c, MPa [psi]	Required Average Strength, f'_{cr} [MPa]	psi
<21 [3000]	[$f'_c + 7.0$]	$f'_c + 1000$
21 to 35 [3000 to 5000]	[$f'_c + 8.3$]	$f'_c + 1200$
>35 [5000]	[$1.10\,f'_c + 5.0$]	$1.10\,f'_c + 700$

X1.1.2 If it is a new mixture or strength level and a strength test record is not available to establish a standard deviation then Table X1.2 provides default levels of strength overdesign.

X1.1.3 Table X1.3 provides calculated values of overdesign and required average strength for selected standard deviations and specified strength levels that might be considered typical. More exact values are obtained from X1.1.2.

TABLE X1.3 Overdesign Necessary to Conform to Specified Compressive Strength

Inch-Pound Units							Required Overdesign	SI Units					
Specified Strength, f'_c, psi	Standard Deviation from Test Record, psi					No data SD unknown	Specified Strength, f'_c, MPa	Standard Deviation from Test Record, MPa					No Data SD Unknown
	300	400	500	600	700			2.0	2.5	3.5	4.0	5.0	
	Overdesign above f'_c							Overdesign above f'_c					
<3000						1000	<21						7.0
3000	400	540	670	810	1130	1200	20	2.7	3.4	4.7	5.8	8.2	8.3
4000	400	540	670	810	1130	1200	30	2.7	3.4	4.7	5.8	8.2	8.3
5000	400	540	670	810	1130	1200	35	2.7	3.4	4.7	5.8	8.2	8.3
6000	400	540	670	800	1030	1300	40	2.7	3.4	4.7	5.8	7.7	9.0
							Required Average Strength						
Specified Strength, f'_c, psi	Standard Deviation from field data, psi					No data SD unknown	Specified Strength, f'_c, MPa	Standard Deviation from field data, MPa					No Data SD Unknown
	300	400	500	600	700			2.0	2.5	3.5	4.0	5.0	
	f'_{cr}, Required Average Strength, psi							f'_{cr}, Required Average Strength, MPa					
<3000						f'_c + 1000	<21						f'_c + 7.0
3000	3400	3540	3670	3810	4130	4200	20	22.7	23.4	24.7	25.8	28.2	28.3
4000	4400	4540	4670	4810	5130	5200	30	32.7	33.4	34.7	35.8	38.2	38.3
5000	5400	5540	5670	5810	6130	6200	35	37.7	38.4	39.7	40.8	43.2	43.3
6000	6400	6540	6670	6800	7030	7300	40	42.7	43.4	44.7	45.8	47.7	49.0

SUMMARY OF CHANGES

Committee C09 has identified the location of selected changes to this standard since the last issue (C94/C94M – 19a) that may impact the use of this standard. (Approved Feb. 1, 2020.)

(1) Revised 18.1.

(2) Added 18.2.

Designation: C138/C138M − 17a

American Association State Highway and Transportation Officials Standard
AASHTO No.: T121

Standard Test Method for Density (Unit Weight), Yield, and Air Content (Gravimetric) of Concrete[1]

This standard is issued under the fixed designation C138/C138M; 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 the density (see Note 1) of freshly mixed concrete and gives formulas for calculating the yield, cement content, and air content of the concrete. Yield is defined as the volume of concrete produced from a mixture of known quantities of the component materials.

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—Unit weight was the previous terminology used to describe the property determined by this test method, which is mass per unit volume.

1.3 The text of this test method references notes and footnotes that provide explanatory information. These notes and footnotes (excluding those in tables) shall not be considered as requirements of this test method.

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—**Fresh hydraulic cementitious mixtures are caustic and may cause chemical burns to skin and tissue upon prolonged exposure.[2])

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:*[3]

C29/C29M Test Method for Bulk Density ("Unit Weight") and Voids in Aggregate
C31/C31M Practice for Making and Curing Concrete Test Specimens in the Field
C143/C143M Test Method for Slump of Hydraulic-Cement Concrete
C150/C150M Specification for Portland Cement
C172/C172M Practice for Sampling Freshly Mixed Concrete
C173/C173M Test Method for Air Content of Freshly Mixed Concrete by the Volumetric Method
C188 Test Method for Density of Hydraulic Cement
C231/C231M Test Method for Air Content of Freshly Mixed Concrete by the Pressure Method
C1758/C1758M Practice for Fabricating Test Specimens with Self-Consolidating Concrete

3. Terminology

3.1 *Symbols:*

A = air content (percentage of voids) in the concrete
C = actual cement content, kg/m^3 [lb/yd^3]
C_b = mass of cement in the batch, kg [lb]
D = density (unit weight) of concrete, kg/m^3 [lb/ft^3]
M = total mass of all materials batched, kg [lb] (see Note 3)
M_c = mass of the measure filled with concrete, kg [lb] or
M_m = mass of the measure, kg [lb]
R_y = relative yield
T = theoretical density of the concrete computed on an airfree basis, kg/m^3 [lb/ft^3] (see Note 2)

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

Current edition approved March 15, 2017. Published May 2017. Originally approved in 1938. Last previous edition approved in 2017 as C138/C138M – 17. DOI: 10.1520/C0138_C0138M-17A.

[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**

Y = yield, volume of concrete produced per batch, m^3 [yd^3]
Y_d = volume of concrete which the batch was designed to produce, m^3 [yd^3]
Y_f = volume of concrete produced per batch, m^3 [ft^3]
V = total absolute volume of the component ingredients in the batch, m^3 [ft^3]
V_m = volume of the measure, m^3 [ft^3]

NOTE 2—The theoretical density is, customarily, a laboratory determination, the value for which is assumed to remain constant for all batches made using identical component ingredients and proportions.

NOTE 3—The total mass of all materials batched is the sum of the masses of the cement, the fine aggregate in the condition used, the coarse aggregate in the condition used, the mixing water added to the batch, and any other solid or liquid materials used.

4. Apparatus

4.1 *Balance*—A balance or scale accurate to 45 g [0.1 lb] or to within 0.3 % of the test load, whichever is greater, at any point within the range of use. The range of use shall be considered to extend from the mass of the measure empty to the mass of the measure plus its contents at 2600 kg/m^3 [160 lb/ft^3].

4.2 *Tamping Rod*—A round, smooth, straight steel rod, with a 16 mm [5⁄8 in.] ± 2 mm [1⁄16 in.] diameter. The length of the tamping rod shall be at least 100 mm [4 in.] greater than the depth of the measure in which rodding is being performed, but not greater than 600 mm [24 in.] in overall length (see Note 4). The rod shall have the tamping end or both ends rounded to a hemispherical tip of the same diameter as the rod.

NOTE 4—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.

4.3 *Internal Vibrator*—The vibrator frequency shall be at least 9000 vibrations per minute [150 Hz] while the vibrator is operating in the concrete. The outside diameter or the side dimension of the vibrating element shall be at least 19 mm [0.75 in.] and not greater than 38 mm [1.50 in.]. 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 with a vibrating reed tachometer at an interval not to exceed two years. If the vibrator manufacturer recommends a shorter verification interval, a verification procedure, or other verification device, the manufacturer's recommendation shall be followed.

4.4 *Measure*—A cylindrical container made of steel or other suitable metal (see Note 5). The minimum capacity of the measure shall conform to the requirements of Table 1 based on the nominal size of aggregate in the concrete to be tested. All measures, except for measuring bowls of air meters which are also used for Test Method C138/C138M tests, shall conform to the requirements of Test Method C29/C29M. When measuring bowls of air meters are used, they shall conform to the requirements of Test Method C231/C231M, and shall be calibrated for volume as described in Test Method C29/C29M. The top rim of the air meter bowls shall be smooth and plane within 0.01 in. [0.3 mm] (see Note 6).

NOTE 5—The metal should not be readily subject to attack by cement paste. However, reactive materials such as aluminum alloys may be used in instances where as a consequence of an initial reaction, a surface film is rapidly formed which protects the metal against further corrosion.

NOTE 6—The top rim is satisfactorily plane if a 0.3-mm [0.01-in.] feeler gage cannot be inserted between the rim and a piece of 6-mm [1⁄4-in.] or thicker plate glass laid over the top of the measure.

TABLE 1 Capacity of Measures

Nominal Maximum Size of Coarse Aggregate		Capacity of Measure[A]	
mm	[in.]	L	[ft^3]
25.0	[1]	6	[0.2]
37.5	[1½]	11	[0.4]
50	[2]	14	[0.5]
75	[3]	28	[1.0]
112	[4½]	70	[2.5]
150	[6]	100	[3.5]

[A] The indicated size of measure shall be used to test concrete containing aggregates of a nominal maximum size equal to or smaller than that listed. The actual volume of the measure shall be at least 95 % of the nominal volume listed.

4.5 *Strike-Off Plate*—A flat rectangular metal plate at least 6 mm [1⁄4 in.] thick or a glass or acrylic plate at least 12 mm [1⁄2 in.] thick with a length and width at least 50 mm [2 in.] greater than the diameter of the measure with which it is to be used. The edges of the plate shall be straight and smooth within a tolerance of 2 mm [1⁄16 in.].

4.6 *Mallet*—A mallet (with a rubber or rawhide head) having a mass of 600 ± 200 g [1.25 ± 0.50 lb] for use with measures of 14 L [0.5 ft^3] or smaller, and a mallet having a mass of 1000 ± 200 g [2.25 ± 0.50 lb] for use with measures larger than 14 L [0.5 ft^3].

4.7 *Scoop*—of a size large enough so each amount of concrete obtained from the sampling receptacle is representative and small enough so it is not spilled during placement in the measure.

5. Sample

5.1 Obtain the sample of freshly mixed concrete in accordance with Practice C172/C172M.

6. Procedure

6.1 Base the selection of the method of consolidation on the slump, unless the method is stated in the specifications under which the work is being performed. The methods of consolidation are rodding and internal vibration. Rod concretes with a slump greater than 75 mm [3 in.]. Rod or vibrate concrete with a slump of 25 to 75 mm [1 to 3 in.]. Consolidate concretes with a slump less than 25 mm [1 in.] by vibration.

NOTE 7—Nonplastic concrete, such as is commonly used in the manufacture of pipe and unit masonry, is not covered by this test method.

6.2 Dampen the interior of the measure and remove any standing water from the bottom. Determine the mass of the empty measure to an accuracy consistent with the requirements of 4.1. Place the measure on a flat, level, firm surface. Place the concrete in the measure using the scoop described in 4.7. Move the scoop around the perimeter of the measure opening to ensure an even distribution of the concrete with minimal segregation. Fill the measure in the number of layers required by the consolidation method (6.3 or 6.4).

6.2.1 Follow the procedures in Practice C1758/C1758M for filling the measure, if self-consolidating concrete is being tested. Upon completion of the filling process, proceed to 6.6.

6.3 *Rodding*—Place the concrete in the measure in three layers of approximately equal volume. Rod each layer with 25 strokes of the tamping rod when nominal 14-L [0.5-ft^3] or smaller measures are used, 50 strokes when nominal 28-L [1-ft^3] measures are used, and one stroke per 20 cm^2 [3 in.^{2}] of surface for larger measures. 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 measure. 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 sides of the measure 10 to 15 times with the appropriate mallet (see 4.6) using such force so as to close any voids left by the tamping rod and to release any large bubbles of air that may have been trapped. Add the final layer so as to avoid overfilling.

6.4 *Internal Vibration*—Fill and vibrate the measure in two approximately equal layers. Place all of the concrete for each layer in the measure before starting vibration of that layer. Insert the vibrator at three different points for each layer. In compacting the bottom layer, do not allow the vibrator to rest on or touch the bottom or sides of the measure. In compacting the final layer, the vibrator shall penetrate into the underlying layer approximately 25 mm [1 in.] . Take care that the vibrator is withdrawn in such a manner that no air pockets are left in the specimen. The duration of vibration required will depend upon the workability of the concrete and the effectiveness of the vibrator (see Note 8). Continue vibration only long enough to achieve proper consolidation of the concrete (see Note 9). Observe a constant duration of vibration for the particular kind of concrete, vibrator, and measure involved.

NOTE 8—Usually, sufficient vibration has been applied as soon as the surface of the concrete becomes relatively smooth.

NOTE 9—Overvibration may cause segregation and loss of appreciable quantities of intentionally entrained air.

6.5 On completion of consolidation the measure must not contain a substantial excess or deficiency of concrete. An excess of concrete protruding approximately 3 mm [⅛ in.] above the top of the mold is optimum. A small quantity of concrete may be added to correct a deficiency. If the measure contains a great excess of concrete at completion of consolidation, remove a representative portion of the excess concrete with a trowel or scoop immediately following completion of consolidation and before the measure is struck-off.

6.6 *Strike-Off*—After consolidation, strike-off the top surface of the concrete and finish it smoothly using the flat strike-off plate so that the measure is level full. Strike-off the measure by pressing the strike-off plate on the top surface of the measure to cover about two thirds of the surface and withdraw the plate with a sawing motion to finish only the area originally covered. Then place the plate on the top of the measure to cover the original two thirds of the surface and advance it with a vertical pressure and a sawing motion to cover the whole surface of the measure and continue to advance it until it slides completely off the measure. Incline the plate and perform final strokes with the edge of the plate to produce a smooth surface.

6.7 *Cleaning and Weighing*—After strike-off, clean all excess concrete from the exterior of the measure and determine the mass of the concrete and measure to an accuracy consistent with the requirements of 4.1.

7. Calculation

7.1 *Density (Unit Weight)*—Calculate the net mass of the concrete in pounds or kilograms by subtracting the mass of the measure, M_m, from the mass of the measure filled with concrete, M_c. Calculate the density, D, kg/m^3 [lb/ft^3] , by dividing the net mass of concrete by the volume of the measure, V_m as follows:

$$D = (M_c - M_m) / V_m \tag{1}$$

7.2 *Theoretical Density*—Calculate the theoretical density as follows:

$$T = M / V \tag{2}$$

7.2.1 The absolute volume of each ingredient in cubic meters is equal to the mass of the ingredient in kilograms divided by 1000 times its relative density (specific gravity). The absolute volume of each ingredient in cubic feet is equal to the quotient of the mass of that ingredient divided by the product of its relative density times 62.4 lb/ft^3. For the aggregate components, base the relative density and mass on the saturated, surface-dry condition. For cement, determine the actual relative density using Test Method C188. It is permitted to use a value of 3.15 for the relative density of portland cements that conform to Specification C150/C150M. The relative density used for other cements and supplementary cementitous material shall be as determined by testing or as supplied by the material's manufacturer.

7.3 *Yield*—Calculate the yield as follows:

$$Y(\text{yd}^3) = M / (D \times 27) \tag{3}$$

or

$$Y(\text{m}^3) = M / D \tag{4}$$

7.4 *Relative Yield*—Relative yield is the ratio of the actual volume of concrete obtained to the volume as designed for the batch (see Note 10) calculated as follows:

$$R_y = Y / Y_d \tag{5}$$

NOTE 10—A value for R_y greater than 1.00 indicates an excess of concrete being produced whereas a value less than 1.00 indicates the batch to be "short" of its designed volume. In the inch-pound system, a ratio of yield in cubic feet per cubic yard of design concrete mixture is frequently used, for example, 27.3 ft^3/yd^3.

7.5 *Cement Content*—Calculate the actual cement content as follows:

$$C = C_b / Y \tag{6}$$

7.6 *Air Content*—Calculate the air content as follows:

$$A = [(T - D) / T] \times 100 \tag{7}$$

or

$$A = [(Y - V) / Y] \times 100 \text{ (SI units)} \quad (8)$$

or

$$A = [(Y_f - V) / Y_f] \times 100 \text{ [inch } - \text{ pound units]} \quad (9)$$

8. Report

8.1 Report the following information:

8.1.1 Identification of concrete represented by the sample.

8.1.2 Date of test.

8.1.3 Volume of density measure to the nearest 0.01 L [0.001 ft^3].

8.1.4 Density (unit weight) to the nearest 1.0 kg/m^3 [0.1 lb/ft^3].

8.1.5 Theoretical density, when requested, to the nearest 1.0 kg/m^3 [0.1 lb/ft^3].

8.1.6 Yield, when requested, to the nearest 0.1 m^3 [0.1 yd^3].

8.1.7 Relative yield, when requested, to the nearest 0.01.

8.1.8 Cement content, when requested, to the nearest 0.5 kg [1.0 lb].

8.1.9 Air content, when requested, to the nearest 0.1 percent.

9. Precision and Bias

9.1 The following estimates of precision for this test method are based on a collection of data from various locations by the National Ready Mixed Concrete Association.[4] The data represent concrete mixtures with slump ranging from 75 to 150 mm [3 to 6 in.] and density ranging from 1842 to 2483 kg/m^3 [115 to 155 lb/ft^3] and included air-entrained and non air-entrained concrete. The study was conducted using 7-L [0.25 ft^3] and 14-L [0.5 ft^3] measures.

9.1.1 *Single-Operator Precision*—The single operator standard deviation of density of freshly mixed concrete has been found to be 0.65 lb/ft^3 [10.4 kg/m^3] (1s). Therefore, results of two properly conducted by the same operator on the same sample of concrete should not differ by more than 1.85 lb/ft^3 [29.6 kg/m^3] (d2s).

9.1.2 *Multi-Operator Precision*—The multi-operator standard deviation of density of freshly mixed concrete has been found to be 13.1 kg/m^3 [0.82 lb/ft^3] (1s). Therefore, results of two properly conducted tests by the two operators on the same sample of concrete should not differ by more than 37.0 kg/m^3 [2.31 lb/ft^3] (d2s).

9.2 *Bias*—This test method has no bias since the density is defined only in terms of this test method.

10. Keywords

10.1 air content; cement content; concrete; relative yield; unit weight; yield

[4] Mullings, G. M., NRMCA/NAA Joint Research Lab Study "Series D324 Accuracy of Concrete Density Test," Feb. 17, 2000.

APPENDIXES

(Nonmandatory Information)

X1. SAMPLE CALCULATIONS (SI UNITS)

X1.1 Concrete Mix Data:

X1.1.1 The following quantities are batched for a designed 10 m^3 load:

Cement	3560 kg
Coarse Aggregate	10 975 kg
Fine Aggregate	8070 kg
Added Water	1216 kg
Total Mass of Materials Batched (*M*)	23 821 kg

X1.1.2 The following are the properties of the aggregates:

Coarse Aggregate	(Moisture content = 2.0%; Absorption = 0.8%; Relative Density (Specific Gravity) SSD = 2.72)
Fine Aggregate	(Moisture content = 4.0%; Absorption = 1.1%; Relative Density (Specific Gravity) SSD = 2.63)

X1.1.3 The following fresh concrete properties were measured at the job site:

Slump	=	115 mm
Air content	=	5.0 %
Density (unit weight)	=	2335 kg/m^3

X1.2 Calculate the Yield (*Y*):

$$Y = M / D = (\text{Total Mass of Materials Batched}) / (\text{Density of Concrete})$$

$$Y = 23821 / 2355 = 10.2 m^3 \quad (X1.1)$$

X1.3 Calculate the Relative Yield (R_Y):

$$R_y = Y / Y_d = (\text{Yield}) / (\text{Design Yield})$$

$$R_y = 10.2 / 10.0 = 1.02 \quad (X1.2)$$

X1.4 Convert the batch mixture proportions of the fine and coarse aggregates to a saturated-surface-dry (SSD) basis, by first dividing the batch quantity of the aggregate by [1 + the moisture content (expressed as a decimal)] to determine the mass of the dry aggregate. Then multiply the mass of the dry aggregate by [1 + the absorption (expressed as a decimal)] to calculate the mass of the SSD aggregate.

Mass of dry coarse aggregate	=	10 975 / 1.02 = 10 760 kg
Mass of coarse aggregate (SSD)	=	10 760 × 1.008 = 10 846 kg
Mixing water contributed by coarse aggregate	=	(2.0 % – 0.8 %) = 1.2 % × 10 760 = 129 kg
Mass of dry fine aggregate	=	8070 / 1.04 = 7760 kg
Mass of fine aggregate (SSD)	=	7760 × 1.011 = 7845 kg
Mixing water contributed by fine aggregate	=	(4.0 % – 1.1%) = 2.9 % × 7760 = 225 kg
Total mixing water	=	batch water + water contributed by aggregates
Total mixing water	=	1216 + 225 + 129 = 1570 kg

X1.5 To obtain the calculated batch quantities per cubic meter, divide the mixture proportions by the actual Yield (*Y*) (10.2 m^3, in this case). Use the SSD basis for the aggregates and the total mixing water. The absolute volume of each ingredient in cubic meters is equal to the mass of the ingredient in kilograms divided by 1000 times its relative density (specific gravity).

	Mass, kg	Absolute Volume, m^3	Calculated Batch Quantity, kg/m^3
Cement	3560	1.13	349
Coarse Agg. (SSD)	10 846	3.99	1063
Fine Agg. (SSD)	7,845	2.983	769
Mixing Water	1570	1.57	154
Total	23 821	9.673	

X1.6 Calculate the Theoretical Density (T) on an air-free basis:

$$T = M / V = \frac{(\text{Total Mass of Materials Batched})}{(\text{Absolute Volume of Mix Components})}$$

$$T = 23821 / 9.673 = 2463 \text{ kg/m}^3 \quad (X1.3)$$

X1.7 The Air Content (A) can be calculated using one of two methods:

$$A = \left[\frac{(T - D)}{T}\right] \times 100 = \left[\frac{(\text{Theoretical Density} - \text{Density})}{\text{Theoretical Density}}\right] \times 100$$

$$A = [(2463 - 2335) / 2463] \times 100 = 5.2 \% \quad (X1.4)$$

or

$$A = \frac{(Y_f - V)}{Y_f} \times 100 = \left[\frac{(\text{Actual Yield} - \text{Sum of Abs. Vols.})}{\text{Actual Yield}}\right] \times 100$$

$$A = [(10.2 - 9.673) / 10.2] \times 100 = 5.2 \% \quad (X1.5)$$

X2. SAMPLE CALCULATIONS (IN-LB UNITS)

X2.1 Concrete Mix Data:

X2.1.1 The following quantities are batched for a designed 10 yd^3 load:

Cement	6000 lb
Coarse Aggregate	18 500 lb
Fine Aggregate	13 600 lb
Added Water	2050 lb (246 gal)
Total Mass of Materials Batched (M)	40 150 lb

X2.1.2 The following are the properties of the aggregates:

Coarse Aggregate	(Moisture content = 2.0%; Absorption = 0.8%; Relative Density (Specific Gravity) SSD = 2.72)
Fine Aggregate	(Moisture content = 4.0%; Absorption = 1.1%; Relative Density (Specific Gravity) SSD = 2.63)

X2.1.3 The following fresh concrete properties were measured at the job site:

Slump	=	4.5 in.
Air content	=	5.0% (by pressure method)
Density (unit weight)	=	145.8 lb/ft^3

X2.2 Calculate the Yield (Y):

$$Y = M / D = \frac{(\text{Total Mass of Materials Batched})}{(\text{Density of Concrete})}$$

$$Y = 40150 / 145.8 = 275.4 \text{ ft}^3$$

$$Y = 275.4 / 27 = 10.2 \text{ yd}^3 \quad (X2.1)$$

X2.3 Calculate the Relative Yield (R_Y).

$$R_Y = Y / Y_d = (\text{Yield}) / (\text{Design Yield})$$

$$R_Y = 10.2 / 10.0 = 1.02 \quad (X2.2)$$

X2.4 Convert the batch mixture proportions of the fine and coarse aggregates to a saturated-surface-dry (SSD) basis, by first dividing the batch quantity of the aggregate by [1 + the moisture content (expressed as a decimal)] to determine the mass of the dry aggregate. Then multiply the mass of the dry aggregate by [1 + the absorption (expressed as a decimal)] to calculate the mass of the SSD aggregate.

Mass of dry coarse aggregate	=	18 500 / 1.02 = 18 137 lb
Mass of coarse aggregate (SSD)	=	18 137 x 1.008 = 18 282 lb
Mixing water contributed by coarse aggregate	=	(2.0 % – 0.8 %) = 1.2 % × 18 137 = 218 lb
Mass of dry fine aggregate	=	13 600 / 1.04 = 13 077 lb
Mass of fine aggregate (SSD)	=	13 077 × 1.011 = 13 221 lb
Mixing water contributed by fine aggregate	=	(4.0 % - 1.1 %) = 2.9% × 13 077 = 379 lb
Total mixing water	=	batch water + water contributed by aggregates
Total mixing water	=	2 050 + 218 + 379 = 2 647 lb

X2.5 To obtain the calculated batch quantities per cubic yard, divide the mixture proportions by the actual Yield (Y) (10.2 yd^3, in this case). Use the SSD basis for the aggregates and the total mixing water. The absolute volume of each ingredient in cubic feet is equal to the mass of the ingredient in pounds (lb) divided by 62.4 times its relative density (specific gravity).

	Mass, lb	Absolute Volume, ft^3	Calculated Batch Quantity, lb/yd^3
Cement	6000	30.53	588
Coarse Agg. (SSD)	18 282	107.71	1792
Fine Agg. (SSD)	13 221	80.56	1296
Mixing Water	2647	42.42	260
Total	40 150	261.22	

X2.6 Calculate the Theoretical Density (T) on an air-free basis:

$$T = M / V = \frac{(\text{Total Mass of Materials Batched})}{(\text{Absolute Volume of Mix Components})}$$

$$T = 40150 / 261.22 = 153.7 \text{ lb/ft}^3 \quad (X2.3)$$

X2.7 The Air Content (A) can be calculated using one of two methods:

$$A = (T - D) / T \times 100 = \left[\frac{(\text{Theoretical Density} - \text{Density})}{\text{Theoretical Density}}\right] \times 100$$

$$A = [(153.7 - 145.8) / 153.7] \times 100 = 5.1 \% \quad (X2.4)$$

or

$$A = [(Y_f - V) / Y_f] \times 100$$

$$A = \left[\frac{(\text{Vol. of Concrete Prod. per Batch} - \text{Sum of Abs. Vols.})}{\text{Vol. of Concrete Prod. per Batch}}\right] \times 100$$

$$A = [(275.38 - 261.22) / 275.38] \times 100 = 5.1 \% \quad (X2.5)$$

SUMMARY OF CHANGES

Committee C09 has identified the location of selected changes to this standard since the last issue (C138/C138M – 17) that may impact the use of this standard. (Approved March 15, 2017.)

(1) Added Practice C1758/C1758M to 2.1.

(2) Added 6.2.1.

Designation: C143/C143M – 15a

Standard Test Method for Slump of Hydraulic-Cement Concrete[1]

This standard is issued under the fixed designation C143/C143M; 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 slump of hydraulic-cement concrete, both in the laboratory and in the field.

1.2 The values stated in either SI units or inch-pound units are to be regarded separately as standard. Within the text, the SI 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 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.

1.4 *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**—Fresh hydraulic cementitious mixtures are caustic and may cause chemical burns to skin and tissue upon prolonged exposure.[2])

2. Referenced Documents

2.1 *ASTM Standards:*[3]

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

C138/C138M Test Method for Density (Unit Weight), Yield, and Air Content (Gravimetric) of Concrete

C172 Practice for Sampling Freshly Mixed Concrete

C173/C173M Test Method for Air Content of Freshly Mixed Concrete by the Volumetric Method

C231 Test Method for Air Content of Freshly Mixed Concrete by the Pressure Method

C670 Practice for Preparing Precision and Bias Statements for Test Methods for Construction Materials

D638 Test Method for Tensile Properties of Plastics

3. Summary of Test Method

3.1 A sample of freshly mixed concrete is placed and compacted by rodding in a mold shaped as the frustum of a cone. The mold is raised, and the concrete allowed to subside. The vertical distance between the original and displaced position of the center of the top surface of the concrete is measured and reported as the slump of the concrete.

4. Significance and Use

4.1 This test method is intended to provide the user with a procedure to determine slump of plastic hydraulic-cement concretes.

NOTE 1—This test method was originally developed to provide a technique to monitor the consistency of unhardened concrete. Under laboratory conditions, with strict control of all concrete materials, the slump is generally found to increase proportionally with the water content of a given concrete mixture, and thus to be inversely related to concrete strength. Under field conditions, however, such a strength relationship is not clearly and consistently shown. Care should therefore be taken in relating slump results obtained under field conditions to strength.

4.2 This test method is considered applicable to plastic concrete having coarse aggregate up to 1½ in. [37.5 mm] in size. If the coarse aggregate is larger than 1½ in. [37.5 mm] in size, the test method is applicable when it is performed on the fraction of concrete passing a 1½-in. [37.5-mm] sieve, with the larger aggregate being removed in accordance with the section titled "Additional Procedure for Large Maximum Size Aggregate Concrete" in Practice C172.

4.3 This test method is not considered applicable to non-plastic and non-cohesive concrete.

NOTE 2—Concretes having slumps less than ½ in. [15 mm] may not be adequately plastic and concretes having slumps greater than about 9 in. [230 mm] may not be adequately cohesive for this test to have significance. Caution should be exercised in interpreting such results.

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

Current edition approved Dec. 15, 2015. Published February 2016. Originally approved in 1922. Last previous edition approved in 2015 as C143/C143M – 15. DOI: 10.1520/C0143_C0143M-15A

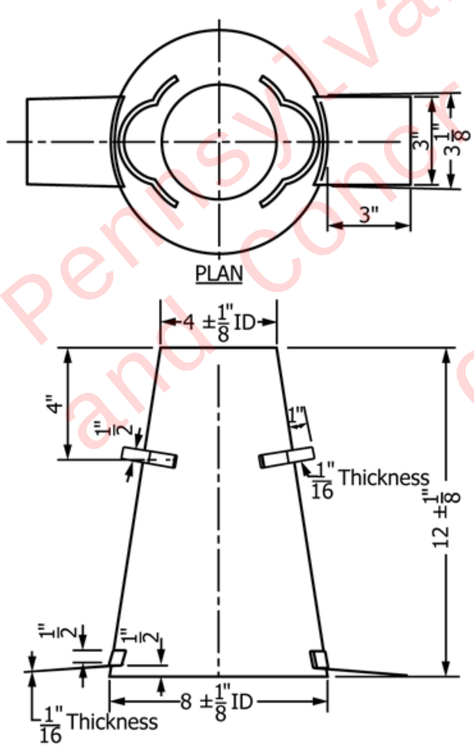
[2] Section on Safety Precautions, Manual of Aggregate and Concrete Testing, *Annual Book of ASTM Standards*, Vol. 04.02.

[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**

5. Apparatus

5.1 *Mold*—The test specimen shall be formed in a mold made of metal or plastic not readily attacked by the cement paste. The mold shall be sufficiently rigid to maintain the specified dimensions and tolerances during use, resistant to impact forces, and shall be non-absorbent. Metal molds shall have an average thickness of not less than 0.060 in. [1.5 mm] with no individual thickness measurement less than 0.045 in. [1.15 mm]. Plastic molds shall be ABS plastic or equivalent (Note 3) with a minimum average wall thickness of 0.125 in. [3 mm], with no individual thickness measurement less than 0.100 in. [2.5 mm]. The manufacturer or supplier shall certify the materials used in mold construction are in compliance with the requirements of this test method. The mold shall be in the form of the lateral surface of the frustum of a cone with the base 8 in. [200 mm] in diameter, the top 4 in. [100 mm] in diameter, and the height 12 in. [300 mm]. Individual diameters and heights shall be within ±⅛ in. [3 mm] of the prescribed dimensions. The base and the top shall be open and parallel to each other and at right angles to the axis of the cone. The mold shall be provided with foot pieces and handles similar to those shown in Fig. 1. The mold shall be constructed without a seam. The interior of the mold shall be relatively smooth and free from projections. The mold shall be free from dents, deformation, or adhered mortar. A mold which clamps to a nonabsorbent base plate is acceptable instead of the one illustrated, provided the clamping arrangement is such that it can be fully released without movement of the mold and the base is large enough to contain all of the slumped concrete in an acceptable test.



Dimensional Units

in.	1⁄16	1⁄8	1⁄2	1	3	3 1⁄8	4	8	12
mm	[2]	[3]	[15]	[25]	[75]	[80]	[100]	[200]	[300]

FIG. 1 Mold for Slump Test

NOTE 3—ABS (Acrylonitrile Butadiene Styrene) plastic exhibits the following minimum mechanical properties:

Tensile modulus of elasticity, at 73 °F [23 °C]	320 000 psi	[2206 MPa]
Tensile strength (Test Method D638)	5670 psi	[39 MPa]
Percent Elongation at Break, at 73 °F [23 °C]	40%	

5.1.1 Check and record conformance to the mold's specified dimensions when it is purchased or first placed in service and at least annually thereafter. To measure the top diameter, bottom diameter, and height, perform two measurements for each, approximately 90° apart, and record the results of each measurement. To verify mold thickness, perform two measurements approximately 180° apart at 1 ± ½ in. [25 ± 10 mm] from the top of the mold, two measurements approximately 180° apart at 1 ± ½ in. [25 ± 10 mm] from the bottom of the mold, and calculate the average of the four measurements.

5.2 *Tamping Rod*—A round, smooth, straight steel rod, with a ⅝ in. [16 mm] ± 1⁄16 in. [2 mm] diameter. The length of the tamping rod shall be at least 4 in. [100 mm] greater than the depth of the mold in which rodding is being performed, but not greater than 24 in. [600 mm] in overall length (Note 4). The rod shall have the tamping end or both ends rounded to a hemispherical tip of the same diameter as the rod.

NOTE 4—A rod length of 16 in. [400 mm] to 24 in. [600 mm] 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.

5.3 *Measuring Device*—A ruler, metal roll-up measuring tape, or similar rigid or semi-rigid length measuring instrument marked in increments of ¼ in. [5 mm] or smaller. The instrument length shall be at least 12 in. [300 mm].

5.4 *Scoop*—of a size large enough so each amount of concrete obtained from the sampling receptacle is representative and small enough so it is not spilled during placement in the mold.

6. Sample

6.1 The sample of concrete from which test specimens are made shall be representative of the entire batch. It shall be obtained in accordance with Practice C172.

7. Procedure

7.1 Dampen the mold and place it on a rigid, flat, level, moist, nonabsorbent surface, free of vibration, and that is large enough to contain all of the slumped concrete. It shall be held firmly in place during filling and perimeter cleaning by the operator standing on the two foot pieces or by a clamping arrangement to a base plate as described in 5.1. From the sample of concrete obtained in accordance with Section 6, immediately fill the mold in three layers, each approximately one third the volume of the mold (See Note 5). Place the concrete in the mold using the scoop described in 5.4. Move the scoop around the perimeter of the mold opening to ensure an even distribution of the concrete with minimal segregation.

NOTE 5—One third of the volume of the slump mold fills it to a depth of 2⅝ in. [70 mm]; two thirds of the volume fills it to a depth of 6⅛ in. [160 mm].

7.2 Rod each layer 25 times uniformly over the cross section with the rounded end of the rod. For the bottom layer, this will necessitate inclining the rod slightly and making approximately half of the strokes near the perimeter, and then progressing with vertical strokes spirally toward the center. Rod the bottom layer throughout its depth. For each upper layer, allow the rod to penetrate through the layer being rodded and into the layer below approximately 1 in. [25 mm].

7.3 In filling and rodding the top layer, heap the concrete above the mold before rodding is started. If the rodding operation results in subsidence of the concrete below the top edge of the mold, add additional concrete to keep an excess of concrete above the top of the mold at all times. After the top layer has been rodded, strike off the surface of the concrete by means of a screeding and rolling motion of the tamping rod. Continue to hold the mold down firmly and remove concrete from the area surrounding the base of the mold to preclude interference with the movement of slumping concrete. Remove the mold immediately from the concrete by raising it carefully in a vertical direction. Raise the mold a distance of 12 in. [300 mm] in 5 ± 2 s by a steady upward lift with no lateral or torsional motion. Complete the entire test from the start of the filling through removal of the mold without interruption and complete it within an elapsed time of 2½ min.

7.4 Immediately measure the slump by determining the vertical difference between the top of the mold and the displaced original center of the top surface of the specimen. If a decided falling away or shearing off of concrete from one side or portion of the mass occurs (Note 6), disregard the test and make a new test on another portion of the sample.

NOTE 6—If two consecutive tests on a sample of concrete show a falling away or shearing off of a portion of the concrete from the mass of the specimen, the concrete probably lacks necessary plasticity and cohesiveness for the slump test to be applicable.

8. Report

8.1 Report the slump in terms of inches [millimetres] to the nearest ¼ in. [5 mm] of subsidence of the specimen during the test.

9. Precision and Bias[4]

9.1 *Precision*—The estimates of precision for this test method are based upon results from tests conducted in Fayetteville, Arkansas by 15 technicians from 14 laboratories representing 3 states. All tests at 3 different slump ranges, from 1.0 in. [25 mm] to 6.5 in. [160 mm], were performed using one load of truck-mixed concrete. The concrete was delivered and tested at a low slump, with water then being added and mixed into the remaining concrete to independently produce moderate and finally high-slump concrete. The concrete mixture that used a No. 67 crushed limestone aggregate and a washed river sand, contained 500 lb of cementitious materials per cubic yard [297 kg of cementitious material per cubic metre]. The 500 lb [227 kg] were equally divided between a C150, Type I/II cement and a Class C fly ash. A double dosage of a chemical retarder was used in an attempt to minimize slump losses and maintain workability of the concrete. Concrete temperatures ranged from 86 to 93 °F [30 to 34 °C]. Slump losses averaged 0.68 in. [17 mm] during the 20 min required to perform a series of 6 tests at 1 slump range. Testing was performed alternately using metal and plastic molds, which were determined to produce comparable results. Precision data thus applies to both metal and plastic molds. A total of 270 slump tests were performed.

9.1.1 *Inch-Pound [SI]*—The data used to develop the precision statement were obtained using metric units (millimetres). The precision values shown in inch-pound units are conversions from the millimetre measurements, which were recorded to the nearest 1 mm.

9.1.2 *Measure of Variability*—The standard deviation was determined to be the most consistent measure of variability and was found to vary with the slump value.

9.1.3 *Single-Operator Precision*—The single-operator standard deviation represented by (1s) is shown in Table 1 by average slump values. The reported results for the replicate readings apply to tests conducted by the same operator performing successive tests, one immediately following the other. Acceptable results of two properly conducted tests by the same operator on the same material (Note 7) will not differ from each other by more than the (d2s) value of the last column of Table 1 for the appropriate slump value and single-operator precision.

9.1.4 *Multilaboratory Precision*—The multilaboratory standard deviation represented by (1s) is shown in Table 1 by average slump values. The reported results for the replicate readings apply to tests conducted by different operators from different laboratories performing tests less than 4 min apart. Therefore, acceptable results of two properly conducted slump tests on the same material (Note 7) by two different laboratories will not differ from each other by more than the (d2s) value of the last column of Table 1 for the appropriate slump value and multilaboratory precision.

TABLE 1 Precision

Slump and Type Index	Standard Deviation (1s)[A]		Acceptable Range of Two Results (d2s)[A]	
Single-Operator Precision:	in.	[mm]	in.	[mm]
Slump 1.2 in. [30 mm]	0.23	[6]	0.65	[17]
Slump 3.4 in. [85 mm]	0.38	[9]	1.07	[25]
Slump 6.5 in. [160 mm]	0.40	[10]	1.13	[28]
Multilaboratory Precision:				
Slump 1.2 in. [30 mm]	0.29	[7]	0.82	[20]
Slump 3.4 in. [85 mm]	0.39	[10]	1.10	[28]
Slump 6.5 in. [160 mm]	0.53	[13]	1.50	[37]

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

[4] The test data used to develop this precision statement were based on tests performed in September 1997. Supporting data have been filed at ASTM International Headquarters and may be obtained by requesting Research Report RR:C09-1022.

NOTE 7—"Same materials," is used to mean freshly mixed concrete from one batch.

9.2 *Bias*—This test method has no bias since slump is defined only in terms of this test method.

10. Keywords

10.1 concrete; concrete slump; cone; consistency; plasticity; slump; workability

SUMMARY OF CHANGES

Committee C09 has identified the location of selected changes to this standard since the last issue (C143/C143M – 15) that may impact the use of this standard. (Approved Dec. 15, 2015.)

(1) Revised 5.1.1.

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: C173/C173M − 16

Standard Test Method for Air Content of Freshly Mixed Concrete by the Volumetric Method[1]

This standard is issued under the fixed designation C173/C173M; 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 the air content of freshly mixed concrete containing any type of aggregate, whether it be dense, cellular, or lightweight.

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 and health 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])

2. Referenced Documents

2.1 *ASTM Standards:*[3]

C29/C29M Test Method for Bulk Density ("Unit Weight") and Voids in Aggregate
C31/C31M Practice for Making and Curing Concrete Test Specimens in the Field
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 Practice for Sampling Freshly Mixed Concrete
C173/C173M Test Method for Air Content of Freshly Mixed Concrete by the Volumetric Method
C231 Test Method for Air Content of Freshly Mixed Concrete by the Pressure Method
C670 Practice for Preparing Precision and Bias Statements for Test Methods for Construction Materials
C1064/C1064M Test Method for Temperature of Freshly Mixed Hydraulic-Cement Concrete

3. Significance and Use

3.1 This test method covers the determination of the air content of freshly mixed concrete. It measures the air contained in the mortar fraction of the concrete, but is not affected by air that may be present inside porous aggregate particles.

3.1.1 Therefore, this is the appropriate test to determine the air content of concretes containing lightweight aggregates, air-cooled slag, and highly porous or vesicular natural aggregates.

3.2 This test method requires the addition of sufficient isopropyl alcohol, when the meter is initially being filled with water, so that after the first or subsequent rollings little or no foam collects in the neck of the top section of the meter. If more foam is present than that equivalent to 2 % air above the water level, the test is declared invalid and must be repeated using a larger quantity of alcohol. Addition of alcohol to dispel foam any time after the initial filling of the meter to the zero mark is not permitted.

3.3 The air content of hardened concrete may be either higher or lower than that determined by this test method. This depends upon the methods and amounts of consolidation effort applied to the concrete from which the hardened concrete specimen is taken; uniformity and stability of the air bubbles in the fresh and hardened concrete; accuracy of the microscopic examination, if used; time of comparison; environmental exposure; stage in the delivery, placement and consolidation processes at which the air content of the unhardened concrete is determined, that is, before or after the concrete goes through a pump; and other factors.

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

Current edition approved Feb. 1, 2016. Published March 2016. Originally approved in 1942. Last previous edition approved in 2014 as C173/C173M – 14. DOI: 10.1520/C0173_C0173M-16.

[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**

4. Apparatus

4.1 *Air Meter*—An air meter consisting of a measuring bowl and a top section (Fig. 1) conforming to the following requirements:

4.1.1 The measuring bowl and top sections shall be of sufficient thickness and rigidity to withstand rough field use. The material shall not be attacked by high pH cement paste, deform when stored at high temperatures in closed spaces, or become brittle or crack at low temperatures. A watertight seal must be obtained when the top section is attached to the measuring bowl.

4.1.2 *Measuring Bowl*—The measuring bowl shall have a diameter equal to 1 to 1.25 times the height and be constructed with a flange at or near the top surface. Measuring bowls shall not have a capacity of less than 2.0 L [0.075 ft^3].

4.1.3 *Top Section*—The top section shall have a capacity at least 20 % larger than the measuring bowl and shall be equipped with a flexible gasket and a device to attach the top section to the measuring bowl. The top section shall be equipped with a transparent scale, graduated in increments not

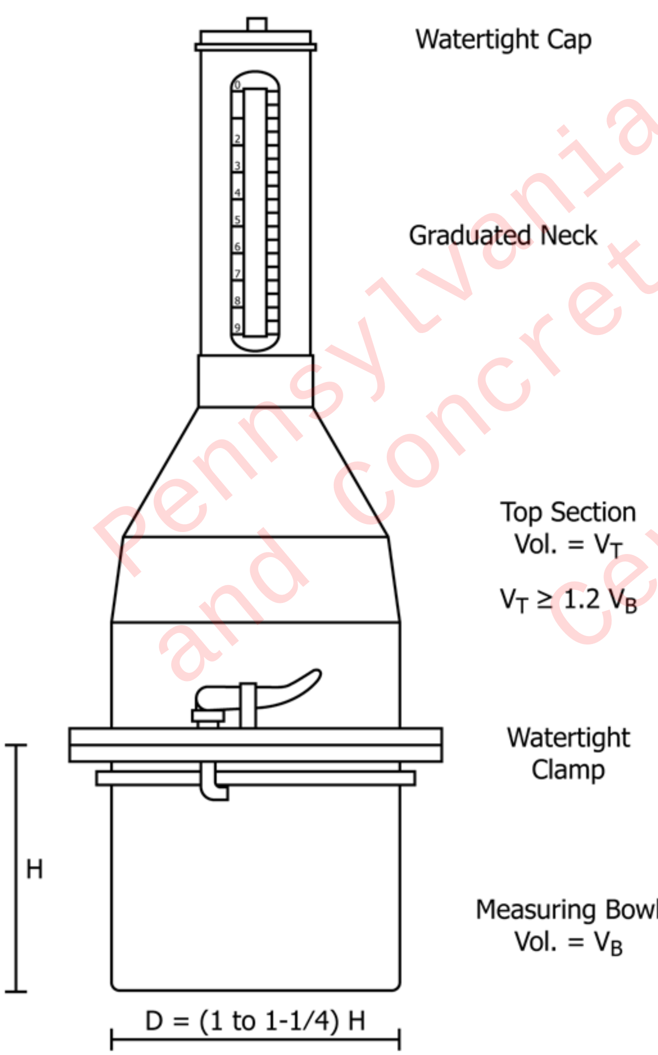


FIG. 1 Apparatus for Measuring Air Content of Fresh Concrete by Volumetric Method (a) Brass Meter

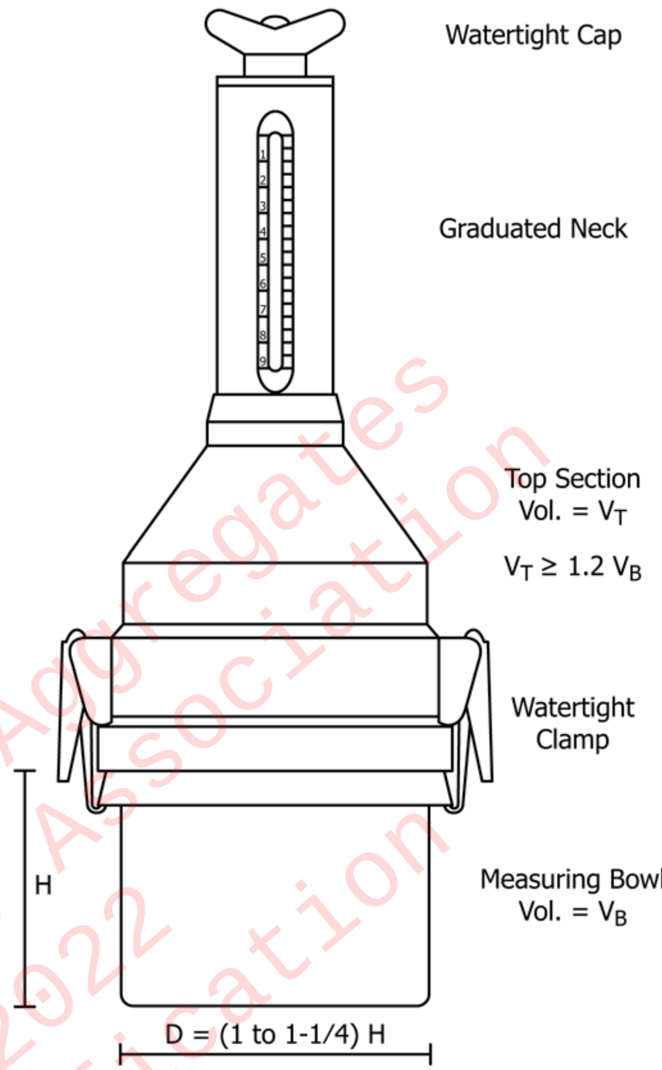


FIG. 1 Apparatus for Measuring Air Content of Fresh Concrete by Volumetric Method (b) Aluminum Meter *(continued)*

greater than 0.5 % from 0 at the top to 9 %, or more, of the volume of the measuring bowl. Graduations shall be accurate to ±0.1 % by volume of the measuring bowl. The upper end of the neck shall have a watertight cap that will maintain a watertight seal when the meter is inverted and rolled.

4.2 *Funnel*—A funnel with a spout of a size permitting it to be inserted through the neck of the top section and long enough to extend to a point just above the bottom of the top section. The discharge end of the spout shall be so constructed that when water is added to the container there will be a minimum disturbance of the concrete.

4.3 *Tamping Rod*—A round, smooth, straight steel, high-density polyethylene, or other plastic rod of equal or greater abrasion resistance with a 16 mm [5⁄8 in.] ± 2 mm [1⁄16 in.] diameter. The length of the tamping rod shall be at least 100 mm [4 in.] greater than the depth of the measuring bowl in which rodding is being performed, but not greater than 600 mm [24 in.] in overall length (Note 1). The rod shall have the

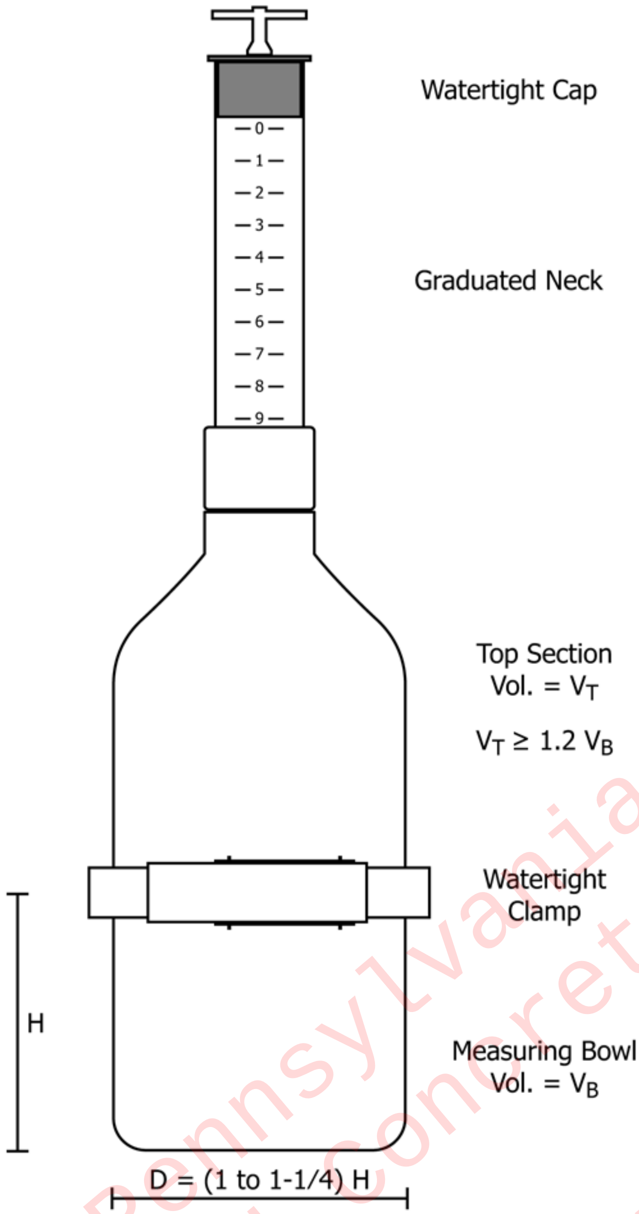


FIG. 1 Apparatus for Measuring Air Content of Fresh Concrete by Volumetric Method (c) High Density Plastic Meter *(continued)*

tamping end or both ends rounded to a hemispherical tip of the same diameter as the rod.

NOTE 1—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.

4.4 *Strike-off Bar*—A flat, straight steel bar at least 3 by 20 by 300 mm [⅛ by ¾ by 12 in.] or a flat, straight high-density polyethylene bar, or other plastic of equal or greater abrasion resistance, at least 6 by 20 by 300 mm [¼ by ¾ by 12 in.].

4.5 *Calibrated Cup*—A metal or plastic cup either having a capacity of or being graduated in increments equal to 1.00 ± 0.04 % of the volume of the measuring bowl of the air meter. The calibrated cup is only to be used to add water when the concrete air content exceeds 9 % or the calibrated range of the meter.

4.6 *Measuring Vessel for Isopropyl Alcohol*—A vessel with a minimum capacity of at least 500 mL [1 pt] with graduations not larger than 100 mL [4 oz] for measuring a quantity of isopropyl alcohol.

4.7 *Syringe*—A rubber syringe having a capacity of at least 50 mL [2 oz].

4.8 *Pouring Vessel for Water*—A container of approximately 1 L [1 qt] capacity.

4.9 *Scoop* of a size large enough so each amount of concrete obtained from the sampling receptacle is representative and small enough so it is not spilled during placement in the measuring bowl.

4.10 *Isopropyl Alcohol*—Use 70 % by volume isopropyl alcohol (approximately 65 % by weight) (Note 2). Other foam-dispersing agents are permitted if tests demonstrate that the use of the agent does not change the indicated air content, in the amounts being used, by more than 0.1 % or if correction factors are developed similar to those in Table 1. When other dispersing agents are used, a copy of the records documenting the testing or calculations shall be available in the laboratory.

NOTE 2—Seventy percent isopropyl alcohol is commonly available as rubbing alcohol. More concentrated grades can be diluted with water to the required concentration.

4.11 *Mallet*—A mallet (with a rubber or rawhide head) with a mass of approximately 600 ± 200 g [1.25 ± 0.5 lb].

5. Calibration

5.1 Calibrate the meter and calibrated cup initially and annually or whenever there is reason to suspect damage or deformation of the meter or calibrated cup.

5.2 Determine the volume of the measuring bowl with an accuracy of at least 0.1 % by determining the mass of water required to fill it at room temperature and dividing it by the density of the water at the same temperature. Follow the calibration procedure outlined in Test Method C29/C29M.

5.3 Determine the accuracy of the graduations on the neck of the top section of the air meter by filling the assembled measuring bowl and top section with water to the level of the mark for highest air content graduation.

5.3.1 Add water in increments of 1.0 % of the volume of the measuring bowl to check accuracy throughout the graduated range of air content. The error at any point throughout the graduated range shall not exceed 0.1 % of air.

TABLE 1 Correction for the Effect of Isopropyl Alcohol on C173/C173M Air Meter Reading

70 % Isopropyl Alcohol Used			
Pints	Fluid Ounces	Litres	Correction, %[A]
≤ 2.0	≤ 32	≤ 1.0	0.0[B]
3.0	48	1.5	0.25
4.0	64	2.0	0.50
5.0	80	2.5	0.75

[A] Subtract from final meter reading.
[B] Corrections are applied only when 1.25 L [2.5 pt] or more of isopropyl alcohol is used. The values given are for air meters that have a measuring bowl volume of 2.1 L [0.075 ft^3] and a top section that is 1.2 times the volume of the meauring bowl.

5.4 Determine the volume of the calibrated cup using water at 21.1°C [70°F] by the method outlined in 5.2. A quick check can be made by adding one or more calibrated cups of water to the assembled apparatus and observing the increase in the height of the water column after filling to a given level.

6. Sampling

6.1 Obtain the sample of freshly mixed concrete in accordance with Practice C172. If the concrete contains coarse aggregate particles that would be retained on a 37.5-mm [1½-in.] sieve, wet sieve a representative sample over a 25-mm [1-in.] sieve to yield somewhat more than enough material to fill the measuring bowl. The wet sieving procedure is described in Practice C172.

6.2 The concrete used to fill the measuring bowl shall not have been previously used in the performance of any other test or practice, other than wet sieving in accordance with Practice C172 or the temperature test in accordance with Test Method C1064/C1064M.

7. Procedure

7.1 *Rodding and Tapping*—Dampen the interior of the measuring bowl and remove any standing water from the bottom. Using the scoop described in 4.9, fill the measuring bowl with freshly mixed concrete in two layers of approximately equal volume. While placing the concrete in the measuring bowl, move the scoop around the perimeter of the measuring bowl opening to ensure an even distribution of the concrete with minimal segregation. Rod each layer 25 times uniformly over the cross section with the rounded end of the rod. Rod the bottom layer throughout its depth. In rodding this layer, use care not to damage the bottom of the measuring bowl. For the 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 sides of the measuring bowl 10 to 15 times with the mallet to close any voids left by the tamping rod and to release any large bubbles of air that may have been trapped. After tapping the final layer, a slight excess of concrete, 3 mm [⅛ in.] or less, above the rim is acceptable. Add or remove a representative sample of concrete if necessary to obtain the required amount of concrete.

7.2 *Striking Off*—After rodding and tapping of the second layer, strike off the excess concrete with the strike-off bar until the surface is flush with the top of the measuring bowl. Wipe the flange of the measuring bowl clean.

7.3 *Adding Water and Alcohol*—Wet the inside of the top section of the meter, including the gasket. Attach the top section to the measuring bowl and insert the funnel. Add at least 0.5 L [1 pt] of water followed by the selected amount (Note 3) of isopropyl alcohol. Record the amount of isopropyl alcohol added. Continue adding water at least until it appears in the graduated neck of the top section (Note 4). Remove the funnel. Adjust the liquid level until the bottom of the meniscus is level with the zero mark on the graduated neck. A rubber syringe is useful for this purpose. Attach and tighten the watertight cap.

NOTE 3—The amount of isopropyl alcohol necessary to obtain a stable reading, and a minimum amount of foam immediately above the water column, will depend upon a number of factors. Many concretes made with less than 300 kg/m^3 [500 lb/yd^3] of cement and air contents less than 4 % may require less than 0.2 L [0.5 pt] of alcohol. Some high-cement mixes made with silica fume that have air contents of 6 % or more may require more than 1.4 L [3 pt] of alcohol. The amount required will vary with the concrete air content, the amount and type of air-entraining admixture, the cement content and cement alkali content, and perhaps other factors. Generally, the amount of alcohol necessary can be established for given mixture proportions and should not change greatly during the course of a job.

NOTE 4—When, if ever, it is necessary to use more than 2.0 L [4 or 4.5 pt] of isopropyl alcohol, it may be necessary to restrict the amount of water added initially to avoid overfilling the meter. However, it is desirable to add at least some water initially to aid in mixing the alcohol and limit the contact of the concentrated alcohol with the top surface of the concrete.

7.4 *Displacing the Volume of Air in the Concrete Specimen Using These Procedures:*

7.4.1 *Free the Concrete from the Measuring Bowl*—Quickly invert the meter, shake the measuring bowl horizontally, and return the meter to the upright position. To prevent the aggregate from lodging in the neck of the unit, do not keep it inverted for more than 5 s at a time. Repeat the inversion and shaking process for a minimum of 45 s and until the concrete has broken free and the aggregate can be heard moving in the meter as it is inverted.

7.4.2 *Rolling*—Place one hand on the neck of the meter and the other on the flange. Using the hand on the neck, tilt the top of the meter approximately 0.8 rad [45°] from the vertical position with the bottom edge of the measuring bowl resting on the floor or on the work surface. Maintain this position through the procedures described in this section. Using the hand on the flange to rotate the meter, vigorously roll the meter ¼ to ½ turn forward and back several times, quickly starting and stopping the roll. Turn the measuring bowl about ⅓ turn and repeat the rolling procedure as stated previously. Continue the turning and rolling procedures for approximately 1 min. The aggregate must be heard sliding in the meter during this process.

7.4.2.1 If, at any time, during the inversion and rolling procedures liquid is found to be leaking from the meter, the test is invalid and a new test shall be started as in 6.1.

7.4.2.2 Set the unit upright and loosen the top to allow any pressure to stabilize. Allow the meter to stand while the air rises to the top and until the liquid level stabilizes. The liquid level is considered stable when it does not change more than 0.25 % air within a 2-min period.

7.4.2.3 If it takes more than 6 min for the liquid level to stabilize or if there is more foam than that equivalent to 2 full percent air content divisions on the meter scale over the liquid level, discard the trial and start a new test as in 6.1. Use a larger addition of alcohol than was used in the initial trial.

7.4.2.4 If the level is stable without excessive foam, read the bottom of the meniscus to the nearest 0.25 % and record the *initial meter reading*.

7.4.2.5 If the air content is greater than the 9 % range of the meter, add a sufficient number of calibrated cups of water to bring the liquid level within the graduate range. Read the bottom of the meniscus to the nearest 0.25 %. Record the number of calibrated cups of water to be added to the final meter reading in 8.2.

7.5 *Confirmation of the Initial Meter Reading:*

7.5.1 When an initial meter reading is obtained as in 7.4.2.4, retighten the top and repeat the 1-min rolling as in 7.4.2, 7.4.2.2, and 7.4.2.3.

7.5.2 When the liquid level is stable as in 7.4.2.2 and the requirements of 7.4.2.3 are met, make a direct reading to the bottom of the meniscus and estimate to 0.25 % air. If this reading has not changed more than 0.25 % from the initial meter reading in 7.4.2.4, record it as the *final meter reading* of the sample tested.

7.5.2.1 If the reading has changed from the *initial meter reading* by more than 0.25 % air, record this reading as a new "*initial reading*" and repeat the 1-min rolling as in 7.4.2. Read the indicated air content. If this reading has not changed by more than 0.25 % air from the "*newest initial reading*" record it as the *final meter reading*.

7.5.2.2 If the reading has changed by more than 0.25 %, discard the test and start a new test on a new sample of concrete as in 6.1 using more alcohol.

7.6 Disassemble the air meter by detaching the top section from the measuring bowl. Allow the liquid to discharge from the air meter. Dump the contents of the measuring bowl. Examine the interior of the measuring bowl to be sure that there are no portions of undisturbed, tightly packed concrete present. If portions of undisturbed concrete are found, the test is invalid.

8. Calculation

8.1 If more than 1.25 L [2.5 pt] of alcohol is used in 7.3, a correction to the final meter reading is required. Round the volume of alcohol used to the nearest 0.5 L [1 pt] and select the correction factor from Table 1.

NOTE 5—When the top section is initially filled to the zero mark with water and isopropyl alcohol that mixture has a defined volume; however, when that solution is further mixed with the water present in the concrete, the concentration of alcohol changes and the new solution occupies a volume slightly smaller than it did when the meter was initially filled to the zero mark. For this reason, the meter tends to indicate a higher than actual air content when more than about 1.2 L [2.5 pt] of alcohol is used. Therefore, when large amounts of alcohol are used, the correction factors in Table 1 reduce the air content indicated by the meter.

8.2 *Air Content*—Calculate the air content of the concrete in the measuring bowl as follows:

$$A = A_R - C + W \quad (1)$$

where:

A = air content, %,
A_R = final meter reading, %,
C = correction factor from Table 1, %, and
W = number of calibrated cups of water added to the meter (See 7.4.2.5)

8.2.1 Report the air content to the nearest 0.25 %.

8.3 When the sample tested represents that portion of the mixture obtained by wet sieving over a 25-mm [1-in.] sieve, calculate the air content of the mortar or of the full mixture using the formulas given in Test Method C231. Use appropriate quantities coarser or finer than the 1-in. sieve instead of the 37.5-mm [1½-in.] sieve specified in Test Method C231.

9. Precision and Bias

9.1 The standard deviation is essentially proportional to the average for different levels of air content. The following precision statement is based on 979 tests made in 6 field experiments by the West Virginia D.O.T. The multi-operator coefficient of variation has been found to be 11 % of the measured air content. Therefore, results of tests by two different operators on specimens taken from a single concrete sample should not differ from each other by more than 32 % of their average air content (Note 6).

NOTE 6—These numbers represent, respectively, the 1s % and d2s % limits described in Practice C670. The data collected for the precision statement was obtained using procedures standard prior to the use of large amounts of isopropyl alcohol in Test Method C173/C173M-01.

9.2 This test method provides volumetric procedures for determining the air content of freshly mixed concrete. When conducted properly, this test method has no bias because the value of the air content can only be defined in terms of this test method.

10. Keywords

10.1 air content; calibration; concrete; correction factor; freshly mixed concrete; measuring bowl; meter; volumetric method

APPENDIX

(Nonmandatory Information)

X1. FLOWCHART FOR PERFORMING THE VOLUMETRIC AIR CONTENT TEST METHOD

X1.1 The following flowchart (see Fig. X1.1) does not include all steps and precautions required to perform this test method properly. It is provided to help users follow the sequence of the procedures.

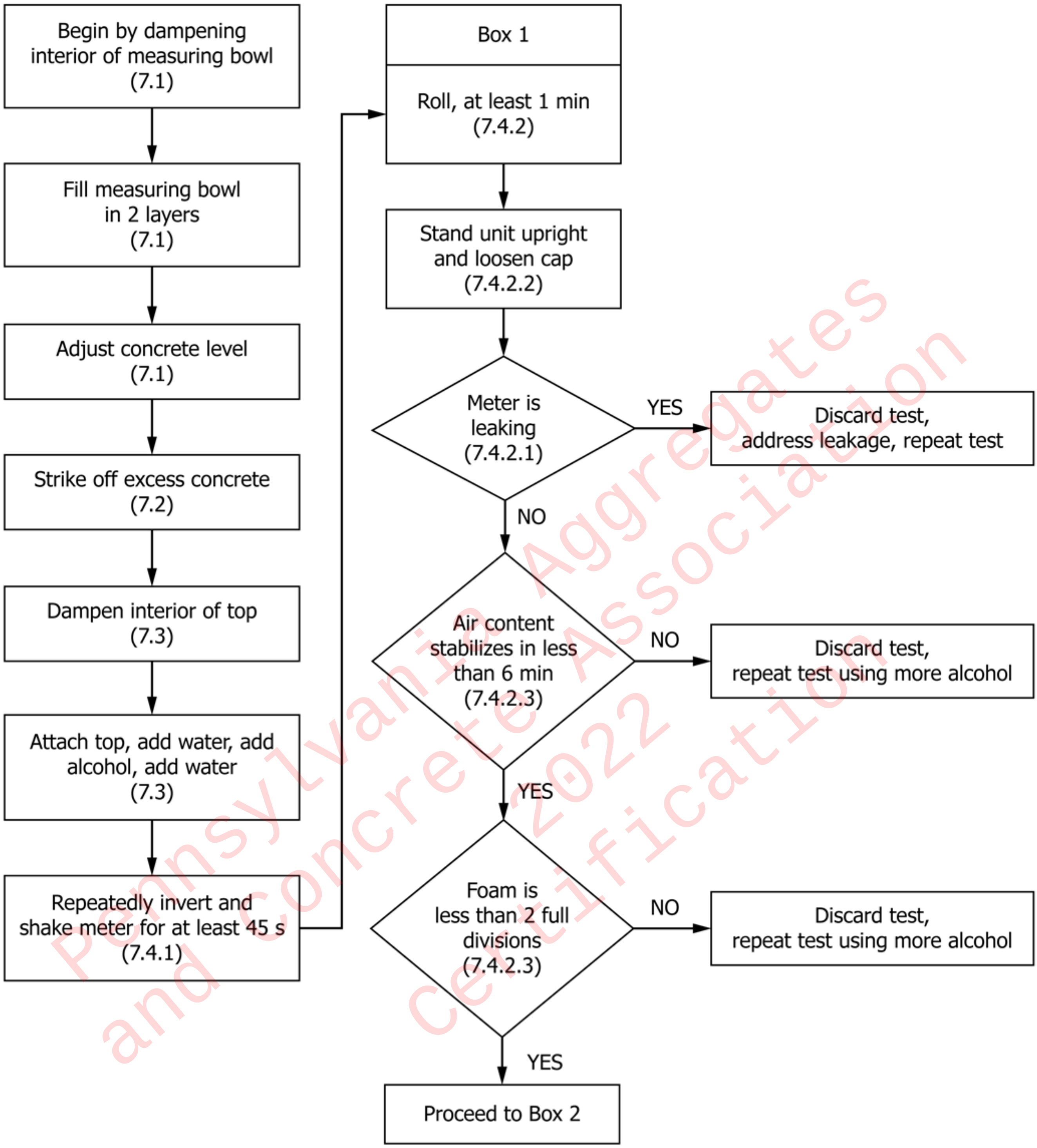


FIG. X1.1 Flowchart for Performing the Volumetric Air Content Test Method

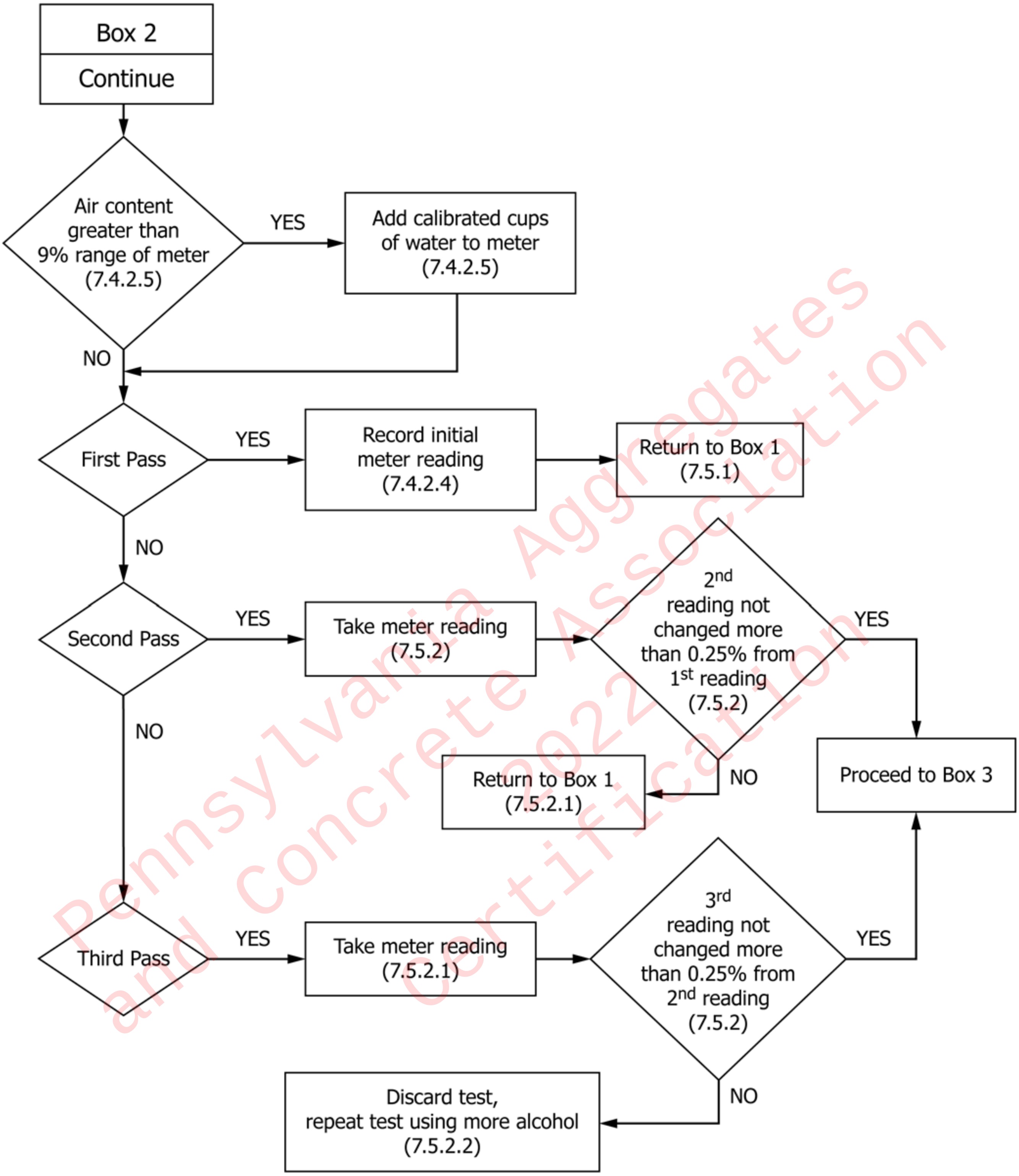


FIG. X1.1 Flowchart for Performing the Volumetric Air Content Test Method *(continued)*

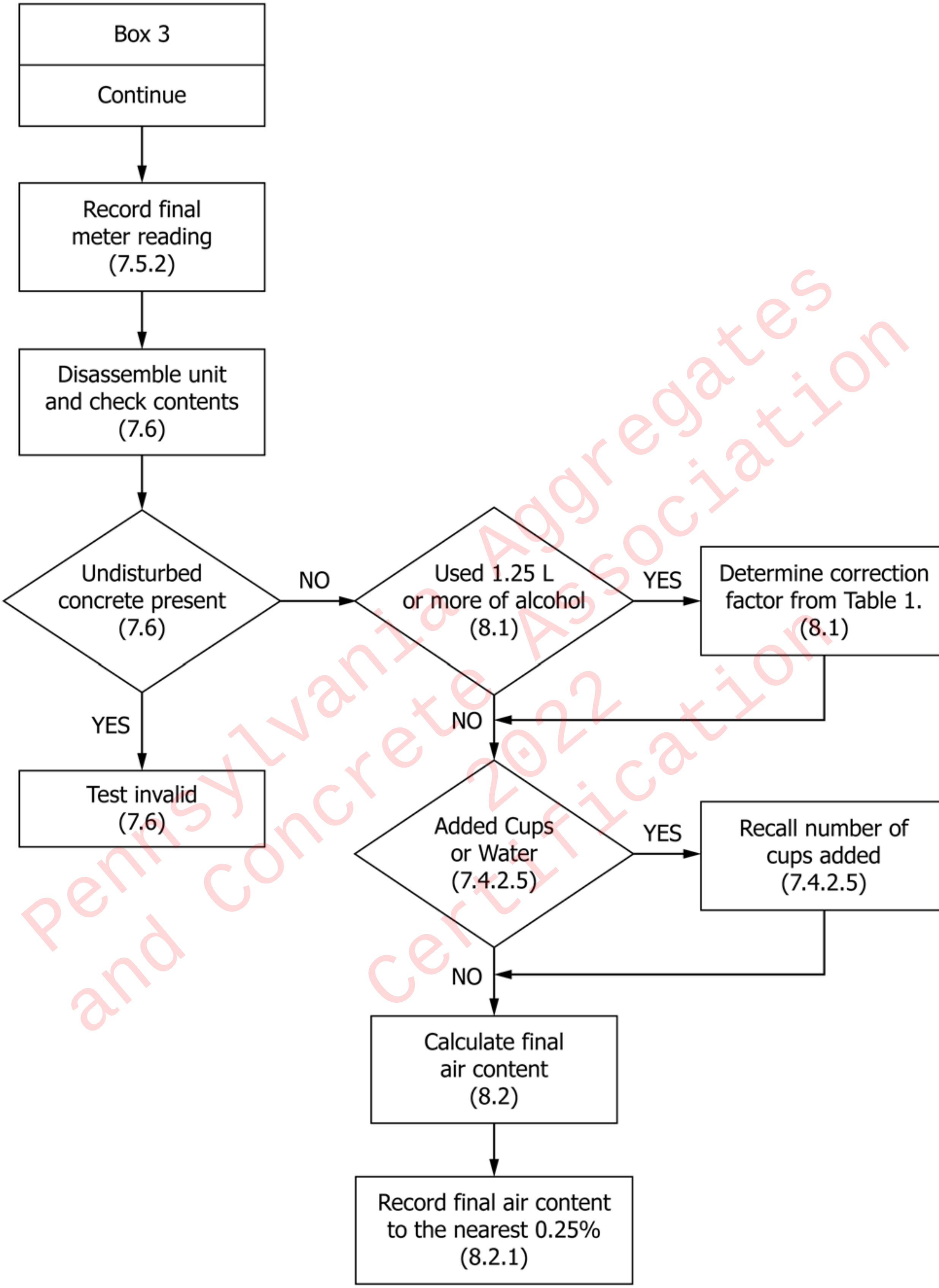


FIG. X1.1 Flowchart for Performing the Volumetric Air Content Test Method *(continued)*

SUMMARY OF CHANGES

Committee C09 has identified the location of selected changes to this test method since the last issue, C173/C173M – 14, that may impact the use of this test method. (Approved Feb. 1, 2016.)

(1) Revised 7.1.

Designation: C231/C231M – 17a

Standard Test Method for Air Content of Freshly Mixed Concrete by the Pressure Method[1]

This standard is issued under the fixed designation C231/C231M; 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 test method covers determination of the air content of freshly mixed concrete from observation of the change in volume of concrete with a change in pressure.

1.2 This test method is intended for use with concretes and mortars made with relatively dense aggregates for which the aggregate correction factor can be satisfactorily determined by the technique described in Section 6. It is not applicable to concretes made with lightweight aggregates, air-cooled blast-furnace slag, or aggregates of high porosity. In these cases, Test Method C173/C173M should be used. This test method is also not applicable to nonplastic concrete such as is commonly used in the manufacture of pipe and concrete masonry units.

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

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 and health 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]

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

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

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

C670 Practice for Preparing Precision and Bias Statements for Test Methods for Construction Materials

3. Significance and Use

3.1 This test method covers the determination of the air content of freshly mixed concrete. The test determines the air content of freshly mixed concrete exclusive of any air that may exist inside voids within aggregate particles. For this reason, it is applicable to concrete made with relatively dense aggregate particles and requires determination of the aggregate correction factor (see 6.1 and 9.1).

3.2 This test method and Test Method C138/C138M and C173/C173M provide pressure, gravimetric, and volumetric procedures, respectively, for determining the air content of freshly mixed concrete. The pressure procedure of this test method gives substantially the same air contents as the other two test methods for concretes made with dense aggregates.

3.3 The air content of hardened concrete may be either higher or lower than that determined by this test method. This

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

Current edition approved April 15, 2017. Published June 2017. Originally approved in 1949. Last previous edition approved in 2017 as C231/C231M – 17. DOI: 10.1520/C0231_C0231M-17A.

[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**

depends upon the methods and amount of consolidation effort applied to the concrete from which the hardened concrete specimen is taken; uniformity and stability of the air bubbles in the fresh and hardened concrete; accuracy of the microscopic examination, if used; time of comparison; environmental exposure; stage in the delivery, placement and consolidation processes at which the air content of the unhardened concrete is determined, that is, before or after the concrete goes through a pump; and other factors.

4. Apparatus

4.1 *Air Meters*—There are available satisfactory apparatus of two basic operational designs employing the principle of Boyle's law. For purposes of reference herein these are designated Meter Type A and Meter Type B.

4.1.1 *Meter Type A*—An air meter consisting of a measuring bowl and cover assembly (see Fig. 1) conforming to the requirements of 4.2 and 4.3. The operational principle of this meter consists of introducing water to a predetermined height above a sample of concrete of known volume, and the application of a predetermined air pressure over the water. The determination consists of the reduction in volume of the air in the concrete sample by observing the amount the water level is lowered under the applied pressure, the latter amount being calibrated in terms of percent of air in the concrete sample.

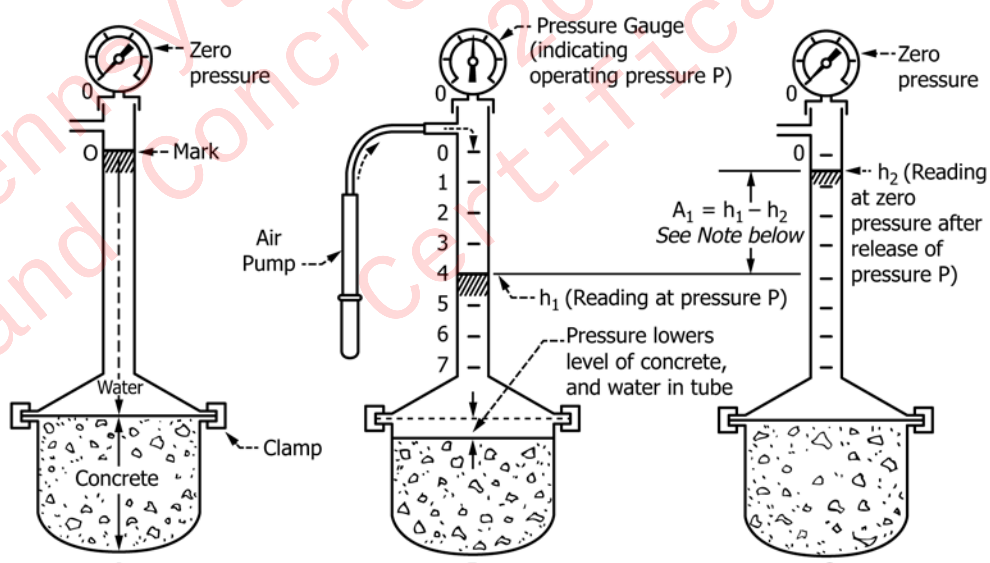
4.1.2 *Meter Type B*—An air meter consisting of a measuring bowl and cover assembly (see Fig. 2) conforming to the requirements of 4.2 and 4.3. The operational principle of this meter consists of equalizing a known volume of air at a known pressure in a sealed air chamber with the unknown volume of air in the concrete sample, the dial on the pressure gauge being calibrated in terms of percent air for the observed pressure at which equalization takes place. Working pressures of 50 to 205 kPa [7.5 to 30.0 psi] have been used satisfactorily.

4.2 *Measuring Bowl*—The measuring bowl shall be essentially cylindrical in shape, made of steel, hard metal, or other hard material not readily attacked by the cement paste, having a minimum diameter equal to 0.75 to 1.25 times the height, and a capacity of at least 6.0 L [0.20 ft^3]. It shall be flanged or otherwise constructed to provide for a pressure tight fit between measuring bowl and cover assembly. The interior surfaces of the measuring bowl and surfaces of rims, flanges, and other component fitted parts shall be machined smooth. The measuring bowl and cover assembly shall be sufficiently rigid to limit the expansion factor, *D*, of the apparatus assembly (Section A1.5) to not more than 0.1 % of air content on the indicator scale when under normal operating pressure.

4.3 *Cover Assembly:*

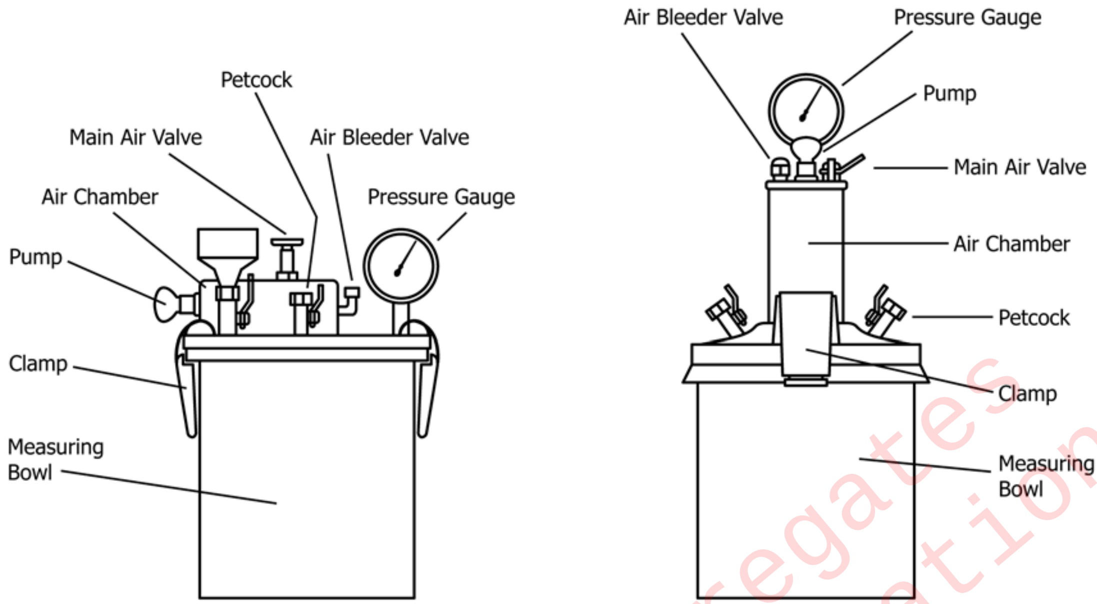
4.3.1 The cover assembly shall be made of steel, hard metal, or other hard material not readily attacked by the cement paste. It shall be flanged or otherwise constructed to provide for a pressure-tight fit between measuring bowl and cover assembly and shall have machined smooth interior surfaces contoured to provide an air space above the level of the top of the measuring bowl. The cover shall be sufficiently rigid to limit the expansion factor of the apparatus assembly as prescribed in 4.2.

4.3.2 The cover assembly shall be fitted with a means of direct reading of the air content. The cover for the Type A meter shall be fitted with a standpipe, made of a transparent graduated tube or a metal tube of uniform bore with a glass water gauge attached. In the Type B meter, the dial of the pressure gauge shall be calibrated to indicate the percent of air. Graduations shall be provided for a range in air content of at



Note: $A_1 = h_1 - h_2$ when measuring bowl contains concrete as shown in this figure; when measuring bowl contains only aggregate and water, $h_1 - h_2 = G$ (aggregate correction factor). $A_1 - G = A$ (entrained air content of concrete)

FIG. 1 Illustration of the Pressure Method for Air Content—Type-A Meter



2a. Horizontal Air Chamber **2b.** Vertical Air Chamber

FIG. 2 Schematic Diagram—Type-B Meter

least 8 % readable to 0.1 % as determined by the proper air pressure calibration test.

4.3.3 The cover assembly shall be fitted with air valves, air bleeder valves, and petcocks for bleeding off or through which water may be introduced as necessary for the particular meter design. Suitable means for clamping the cover to the measuring bowl shall be provided to make a pressure-tight seal without entrapping air at the joint between the flanges of the cover and measuring bowl. A suitable hand pump shall be provided with the cover either as an attachment or as an accessory.

4.4 *Calibration Vessel*—A measure having an internal volume equal to a percent of the volume of the measuring bowl corresponding to the approximate percent of air in the concrete to be tested; or, if smaller, it shall be possible to check calibration of the meter indicator at the approximate percent of air in the concrete to be tested by repeated filling of the measure. When the design of the meter requires placing the calibration vessel within the measuring bowl to check calibration, the measure shall be cylindrical in shape.

NOTE 1—A satisfactory calibration vessel to place within the measuring bowl may be machined from No. 16 gauge brass tubing, of a diameter to provide the volume desired, to which a brass disk 13 mm [½ in.] in thickness is soldered to form an end. When design of the meter requires withdrawing of water from the water-filled measuring bowl and cover assembly, to check calibration, the measure may be an integral part of the cover assembly or may be a separate cylindrical measure similar to the above-described cylinder.

4.5 The designs of various available types of air meters are such that they differ in operating techniques; therefore, all of the items described in 4.6 – 4.16 may not be required. The items required shall be those necessary for use with the particular design of apparatus used to satisfactorily determine air content in accordance with the procedures prescribed herein.

4.6 *Coil Spring or Other Device for Holding Calibration Cylinder in Place.*

4.7 *Spray Tube*—A brass tube of appropriate diameter, which may be an integral part of the cover assembly, or which may be provided separately. It shall be so constructed that when water is added to the container, it is sprayed to the walls of the cover in such a manner as to flow down the sides causing a minimum of disturbance to the concrete.

4.8 *Trowel*—A standard brick mason's trowel.

4.9 *Tamping Rod*—A round, smooth, straight steel rod, with a 16 mm [⅝ in.] ± 2 mm [1⁄16 in.] diameter. The length of the tamping rod shall be at least 100 mm [4 in.] greater than the depth of the measuring bowl 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.

4.10 *Mallet*—A mallet (with a rubber or rawhide head) weighing approximately 0.60 ± 0.25 kg [1.25 ± 0.50 lb] for use with measures of 14 L [0.5 ft^3] or smaller, and a mallet weighing approximately 1.0 ± 0.25 kg [2.25 ± 0.50 lb] for use with measures larger than 14 L [0.5 ft^3].

4.11 *Strike-Off Bar*—A flat straight bar of steel or other suitable metal at least 3 mm [⅛ in.] thick and 20 mm [¾ in.] wide by 300 mm [12 in.] long.

4.12 *Strike-Off Plate*—A flat rectangular metal plate at least 6 mm [¼ in.] thick or a glass or acrylic plate at least 13 mm [½ in.] thick with a length and width at least 50 mm [2 in.]

greater than the diameter of the measure with which it is to be used. The edges of the plate shall be straight and smooth within a tolerance of 1.5 mm [1⁄16 in.].

4.13 *Funnel,* with the spout fitting into spray tube.

4.14 *Measure for Water,* having the necessary capacity to fill the indicator with water from the top of the concrete to the zero mark.

4.15 *Vibrator,* as described in Practice C192/C192M.

4.16 *Sieves,* 37.5-mm (1½-in.) with not less than 0.2 m^2 [2 ft^2] of sieving area.

4.17 *Scoop*—of a size large enough so each amount of concrete obtained from the sampling receptacle is representative and small enough so it is not spilled during placement in the measuring bowl.

5. Calibration of Apparatus

5.1 Make calibration tests in accordance with procedures prescribed in the annex. Rough handling will affect the calibration of both Types A and B meters. Changes in barometric pressure will affect the calibration of Type A meter but not Type B meter. The steps described Sections A1.2 – A1.6, as applicable to the meter type under consideration, are prerequisites for the final calibration test to determine the operating pressure, *P*, on the pressure gauge of the Type A meter as described in Section A1.7, or to determine the accuracy of the graduations indicating air content on the dial face of the pressure gauge of the Type B meter as described in Section A1.9. The steps in Sections A1.2 – A1.6 need be made only once (at the time of initial calibration), or only occasionally to check volume constancy of the calibration cylinder and measuring bowl. The calibration test described in Sections A1.7 and A1.9, as applicable to the meter type being checked, must be made as frequently as necessary and at intervals not to exceed three months to ensure that the proper gauge pressure, *P*, is being used for the Type A meter or that the correct air contents are being indicated on the pressure gauge air content scale for the Type B meter. A change in elevation of more than 180 m [600 ft] from the location at which a Type A meter was last calibrated will require recalibration in accordance with Section A1.7.

5.2 *Calibration Records*—Information to be maintained in the records shall include determination of expansion factor; size of the calibration vessel used; and the reading of the meter at the calibration test point(s).

6. Determination of Aggregate Correction Factor

6.1 *Procedure*—Determine the aggregate correction factor on a combined sample of fine and coarse aggregate as directed in 6.2 to 6.4. It is determined independently by applying the calibrated pressure to a sample of inundated fine and coarse aggregate in approximately the same moisture condition, amount, and proportions occurring in the concrete sample under test.

6.2 *Aggregate Sample Size*—Calculate the weights of fine and coarse aggregate present in the sample of fresh concrete whose air content is to be determined, as follows:

$$F_s = (S/B) \times F_b \quad (1)$$

$$C_s = (S/B) \times C_b \quad (2)$$

where:

F_s = mass of fine aggregate in concrete sample under test, kg [lb],
S = volume of concrete sample (same as volume of measuring bowl), m^3 [ft^3],
B = volume of concrete produced per batch (Note 3), m^3 [ft^3],
F_b = total mass of fine aggregate in the moisture condition used in batch, kg [lb],
C_s = mass of coarse aggregate in concrete sample under test, kg [lb], and
C_b = total mass of coarse aggregate in the moisture condition used in batch, kg [lb].

NOTE 3—The volume of concrete produced per batch can be determined in accordance with applicable provisions of Test Method C138/C138M.

NOTE 4—The term "weight" is temporarily used in this test method because of established trade usage. The word is used to mean both "force" and "mass," and care must be taken to determine which is meant in each case (SI unit for force = newton and for mass = kilogram).

6.3 *Placement of Aggregate in Measuring Bowl*—Mix representative samples of fine aggregate F_s and coarse aggregate C_s, and place in the measuring bowl filled one-third full with water. Place the mixed aggregate, a small amount at a time, into the measuring bowl; if necessary, add additional water so as to inundate all of the aggregate. Add each scoopful in a manner that will entrap as little air as possible and remove accumulations of foam promptly. Tap the sides of the measuring bowl and lightly rod the upper 25 mm [1 in.] of the aggregate eight to twelve times. Stir after each addition of aggregate to eliminate entrapped air.

6.4 *Aggregate Correction Factor Determination:*

6.4.1 *Initial Procedure for Types A and B Meters*—When all of the aggregate has been placed in the measuring bowl, remove excess foam and keep the aggregate inundated for a period of time approximately equal to the time between introduction of the water into the mixer and the time of performing the test for air content before proceeding with the determination as directed in 6.4.2 or 6.4.3.

6.4.2 *Type A Meter*—Complete the test as described in 8.2.1 – 8.2.3. The aggregate correction factor, *G*, is equal to $h_1 - h_2$ (see Fig. 1) (Note 5).

6.4.3 *Type B Meter*—Perform the procedures as described in 8.3.1. Remove a volume of water from the assembled and filled apparatus approximately equivalent to the volume of air that would be contained in a typical concrete sample of a size equal to the volume of the measuring bowl. Remove the water in the manner described in Section A1.9 for the calibration tests. Complete the test as described in 8.3.2. The aggregate correction factor, *G*, is equal to the reading on the air-content scale minus the volume of water removed from the measuring bowl expressed as a percent of the volume of the measuring bowl (see Fig. 1).

NOTE 5—The aggregate correction factor will vary with different aggregates. It can be determined only by test, since apparently it is not directly related to absorption of the particles. The test can be made easily. Ordinarily the factor will remain reasonably constant for given aggregates, but an occasional check test is recommended.

7. Preparation of Concrete Test Sample

7.1 Obtain the sample of freshly mixed concrete in accordance with applicable procedures of Practice C172/C172M. If the concrete contains coarse aggregate particles that would be retained on a 50-mm (2-in.) sieve, wet-sieve a sufficient amount of the representative sample over a 37.5-mm (1½-in.) sieve, as described in Practice C172/C172M, to yield sufficient material to completely fill the measuring bowl of the size selected for use. Carry out the wet-sieving operation with the minimum practicable disturbance of the mortar. Make no attempt to wipe adhering mortar from coarse aggregate particles retained on the sieve.

8. Procedure for Determining Air Content of Concrete

8.1 *Placement and Consolidation of Sample:*

8.1.1 Prepare the concrete as described in 7.1. Dampen the interior of the measuring bowl and place it on a flat, level, firm surface. Using the scoop described in 4.17, place the concrete in the measuring bowl in the number of layers required by the consolidation method (8.1.2 or 8.1.3). While placing the concrete in the bowl, move the scoop around the perimeter of the bowl opening to ensure an even distribution of the concrete with minimal segregation. Consolidate each layer by the rodding procedure (8.1.2) or by vibration (8.1.3). Strike-off the finally consolidated layer (8.1.4). Rod concretes with a slump greater than 75 mm [3 in.]. Rod or vibrate concrete with a slump of 25 to 75 mm [1 to 3 in.]. Consolidate concretes with a slump less than 25 mm [1 in.] by vibration.

8.1.2 *Rodding*—Place the concrete in the measuring bowl in three layers of approximately equal volume. Rod each layer 25 times uniformly over the cross section with the rounded end of the rod. Rod the bottom layer throughout its depth. In rodding this layer, use care not to damage the bottom of the measuring bowl. 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 sides of the measuring bowl smartly 10 to 15 times with the mallet to close any voids left by the tamping rod and to release any large bubbles of air that may have been trapped. Add the final layer of concrete in a manner to avoid excessive overfilling (8.1.4).

8.1.3 *Vibration*—Place the concrete in the measuring bowl in two layers of approximately equal volume. Place all of the concrete for each layer before starting vibration of that layer. Consolidate each layer by three insertions of the vibrator evenly distributed over the cross section. Add the final layer in a manner to avoid excessive overfilling (8.1.4). In consolidating each layer, do not allow the vibrator to rest on or touch the measuring bowl. Take care in withdrawing the vibrator to ensure that no air pockets are left in the specimen. Observe a standard duration of vibration for the particular kind of concrete, vibrator, and measuring bowl involved. The duration of vibration required will depend upon the workability of the concrete and the effectiveness of the vibrator. Continue vibration until the concrete is properly consolidated. Never continue vibration long enough to cause escape of froth from the sample.

NOTE 6—Overvibration may cause segregation and loss of intentionally entrained air. Usually, sufficient vibration has been applied as soon as the surface of the concrete becomes relatively smooth and has a glazed appearance.

8.1.4 *Strike Off*—After consolidation of the concrete, strike off the top surface by sliding the strike-off bar across the top flange or rim of the measuring bowl with a sawing motion until the bowl is just level full. On completion of consolidation, the measuring bowl must not contain an excess or deficiency of concrete. Removal of 3 mm [⅛ in.] during strike off is optimum. When a strike-off plate is used, strike off concrete as prescribed in Test Method C138/C138M.

NOTE 7—A small quantity of representative concrete may be added to correct a deficiency. If the measure contains a great excess, remove a representative portion of concrete with a trowel or scoop before the measure is struck off.

NOTE 8—The use of the strike-off plate on cast aluminum or other relatively soft metal air meter bases may cause rapid wear of the rim and require frequent maintenance, calibration, and ultimately, replacement.

8.1.5 *Application of Test Method*—Any portion of the test method not specifically designated as pertaining to Type A or Type B meter shall apply to both types.

8.2 *Procedure—Type A Meter:*

8.2.1 *Preparation for Test*—Thoroughly clean the flanges or rims of the measuring bowl and of the cover assembly so that when the cover is clamped in place a pressure-tight seal will be obtained. Assemble the apparatus and add water over the concrete by means of the tube until it rises to about the halfway mark in the standpipe. Incline the apparatus assembly about 0.5 rad [30°] from vertical and, using the bottom of the measuring bowl as a pivot, describe several complete circles with the upper end of the column, simultaneously tapping the cover lightly to remove any entrapped air bubbles above the concrete sample. Return the apparatus assembly to a vertical position and fill the water column slightly above the zero mark, while lightly tapping the sides of the measuring bowl. Bring the water level to the zero mark of the graduated tube before closing the vent at the top of the water column (see Fig. 1 A).

NOTE 9—Some Type A meters have a calibrated starting fill mark above the zero mark. Generally, this starting mark should not be used since, as noted in 8.2.3, the apparent air content is the difference between the water level reading H, at pressure P and the water level h_2 at zero pressure after release of pressure P.

8.2.2 The internal surface of the cover assembly shall be kept clean and free from oil or grease; the surface shall be wet to prevent adherence of air bubbles that might be difficult to dislodge after assembly of the apparatus.

8.2.3 *Test Procedure*—Apply more than the desired test pressure, P, (about 1.4 kPa [0.2 psi] more) to the concrete by means of the small hand pump. To relieve local restraints, tap the sides of the measuring bowl sharply and, when the pressure gauge indicates the exact test pressure, P, as determined in accordance with Section A1.7, read the water level, h_1, and record to the nearest division or half-division on the graduated precision-bore tube or gauge glass of the standpipe (see Fig. 1 B). For extremely harsh mixes tap the measuring bowl vigorously until further tapping produces no change in the indicated air content. Gradually release the air pressure through the vent at the top of the water column and tap the sides of the measuring bowl lightly for about 1 min. Record the water level, h_2, to the nearest division or half-division (see Fig. 1 C). Calculate the apparent air content as follows:

$$A_1 = h_1 - h_2 \quad (3)$$

where:

A_1 = apparent air content,
h_1 = water level reading at pressure, P (see Note 10), and
h_2 = water level reading at zero pressure after release of pressure, P.

8.2.4 *Check Test*—Repeat the steps described in 8.2.3 without adding water to reestablish the water level at the zero mark. The two consecutive determinations of apparent air content should check within 0.2 % of air and shall be averaged to give the value A_1 to be used in calculating the air content, A_s, in accordance with Section 9.

8.2.5 In the event the air content exceeds the range of the meter when it is operated at the normal test pressure P, reduce the test pressure to the alternative test pressure P_1 and repeat the steps outlined in 8.2.2 and 8.2.3.

NOTE 10—See Section A1.7 for exact calibration procedures. An approximate value of the alternative pressure, P_1, such that the apparent air content will equal twice the meter reading can be computed from the following relationship:

$$P_1 = P_a P/(2P_a + P) \quad (4)$$

where:

P_1 = alternative test pressure, kPa or [psi],
P_a = atmospheric pressure, kPa or [psi], (approximately 100 kPa [14.7 psi] but will vary with altitude and weather conditions), and
P = normal test or operating gauge pressure, kPa or [psi].

8.3 *Procedure—Type B Meter:*

8.3.1 *Preparation for Test*—Thoroughly clean the flanges or rims of the measuring bowl and the cover assembly so that when the cover is clamped in place a pressure-tight seal will be obtained. Assemble the apparatus. Close the main air valve between the air chamber and the measuring bowl and open both petcocks on the holes through the cover. Add water through one petcock until water emerges from the opposite petcock (Note 11). Jar the meter gently until all air is expelled from this same petcock.

NOTE 11—Gently squeezing water into the petcock using a bulb syringe or plastic wash bottle has been found to be satisfactory for adding water to the meter.

8.3.2 *Test Procedure*—Close the air bleeder valve on the air chamber and pump air into the air chamber until the gauge hand is on the initial pressure line. Allow a few seconds for the compressed air to cool to normal temperature. Stabilize the gauge hand at the initial pressure line by pumping or bleeding-off air as necessary, tapping the gauge lightly by hand. Close both petcocks on the holes through the cover. Open the main air valve between the air chamber and the measuring bowl. Tap the sides of the measuring bowl smartly with the mallet to relieve local restraints. Lightly tap the pressure gauge by hand to stabilize the gauge hand. Read the percentage of air on the dial of the pressure gauge. Release the main air valve. Failure to close the main air valve before releasing the pressure from either the container or the air chamber will result in water being drawn into the air chamber, thus introducing error in subsequent measurements. In the event water enters the air chamber, it must be bled from the air chamber through the air bleeder valve followed by several strokes of the pump to blow out the last traces of water. Release the pressure by opening both petcocks (Fig. 2) before removing the cover.

9. Calculation

9.1 *Air Content of Sample Tested*—Calculate the air content of the concrete in the measuring bowl as follows:

$$A_s = A_1 - G \quad (5)$$

where:

A_s = air content of the sample tested, %,
A_1 = apparent air content of the sample tested, % (see 8.2.3 and 8.3.2), and
G = aggregate correction factor, % (Section 6).

9.2 *Air Content of Full Mixture*—When the sample tested represents that portion of the mixture that is obtained by wet sieving to remove aggregate particles larger than a 37.5-mm (1½-in.) sieve, the air content of the full mixture is calculated as follows:

$$A_t = 100\,A_s V_c/(100\,V_t - A_s V_a) \quad (6)$$

where (Note 12):

A_t = air content of the full mixture, %,
V_c = absolute volume of the ingredients of the mixture passing a 37.5-mm (1½-in.) sieve, airfree, as determined from the original batch weights, m^3 [ft^3],
V_t = absolute volume of all ingredients of the mixture, airfree, m^3 [ft^3], and
V_a = absolute volume of the aggregate in the mixture coarser than a 37.5-mm (1½-in.) sieve, as determined from original batch weights, m^3 [ft^3].

9.3 *Air Content of the Mortar Fraction*—When it is desired to know the air content of the mortar fraction of the mixture, calculate it as follows:

$$A_m = 100\,A_s\,V_c/[100\,V_m + A_s(V_c - V_m)] \quad (7)$$

where (Note 12):

A_m = air content of the mortar fraction, %, and
V_m = absolute volume of the ingredients of the mortar fraction of the mixture, airfree, m^3 [ft^3].

NOTE 12—The values for use in Eq 6 and Eq 7 are most conveniently obtained from data on the concrete mixture tabulated as follows for a batch of any size:

		Absolute Volume, m^3 [ft^3]
Cement	______	V_m (Cement, Water, Fine aggregate); V_c (Cement through Coarse aggregate 4.75-mm to 37.5-mm)
Water	______	
Fine aggregate	______	
Coarse aggregate (4.75-mm (No. 4) to 37.5-mm (1½-in.))	______	
Coarse aggregate (37.5-mm (1½-in.))	______	V_a
Total	______	V_t

10. Report

10.1 Report the following information:

10.1.1 The air content of the concrete sample to the nearest 0.1 % after subtracting the aggregate correction factor, unless the gauge reading of the meter exceeds 8 %, in which case the corrected reading shall be reported to the nearest ½ scale division on the dial.

10.1.2 The date and time of the test.

10.1.3 When requested, and when the absolute volume of the ingredients of the mortar fraction of the mixture can be determined, the air content of the mortar fraction of the mixture to the nearest ¼ %.

11. Precision and Bias

11.1 *Precision, Type A Meter:*

11.1.1 *Single-Operator Precision*—The single-operator standard deviation has not been established.

11.1.2 *Multilaboratory Precision*—The multilaboratory standard deviation has not been established.

11.1.3 *Multioperator Precision*—The multioperator standard deviation of a single test result has been found to be 0.28 % air by volume of concrete for Type A air meters as long as the air content does not exceed 7 %. Therefore results of two tests properly conducted by different operators but on the same material should not differ by more than 0.8 % air by volume of concrete.

NOTE 13—The number 0.8% represents the difference limit (d2s) as described in Practice C670. The precision statements are based on the variations in tests on three different concretes, each tested by eleven different operators.[4]

11.2 *Precision, Type B Meter:*

11.2.1 *Single-Operator Precision:*

11.2.1.1 *Air Content Less Than 3 %*—The maximum single-operator standard deviation was found to be 0.18 %. Therefore, the air contents from two properly conducted tests by the same operator on the same material are not expected to differ from each other by more than 0.5 %.[5]

11.2.1.2 *Air Content in the Range of 3 to 8 %*—The single-operator standard deviation was found to increase with air content as shown in Table 1. Therefore, results of two properly conducted tests by the same operator on the same material are not expected to differ from each other by more than the value shown in the last column of the upper half of Table 1.

TABLE 1 Indexes of Precision for Air Contents Between 3 and 8 %[A]

Air Content	Standard Deviation %	Acceptable Difference Between Two Results,[B] %
Single-operator precision:		
3 %	0.12	0.33
4 %	0.16	0.44
5 %	0.19	0.55
6 %	0.23	0.66
7 %	0.27	0.77
8 %	0.31	0.88
Multilaboratory precision:		
3 %	0.17	0.49
4 %	0.23	0.65
5 %	0.29	0.81
6 %	0.35	0.98
7 %	0.40	1.14
8 %	0.46	1.30

[A] Use interpolation to determine precision values for air contents between the values given in the table.

[B] These numbers represent the difference limits (d2s) as described in Practice C670.

11.2.2 *Multilaboratory Precision:*

11.2.2.1 *Air Content Less Than 3 %*—The maximum multilaboratory standard deviation was found to be 0.26 %. Therefore, the air contents from two properly conducted testes by different laboratories on the same material are not expected to differ from each other by more than 0.75 %.[5]

11.2.2.2 *Air Content in the Range of 3 to 8 %*—The multilaboratory standard deviation was found to increase with air content as shown in Table 1. Therefore, results of two properly conducted tests by different laboratories on the same material are not expected to differ from each other by more than the value shown in the last column of the lower half of Table 1.

NOTE 14—These precision statements are based on an interlaboratory study that involved 16 operators, six values of air content ranging from 1.3 to 7.6 %, and three replicate tests per operator. The results showed different precision performance for the two air contents less than 3 %, than for the 4 air contents above 3 %. Supporting data have been filed at ASTM International Headquarters and may be obtained by requesting Research Report RR:C09-1049. Contact ASTM Customer Service at service@astm.org.

11.3 *Bias*—This test method has no bias because the air content of freshly mixed concrete can only be defined in terms of the test methods.

12. Keywords

12.1 air content; calibration; concrete; correction factor; measuring bowl; meter; pressure; pump; unit weight

[4] Reidenour, D. R., and Howe, R. H., "Air Content of Plastic and Hardened Concrete," presented at the 2nd International Conference on" Durability of Building Materials and Components" Sept. 14–16, 1981. Reprints compiled by: G. Frohnsdorff and B. Horner, National Institute for Standards and Technology, Gaithersburg, MD 20899, formerly National Bureau of Standards, Washington, DC 20234.

[5] These numbers represent the difference limits (d2s) as described in Practice C670.

ANNEX

(Mandatory Information)

A1. CALIBRATION OF APPARATUS

A1.1 Calibration tests shall be performed in accordance with the following procedures as applicable to the meter type being employed.

A1.2 *Calibration of the Calibration Vessel*—Determine accurately the weight of water, *w*, required to fill the calibration vessel, using a scale accurate to 0.1 % of the weight of the vessel filled with water. This step shall be performed for Type A and B meters.

A1.3 *Calibration of the Measuring Bowl*—Determine the weight of water, *W*, required to fill the measuring bowl, using a scale accurate to 0.1 % of the weight of the measuring bowl filled with water. Slide a glass plate carefully over the flange of the measuring bowl in a manner to ensure that the measuring bowl is completely filled with water. A thin film of cup grease smeared on the flange of the measuring bowl will make a watertight joint between the glass plate and the top of the measuring bowl. This step shall be performed for Type A and B meters.

A1.4 *Effective Volume of the Calibration Vessel, R*—The constant *R* represents the effective volume of the calibration vessel expressed as a percentage of the volume of the measuring bowl.

A1.4.1 For meter Types A, calculate *R* as follows (Note A1.1):

$$R = 0.98\, w/W \tag{A1.1}$$

where:

w = weight of water required to fill the calibration vessel, and
W = weight of water required to fill the measuring bowl.

NOTE A1.1—The factor 0.98 is used to correct for the reduction in the volume of air in the calibration vessel when it is compressed by a depth of water equal to the depth of the measuring bowl. This factor is approximately 0.98 for a 200-mm [8-in.] deep measuring bowl at sea level. Its value decreases to approximately 0.975 at 1500 m [5000 ft] above sea level and 0.970 at 4000 m [13 000 ft] above sea level. The value of this constant will decrease by about 0.01 for each 100-mm [4-in.] increase in measuring bowl depth. The depth of the measuring bowl and atmospheric pressure do not affect the effective volume of the calibration vessel for meter Types B.

A1.4.2 For meter Types B calculate *R* as follows (Note A1.1):

$$R = w/W \tag{A1.2}$$

A1.5 *Determination of, or Check of, Allowance for Expansion Factor, D:*

A1.5.1 For meter assemblies of Type A determine the expansion factor, *D* (Note A1.2) by filling the apparatus with water only (making certain that all entrapped air has been removed and the water level is exactly on the zero mark (Note A1.3) and applying an air pressure approximately equal to the operating pressure, *P*, determined by the calibration test described in A1.7. The amount the water column lowers will be the equivalent expansion factor, *D*, for that particular apparatus and pressure (Note A1.5).

NOTE A1.2—Although the measuring bowl, cover, and clamping mechanism of the apparatus must of necessity be sturdily constructed so that it will be pressure-tight, the application of internal pressure will result in a small increase in volume. This expansion will not affect the test results because, with the procedure described in Sections 6 and 8, the amount of expansion is the same for the test for air in concrete as for the test for aggregate correction factor on combined fine and coarse aggregates, and is thereby automatically cancelled. However, it does enter into the calibration test to determine the air pressure to be used in testing fresh concrete.

NOTE A1.3—The water columns on some meters of Type-A design are marked with an initial water level and a zero mark, the difference between the two marks being the allowance for the expansion factor. This allowance should be checked in the same manner as for meters not so marked and in such a case, the expansion factor should be omitted in computing the calibration readings in A1.7.

NOTE A1.4—It will be sufficiently accurate for this purpose to use an approximate value for *P* determined by making a preliminary calibration test as described in A1.7 except that an approximate value for the calibration factor, *K*, should be used. For this test $K = 0.98R$ which is the same as Eq A1.2 except that the expansion reading, *D*, as yet unknown, is assumed to be zero.

A1.5.2 For meters of Type B design, the allowance for the expansion factor, *D*, is included in the difference between the initial pressure indicated on the pressure gauge and the zero percent mark on the air-content scale on the pressure gauge. This allowance shall be checked by filling the apparatus with water (making certain that all entrapped air has been removed), pumping air into the air chamber until the gauge hand is stabilized at the indicated initial pressure line, and then releasing the air to the measuring bowl (Note A1.5). If the initial pressure line is correctly positioned, the gauge should read zero percent. The initial pressure line shall be adjusted if two or more determinations show the same variation from zero percent and the test repeated to check the adjusted initial pressure line.

NOTE A1.5—This procedure may be accomplished in conjunction with the calibration test described in Section A1.9.

A1.6 *Calibration Reading, K*—The calibration reading, *K*, is the final meter reading to be obtained when the meter is operated at the correct calibration pressure.

A1.6.1 For meter Types A, the calibration reading, *K*, is as follows:

$$K = R + D \tag{A1.3}$$

where:

R = effective volume of the calibration vessel (A1.4.1), and
D = expansion factor (A1.5.1, Note A1.6).

A1.6.2 For meter Types B the calibration reading, K, equals the effective volume of the calibration vessel (A1.4.2) as follows:

$$K = R \tag{A1.4}$$

NOTE A1.6—If the water column indicator is graduated to include an initial water level and a zero mark, the difference between the two marks being equivalent to the expansion factor, the term D shall be omitted from Eq A1.3.

A1.7 *Calibration Test to Determine Operating Pressure, P, on Pressure Gauge, Type A Meter*—If the rim of the calibration cylinder contains no recesses or projections, fit it with three or more spacers equally spaced around the circumference. Invert the cylinder and place it at the center of the dry bottom of the measuring bowl. The spacers will provide an opening for flow of water into the calibration cylinder when pressure is applied. Secure the inverted cylinder against displacement and carefully lower the cover assembly. After the cover is clamped in place, carefully adjust the apparatus assembly to a vertical position and add water at air temperature, by means of the tube and funnel, until it rises above the zero mark on the standpipe. Close the vent and pump air into the apparatus to the approximate operating pressure. Incline the assembly about 0.5 rad [30°] from vertical and, using the bottom of the measuring bowl as a pivot, describe several complete circles with the upper end of the standpipe, simultaneously tapping the cover and sides of the measuring bowl lightly to remove any entrapped air adhering to the inner surfaces of the apparatus. Return the apparatus to a vertical position, gradually release the pressure (to avoid loss of air from the calibration vessel), and open the vent. Bring the water level exactly to the zero mark by bleeding water through the petcock in the top of the conical cover. After closing the vent, apply pressure until the water level has dropped an amount equivalent to about 0.1 to 0.2 % of air more than the value of the calibration reading, K, determined as described in Section A1.6. To relieve local restraints, lightly tap the sides of the measuring bowl, and when the water level is exactly at the value of the calibration reading, K, read the pressure, P, indicated by the gauge and record to the nearest 700 Pa [0.1 psi]. Gradually release the pressure and open the vent to determine whether the water level returns to the zero mark when the sides of the measuring bowl are tapped lightly (failure to do so indicates loss of air from the calibration vessel or loss of water due to a leak in the assembly). If the water levels fails to return to within 0.05 % air of the zero mark and no leakage beyond a few drops of water is found, some air probably was lost from the calibration cylinder. In this case, repeat the calibration procedure step by step from the beginning of this paragraph. If the leakage is more than a few drops of water, tighten the leaking joint before repeating the calibration procedure. Check the indicated pressure reading promptly by bringing the water level exactly to the zero mark, closing the vent, and applying the pressure, P, just determined. Tap the gauge lightly with a finger. When the gauge indicates the exact pressure, P, the water column should read the value of the calibration factor, K, used in the first pressure application within about 0.05 % of air.

A1.7.1 The apparatus assembly must not be moved from the vertical position until pressure has been applied, which will force water about one third of the way up into the calibration cylinder. Any loss of air from this cylinder will nullify the calibration.

A1.8 *Calibration Test to Determine Alternative Operating Pressure P_1—Meter Type A*—The range of air contents which can be measured with a given meter can be doubled by determining an alternative operating pressure P_1 such that the meter reads half of the calibration reading, K, (Eq A1.3). Exact calibration will require determination of the expansion factor at the reduced pressure in Section A1.5. For most purposes the change in expansion factor can be disregarded and the alternative operating pressure determined during the determination of the regular operating pressure in Section A1.7.

A1.9 *Calibration Test to Check the Air Content Graduations on the Pressure Gauge, Type B Meter*—Fill the measuring bowl with water as described in A1.3. Screw the short piece of tubing or pipe furnished with the apparatus into the threaded petcock hole on the underside of the cover assembly. Assemble the apparatus. Close the main air valve between the air chamber and the measuring bowl and open the two petcocks on holes through the cover assembly. Add water through the petcock on the cover assembly having the extension below until all air is expelled from the second petcock. Pump air into the air chamber until the pressure reaches the indicated initial pressure line. Allow a few seconds for the compressed air to cool to normal temperature. Stabilize the gauge hand at the initial pressure line by pumping or bleeding off air as necessary, tapping the gauge lightly. Close the petcock not provided with the tube or pipe extension on the under side of the cover. Remove water from the assembly to the calibrating vessel controlling the flow, depending on the particular meter design, by opening the petcock provided with the tube or pipe extension and cracking the main air valve between the air chamber and the measuring bowl, or by opening the main air valve and using the petcock to control flow. Perform the calibration at an air content which is within the normal range of use. If the calibration vessel (Section A1.2) has a capacity within the normal range of use, remove exactly that amount of water. With some meters the calibrating vessel is quite small and it will be necessary to remove several times that volume to obtain an air content within the normal range of use. In this instance, carefully collect the water in an auxiliary container and determine the amount removed by weighing to the nearest 0.1 %. Calculate the correct air content, R, by using Eq A1.2. Release the air from the apparatus at the petcock not used for filling the calibration vessel and if the apparatus employs an auxiliary tube for filling the calibration container, open the petcock to which the tube is connected to drain the tube back into the measuring bowl (see A1.7.1). At this point of procedure the measuring bowl contains the percentage of air determined by the calibration test of the calibrating vessel. Pump air into the air chamber until the pressure reaches the initial pressure line marked on the pressure gauge, close both petcocks in the cover assembly, and then open the main air valve between the air chamber and the measuring bowl. The indicated air content on the pressure gauge dial should correspond to the percentage of air determined to be in the measuring bowl. If two or more determinations show the same variation from the correct air content, the dial hand shall be reset to the correct air content and the test repeated until the gauge reading corresponds to the calibrated air content within 0.1 % for readings up to and including 8.0 % and to ½ dial scale division above 8.0 %. If the dial hand was reset to obtain the correct air content, recheck the initial pressure mark as in A1.5.2. If a new initial pressure reading is required, repeat the calibration to check the accuracy of the graduation on the pressure gauge described earlier in this section. If difficulty is encountered in obtaining consistent readings, check for leaks, for the presence of water inside the air chamber (see Fig. 2), or the presence of air bubbles clinging to the inside surfaces of the meter from the use of cool aerated water. In this latter instance use deaerated water which can be obtained by cooling hot water to room temperature.

NOTE A1.7—If the calibrating vessel is an integral part of the cover assembly, the petcock used in filling the vessel should be closed immediately after filling the calibration vessel and not opened until the test is complete.

SUMMARY OF CHANGES

Committee C09 has identified the location of selected changes to this standard since the last issue (C231/C231M – 17) that may impact the use of this standard. (Approved April 15, 2017.)

(1) Section 11.1.1 was revised.
(2) Added new Section 11.2 to include precision information on the Type B meter.
(3) Revised Note 14.
(4) Renumbered Section on Bias to 11.3.

Committee C09 has identified the location of selected changes to this standard since the last issue (C231/C231M – 14) that may impact the use of this standard. (Approved Feb. 1, 2017.)

(1) Revised 8.3.1 to remove bulb syringe.
(2) Added new Note 11.

Designation: C1064/C1064M – 17

Standard Test Method for Temperature of Freshly Mixed Hydraulic-Cement Concrete[1]

This standard is issued under the fixed designation C1064/C1064M; 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 the determination of temperature of freshly mixed hydraulic-cement concrete.

1.2 The values stated in either SI 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.

1.3 The text of this standard references notes and footnotes that provide explanatory information. 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.* (**Warning**—Fresh hydraulic cementitious mixtures are caustic and may cause chemical burns to skin and tissue upon prolonged exposure.[2])

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:*[3]

C125 Terminology Relating to Concrete and Concrete Aggregates

C172/C172M Practice for Sampling Freshly Mixed Concrete

C670 Practice for Preparing Precision and Bias Statements for Test Methods for Construction Materials

3. Terminology

3.1 For definitions of the terms used in this test method, refer to Terminology C125.

4. Significance and Use

4.1 This test method provides a means for measuring the temperature of freshly mixed concrete. The measured temperature represents the temperature at the time of testing and may not be an indication of the temperature of the freshly mixed concrete at a later time. It may be used to verify conformance to a specified requirement for temperature of concrete.

4.2 Concrete containing aggregate of a nominal maximum size greater than 75 mm [3 in.] may require up to 20 min for the transfer of heat from aggregate to mortar. (See ACI Committee 207.1R Report.[4])

5. Apparatus

5.1 *Container,* shall be large enough to provide at least 75 mm [3 in.] of concrete in all directions around the sensor of the temperature measuring device; concrete cover must also be at least three times the nominal maximum size of the coarse aggregate.

5.2 *Temperature Measuring Device,* shall be capable of accurately measuring the temperature of the freshly mixed concrete to ± 0.5 °C [±1 °F] throughout a range of 0° to 50 °C [30° to 120 °F]. The design of the temperature measuring device shall be such that it allows 75 mm [3 in.] or more immersion during operation.

5.3 Partial immersion liquid-in-glass thermometers (and possibly other types) shall have a permanent mark to which the device must be immersed without applying a correction factor.

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

Current edition approved Oct. 1, 2017. Published October 2017. Originally approved in 1986. Last previous edition approved in 2012 as C1064/C1064M–12. DOI: 10.1520/C1064_C1064M-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.

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

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

5.4 *Reference Temperature Measuring Device,* shall be readable and accurate to ± 0.2 °C [0.5 °F] at the verification points in 6.1. A certificate or report that verifies the accuracy shall be available in the laboratory for review. Accuracy of liquid-in-glass reference temperature measuring devices shall be verified once. Verification of direct-reading resistance reference temperature measuring devices shall be performed at least every twelve months. The certificate or report shall provide documentation that the reference standard used in the verification is traceable to the National Institute of Standards and Technology (NIST).

6. Verification of the Accuracy of Temperature Measuring Devices

6.1 The accuracy of each temperature measuring device used for determining the temperature of freshly mixed concrete shall be verified at least annually, or whenever there is a question of accuracy. Verify the accuracy of the temperature measuring device by comparing the readings of the reference temperature measuring device to the temperature measuring device at two temperatures at least 15 °C [30 °F] apart.

6.2 Verification of the accuracy of the temperature measuring devices may be made in oil or other suitable bath liquids having uniform density if provision is made to:

6.2.1 Maintain the bath temperature constant within 0.2 °C [0.5 °F] during the verification process.

6.2.2 Continuously circulate the bath liquid to provide a uniform temperature throughout the bath.

6.2.3 Suspend the temperature measuring devices in such a manner that the devices are not contacting the sides or bottom of the bath container during verification.

6.3 Place both the temperature and reference temperature measuring devices in the bath for at least 5 min before reading temperatures at the test points specified in 6.1.

6.4 Prior to reading the temperature measuring devices, if the temperature in the bath has been reduced, slightly tap thermometers containing liquid to avoid adhesion of the liquid to the glass.

6.5 Read and record the temperature of both the reference temperature measuring device and the temperature measuring device. Reject the temperature measuring device if the difference in readings exceeds 0.5 °C [1 °F] at either test point. If the indicator of the rejected temperature measuring device is adjustable, reverification is permitted after adjustment. In addition to the temperature readings, record the identification numbers of both devices used, the date verified, and the name of individual performing the verification.

7. Sampling Concrete

7.1 It is acceptable to measure the temperature of freshly mixed concrete in either the transporting equipment or the forms after discharge provided the sensor of the temperature measuring device has at least 75 mm [3 in.] of concrete cover in all directions.

7.2 If the transporting equipment or placement forms are not used as the container, a sample shall be prepared as follows:

7.2.1 Immediately, prior to sampling the freshly mixed concrete, dampen (with water) the sample container.

7.2.2 Sample the freshly mixed concrete in accordance with Practice C172/C172M, except that composite samples are not required if the only purpose for obtaining the sample is to determine temperature.

7.2.3 Place the freshly mixed concrete into the container.

8. Procedure

8.1 Position the temperature measuring device so that the end of the temperature sensing portion is submerged a minimum of 75 mm [3 in.] into the freshly mixed concrete. Close the void left by the placement by gently pressing the concrete around the temperature measuring device at the surface of the concrete to prevent ambient air temperature from affecting the reading.

8.2 Leave the temperature measuring device in the freshly mixed concrete for at least 2 min but not more than 5 min, then read and record the temperature to the nearest 0.5 °C [1 °F]. Do not remove the device from the concrete when reading the temperature.

9. Report

9.1 Report the measured temperature of the freshly mixed concrete to the nearest 0.5 °C [1 °F].

10. Precision and Bias

10.1 The data used to develop the precision statement were obtained using the inch-pound version of this test method. The precision indices shown in SI units are conversions of the values in brackets.

10.2 The single operator standard deviation for measurement of concrete temperature has been found to be 0.3 °C [0.5 °F]. [5] Therefore, results of two properly conducted tests by the same operator on the same sample of material should not differ by more than 0.7 °C [1.3 °F]. [5]

10.3 The multi-operator standard deviation for the measurement of concrete temperature on the same sample has been found to be 0.4 °C [0.7 °F]. [5] Therefore, two tests properly conducted by different operators but on the same material should not differ by more than 1.1 °C [1.9 °F]. [5]

10.4 The precision values given were derived from an inter-laboratory study using 11 operators on two concrete batches at around 24 °C [75 °F]. [6]

10.5 Since there is no accepted reference material suitable for determining the bias of this test method, no statement on bias is being made.

11. Keywords

11.1 freshly mixed concrete; temperature; temperature measuring device

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

[6] Supporting data have been filed at ASTM International Headquarters and may be obtained by requesting Research Report RR:C09-1028.

SUMMARY OF CHANGES

Committee C09 has identified the location of selected changes to this specification since the last issue, C1064/C1064M–12, that may impact the use of this specification. (Approved October 1, 2017)

(1) Added Terminology (Section 3).
(2) Revised 5.4 to add the wording "at least."
(3) Revised 6.1 to add the wording "at least."