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

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This standard has been approved for use by agencies of the 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])

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 Specification for Portland Cement
C172 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 Test Method for Air Content of Freshly Mixed Concrete by the Pressure Method

3. Terminology

3.1 *Symbols:*

A = air content (percentage of voids) in the concrete
~~C = actual cement content, lb/yd^3 or kg/m^3~~
~~C_b = mass of cement in the batch, lb or kg~~

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

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

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

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

~~D = density (unit weight) of concrete, lb/ft^3 or kg/m^3~~
~~M = total mass of all materials batched, lb or kg (see Note 3)~~
~~M_c = mass of the measure filled with concrete, lb or kg~~
~~M_m = mass of the measure, lb or kg~~
R_y = relative yield
~~T = theoretical density of the concrete computed on an airfree basis, lb/ft^3 or kg/m^3 (see Note 2)~~
~~Y = yield, volume of concrete produced per batch, yd^3 or m^3~~
~~Y_d = volume of concrete which the batch was designed to produce, yd^3 or m^3~~
~~Y_f = volume of concrete produced per batch, ft^3~~
~~V = total absolute volume of the component ingredients in the batch, ft^3 or m^3~~
~~V_m = volume of the measure, ft^3 or m^3~~

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)
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. ~~It is calculated from the following equation:~~

~~$$T = M/V \quad (1)$$~~

~~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 specific gravity times 62.4. The absolute volume of each ingredient in cubic metres is equal to the mass of the ingredient in kilograms divided by 1000 times its specific gravity. For the aggregate components, the bulk specific gravity and mass should be based on the saturated, surface-dry condition. For cement, the actual specific gravity should be determined by Test Method C188. A value of 3.15 may be used for cements manufactured to meet the requirements of Specification C150.~~

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 ~~0.1 lb [45 g]~~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 ~~160 lb/ft~~2600 kg/m^3 ~~[2600 kg/m~~ [160 lb/ft^3].

4.2 *Tamping Rod*—A round, smooth, straight steel rod, with a 16 mm [⅝ ~~in. [16 mm] ±~~ in.] ± 2 mm [1⁄16 ~~in. [2 mm]~~ in.] diameter. The length of the tamping rod shall be at least ~~4 in. [100 mm]~~100 mm [4 in.] greater than the depth of the measure in which rodding is being performed, but not greater than ~~24 in. [600 mm]~~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 ~~16 in. [400 mm] to 24 in. [600 mm]~~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.

4.3 *Internal Vibrator*—Internal vibrators may have rigid or flexible shafts, preferably powered by electric motors. The frequency of vibration shall be 7000 vibrations per minute or greater while in use. The outside diameter or the side dimension of the vibrating element shall be at least ~~0.75 in. [19 mm]~~19 mm [0.75 in.] and not greater than ~~1.50 in. [38 mm].~~38 mm [1.50 in.]. The length of the shaft shall be at least ~~24 in. [600 mm].~~600 mm [24 in.].

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, 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.

TABLE 1 Capacity of Measures

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

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.

NOTE 6—The top rim is satisfactorily plane if a ~~0.01-in. [0.3-mm]~~0.3-mm [0.01-in.] feeler gage cannot be inserted between the rim and a piece of ~~¼-in. [6-mm]~~6-mm [¼-in.] or thicker plate glass laid over the top of the measure.

4.5 *Strike-Off Plate*—A flat rectangular metal plate at least 6 mm [¼ ~~in. [6 mm]~~in.] thick or a glass or acrylic plate at least 12 mm [½ ~~in. [12 mm]~~in.] thick with a length and width at least ~~2 in. [50 mm]~~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. [2 mm]~~.in.].

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

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 ~~3 in. [75 mm]~~.75 mm [3 in.]. Rod or vibrate concrete with a slump of ~~1 to 3 in. [25 to 75 mm]~~.25 to 75 mm [1 to 3 in.]. Consolidate concretes with a slump less than ~~1 in.~~ 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 place it 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).

6.3 *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 ~~0.5-ft~~14-L ~~[14-L]~~ [0.5-ft^3] or smaller measures are used, 50 strokes when nominal ~~1-ft~~28-L ~~[28-L]~~ [1-ft^3] measures are used, and one stroke per ~~3 in.~~20 cm^2 ~~[20 cm~~[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 ~~1 in. [25 mm]~~.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