



# Standard Test Method for Density (Unit Weight), Yield, and Air Content (Gravimetric) of Concrete<sup>1</sup>

This standard is issued under the fixed designation C 138/C 138M; 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 reappraisal. A superscript epsilon ( $\epsilon$ ) indicates an editorial change since the last revision or reappraisal.

*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 inch-pound or SI units shall be regarded separately as standard. The SI units are shown in brackets. The values stated might not be exact equivalents; therefore each system must be used independently of the other.

**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.

## 2. Referenced Documents

- 2.1 *ASTM Standards*:<sup>2</sup>
- C 29/C 29M** Test Method for Bulk Density (“Unit Weight”) and Voids in Aggregate
  - C 150** Specification for Portland Cement
  - C 172** Practice for Sampling Freshly Mixed Concrete
  - C 188** Test Method for Density of Hydraulic Cement
  - C 231** Test Method for Air Content of Freshly Mixed Concrete by the Pressure Method

## 3. Terminology

### 3.1 Symbols:

<sup>1</sup> 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.

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<sup>2</sup> 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.

- $A$  = air content (percentage of voids) in the concrete
- $C$  = actual cement content, lb/yd<sup>3</sup> or kg/m<sup>3</sup>
- $C_b$  = mass of cement in the batch, lb or kg
- $D$  = density (unit weight) of concrete, lb/ft<sup>3</sup> or kg/m<sup>3</sup>
- $M$  = 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<sup>3</sup> or kg/m<sup>3</sup> (see **Note 2**)
- $Y$  = yield, volume of concrete produced per batch, yd<sup>3</sup> or m<sup>3</sup>
- $Y_d$  = volume of concrete which the batch was designed to produce, yd<sup>3</sup> or m<sup>3</sup>
- $Y_f$  = volume of concrete produced per batch, ft<sup>3</sup>
- $V$  = total absolute volume of the component ingredients in the batch, ft<sup>3</sup> or m<sup>3</sup>
- $V_m$  = volume of the measure, ft<sup>3</sup> or m<sup>3</sup>

**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 **C 188**. A value of 3.15 may be used for cements manufactured to meet the requirements of Specification **C 150**.

**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.

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

#### 4. Apparatus

4.1 *Balance*—A balance or scale accurate to 0.1 lb [45 g] 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<sup>3</sup> [2600 kg/m<sup>3</sup>].

4.2 *Tamping Rod*—A round, straight steel rod, 5/8 in. [16 mm] in diameter and approximately 24 in. [600 mm] in length, having the tamping end rounded to a hemispherical tip the diameter of which is 5/8 in.

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] and not greater than 1.50 in. [38 mm]. The length of the shaft shall be at least 24 in. [600 mm].

4.4 *Measure*—A cylindrical container made of steel or other suitable metal (see **Note 4**). 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 C 138/C 138M tests, shall conform to the requirements of Test Method C 29/C 29M. When measuring bowls of air meters are used, they shall conform to the requirements of Test Method C 231, and shall be calibrated for volume as described in Test Method C 29/C 29M. The top rim of the air meter bowls shall be smooth and plane within 0.01 in. [0.3 mm] (see **Note 5**).

**NOTE 4**—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 5**—The top rim is satisfactorily plane if a 0.01-in. [0.3-mm] feeler gage cannot be inserted between the rim and a piece of 1/4-in. [6-mm] or thicker plate glass laid over the top of the measure.

4.5 *Strike-Off Plate*—A flat rectangular metal plate at least 1/4 in. [6 mm] thick or a glass or acrylic plate at least 1/2 in. [12 mm] thick with a length and width at least 2 in. [50 mm] 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 1/16 in. [2 mm].

4.6 *Mallet*—A mallet (with a rubber or rawhide head) having a mass of 1.25 ± 0.50 lb [600 ± 200 g] for use with

measures of 0.5 ft<sup>3</sup> [14 L] or smaller, and a mallet having a mass of 2.25 ± 0.50 lb [1000 ± 200 g] for use with measures larger than 0.5 ft<sup>3</sup>.

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 C 172.

#### 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]. Rod or vibrate concrete with a slump of 1 to 3 in. [25 to 75 mm]. Consolidate concretes with a slump less than 1 in. by vibration.

**NOTE 6**—Nonplastic concrete, such as is commonly used in the manufacture of pipe and unit masonry, is not covered by this test method.

6.2 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<sup>3</sup> [14-L] or smaller measures are used, 50 strokes when nominal 1-ft<sup>3</sup> [28-L] measures are used, and one stroke per 3 in.<sup>2</sup> [20 cm<sup>2</sup>] of surface for larger measures. Rod the bottom layer through-out its depth but the rod shall not forcibly strike the bottom of the measure. Distribute the strokes uniformly over the cross section of the measure and for the top two layers, penetrate about 1 in. [25 mm] into the underlying layer. 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 1 in. [25 mm]. 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 7**). Continue vibration only long enough to achieve proper consolidation of the concrete (see **Note 8**). Observe a constant duration of vibration for the particular kind of concrete, vibrator, and measure involved.

**NOTE 7**—Usually, sufficient vibration has been applied as soon as the

**TABLE 1 Capacity of Measures**

Nominal Maximum Size of Coarse Aggregate		Capacity of Measure <sup>A</sup>	
in.	mm	ft <sup>3</sup>	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

<sup>A</sup> 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.