



# 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 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 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.

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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>

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 <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

<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 Summary of Changes section appears at the end of this standard.

- $R_y$  = 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>  
 $\bar{V}$  = 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:

$$(1) \quad T = M/\bar{V}$$

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] 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, with a 5/8 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 measure in which rodding is being performed, but not greater than 24 in. [600 mm] in overall length (See Note 4). The length tolerance for the tamping rod shall be ± 1/8 in. [4 mm]. 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.

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 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.

NOTE 6—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

**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.