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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 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 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 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:* [2]

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*:

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

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

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.

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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.

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

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

4. 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^3 [2600 kg/m^3].

4.2 *Tamping Rod*—A round, straight steel rod, ⅝ 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 ⅝ 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 ¼-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 ¼ in. [6 mm] thick or a glass or acrylic plate at least ½ 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^3 [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^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.

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

[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.

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^3 [14-L] or smaller measures are used, 50 strokes when nominal 1-ft^3 [28-L] measures are used, and one stroke per 3 in.^{2} [20 cm^3] of surface for larger measures. Rod the bottom layer throughout 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 surface of the concrete becomes relatively smooth.

NOTE 8—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 ⅛ in. [3 mm] 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 with the flat strike-off plate using great care to leave the measure just level full. The strike-off is best accomplished by pressing the strike-off plate on the top surface of the measure to cover about two thirds of the surface and withdrawing 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. Several final strokes with the inclined edge of the plate will produce a smooth finished 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, ft^3 or yd^3,by dividing the net mass of concrete by the volume of the measure, V_m as follows:

$$D = (M_c - M_m)/V_m \quad (2)$$

7.2 *Yield*—Calculate the yield as follows:

$$Y(yd^3) = M/(D \times 27) \quad (3)$$

or

$$Y(m^3) = M/D \quad (4)$$

7.3 *Relative Yield*—Relative yield is the ratio of the actual volume of concrete obtained to the volume as designed for the batch (see Note 9) calculated as follows:

$$R_y = Y/Y_d \quad (5)$$

NOTE 9—A value for R_y greater than 1.00 indicates an excess of concrete being produced whereas a value less than this indicates the batch to be "short" of its designed volume. In practice, 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.

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

$$C = C_b/Y \quad (6)$$

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

$$A = [(T - D)/T] \times 100 \quad (7)$$

or

$$A = [(Y_f - V)/Y_f] \times 100 \text{ (inch-pound units)} \quad (8)$$

or

$$A = [(Y - V)/Y] \times 100 \text{ (SI units)} \quad (9)$$

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 0.001 ft^3 [0.01 L].

8.1.4 Density (Unit Weight) to the nearest 0.1 lbs/ft^3 [1.0 kg/m^3].

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

8.1.6 Relative Yield, when requested, to the nearest 0.01.

8.1.7 Cement Content, when requested, to the nearest 1.0 lb [0.5 kg].

8.1.8 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.[3] The data represent concrete mixtures with slump ranging from 3 to 6 in. [75 to 150 mm] and density ranging from 115 to 155 lb/ft^3 [1842 to 2483 kg/m^3] and included air-entrained and non air-entrained concrete. The study was conducted using 0.25 ft^3 [7-L] and 0.5 ft^3 [14-L] 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 0.82 lb/ft^3 [13.1 kg/m^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 2.31 lb/ft^3 [37.0 kg/m^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

[3] Mullings, G. M., NRMCA/NAA Joint Research Lab Study "Series D 324 Accuracy of Concrete Density Test," Feb. 17, 2000.

SUMMARY OF CHANGES

Committee C09 has identified the location of selected changes to this test method since the last issue, C 138/C 138M – 07, that may impact the use of this test method. (Approved March 1, 2008)

(*1*) Added new 4.7 to define a scoop.

(*2*) Added new 6.2 to describe how to use a scoop.

Committee C09 has identified the location of selected changes to this test method since the last issue, C 138/C 138M – 01a, that may impact the use of this test method. (Approved August 15, 2007)

(*1*) Added new Section 8.