



Standard Test Method for Bulk Density (“Unit Weight”) and Voids in Aggregate¹

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 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 must be used independently of the other, without combining values in any way.~~ 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.*

2. Referenced Documents

2.1 ASTM Standards:²

C125 Terminology Relating to Concrete and Concrete Aggregates

C127 Test Method for Density, Relative Density (Specific Gravity), and Absorption of Coarse Aggregate

C128 Test Method for Density, Relative Density (Specific Gravity), and Absorption of Fine Aggregate

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

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

C702 Practice for Reducing Samples of Aggregate to Testing Size

D75 Practice for Sampling Aggregates

D123 Terminology Relating to Textiles

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 Aggregate³

3. Terminology

3.1 *Definitions*—Definitions are in accordance with Terminology C125 unless otherwise indicated.

3.1.1 *bulk density, n*—of aggregate, the mass of a unit volume of bulk aggregate material, in which the volume includes the volume of the individual particles and the volume of the voids between the particles. Expressed in kg/m^3 [lb/ft^3].

3.1.2 *unit weight, n*—weight (mass) per unit volume. (Deprecated term used—preferred term **bulk density**.)

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

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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.

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.

3.1.2.1 *Discussion*—Weight is equal to the mass of the body multiplied by the acceleration due to gravity. Weight may be expressed in absolute units (newtons, poundals) or in gravitational units (kgf, lbf), for example: on the surface of the earth, a body with a mass of 1 kg has a weight of 1 kgf (approximately 9.81 N), or a body with a mass of 1 lb has a weight of 1 lbf (approximately 4.45 N or 32.2 poundals). Since weight is equal to mass times the acceleration due to gravity, the weight of a body will vary with the location where the weight is determined, while the mass of the body remains constant. On the surface of the earth, the force of gravity imparts to a body that is free to fall an acceleration of approximately 9.81 m/s² [32.2 ft/s²]. **D123**

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.

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 within 0.1 % of the test load at any point within the range of use, graduated to at least 0.05 kg [0.1 lb]. 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/m³ [120 lb/ft³].

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

5.3 *Measure*—A cylindrical metal measure, preferably provided with handles. It shall be watertight, with the top and bottom true and even, and sufficiently rigid to retain its form under rough usage. The measure shall have a height approximately equal to the diameter, but in no case shall the height be less than 80 % nor 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 0.25 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.

NOTE 2—The top rim is satisfactorily plane if a 0.25-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 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 If the measure is to also be used for testing for bulk density of freshly-mixed concrete according to Test Method C138/C138M, the measure shall be made of steel or other suitable metal not readily subject to attack by cement paste. Reactive materials, such as aluminum alloys are permitted, where as a consequence of an initial reaction, a surface film is formed which protects the metal against further corrosion.

5.3.2 Measures larger than nominal 28 L [1 ft³] capacity shall be made of steel for rigidity, or the minimum thicknesses of metal listed in Table 2 shall be suitably increased.

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

5.5 *Calibration Equipment:*

5.5.1 *Plate Glass*—A piece of plate glass, preferably at least 6 mm [¹/₄ in.] thick and at least 25 mm [1 in.] larger than the diameter of the measure to be calibrated.

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] | ¼ 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

| Capacity of Measure | Thickness of Metal, min | | |
|---|-------------------------|--|-------------------|
| | Bottom | Upper 38 mm or 1½ in. of wall ^A | Remainder of wall |
| 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 |
| 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.

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, and reduce to test sample size in accordance with Practice C702.

7. Test Sample

7.1 The size of the sample shall be approximately 125 to 200 % of the quantity required to fill the measure, and shall be handled in a manner to avoid segregation. Dry the aggregate sample to essentially constant mass, preferably in an oven at 110 ± 5 °C [230 ± 9 °F].

8. Calibration of Measure

8.1 Measures shall be recalibrated at least once a year or whenever there is reason to question the accuracy of the calibration.

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.

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

NOTE 3—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/m³. However, for convenience the size of the measure may be expressed in litres.

9. Selection of Procedure

9.1 The shoveling procedure for loose bulk density shall be used only when specifically stipulated. Otherwise, the compact bulk density shall be determined by the rodding procedure for aggregates having a nominal maximum size of 37.5 mm [1½ in.] or less, or by the jiggling procedure for aggregates having a nominal maximum size greater than 37.5 mm [1½ in.] and not exceeding 125 mm [5 in.].

10. Rodding Procedure

10.1 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

TABLE 3 Density of Water

| Temperature | | kg/m ³ | lb/ft ³ |
|-------------|------|-------------------|--------------------|
| °C | °F | | |
| 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 |