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American Association of State
Highway and Transportation Officials Standard
AASHTO No.: T19/T19M

Standard Test Method for Bulk Density ("Unit Weight") and Voids in Aggregate[1]

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 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 Aggregate[3]

3. Terminology

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

3.2 *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].

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

3.3.1 *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

[1] This test method is under the jurisdiction of ASTM Committee C09 on Concrete and Concrete Aggregatesand 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**

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/s^2 [32.2 ft/s^2]. D123

3.4 *Definitions of Terms Specific to This Standard:*

3.4.1 *voids, n—in unit volume of aggregate,* the space between particles in an aggregate mass not occupied by solid mineral matter.

3.4.1.1 *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/m^3 [120 lb/ft^3].

5.2 *Tamping Rod*—A round, straight steel rod, 16 mm [⅝ 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 [⅝ 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.

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]	1/10
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.

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 [¼-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 ft^3] 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, at least 6 mm [¼ in.] thick and at least 25 mm [1 in.] larger than the diameter of the measure to be calibrated.

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].

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.

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 $1/m^3$. 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 jigging 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 measure to overflowing and rod again in the manner previously mentioned. Level the surface of the aggregate with the fingers or a straightedge in such a way that any slight projections of the larger pieces of the coarse aggregate approximately balance the larger voids in the surface below the top of the measure.

TABLE 3 Density of Water

Temperature		kg/m³	lb/ft³
°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

10.2 In rodding the first layer, do not allow the rod to strike the bottom of the measure forcibly. In rodding the second and third layers, use vigorous effort, but not more force than to cause the tamping rod to penetrate to the previous layer of aggregate.

NOTE 4—In rodding the larger sizes of coarse aggregate, it may not be possible to penetrate the layer being consolidated, especially with angular aggregates. The intent of the procedure will be accomplished if vigorous effort is used.

10.3 Determine the mass of the measure plus its contents, and the mass of the measure alone, and record the values to the nearest 0.05 kg [0.1 lb].

11. Jigging Procedure

11.1 Fill the measure in three approximately equal layers as described in 10.1, compacting each layer by placing the measure on a firm base, such as a cement-concrete floor, raising the opposite sides alternately about 50 mm [2 in.], and allowing the measure to drop in such a manner as to hit with a sharp, slapping blow. The aggregate particles, by this procedure, will arrange themselves in a densely compacted condition. Compact each layer by dropping the measure 50 times in the manner described, 25 times on each side. Level the surface of the aggregate with the fingers or a straightedge in such a way that any slight projections of the larger pieces of the coarse aggregate approximately balance the larger voids in the surface below the top of the measure.

11.2 Determine the mass of the measure plus its contents, and the mass of the measure alone, and record the values to the nearest 0.05 kg [0.1 lb].

12. Shoveling Procedure

12.1 Fill the measure to overflowing by means of a shovel or scoop, discharging the aggregate from a height not to exceed 50 mm [2 in.] above the top of the measure. Exercise care to prevent, so far as possible, segregation of the particle sizes of which the sample is composed. Level the surface of the aggregate with the fingers or a straightedge in such a way that any slight projections of the larger pieces of the coarse aggregate approximately balance the larger voids in the surface below the top of the measure.

12.2 Determine the mass of the measure plus its contents, and the mass of the measure alone, and record the values to the nearest 0.05 kg [0.1 lb].

13. Calculation

13.1 *Bulk Density*—Calculate the bulk density for the rodding, jigging, or shoveling procedure as follows:

$$M = (G - T)/V \quad (1)$$

or

$$M = (G - T) \times F \quad (2)$$

where:

M = bulk density of the aggregate, kg/m³ [lb/ft³],
G = mass of the aggregate plus the measure, kg [lb],
T = mass of the measure, kg [lb],

V = volume of the measure, m^3 [ft^3], and
F = factor for measure, m^{-3} [ft^{-3}].

13.1.1 The bulk density determined by this test method is for aggregate in an oven-dry condition. If the bulk density in terms of saturated-surface-dry (SSD) condition is desired, use the exact procedure in this test method, and then calculate the SSD bulk density using the following formula:

$$Mssd = M[1 + (A/100)] \quad (3)$$

where:

M_{SSD} = bulk density in SSD condition, kg/m^3 [lb/ft^3], and
A = % absorption, determined in accordance with Test Method C127 or Test Method C128.

13.2 *Void Content*—Calculate the void content in the aggregate using the bulk density determined by either the rodding, jigging, or shoveling procedure, as follows:

$$\%\ Voids = 100[(S \times W) - M]/(S \times W) \quad (4)$$

where:

M = bulk density of the aggregate, kg/m^3 [lb/ft^3],
S = bulk specific gravity (dry basis) as determined in accordance with Test Method C127 or Test Method C128, and
W = density of water, 998 kg/m^3 [62.3 lb/ft^3].

13.3 *Volume of Measure*—Calculate the volume of a measure as follows:

$$V = (W - M)/D \quad (5)$$

$$F = D/(W - M) \quad (6)$$

where:

V = volume of the measure, m^3 [ft^3]
W = mass of the water, plate glass, and measure, kg [lb]
M = mass of the plate glass and measure, kg [lb]
D = density of the water for the measured temperature, kg/m^3 [lb/ft^3], and
F = factor for the measure, $1/m^3$ [$1/ft^3$]

14. Report

14.1 Report the results for the bulk density to the nearest 10 kg/m^3 [1 lb/ft^3] as follows:

14.1.1 Bulk density by rodding, or
14.1.2 Bulk density by jigging, or
14.1.3 Loose bulk density.

14.2 Report the results for the void content to the nearest 1 % as follows:

14.2.1 Voids in aggregate compacted by rodding, %, or
14.2.2 Voids in aggregate compacted by jigging, %, or
14.2.3 Voids in loose aggregate, %.

15. Precision and Bias

15.1 The following estimates of precision for this test method are based on results from the AASHTO Materials Reference Laboratory (AMRL) Proficiency Sample Program, with testing conducted using this test method and AASHTO Method T 19/T19M. There are no significant differences between the two test methods. The data are based on the analyses of more than 100 paired test results from 40 to 100 laboratories.

15.2 *Coarse Aggregate (bulk density):*

15.2.1 *Single-Operator Precision*—The single-operator standard deviation has been found to be 14 kg/m^3 [0.88 lb/ft^3] (1s). Therefore, results of two properly conducted tests by the same operator on similar material should not differ by more than 40 kg/m^3 [2.5 lb/ft^3] (d2s).

15.2.2 *Multilaboratory Precision*—The multilaboratory standard deviation has been found to be 30 kg/m^3 [1.87 lb/ft^3] (1s). Therefore, results of two properly conducted tests from two different laboratories on similar material should not differ by more than 85 kg/m^3 [5.3 lb/ft^3] (d2s).

15.2.3 These numbers represent, respectively, the (1s) and (d2s) limits as described in Practice C670. The precision estimates were obtained from the analysis of AMRL proficiency sample data for bulk density by rodding of normal weight aggregates having a nominal maximum aggregate size of 25.0 mm [1 in.], and using a 14-L [½-ft^3] measure.

15.3 *Fine Aggregate (bulk density):*

15.3.1 *Single-Operator Precision*—The single-operator standard deviation has been found to be 14 kg/m^3 [0.88 lb/ft^3] (1s). Therefore, results of two properly conducted tests by the same operator on similar material should not differ by more than 40 kg/m^3 [2.5 lb/ft^3] (d2s).

15.3.2 *Multilaboratory Precision*—The multilaboratory standard deviation has been found to be 44 kg/m^3 [2.76 lb/ft^3] (1s). Therefore, results of two properly conducted tests from two different laboratories on similar material should not differ by more than 125 kg/m^3 [7.8 lb/ft^3] (d2s).

15.3.3 These numbers represent, respectively, the (1s) and (d2s) limits as described in Practice C670. The precision estimates were obtained from the analysis of AMRL proficiency sample data for loose bulk density from laboratories using a 2.8-L [1/10-ft^3] measure.

15.4 No precision data on void content are available. However, as the void content in aggregate is calculated from bulk density and bulk specific gravity, the precision of the voids content reflects the precision of these measured parameters given in 15.2 and 15.3 of this test method and in Test Methods C127 and C128.

15.5 *Bias*—The procedure in this test method for measuring bulk density and void content has no bias because the values for bulk density and void content can be defined only in terms of a test method.

16. Keywords

16.1 aggregates; bulk density; coarse aggregate; density; fine aggregate; unit weight; voids in aggregates

SUMMARY OF CHANGES

Committee C09 has identified the location of selected changes to this test method since the last issue, C29/C29M – 07, that may impact the use of this test method. (Approved December 1, 2009)

(*1*) Revised 5.5.1.