Designation: C29/C29M – 17a

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 U.S. 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.*

1.4 *This international standard was developed in accordance with internationally recognized principles on standardization established in the Decision on Principles for the Development of International Standards, Guides and Recommendations issued by the World Trade Organization Technical Barriers to Trade (TBT) Committee.*

2. Referenced Documents

2.1 *ASTM Standards:*[2]

C125 Terminology Relating to Concrete and Concrete Aggregates

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

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

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

C702/C702M Practice for Reducing Samples of Aggregate to Testing Size

C1077 Practice for Agencies Testing Concrete and Concrete Aggregates for Use in Construction and Criteria for Testing Agency Evaluation

D75/D75M Practice for Sampling Aggregates

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*—The terms used in this test method are defined in Terminology C125.

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.

[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**

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 to within 0.05 kg [0.1 lb] or to within 0.1% 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 1920 kg/m^3 [120 lb/ft^3].

5.2 *Tamping Rod*—A round, plain steel rod with a diameter of 16 ± 2 mm [⅝ ± 1/16 in.]. The length of the tamping rod shall be at least 100 mm [4 in.] greater than the depth of the measure or mold in which rodding is being performed, but not greater than 750 mm [30 in.] in overall length (see Note 2). The rod shall have the tamping end, or both ends, rounded to a hemispherical tip of the same diameter as the rod. The rod shall be straight over its length to a tolerance of 0.5 % of its length.

5.3 *Measure*—A cylindrical container made of steel or other suitable metal that complies with the requirements of this section, preferably provided with handles. The measure shall be watertight and sufficiently rigid to retain its form under rough usage. The measure shall have a height at least 80 % and not 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 0.3 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.

TABLE 2 Requirements for Measures

Units	Capacity of Measure	Thickness of Metal, min		
		Bottom	Upper 38 mm or 1½ in. of wall[A]	Remainder of wall
SI	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
Inch-pound	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.

NOTE 2—The top rim is satisfactorily plane if a 0.3-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 Measures larger than nominal 28 L [1 ft^3] capacity shall be made of steel.

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

5.5 *Equipment for Measuring Volume of Measure:*

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/D75M, and reduce to test sample size in accordance with Practice C702/C702M.

7. Test Sample

7.1 The size of the test sample shall be between 125 and 200 % of the quantity required to fill the measure, and shall be handled in a manner to avoid segregation.

7.2 Dry the aggregate sample to constant mass in an oven at 110 ± 5 °C [230 ± 10 °F]. The sample is considered to be at constant mass when the difference in mass between two consecutive weighings taken one hour apart is less than 0.1% of the last weighing.

NOTE 3—Alternative means of drying are sometimes chosen for quick determinations where rapid results are desired or if an oven is not available. Alternative drying methods should not cause fracturing of particles or chemical breakdown of the aggregate. Use of alternative drying methods does not conform with this test method.

8. Determination of Volume of Measure

8.1 Determine the volume of the measure upon initial use and subsequently at a frequency not to exceed twelve months, or whenever there is reason to question the accuracy of the volumetric capacity of the measure. If required, retain a record of volume determination in accordance with Practice C1077.

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.

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

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

NOTE 4—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. Procedure

9.1 Determine and record the mass of the empty measure to the nearest 0.05 kg [0.1 lb].

9.2 To determine the compacted bulk density of aggregates having a nominal maximum size of 37.5 mm [1½ in.] or less, consolidate the sample in the measure using *Method A—Rodding*; use *Method B—Jigging* for aggregates having a nominal maximum size greater than 37.5 mm [1½ in.] and not exceeding 125 mm [5 in.]. To determine the loose bulk density of the aggregate, when stipulated, fill the measure by *Method C—Shoveling*.

9.2.1 *Method A—Rodding:*

9.2.1.1 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.

9.2.1.2 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 5—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.

9.2.2 *Method B—Jigging:*

9.2.2.1 Fill the measure in three approximately equal layers as described in 9.2.1.1, 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.

9.2.3 *Method C—Shoveling:*

9.2.3.1 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.

9.3 Determine and record the mass of the measure plus its contents to the nearest 0.05 kg [0.1 lb].

10. Calculation

10.1 *Bulk Density*—Calculate the bulk density as follows:

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

or

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

where:

M = bulk density of the aggregate, kg/m^3 [lb/ft^3],
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}].

10.1.1 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.

10.2 *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].

10.3 *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]

11. Report

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

11.1.1 Bulk density consolidated by *Method A—Rodding*, or

11.1.2 Bulk density consolidated by *Method B—Jigging*, or

11.1.3 Loose bulk density by *Method C—Shoveling*.

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

11.2.1 Voids in aggregate consolidated by *Method A—Rodding*, %, or

11.2.2 Voids in aggregate consolidated by *Method B—Jigging*, %, or

11.2.3 Voids in loose aggregate by *Method C—Shoveling*, %.

12. Precision and Bias

12.1 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.

12.2 *Coarse Aggregate (bulk density):*

12.2.1 *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).

12.2.2 *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).

12.2.3 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.

12.3 *Fine Aggregate (bulk density):*

12.3.1 *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).

12.3.2 *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).

12.3.3 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 [⅒-ft^3] measure.

12.4 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 12.2 and 12.3 of this test method and in Test Methods C127 and C128.

12.5 *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.

13. Keywords

13.1 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 – 17, that may impact the use of this test method. (Approved April 1, 2017.)

(1) Revised 7.1.
(2) Added 7.2 and Note 3 (renumbered subsequent Notes accordingly).
(3) Consolidated previous Sections 9, 10, 11, and 12. Revised 9, 10, and 11.

Committee C09 has identified the location of selected changes to this test method since the last issue, C29/C29M – 16, that may impact the use of this test method. (Approved Jan. 1, 2017.)

(1) Revised 5.1 – 5.3.
(2) Deleted 5.3.1 and renumbered subsequent section.
(3) Revised 8.1.