Designation: D558 – 11

Standard Test Methods for Moisture-Density (Unit Weight) Relations of Soil-Cement Mixtures [1]

This standard is issued under the fixed designation D558; 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 These test methods cover the determination of the relationship between the water content and the density of soil-cement mixtures when compacted before cement hydration as prescribed.

1.2 A 1/30-ft^3 (944-cm^3) mold and a 5.50-lbf (24.5-N or mass of 2.49-kg) rammer dropped from a height of 12.0 in. (30.5 cm) are used and two methods, depending on soil gradation, are covered, as follows:

	Sections
Test Method A, using soil material passing a No. 4 (4.75-mm) sieve. This method shall be used when 100 % of the soil sample passes the No. 4 (4.75-mm) sieve	7
Test Method B, using soil material passing a ¾-in. (19.0-mm) sieve. This method shall be used when part of the soil sample is retained on the No. 4 (4.75-mm) sieve. This test method may be used only on materials with 30 % or less retained on the ¾-in. (19.0-mm) sieve	8

1.3 All observed and calculated values shall conform to the guidelines for significant digits and rounding established in Practice D6026.

1.4 The values stated in inch-pound units are to be regarded as standard, except as noted below. The values given in parentheses are mathematical conversions to SI units that are provided for information only and are not considered standard.

1.4.1 The gravitational system of inch-pound units is used when dealing with inch-pound units. In this system, the pound (lbf) represents a unit of force (weight), while the unit for mass is slugs.

1.4.2 The slug unit of mass is almost never used in commercial practice (density, scales, balances, etc.). Therefore, the standard unit for mass in this standard is either kilogram (kg) or gram (g) or both. Also, the equivalent inch-pound unit (slug) is not given.

1.4.3 It is common practice in the engineering/construction profession to concurrently use pounds to represent both a unit of mass (lbm) and of force (lbf). This implicitly combines two separate systems of units; that is, the absolute system and the gravitational system. It is scientifically undesirable to combine the use of two separate sets of inch-pound units within a single standard. As stated in 1.4.2, this standard includes the gravitational system of inch-pound units and does not use/present the slug unit for mass. However, the use of balances or scales recording pounds of mass (lbm) or recording density in lbm/ft^3 shall not be regarded as nonconformance with this standard.

1.5 *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]

C150 Specification for Portland Cement

C595 Specification for Blended Hydraulic Cements

D559 Test Methods for Wetting and Drying Compacted Soil-Cement Mixtures (Withdrawn 2012)[3]

D560 Test Methods for Freezing and Thawing Compacted Soil-Cement Mixtures (Withdrawn 2012)[3]

D653 Terminology Relating to Soil, Rock, and Contained Fluids

D698 Test Methods for Laboratory Compaction Characteristics of Soil Using Standard Effort (12 400 ft-lbf/ft^3 (600 kN-m/m^3))

D2168 Practices for Calibration of Laboratory Mechanical-Rammer Soil Compactors

D2216 Test Methods for Laboratory Determination of Water (Moisture) Content of Soil and Rock by Mass

D3740 Practice for Minimum Requirements for Agencies Engaged in Testing and/or Inspection of Soil and Rock as Used in Engineering Design and Construction

[1] These test methods are under the jurisdiction of ASTM Committee D18 on Soil and Rock and are the direct responsibility of Subcommittee D18.15 on Stabilization With Admixtures.

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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] The last approved version of this historical standard is referenced on www.astm.org.

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

D4753 Guide for Evaluating, Selecting, and Specifying Balances and Standard Masses for Use in Soil, Rock, and Construction Materials Testing
D6026 Practice for Using Significant Digits in Geotechnical Data
E11 Specification for Woven Wire Test Sieve Cloth and Test Sieves
E145 Specification for Gravity-Convection and Forced-Ventilation Ovens

3. Terminology

3.1 For common definitions of terms used in this standard, refer to Terminology D653.

4. Significance and Use

4.1 These tests determine the optimum water content and maximum density (unit weight) to be used for molding soil-cement specimens in accordance with Test Methods D559 and D560.

NOTE 1—Since these tests are used in conjunction with Test Methods D559 and D560 and the criteria referenced therein, the test differs in several aspects from Test Method D698. There are three main differences between this standard and Test Method D698. Firstly, this standard allows a maximum particle size of ¾-in. (19.0 mm) for a 4-in. (101.6-mm) mold while Test Method D698 allows a maximum particle size of ⅜-in. (9.5-mm) for the same size mold. Secondly, this standard permits the material leftover after the water content specimen has been obtained to be mixed with the rest of the sample and reused for the next determination. Test Method D698 does not permit the material to be reused. Thirdly, this standard allows the material that is retained on the ¾-in. (19.0-mm) and passing the 3-in. (75-mm) to be discarded (scalping technique) and replaced with an equal mass of material that passes the ¾-in. (19.0-mm) sieve and is retained on the No.4 (4.75-mm) sieve. Test Method D698 does not permit the scalp and replacement technique.

NOTE 2—The quality of the result produced by this standard is dependent on the competence of the personnel performing it, and the suitability of the equipment and facilities used. Agencies that meet the criteria of Practice D3740 are generally considered capable of competent and objective testing/sampling/inspection/etc. Users of this standard are cautioned that compliance with Practice D3740 does not in itself assure reliable results. Reliable results depend on many factors; Practice D3740 provides a means of evaluating some of those factors.

5. Apparatus

5.1 *Mold*—A cylindrical metal mold having a volume of 1/30 ± 0.00040 ft^3 (944 ± 11 cm^3) with an internal diameter of 4.0 ± 0.016 in. (101.60 ± 0.41 mm) and conforming to Fig. 1 to permit preparing compacted specimens of soil-cement mixtures of this size. The mold shall be provided with a detachable collar assembly approximately 2½-in. (63.5 mm) in height. The mold may be of the split type consisting of two half-round sections or section of pipe with one side split perpendicular to the pipe circumference and that can be securely locked in place to form a closed cylinder having the dimensions described above. The mold and collar assembly shall be so constructed that it can be fastened firmly to a detachable base (Fig. 1).

5.2 *Rammer*—A rammer, either manually operated as described further in 5.2.1 or mechanically operated as described in 5.2.2. The rammer shall fall freely through a distance of 12.00 ± 0.05 in. (304.8 ± 1 mm) from the surface of the specimen. The weight of the rammer shall be 5.50 ± 0.02 lbf (24.47 ± 0.09 N, or mass of 2.495 ± 0.023 kg), except that the weight of the mechanical rammers may be adjusted as described in Practices D2168 (See Note 3). The striking face of the rammer shall be planar and circular, except as noted in 5.2.2, with a diameter when new of 2.000 ± 0.005 in. (50.80 ± 0.13 mm). The rammer shall be replaced if the striking face becomes worn or bellied to the extent that the diameter exceeds 2.000 ± 0.01 in. (50.80 ± 0.25 mm).

NOTE 3—It is a common and acceptable practice to determine the weight of the rammer using either a kilogram or pound balance and assume 1 lbf is equivalent to 0.4536 kg, 1 lbf is equivalent to 1 lbm, or 1 N is equivalent to 0.2248 lbf or 0.1020 kg.

5.2.1 *Manual Rammer*—The rammer shall be equipped with a guide sleeve that has sufficient clearance that the free fall of the rammer shaft and head is not restricted. The guide sleeve shall have at least four vent holes at each end (eight holes total) located with centers ¾ ± 1/16 in. (19.0 ± 2 mm) from each end and spaced 90 degrees apart. The minimum diameter of the vent holes shall be ⅜ in. (9.5 mm). Additional holes or slots may be incorporated in the guide sleeve.

5.2.2 *Mechanical Rammer-Circular Face*—The rammer shall operate mechanically in such a manner as to provide uniform and complete coverage of the specimen surface. There shall be 0.10 ± 0.03 in. (2.5 ± 0.8mm) clearance between the rammer and the inside surface of the mold at its smallest diameter. The mechanical rammer shall meet the standardization/calibration requirements of Practices D2168. The mechanical rammer shall be equipped with a positive mechanical means to support the rammer when not in operation.

5.2.3 *Mechanical Rammer-Sector Face (See Note 4)*—When used with the 6 in. (152.4 mm) mold, a sector face rammer may be used in place of the circular face rammer. The use of a sector face rammer should be noted in the test report. The specimen contact face shall have the shape of a sector of a circle of radius equal to 2.90 ± 0.02 in. (73.7 ± 0.5 mm). The rammer shall operate in such a manner that the vertex of the sector is positioned at the center of the specimen.

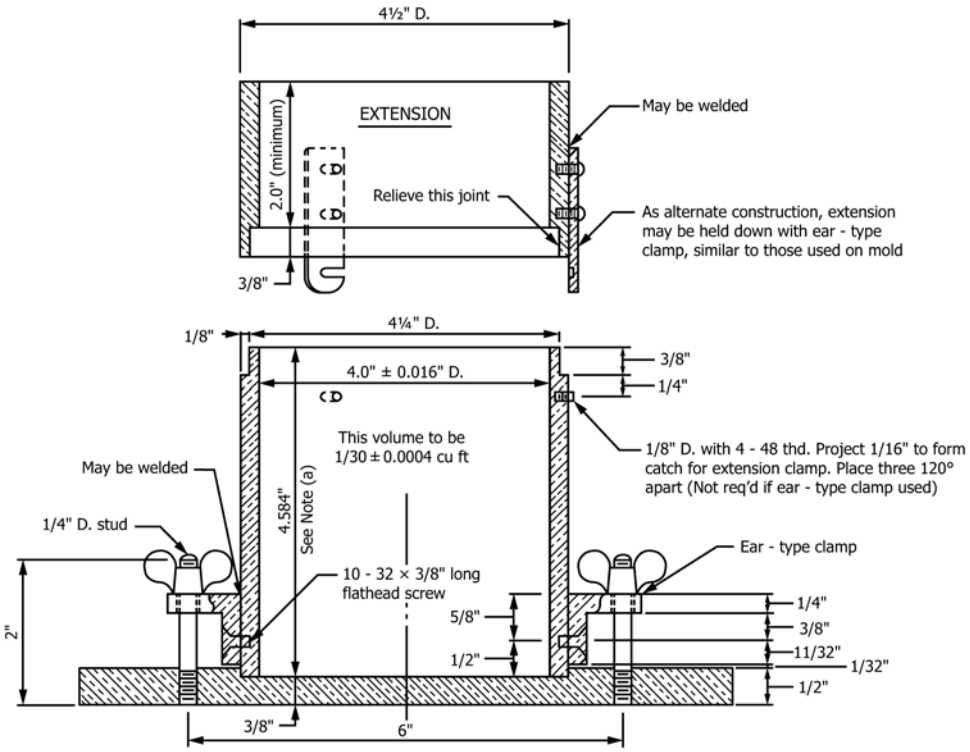
NOTE 4—The sector face rammer shall not be used to compact test specimens in accordance with Test Methods D559 and D560, unless previous tests on like soils show strength and resistance to wetting-and-drying and freezing-and-thawing of specimens compacted with this rammer are similar to that of specimens compacted with the circular face rammer.

5.3 *Sample Extruder*—A jack, lever frame, or other device adapted for the purpose of extruding compacted specimens from the mold. Not required when a split-type mold is used.

5.4 *Balances*—A balance or scale conforming to the requirements of Class GP5 with a readability of 1g in Specification D4753, except that a Class GP2 balance of 0.1g readability is required for water content determination.

5.5 *Drying Oven*—Thermostatically controlled, preferably of the forced-draft type, meeting the requirements of Specification E145 and capable of maintaining a uniform temperature of 230 ± 9 °F (110 ± 5 °C) throughout the drying chamber.

5.6 *Straightedge*—A stiff steel straightedge of any convenient length but not less than 10-in. (254-mm). The total length



Metric Equivalents

in.	mm
0.016	0.41
0.026	0.66
1/32	0.80
1/16	1.6
1/8	3.2
1/4	6.4
11/32	8.7
3/8	9.5
1/2	12.7
5/8	15.9
2	50.8
2½	63.5
4	101.6
4¼	108.0
4½	114.3
4.584	116.43
6	152.4
6½	165.1
8	203.2
ft^3	cm
1/30	944
0.004	11
1/13.333	2124
0.0009	25

NOTE 1—(a)—The tolerance on the height is governed by the allowable volume and diameter tolerances.

NOTE 2—(b)—The methods shown for attaching the extension collar to the mold and the mold to the base plate are recommended. However, other methods are acceptable, providing the attachments are equally as rigid as those shown.

FIG. 1 Cylindrical Mold

of the straightedge shall be machined straight to a tolerance of ± 0.005-in. (± 0.1-mm). The scraping edge shall be beveled if it is thicker than ⅛-in. (3-mm).

5.7 *Sieves*—3-in. (75-mm), ¾-in. (19.0-mm), and No. 4 (4.75-mm) sieves conforming to the requirements of Specification E11.

5.8 *Mixing Tools*—Miscellaneous tools such as mixing pan, spoon, trowel, and spatula, or a suitable mechanical device for thoroughly mixing the sample of soil with cement and with increments of water.

5.9 *Container*—A flat, round pan for moisture absorption by soil-cement mixtures, about 12 in. (305 mm) in diameter and 2 in. (50 mm) deep.

5.10 *Water Content Cans*—Suitable containers made of material resistant to corrosion and change in mass upon repeated heating, cooling, exposure to materials of varying pH, and cleaning. Unless a desiccator is used, containers with close fitting lids shall be used for testing specimens having a mass of about 200 g; while for specimens having a mass greater than about 200g, containers without lids may be used. One container is needed for each water content determination.

5.11 *Butcher Knife*—A butcher knife approximately 10 in. (250 mm) in length for trimming the top of the specimens.

6. Calibration

6.1 Perform calibrations before initial use, after repairs or other occurrences that might affect the test results, at intervals not exceeding 1,000 test specimens, or annually, whichever occurs first, for the following apparatus:

6.1.1 *Balance*—Evaluate in accordance with Specification D3740.

6.1.2 *Molds*—Determine the volume as described in D698, Annex 1.

6.1.3 *Manual Rammer*—Verify the free fall distance, rammer mass, and rammer force in accordance with 5.2. Verify the sleeve requirements in accordance with 5.2.1.

6.1.4 *Mechanical Rammer*—Calibrate and adjust the mechanical rammer in accordance with Practices D2168.

7. Test Method A, Using Soil Material Passing a No. 4 (4.75-mm) Sieve

7.1 *Sample:*

7.1.1 Prepare the sample for testing by breaking up the soil aggregations to pass the No. 4 (4.75-mm) sieve in such a manner as to avoid reducing the natural size of the individual particles. When necessary, first dry the sample until it is friable under a trowel. Drying may be accomplished by air drying or by the use of drying apparatus such that the temperature of the sample does not exceed 140 °F (60 °C).

7.1.2 Select a representative sample, having a mass of approximately 6.0 lbm (2.7 kg) or more, of the soil prepared as described in 7.1.1.

7.2 *Procedure:*

7.2.1 Add to the soil the required amount of cement conforming to Specification C150 or Specification C595. Mix the cement and soil thoroughly to a uniform color.

7.2.2 When needed, add sufficient potable water to dampen the mixture to approximately four to six percentage points below the estimated optimum water content and mix thoroughly. At this water content, plastic soils, tightly squeezed in the palm of the hand, will form a cast that will fracture with only slight pressure applied by the thumb and fingertips; nonplastic soils will bulk noticeably.

7.2.3 When the soil is a clayey material, compact the mixture of soil, cement, and water in the container to a depth of about 2 in. (50 mm) using the rammer described in 5.2 or a similar hand tamper. Cover, and allow to stand for not less than 5 min but not more than 10 min to aid dispersion of the moisture and to permit more complete absorption by the soil-cement.

7.2.4 After the absorption period, thoroughly break up the mixture, without reducing the natural size of individual particles, until it will pass a No. 4 (4.75-mm) sieve and then remix.

7.2.5 Form a specimen by compacting the prepared soil-cement mixture in the mold, with the collar attached, in three equal layers so as to give a total compacted depth of about 5 in. (130 mm). Compact each layer by 25 blows from the rammer dropping free from a height of 12 in. (305 mm) above the elevation of the soil-cement when a sleeve-type rammer is used, or from 12 in. (305 mm) above the approximate elevation of each finally compacted layer when a stationary-mounted type rammer is used. The blows shall be uniformly distributed over the surface of the layer being compacted. During compaction, the mold shall rest on a uniform, rigid foundation such as provided by a cylinder or a cube of concrete with a mass not less than 200 lbm (91 kg).

7.2.6 Remove the extension collar after compaction and carefully trim the compacted mixture even with the top of the mold by means of a knife and straightedge. Determine and record the mass of the mixture and mold to four significant digits.

7.2.7 Remove the material from the mold and slice vertically through the center. Take a representative sample of the material, weighing not less than 0.2 lbm (100 g), from the full height of one of the cut faces. Immediately, determine and record the mass of the moist material and container to four significant digits. Dry in an oven at 230 ± 9 °F (110 ± 5 °C) for at least 12 hours or to a constant mass. Determine the mass of the dry soil and container to four significant digits.

7.2.8 Thoroughly break up the remainder of the material as before until it will pass a No. 4 (4.75-mm) sieve, as judged by eye, and add all other material remaining after obtaining the moisture sample.

7.2.9 Add water in sufficient amount to increase the water content of the soil-cement mixture by one or two percentage points, mix, and repeat the procedure given in 7.2.5 – 7.2.8 for each increment of water added.

7.2.10 Continue this series of determinations until there is either a decrease or no change in the mass of the moist material and mold.

NOTE 5—This procedure has been found satisfactory in most cases. However, in instances where the soil material is fragile in character and will reduce significantly in grain size due to repeated compaction, a separate and new sample shall be used for each moisture-density (unit weight) determination.

NOTE 6—To minimize the effect of cement hydration, perform the test expeditiously and continuously to completion.

8. Test Method B, Using Soil Material Passing a ¾-in. (19.0-mm) Sieve

8.1 *Sample:*

8.1.1 Prepare the sample for testing by segregating the aggregate retained on a No. 4 (4.75-mm) sieve and breaking up the remaining soil aggregations to pass the No. 4 (4.75-mm) sieve in such a manner as to avoid reducing the natural size of individual particles. When necessary, first dry the sample until it is friable under a trowel. Drying may be accomplished by air drying or by the use of drying apparatus such that the temperature of the sample does not exceed 140 °F (60 °C).

8.1.2 Sieve the prepared soil over the 3-in. (75-mm) (Note 2), ¾-in., (19.0-mm), and No. 4 (4.75-mm) sieves. Discard the material retained on the 3-in. (75-mm) sieve. Determine the percentage of material, by oven-dry mass, retained on the ¾-in. (19.0-mm) and No. 4 sieves.

8.1.3 Saturate the aggregate passing the ¾-in. (19.0-mm) sieve and retained on the No. 4 (4.75-mm) sieve by soaking in potable water; surface-dry the material as required for later testing.

NOTE 7—Most soil-cement construction specifications covering soil gradation limit maximum size material to 3 in. (75 mm) or less.

8.1.4 Select and maintain separate representative samples of soil passing the No. 4 (4.75-mm) sieve and of saturated, surface-dry aggregate passing the ¾-in. (19.0-mm) sieve and retained on the No. 4 sieve so that the total sample will weigh approximately 11 lbm (5 kg) or more. The percentage, by oven-dry mass, of aggregate passing the ¾-in. (19.0-mm) sieve and retained on the No. 4 (4.75-mm) sieve shall be the same as the percentage passing the 3-in. (75-mm) sieve and retained on the No. 4 sieve in the original sample.

Original Gradation		Correction Factor	Corrected Percent Passing	Sample Builder for 5,000 g	Cumulative Build, g	Build Gradation
Sieve Size	Percent Passing					Sieve Size
1 ½ in. (37.5 mm)	100					
1 in. (25.0 mm)	96					
¾ in. (19.0 mm)	80	100/80 = 1.25	80 × 1.25 = 100	5,000	5,000 × 100 % = 5,000	½ in. (12.5 mm)
½ in. (12.5 mm)	76	1.25	76 × 1.25 = 95.0	5,000	5,000 × 95.0 % = 4,750	⅜ in. (9.5 mm)
⅜ in. (9.5 mm)	68	1.25	68 × 1.25 = 85.0	5,000	5,000 × 85.0 % = 4,250	No. 4 (4.75 mm)
No. 4 (4.75 mm)	63	1.25	63 × 1.25 = 78.8	5,000	5,000 × 78.8 % = 3,940	< No. 4 (< 4.75 mm)

8.2 *Procedure:*

8.2.1 Add to the portion of the soil sample passing the No. 4 sieve, the amount of cement conforming to Specification C150 or Specification C595, required for the total sample specified in 8.1.4. Mix the cement and soil thoroughly to a uniform color.

8.2.2 When needed, add water to this soil-cement mixture and facilitate moisture dispersion as described for Method A in 7.2.2 – 7.2.4. After this preparation, add the saturated, surface-dry aggregate to the soil-cement mixture passing the No. 4 (4.75-mm) sieve and mix thoroughly.

8.2.3 Form a specimen by compacting the prepared soil-cement mixture in the mold (with the collar attached) and trim the compacted specimen as described for Method A in 7.2.5 and 7.2.6. During the trimming operation remove all particles that extend above the top level of the mold. Correct all irregularities in the surface by hand-tamping fine material into these irregularities and leveling the specimen again with the straightedge. Determine and record the mass of the mixture and the mold to four significant digits.

8.2.4 Remove the material from the mold and take a sample for determining the water content as described for Method A in 7.2.7 except that the water content sample shall have a mass of at least 1.1 lbm (500 g). Record the result as the water content, *w*, of the compacted soil-cement mixture.

8.2.5 Thoroughly break up the remainder of the material as before until it will pass a ¾-in. (19.0-mm) sieve and at least 90 % of the soil particles smaller than a No. 4 (4.75-mm) sieve will pass a No. 4 sieve, as judged by eye, and add all other material remaining after obtaining the water content sample.

8.2.6 Add sufficient water to increase the water content of the soil-cement mixture by one or two percentage points, mix, and repeat the procedure described in 8.2.3 – 8.2.5 for each increment of water added. Continue this series of determinations until there is either a decrease or no change in the mass of the moist material and the mold (Note 4 and Note 5).

9. Calculations

9.1 Calculate the volume of the mold used to compact the soil-cement mixture for each trial in accordance with Test Method D698, Annex A1, to four significant digits.

9.2 Calculate the water content of the soil-cement mixture for each trial in accordance with D2216 to 0.1 %.

9.3 Calculate the moist density (Eq 1), the dry density (Eq 2), and then the dry unit weight (Eq 3) to the nearest 0.1 lbf/ft^3 for each trial as follows:

$$\rho_m = \frac{(M_m - M_{md})}{V} \quad (1)$$

where:

ρ_m = moist density of compacted soil-cement specimen, lbm/ft^3 (kg/m^3),
M_m = mass of moist specimen and mold, lbm (kg),
M_{md} = mass of compaction mold, lbm (kg), and
V = volume of compaction, ft^3 (m^3) (See Test Method D698, Annex A1).

$$\rho_d = \frac{\rho_m}{\left(1 + \frac{w}{100}\right)} \quad (2)$$

where:

ρ_d = dry density of compacted soil-cement specimen, lbm/ft^3 (kg/m^3),
ρ_m = moist density of compacted soil-cement specimen, lbm/ft^3 (kg/m^3), and
w = water content, %.

$$\gamma_d = \frac{\rho_d g}{g_c}\,[U.S.] \quad (3)$$

or

$$\gamma_d = \rho_d g\,[SI] \quad (4)$$

where:

g = acceleration of gravity, 32.2 ft/sec^2 (9.81 m/sec^2)
g_c = gravitational constant, 32.2 ft-lbm/lbf-sec^2
γ_d = dry unit weight of compacted soil-cement specimen

10. Moisture-Density (Unit Weight) Relationship

10.1 The values of water content and dry unit weight calculated in Section 9 for each compacted soil-cement specimen are then plotted. The dry unit weight in lbf/ft ^{3} shall be plotted to the nearest 0.1 lbf/ft^3 on the ordinate scale and the corresponding water content to the nearest 0.1 % on the abscissa scale. Draw the compaction curve as a smooth curve through the plotted points.

NOTE 8—Experience has shown that it is very important to use consistent scales when plotting these curves. One satisfactory approach is to plot the dry unit weight using a scale of 1" = 5 lbf/ft^3 for the ordinate and the water content using a scale of 1" = 2 % as the abscissa.

10.2 *Optimum Water Content, w_o*—The water content corresponding to the peak of the curve plotted according to 10.1 shall be termed the " optimum water content" of the soil-cement mixture under the compaction process described in these methods.

10.3 *Maximum Dry Unit Weight, γ_{dmax}*—The dry unit weight, in lbf/ft^3 corresponding to the optimum water content shall be termed "maximum dry unit weight" under the compaction process described in these test methods.

11. Report

11.1 The report shall include the following:

11.1.1 Sample identification (i.e., sample number, project, location, depth, etc.),

11.1.2 Procedure used (Method A or Method B),

11.1.3 Optimum water content, to the nearest 0.5 %,

11.1.4 Maximum dry unit weight, to the nearest 0.5 lbf/ft^3, and

11.1.5 Compaction curve plot showing compaction points used to establish the compaction curve, point of maximum dry unit weight and optimum water content.

12. Precision and Bias

12.1 *Precision*—Test data on precision are not presented due to the nature of the materials being tested by this test method. It is either not feasible or too costly at this time to have ten or more laboratories participate in a round-robin testing program. Subcommittee D 18.15 is seeking any data from the users of this test method that might be used to make a limited statement on precision.

12.2 *Bias*—There are no accepted reference values for this test method, therefore, bias cannot be determined.

13. Keywords

13.1 compaction; dry density; optimum water content; soil-cement; soil-stabilization; unit weight

SUMMARY OF CHANGES

Committee D18 has identified the location of selected changes to these test methods since the last issue, D558–04, that may impact the use of these test methods. (Approved January 1, 2011)

(*1*) Revised Sections 1, 5, 7, 8, and 9 to include both inch-pound and SI units.
(*2*) Added text to 5.2 so the rammer specifications are consistent with Test Method D698.
(*3*) Added new Note 3 under 5.2 and renumbered subsequent notes.
(*4*) Revised 5.2.1 so the manual rammer specifications are consistent with Test Method D698.
(*5*) Revised 5.2.2 so the mechanical rammer-circular face specifications are consistent with Test Method D698.