~~Designation:D558–04~~ 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 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 ~~the~~ standard, except as noted below. The values given in parentheses are mathematical conversions to SI ~~units, and~~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

[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 of Additives.~~

~~Current edition approved Nov. 1, 2004. Published November 2004. Originally approved in 1938. Last previous edition approved in 2003 as D558 –03. DOI: 10.1520/D0558-04.~~on Stabilization With Admixtures.

Current edition approved Jan. 1, 2011. Published February 2011. Originally approved in 1938. Last previous edition approved in 2003 as D558–03. DOI: 10.1520/D0558-11.

[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.**

D560 Test Methods for Freezing and Thawing Compacted Soil-Cement Mixtures
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
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 ~~Methods~~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

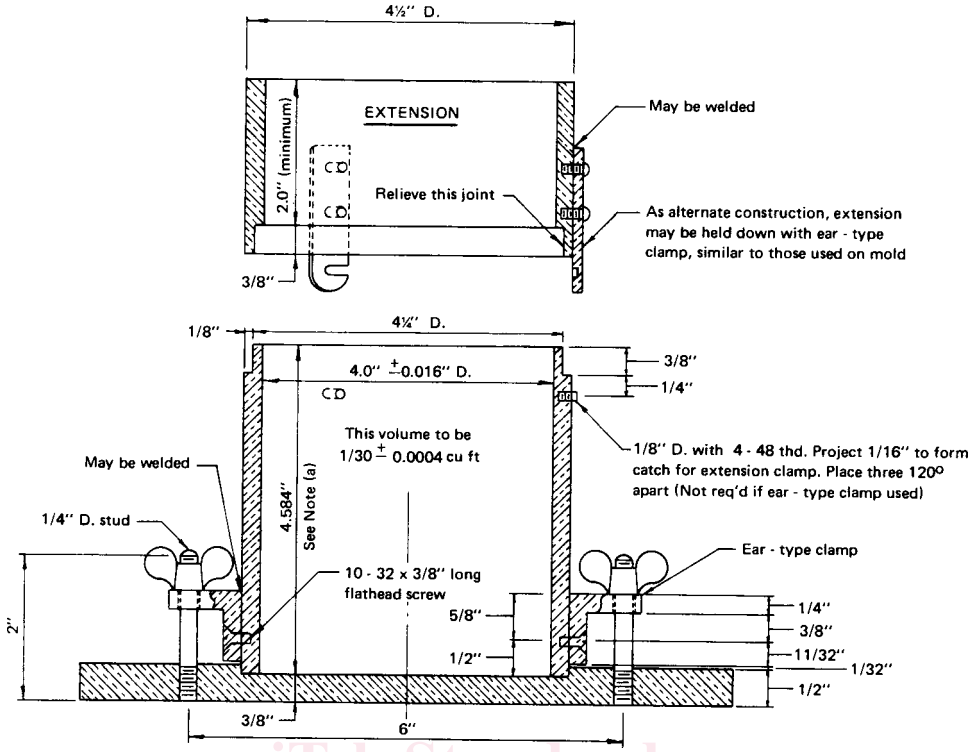
5.1 *Mold*—A cylindrical metal mold having a volume of 1/30 ± 0.00040 ft^3 (944 ± 11 cm^3) with an internal diameter of 4.0 ± 0.016 in. (101.60 ± 0.41 mm) and conforming to Fig. 1 to permit preparing compacted specimens of soil-cement mixtures of this size. The mold shall be provided with a detachable 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*—~~A manually operated metal rammer having a 2.000 ± 0.005-in. (50.80 ± 0.13-mm) diameter circular face as manufactured and a mass of 5.5 ± 0.02 lbm (2.49 ± 0.01 kg). 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). The rammer shall be equipped with a suitable guidesleeve to control the height of drop to a free fall of 12.0 ± 0.05 in. (304.8 ± 1.3 mm) above the elevation of the soil-cement without restricting the free fall of the hammer. The guidesleeve shall have at least four vent holes not smaller than ⅜ in. (9.5 mm) spaced 90° apart and located with centers ¾~~—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 ± 1.6 mm) from each end and shall provide sufficient clearance that free-falls of the rammer shaft and head will not be restricted.~~ 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*—~~, A mechanically operated metal rammer shall operate in such a manner as to provide uniform and complete coverage of the specimen area. There shall be 0.10 ± 0.03 in. (2.5 ± 0.8mm) clearance between~~



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

~~the rammer and the inside surface of the mold at its smallest diameter. The mechanical rammer will have a 2.0 ± 0.005-in. (50.80 ± 0.13-mm) diameter face as manufactured and a manufactured mass of 5.5 ± 0.02 lbm (2.49 ± 0.01 kg), except that the mass of the mechanical rammer may be adjusted as described in Methods D2168. The rammer shall be equipped with a suitable arrangement to control the height of drop to a free-fall of 12.0 ± 0.05 in. (304.8 ± 1.3 mm) above the elevation of the soil-cement. The mechanical rammer shall be equipped with a positive mechanical means to support the rammer when not in operation~~

~~*5.2.3Mechanical Rammer-Sector Face; See Note 3*—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 2.9 ± 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 enter of the specimen. —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 3—The 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 110230 ± 5°C (238 9 °F (110 ± 9°F)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 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 5001,000 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 Test Method 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.

7.2.3When7.2.3 When the soil is a clayey material, compact the mixture of soil, cement, and water in the container to a depth