Designation: D559/D559M – 15 (Reapproved 2023)

Standard Test Methods for Wetting and Drying Compacted Soil-Cement Mixtures[1]

This standard is issued under the fixed designation D559/D559M; 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 procedures for determining the soil-cement losses, water content changes, and volume changes (swell and shrinkage) produced by repeated wetting and drying of hardened soil-cement specimens. The specimens are compacted in a mold, before cement hydration, to maximum density at optimum water content using the compaction procedure described in Test Methods D558/D558M.

1.2 Two test methods, depending on soil gradation, are covered for preparation of material for molding specimens and for molding specimens as follows:

	Sections
Test Method A, using soil material passing a 4.75-mm [No. 4] sieve. This method shall be used when 100 % of the soil sample passes the 4.75-mm [No. 4] sieve.	7
Test Method B, using soil material passing a 19.0 mm [0.75-in.] sieve. This method shall be used when part of the soil sample is retained on the 4.75-mm [No. 4] sieve. This test method may be used only on materials with 30 % or less retained on the 19.0-mm [0.75-in.] sieve.	8

1.3 All observed and calculated values shall conform to the guidelines for significant digits and rounding established in Practice D6026, unless superseded by this test method.

1.3.1 The procedures used to specify how data are collected/recorded and calculated in the standard are regarded as the industry standard. In addition, they are representative of the significant digits that generally should be retained. The procedures used do not consider material variation, purpose for obtaining the data, special purpose studies, or any considerations for the user's objectives; and it is common practice to increase or reduce significant digits of reported data to be commensurate with these considerations. It is beyond the scope of these test methods to consider significant digits used in analysis methods for engineering data.

1.4 *Units*—The values stated in either SI units or inch-pound units [presented in brackets] are to be regarded separately as standard. The values stated in each system shall be used independently of the other. Combining values from the two systems may result in non-conformance with the standard. Sieve size is identified by its standard designation in Specification E11. The alternative designation given in parentheses is for information only and does not represent a different standard sieve size.

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. The rationalized slug unit is not given, unless dynamic (F = ma) calculations are involved.

1.4.2 It is common practice in the engineering/construction profession to 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, 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, health, and environmental practices and determine the applicability of regulatory limitations prior to use.*

1.6 *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]

C150/C150M Specification for Portland Cement

[1] These test methods are under the jurisdiction of the 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.

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

C595/C595M Specification for Blended Hydraulic Cements
D558/D558M Test Methods for Moisture-Density (Unit Weight) Relations of Soil-Cement Mixtures
D560/D560M 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
D3282 Practice for Classification of Soils and Soil-Aggregate Mixtures for Highway Construction Purposes
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 and Data Records in Geotechnical Data
E11 Specification for Woven Wire Test Sieve Cloth and Test Sieves
E145 Specification for Gravity-Convection and Forced-Ventilation Ovens

2.2 *AASHTO Standards:*[3]
M 145 Classifications of Soils and Soil-Aggregate Mixtures for Highway Construction Purposes

3. Terminology

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

4. Significance and Use

4.1 These test methods are used to determine the resistance of compacted soil-cement specimens to repeated wetting and drying. These test methods were developed to be used in conjunction with Test Methods D560/D560M and criteria given in the *Soil-Cement Laboratory Handbook*[4] to determine the minimum amount of cement required in soil-cement to achieve a degree of hardness adequate to resist field weathering.

NOTE 1—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 ensure reliable results. Reliable results depend on many factors; Practice D3740 provides a means of evaluating some of those factors.

[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.

[4] *Soil-Cement Laboratory Handbook*, Portland Cement Assn., 1992.

5. Apparatus

5.1 *Mold, Rammer, and Sample Extruder*—Refer to Test Methods D698 for detailed specifications.

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

5.3 *Drying Ovens*—Thermostatically controlled, preferably forced-draft type, meeting the requirements of Specification E145 and capable of maintaining a uniform temperature of 110 ± 5°C [230 ± 9°F] throughout the chamber for the water content specimens, and a temperature of 71 ± 3°C [160 ± 5°F] throughout the drying chamber for drying compacted soil-cement specimens.

5.4 *Moist Room*—A moist room or suitable covered container capable of maintaining a temperature of 21 ± 2°C [70 ± 3°F] and a relative humidity of 100 % for seven-day storage of compacted specimens.

5.5 *Water Bath*—Suitable tank for submerging compacted specimens in water at room temperature.

5.6 *Wire Scratch Brush*—A wire scratch brush made of 50-mm [2-in.] long by 1.6-mm [0.06-in.] wide by 0.5-mm [No. 26 gage] thick flat wire bristles assembled in 50 groups of 10 bristles each and mounted to form five longitudinal rows and ten transverse rows of bristles on a 190 by 65-mm [7.5- by 2.5-in.] hardwood block.

5.7 *Straightedge*—A stiff metal straightedge of any convenient length but not less than 250-mm [10-in.]. The total length of the straightedge shall be machined straight to a tolerance of ±0.1-mm [±0.004-in.]. The scraping edge shall be beveled, if it is thicker than 3-mm [0.12-in.].

5.8 *Sieves*—75-mm [3-in.], 19.0-mm [0.75-in.], and 4.75-mm [No. 4] sieves conforming to the requirements of Specification E11.

5.9 *Mixing Tools*—Miscellaneous tools such as mixing pan, and trowel, or a suitable mechanical device for thoroughly mixing the soil with cement and water.

5.10 *Butcher Knife*—A butcher knife approximately 250 mm [10 in.] in length for trimming the top of the specimens.

5.11 *Scarifier*—A six-pronged ice pick or similar apparatus to remove the smooth compaction plane at the top of the first and second layers of the specimen.

5.12 *Container*—A flat, round pan for initial preparation of heavy textured clayey material to facilitate moisture absorption by the soil-cement mixtures, about 300 mm [12 in.] in diameter and at least 50 mm [2 in.] deep.

5.13 *Measuring Device*—A measuring device suitable for accurately measuring the heights and diameters of test specimens to the nearest 0.25 mm [0.01 in.].

5.14 *Pans and Carriers*—Suitable pans for handling materials and carriers or trays for handling test specimens.

5.15 *Graduate*—A graduated cylinder of 250-mL [8.4-oz] capacity for measuring water.

5.16 *Water Content Containers*—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 [0.4 lbf]; while for specimens having a mass greater than about 200 g [0.4 lbf], containers without lids may be used. One container is needed for each water content determination.

6. Standardization/Verification

6.1 Perform verifications of molds and rammers in accordance with Test Methods D698 before initial use, after repairs or other occurrences that might affect the test results, at intervals not exceeding 500 test specimens, or annually, whichever occurs first.

6.1.1 *Balance*—Evaluate in accordance with Specification D4753 as required by Test Methods D698.

7. Test Method A—Using Soil Material Passing a 4.75-mm [No. 4] Sieve

7.1 *Preparation of Material for Molding Specimens:*

7.1.1 Collect a soil sample that is visually representative of the project material.

7.1.2 Prepare the soil sample in accordance with the procedure described in Test Method A of Test Methods D558/D558M.

7.1.3 Select a sufficient quantity of the soil prepared as described in 7.1.2 to provide two (Note 2) compacted specimens and required moisture samples.

NOTE 2—(*Optional*) Usually only one specimen (identified as No. 2) is required for routine testing. The other specimen (identified as No. 1) is made for research work and for testing unusual soils.

7.1.4 Add to the soil the required amount of cement conforming to Specification C150/C150M or Specification C595/C595M. Mix the cement and soil thoroughly to a uniform color.

7.1.5 Add sufficient potable water to raise the soil-cement mixture to optimum water content at the time of compaction and mix thoroughly.

7.1.6 When the soil used is a heavy textured clayey material, transfer the mixture to the flat round pan and lightly tamp the mixture until firm using the rammer described in 5.2 or a cylinder about 50 mm [2 in.] in diameter. Cover the mixture 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.

7.1.7 After the absorption period, thoroughly break up the mixture, without reducing the natural size of individual particles, until it will pass a 4.75-mm [No. 4] sieve, as judged by eye, and then remix.

7.2 *Molding Specimens:*

7.2.1 Form a specimen by immediately compacting the soil-cement mixture in the mold, with the collar attached, and later trimming the specimen in the same manner as directed for Test Method A of Test Methods D558/D558M, and in addition scarify the tops of the first and second layers to remove smooth compaction planes before placing and compacting the succeeding layers. This scarification shall form grooves at right angles to each other, approximately 3 mm [0.12 in.] in width and 3 mm [0.12 in.] in depth and approximately 6 mm [0.2 in.] apart.

7.2.2 During compaction, take a representative sample from the batch of soil-cement mixture that has a mass of at least, 100 g [0.2 lbf]. Determine and record the mass. Immediately, dry the specimen in a drying oven at 110 ± 5°C [230 ± 9°F] for at least 12 h or to a constant mass. Determine and record the oven-dry mass of the specimen to four significant digits. Calculate the water content in accordance with Test Methods D2216 and D698 and check against the design water content (Note 6).

7.2.3 Determine and record the mass of the compacted specimen to four significant digits and remove it from the mold. Calculate the dry unit weight in kg/m^3 [lbf/ft^3] in accordance with Test Method D558/D558M to check against the design dry density (Note 6).

7.2.3.1 If the dry unit weight obtained is within the design tolerances specified, identify the specimen with a metal tag (or other suitable device) as No. 1 together with any other needed identification marks. This specimen will be used to obtain data on water content and volume changes during the test.

7.2.3.2 If the dry unit weight obtained does not meet the tolerances specified, then another specimen will need to be compacted.

7.2.4 Form a second specimen as rapidly as possible and determine the water content and oven-dry weight as described in 7.2.1 – 7.2.3. Identify this specimen as No. 2, together with other needed identification marks and use to obtain data on soil-cement losses during the test.

7.2.5 Determine the average diameter and height of the No. 1 specimen and calculate its volume.

7.2.6 Place the specimens on suitable carriers in the moist room and protect them from free water for a period of seven days.

7.2.7 Determine and record the mass and measurements of the No. 1 specimen at the end of the seven-day storage period to provide data for calculating its water content and volume.

7.2.8 It is important that all height and diameter measurements be accurate to within 0.25 mm [0.01 in.] and be taken at the same points on the specimen at all times.

7.3 *Procedure:*

7.3.1 At the end of storage in the moist room, submerge the specimens in potable water at room temperature for a period of 5 h and remove. Determine and record the mass and measurements of the No. 1 specimen (water content and volume change specimen).

7.3.2 Place both specimens in an oven at 71 ± 3°C [160 ± 5°F] for 42 h and remove. Determine and record the mass and measurements of the No. 1 specimen.

7.3.3 Give specimen No. 2 (soil-cement loss specimen) two firm strokes on all areas with the wire scratch brush. The brush shall be held with the long axis of the brush parallel to the longitudinal axis of the specimen or parallel to the ends as required to cover all areas of the specimen. Apply these strokes to the full height and width of the specimen with a firm stroke corresponding to approximately 13-N [3-lbf] force (Note 3).