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Standard Test Methods for Laboratory Compaction Characteristics of Soil Using Modified Effort (56,000 ft-lbf/ft^3 (2,700 kN-m/m^3))[1]

This standard is issued under the fixed designation D1557; 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 laboratory compaction methods used to determine the relationship between molding water content and dry unit weight of soils (compaction curve) compacted in a 4- or 6-in. (101.6- or 152.4-mm) diameter mold with a 10.00-lbf. (44.48-N) rammer dropped from a height of 18.00 in. (457.2 mm) producing a compactive effort of 56 000 ft-lbf/ft^3 (2700 kN-m/m^3).

NOTE 1—The equipment and procedures are the same as proposed by the U.S. Corps of Engineers in 1945. The modified effort test (see 3.1.3) is sometimes referred to as the Modified Proctor Compaction Test.

1.1.1 Soils and soil-aggregate mixtures are to be regarded as natural occurring fine- or coarse-grained soils, or composites or mixtures of natural soils, or mixtures of natural and processed soils or aggregates such as gravel or crushed rock. Hereafter referred to as either soil or material.

1.2 These test methods apply only to soils (materials) that have 30 % or less by mass of their particles retained on the ¾-in. (19.0-mm) sieve and have not been previously compacted in the laboratory; that is, do not reuse compacted soil.

1.2.1 For relationships between unit weights and molding water contents of soils with 30 % or less by weight of material retained on the ¾-in. (19.0-mm) sieve to unit weights and molding water contents of the fraction passing the ¾-in. (19.0-mm) sieve, see Practice D4718/D4718M.

1.3 Three alternative methods are provided. The method used shall be as indicated in the specification for the material being tested. If no method is specified, the choice should be based on the material gradation.

1.3.1 *Method A:*

1.3.1.1 *Mold*—4-in. (101.6-mm) diameter.

1.3.1.2 *Material*—Passing No. 4 (4.75-mm) sieve.

1.3.1.3 *Layers*—Five.

1.3.1.4 *Blows per layer*—25.

1.3.1.5 *Usage*—May be used if 25 % or less by mass of the material is retained on the No. 4 (4.75-mm) sieve. However, if 5 to 25 % by mass of the material is retained on the No. 4 (4.75-mm) sieve, Method A can be used but oversize corrections will be required (See 1.4) and there are no advantages to using Method A in this case.

1.3.1.6 *Other Use*—If this gradation requirement cannot be met, then Methods B or C may be used.

1.3.2 *Method B:*

1.3.2.1 *Mold*—4-in. (101.6-mm) diameter.

1.3.2.2 *Material*—Passing ⅜-in. (9.5-mm) sieve.

1.3.2.3 *Layers*—Five.

1.3.2.4 *Blows per layer*—25.

1.3.2.5 *Usage*—May be used if 25 % or less by mass of the material is retained on the ⅜-in. (9.5-mm) sieve. However, if 5 to 25 % of the material is retained on the ⅜-in. (9.5-mm) sieve, Method B can be used but oversize corrections will be required (See 1.4). In this case, the only advantages to using Method B rather than Method C are that a smaller amount of sample is needed and the smaller mold is easier to use.

1.3.2.6 *Other Usage*—If this gradation requirement cannot be met, then Method C may be used.

1.3.3 *Method C:*

1.3.3.1 *Mold*—6-in. (152.4-mm) diameter.

1.3.3.2 *Material*—Passing ¾-in. (19.0-mm) sieve.

1.3.3.3 *Layers*—Five.

1.3.3.4 *Blows per layer*—56.

1.3.3.5 *Usage*—May be used if 30 % or less (see 1.4) by mass of the material is retained on the ¾-in. (19.0-mm) sieve.

1.3.4 The 6-in. (152.4-mm) diameter mold shall not be used with Method A or B.

NOTE 2—Results have been found to vary slightly when a material is tested at the same compactive effort in different size molds, with the smaller mold size typically yielding larger values of unit weight and density (**1**).[2]

1.4 If the test specimen contains more than 5 % by mass of oversize fraction (coarse fraction) and the material will not be

[1] These test methods are under the jurisdiction of ASTM Committee D18 on Soil and Rock and are the direct responsibility of Subcommittee D18.03 on Texture, Plasticity and Density Characteristics of Soils.

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[2] The boldface numbers in parentheses refer to the list of references at the end of this standard.

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

included in the test, corrections must be made to the unit weight and molding water content of the test specimen or to the appropriate field in-place unit weight (or density) test specimen using Practice D4718/D4718M.

1.5 This test method will generally produce a well-defined maximum dry unit weight for non-free draining soils. If this test method is used for free-draining soils the maximum unit weight may not be well defined, and can be less than obtained using Test Methods D4253.

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

1.6.1 For purposes of comparing measured or calculated value(s) with specified limits, the measured or calculated value(s) shall be rounded to the nearest decimal or significant digits in the specified limits.

1.6.2 The procedures used to specify how data are collected/recorded or calculated in this 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; 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 analytical methods for engineering design.

1.7 The values in inch-pound units are to be regarded as the standard. The values stated in SI units are provided for information only, except for units of mass. The units for mass are given in SI units only, g or kg.

1.7.1 It is common practice in the engineering profession to concurrently use pounds to represent both a unit of mass (lbm) and a 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. These test methods have been written using the gravitational system of units when dealing with the inch-pound system. In this system, the pound (lbf) represents a unit of force (weight). However, the use of balances or scales recording pounds of mass (lbm) or the recording of density in lbm/ft^3 shall not be regarded as a nonconformance with this standard.

1.8 *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.*

1.9 **Warning—**Mercury has been designated by EPA and many state agencies as a hazardous material that can cause central nervous system, kidney, and liver damage. Mercury, or its vapor, may be hazardous to health and corrosive to materials. Caution should be taken when handling mercury and mercury containing products. See the applicable product Material Safety Data Sheet (MSDS) for details and EPA's website (http://www.epa.gov/mercury/faq.htm) for additional information. Users should be aware that selling mercury or mercury containing products or both into your state may be prohibited by state law.

1.10 *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:*[3]

C127 Test Method for Relative Density (Specific Gravity) and Absorption of Coarse Aggregate
C136/C136M Test Method for Sieve Analysis of Fine and Coarse Aggregates
C670 Practice for Preparing Precision and Bias Statements for Test Methods for Construction Materials
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))
D854 Test Methods for Specific Gravity of Soil Solids by Water Pycnometer
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
D2487 Practice for Classification of Soils for Engineering Purposes (Unified Soil Classification System)
D2488 Practice for Description and Identification of Soils (Visual-Manual Procedures)
D3740 Practice for Minimum Requirements for Agencies Engaged in Testing and/or Inspection of Soil and Rock as Used in Engineering Design and Construction
D4220/D4220M Practices for Preserving and Transporting Soil Samples
D4253 Test Methods for Maximum Index Density and Unit Weight of Soils Using a Vibratory Table
D4718/D4718M Practice for Correction of Unit Weight and Water Content for Soils Containing Oversize Particles
D4753 Guide for Evaluating, Selecting, and Specifying Balances and Standard Masses for Use in Soil, Rock, and Construction Materials Testing
D4914/D4914M Test Methods for Density of Soil and Rock in Place by the Sand Replacement Method in a Test Pit
D5030/D5030M Test Methods for Density of In-Place Soil and Rock Materials by the Water Replacement Method in a Test Pit
D6026 Practice for Using Significant Digits and Data Records in Geotechnical Data
D6913/D6913M Test Methods for Particle-Size Distribution

[3] 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.

(Gradation) of Soils Using Sieve Analysis

E11 Specification for Woven Wire Test Sieve Cloth and Test Sieves

E319 Practice for the Evaluation of Single-Pan Mechanical Balances

IEEE/ASTM SI 10 Standard for Use of the International System of Units (SI): The Modern Metric System

3. Terminology

3.1 *Definitions:*

3.1.1 See Terminology D653 for general definitions.

3.1.2 *molding water content, n*—the water content of the soil (material) specimen in the mold after it has been reconstituted and compacted.

3.1.3 *modified effort*—in compaction testing, the term for the 56 000 ft-lbf/ft^3 (2700 kN-m/m^3) compactive effort applied by the equipment and methods of this test.

3.1.4 *modified maximum dry unit weight, $\gamma_{d,max}$ (lbf/ft^3 (kN/m^3))*—in compaction testing, the maximum value defined by the compaction curve for a compaction test using modified effort.

3.1.5 *modified optimum water content, w_{opt} (%)*—in compaction testing, the water content at which the soil can be compacted to the maximum dry unit weight using modified compactive effort.

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *oversize fraction (coarse fraction), P_C (%)*—the portion of total specimen not used in performing the compaction test; it may be the portion of total specimen retained on the No. 4 (4.75-mm) sieve in Method A, ⅜-in. (9.5-mm) sieve in Method B, or ¾-in. (19.0-mm) sieve in Method C.

3.2.2 *test fraction (finer fraction), P_F (%)*—the portion of the total specimen used in performing the compaction test; it may be fraction passing the No. 4 (4.75-mm) sieve in Method A, passing the ⅜-in. (9.5-mm) sieve in Method B, or passing the ¾-in. (19.0-mm) sieve in Method C.

4. Summary of Test Method

4.1 A soil at a selected molding water content is placed in five layers into a mold of given dimensions, with each layer compacted by 25 or 56 blows of a 10.00-lbf (44.48-N) rammer dropped from a distance of 18.00 in. (457.2 mm), subjecting the soil to a total compactive effort of about 56 000 ft-lbf/ft^3 (2700 kN-m/m^3). The resulting dry unit weight is determined. The procedure is repeated for a sufficient number of molding water contents to establish a relationship between the dry unit weight and the molding water content for the soil. This data, when plotted, represent a curvilinear relationship known as the compaction curve. The values of optimum water content and modified maximum dry unit weight are determined from the compaction curve.

5. Significance and Use

5.1 Soil placed as engineering fill (embankments, foundation pads, road bases) is compacted to a dense state to obtain satisfactory engineering properties such as shear strength, compressibility, or permeability. In addition, foundation soils are often compacted to improve their engineering properties. Laboratory compaction tests provide the basis for determining the percent compaction and molding water content needed to achieve the required engineering properties, and for controlling construction to assure that the required compaction and water contents are achieved.

NOTE 3—The degree of soil compaction required to achieve the desired engineering properties is often specified as a percentage of the modified maximum dry unit weight as determined using this test method. If the required degree of compaction is substantially less than the modified maximum dry unit weight using this test method, it may be practicable for testing to be performed using Test Method and to specify the degree of compaction as a percentage of the standard maximum dry unit weight. Since more energy is applied for compaction using this test method, the soil particles are more closely packed than when D698 is used. The general overall result is a higher maximum dry unit weight, lower optimum moisture content, greater shear strength, greater stiffness, lower compressibility, lower air voids, and decreased permeability. However, for highly compacted fine-grained soils, absorption of water may result in swelling, with reduced shear strength and increased compressibility, reducing the benefits of the increased effort used for compaction (**2**). Use of D698, on the other hand, allows compaction using less effort and generally at a higher optimum moisture content. The compacted soil may be less brittle, more flexible, more permeable, and less subject to effects of swelling and shrinking. In many applications, building or construction codes may direct which test method, D698 or this one, should be used when specifying the comparison of laboratory test results to the degree of compaction of the in-place soil in the field.

5.2 During design of an engineered fill, testing performed to determine shear, consolidation, permeability, or other properties requires test specimens to be prepared by compacting the soil at a prescribed molding water content to obtain a predetermined unit weight. It is common practice to first determine the optimum water content (w_{opt}) and maximum dry unit weight (γ_{dmax}) by means of a compaction test. Test specimens are compacted at a selected molding water content (w), either wet or dry of optimum (w_{opt}) or at optimum (w_{opt}), and at a selected dry unit weight related to a percentage of maximum dry unit weight (γ_{dmax}). The selection of molding water content (w), either wet or dry of optimum (w_{opt}) or at optimum (w_{opt}) and the dry unit weight (γ_{dmax}) may be based on past experience, or a range of values may be investigated to determine the necessary percent of compaction.

5.3 Experience indicates that the methods outlined in 5.2 or the construction control aspects discussed in 5.1 are extremely difficult to implement or yield erroneous results when dealing with some soils. The following subsections describe typical problem soils, the problems encountered when dealing with such soils and possible solutions for these problems.

5.3.1 *Oversize Fraction*—Soils containing more than 30 % oversize fraction (material retained on the ¾-in. (19-mm) sieve) are a problem. For such soils, there is no ASTM test method to control their compaction and very few laboratories are equipped to determine the laboratory maximum unit weight (density) of such soils (USDI Bureau of Reclamation, Denver, CO and U.S. Army Corps of Engineers, Vicksburg, MS). Although Test Methods D4914/D4914M and D5030/D5030M determine the "field" dry unit weight of such soils, they are difficult and expensive to perform.

5.3.1.1 One method to design and control the compaction of such soils is to use a test fill to determine the required degree