



Designation: D 7382 – 07

Standard Test Methods for Determination of Maximum Dry Unit Weight and Water Content Range for Effective Compaction of Granular Soils Using a Vibrating Hammer¹

This standard is issued under the fixed designation D 7382; 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.

1. Scope

1.1 These test methods cover the determination of the maximum dry unit weight and water content range for effective compaction of granular soils. A vibrating hammer is used to impart a surcharge and compactive effort to the soil specimen.

1.2 These test methods apply to soils with up to 35 %, by dry mass, passing a No. 200 (75- μ m) sieve if the portion passing the No. 40 (425- μ m) sieve is nonplastic.

1.3 These test methods apply to soils with up to 15 %, by dry mass, passing a No. 200 (75- μ m) sieve if the portion passing the No. 40 (425- μ m) sieve exhibits plastic behavior.

1.4 These test methods apply to soils in which 100 %, by dry mass, passes the 2-in. (50-mm) sieve.

1.5 These test methods apply only to soils (materials) that have 30 % or less, by dry mass of their particles retained on the $\frac{3}{4}$ -in. (19.0-mm) sieve.

NOTE 1—For relationships between unit weights and water contents of soils with 30 % or less, by dry mass, of material retained on the $\frac{3}{4}$ -in. (19.0-mm) sieve to unit weights and water contents of the fraction passing the $\frac{3}{4}$ -in. (19.0-mm) sieve, see Practice D 4718.

1.6 These test methods will typically produce a higher maximum dry density/unit weight for the soils specified in 1.2 and 1.3 than that obtained by impact compaction in which a well-defined moisture-density relationship is not apparent. However, for some soils containing more than 15 % fines, the use of impact compaction (Test Methods D 698 or D 1557) may be useful in evaluating what is an appropriate maximum index density/unit weight.

1.7 Two alternative test methods are provided, with the variation being in mold size. 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 maximum particle size of the material.

1.7.1 Method A:

1.7.1.1 Mold—6-in. (152.4-mm) diameter.

1.7.1.2 *Material*—Passing $\frac{3}{4}$ -in. (19.0-mm) sieve and consistent with the requirements of 1.2 and 1.3.

1.7.1.3 *Layers*—Three.

1.7.1.4 *Time of Compaction per layer*— 60 ± 5 s.

1.7.2 Method B:

1.7.2.1 *Mold*—11-in. (279.4-mm) diameter.

1.7.2.2 *Material*—Passing 2-in. (50-mm) sieve and consistent with the requirements of 1.2 and 1.3.

1.7.2.3 *Layers*—Three.

1.7.2.4 *Time of Compaction per layer*— 52 ± 5 s at each of 8 locations.

NOTE 2—Method A (with the correction procedure of Practice D 4718, if appropriate), has been shown (reference thesis or paper) to provide consistent results with Method B. Therefore, for ease of operations, it is highly recommended to use Method A, unless Method B is required due to soil gradations not meeting Practice D 4718.

NOTE 3—Results have been found to vary slightly when a material is tested at the same compaction effort in different size molds.

1.7.3 Either method, A or B, can be performed with the material in an oven-dried or wet/saturated state, whichever provides the maximum dry unit weight.

1.8 If the test specimen contains more than 5 % by mass of oversize fraction (coarse fraction) and the material will not be included in the test, corrections must be made to the unit weight and water content of the test specimen or to the appropriate field in-place density test specimen using Practice D 4718.

1.9 This test method causes a minimal amount of degradation (particle breakdown) of the soil. When degradation occurs, typically there is an increase in the maximum unit weight obtained, and comparable test results may not be obtained when different size molds are used to test a given soil. For soils where degradation is suspected, a sieve analysis of the specimen should be performed before and after the compaction test to determine the amount of degradation.

1.10 *Units*—The values stated in either SI units or inch-pound units are to be regarded separately as standard. 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 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.

Current edition approved Sept. 1, 2007. Published October 2007.

1.11 The vibrating hammer test method may be performed in the field or in the laboratory.

1.12 *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

- C 127 Test Method for Density, Relative Density (Specific Gravity), and Absorption of Coarse Aggregate
- C 136 Test Method for Sieve Analysis of Fine and Coarse Aggregates
- C 778** Specification for Standard Sand
- D 422 Test Method for Particle-Size Analysis of Soils
- D 653** Terminology Relating to Soil, Rock, and Contained Fluids
- D 698** Test Methods for Laboratory Compaction Characteristics of Soil Using Standard Effort (12 400 ft-lbf/ft³ (600 kN-m/m³))
- D 854** Test Methods for Specific Gravity of Soil Solids by Water Pycnometer
- D 1140 Test Methods for Amount of Material in Soils Finer than No. 200 (75-μm) Sieve
- D 1557** Test Methods for Laboratory Compaction Characteristics of Soil Using Modified Effort (56,000 ft-lbf/ft³ (2,700 kN-m/m³))
- D 2216** Test Methods for Laboratory Determination of Water (Moisture) Content of Soil and Rock by Mass
- D 2487** Practice for Classification of Soils for Engineering Purposes (Unified Soil Classification System)
- D 2488** Practice for Description and Identification of Soils (Visual-Manual Procedure)
- D 3282** Practice for Classification of Soils and Soil-Aggregate Mixtures for Highway Construction Purposes
- D 3740** Practice for Minimum Requirements for Agencies Engaged in the Testing and/or Inspection of Soil and Rock as Used in Engineering Design and Construction
- D 4220 Practices for Preserving and Transporting Soil Samples
- D 4253 Test Methods for Maximum Index Density and Unit Weight of Soils Using a Vibratory Table
- D 4254 Test Methods for Minimum Index Density and Unit Weight of Soils and Calculation of Relative Density
- D 4318 Test Methods for Liquid Limit, Plastic Limit, and Plasticity Index of Soils
- D 4718** Practice for Correction of Unit Weight and Water Content for Soils Containing Oversize Particles
- D 4753** Guide for Evaluating, Selecting, and Specifying Balances and Standard Masses for Use in Soil, Rock, and Construction Materials Testing
- D 6026 Practice for Using Significant Digits in Geotechnical Data

E 11 Specification for Wire Cloth and Sieves for Testing Purposes

E 145 Specification for Gravity-Convection and Forced-Ventilation Ovens

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

2.2 *American Association of State Highway and Transportation Officials Standards:*³

M092-05-UL Standard Specification for Wire-Cloth Sieves for Testing Purposes

M145-91-UL Standard Specification for Classification of Soils and Soil-Aggregate Mixtures for Highway Construction Purposes

M231-95-UL Standard Specification for Weighing Devices Used in the Testing of Materials

3. Terminology

3.1 Definitions:

3.1.1 For definitions of terms used in this test method, refer to Terminology **D 653**.

3.2 Definitions of Terms Specific to This Standard:

3.2.1 *granular soil, n*—any soil with less than 35 %, by dry mass, passing the No. 200 (75-μm) sieve.

3.2.2 *nonplastic, adj*—description for a soil sample when any one of the liquid limit, plastic limit, or plasticity index can not be determined.

3.2.3 *plastic, adj*—description for a soil sample when the liquid limit, plastic limit, and plasticity index can all be determined.

3.2.4 *water content range for effective compaction, n*—the range of water contents, expressed as a percentage, bounded by 80 % of w_{ZAV} and w_{ZAV} .

3.2.5 *zero air voids water content, w_{ZAV} , n*—the water content, expressed as a percentage, that corresponds to saturation at the maximum dry unit weight.

3.2.6 *oversize fraction (coarse fraction), P_c (%)*, *n*—the portion of total sample not used in performing the compaction test; it is the portion of total sample retained the 3/4-in. (19.0-mm) sieve.

3.2.7 *test fraction (finer fraction), P_f (%)*, *n*—the portion of total sample used in performing the compaction test; it is the portion of total sample passing the 3/4-in. (19.0-mm) sieve.

4. Summary of Test Method

4.1 The maximum dry unit weight and water content range for effective compaction of a given free-draining soil is determined using either an oven-dried or wet/saturated soil. Soil is placed in three layers into a mold of given dimensions. Each layer is compacted for a given amount of time by a vibrating hammer that applies vibration and surcharge to the soil. The dry unit weight is calculated by dividing the oven-dried weight of the densified soil by the volume of the mold containing the soil. The water content range for effective

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>.

compaction is determined from the maximum dry unit weight and the specific gravity of solids.

5. Significance and Use

5.1 For many cohesionless, free-draining soils, the maximum dry unit weight is one of the key components in evaluating the state of compactness of a given soil mass that is either naturally occurring or is constructed (fill).

5.2 Soil placed as an engineered fill is compacted to a dense state to obtain satisfactory engineering properties such as shear strength, compressibility, permeability, or combinations thereof. Also, foundation soils are often compacted to improve their engineering properties. Laboratory compaction tests provide the basis for determining the percent compaction and water content needed at the time of compaction to achieve the required engineering properties, and for controlling construction to assure that the required unit weights and water contents are achieved.

5.3 It is generally recognized that percent compaction is a good indicator of the state of compactness of a given soil mass. However, the engineering properties, such as strength, compressibility, and permeability of a given soil, compacted by various methods to a given state of compactness can vary considerably. Therefore, considerable engineering judgment must be used in relating the engineering properties of soil to the state of compactness.

5.4 Experience indicates that the construction control aspects discussed in 5.2 are extremely difficult to implement or yield erroneous results when dealing with certain soils. 5.4.1, 5.4.2, and 5.4.3 describe typical problem soils, the problems encountered when dealing with such soils, and possible solutions to these problems.

5.4.1 *Degradation*—Soils containing particles that degrade during compaction are a problem, especially when more degradation occurs during laboratory compaction than field compaction, as is typical. Degradation typically occurs during the compaction of a granular-residual soil or aggregate. When degradation occurs, the maximum dry unit weight increases⁴ so that the laboratory maximum value is not representative of field conditions. Often, in these cases, the maximum dry unit weight is impossible to achieve in the field.

5.4.1.1 One method to design and control the compaction of such soils is to use a test fill to determine the required degree of compaction and the method to obtain that compaction, followed by the use of a method specification to control the compaction. Components of a method specification typically contain the type and size of compaction equipment to be used, the lift thickness, and the number of passes.

NOTE 4—Success in executing the compaction control of an earthwork project, especially when a method specification is used, is highly dependent upon the quality and experience of the “contractor” and “inspector.”

5.4.2 *Gap Graded*—Gap-graded soils (soils containing many large particles with limited small particles) are a problem

because the compacted soil will have larger voids than usual. To handle these large voids, standard test methods (laboratory or field) typically have to be modified using engineering judgment.

5.4.3 *Gravelly Soils Possessing Low Angularity and High Percentage of Fines*—Gravelly soils possessing low angularity and a high percentage of fines can lead to poor results for dry unit weight when using the wet/saturated method. However, when water contents at the time of compaction are near saturation with no free water, the dry unit weight achieved may result in a higher value than that from the dry method. Ultimately, during densification, the material may reach a saturated state. Therefore, for these soils, a water content of 1 or 2 % less than the w_{zav} for the density achieved by using the dry method is recommended. This is more of a concern for testing in the 11-in. mold than in the 6-in. mold.

5.5 An absolute maximum dry unit weight is not necessarily obtained by these test methods.

NOTE 5—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 D 3740 are generally considered capable of competent and objective testing/sampling/inspection, and the like. Users of this standard are cautioned that compliance with Practice D 3740 does not in itself assure reliable results. Reliable results depend on many factors; Practice D 3740 provides a means of evaluating some of those factors.

6. Apparatus

6.1 *Vibrating Hammer*—The vibrating hammer used for this test should be one that is commercially available and provides reliable performance. The vibration hammer shall operate at a frequency of 3200 to 3500 beats per minute and the manufacturer’s rated impact energy shall be in the range of 7 to 9 ft-lbf (9.5 to 12 m-N) and weigh 12 to 20 lbf (53 to 89 N), not including the weight of the tamper.

NOTE 6—It has been found that a Bosch model 11248EVS will provide the above specified characteristics. Other vibrating hammers also may provide satisfactory compaction and may be used if they meet the calibration required in Annex A2. Some characteristics of candidate hammers are shown in Table 1. Subcommittee D18.03 is open to identifying other makes and models that would meet these requirements.

6.2 *Mold Assembly*—The molds shall be cylindrical in shape, made of rigid metal and be within the capacity and dimensions indicated in 6.2.1 or 6.2.2 and Figs. 1 and 2. See also Table 2. The walls of the mold may be solid, split, or tapered. The “split” type may consist of two half-round

TABLE 1 Characteristics of Candidate Vibratory Hammers

	Bosch 11248EVS	Bosch 11318EVS	Milwaukee 5327-21	Milwaukee 5336-22
Volts	120	120	120	120
Amps	11	11	11	13
Beats/min	1700-3300	1300-3300	3400	1300-3450
Hertz	28-55	22-55	57	22-58
Impact Energy (ft-lb)	7.4	8.8	7.9	8.6
	(10 m-N)	(12 m-N)	(11 m-N)	(12 m-N)
Length (in.)	18	17.75	17.5	18.5
	(46 cm)	(45 cm)	(44 cm)	(47 cm)
Weight (lb)	14.4	12.5	12.9	15
	(64 N)	(56 N)	(57 N)	(67 N)

⁴ Johnson, A. W., and Sallberg, J. R., Factors Influencing Compaction Test Results, Highway Research Board, Bulletin 318, Publication 967, National Academy of Sciences-National Research Council, Washington, DC, 1962, p. 73.

As an option to the full length stud, a 2 1/2" x 3/8" stud may be used. Then as an alternative construction, the collar may be held down with a slotted bracket attached to the collar and a pin in the mold.

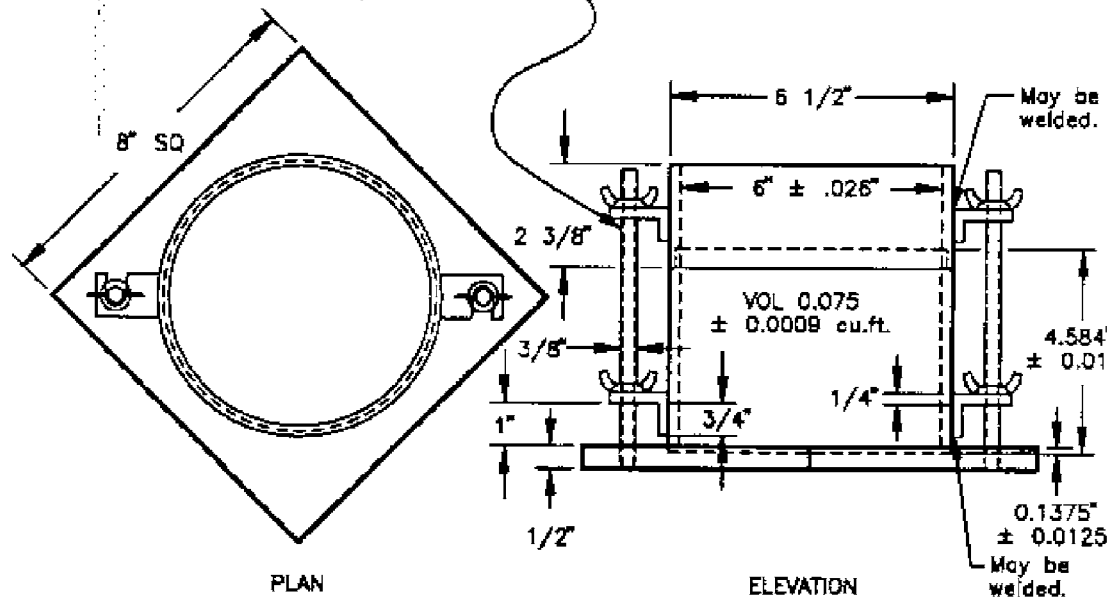
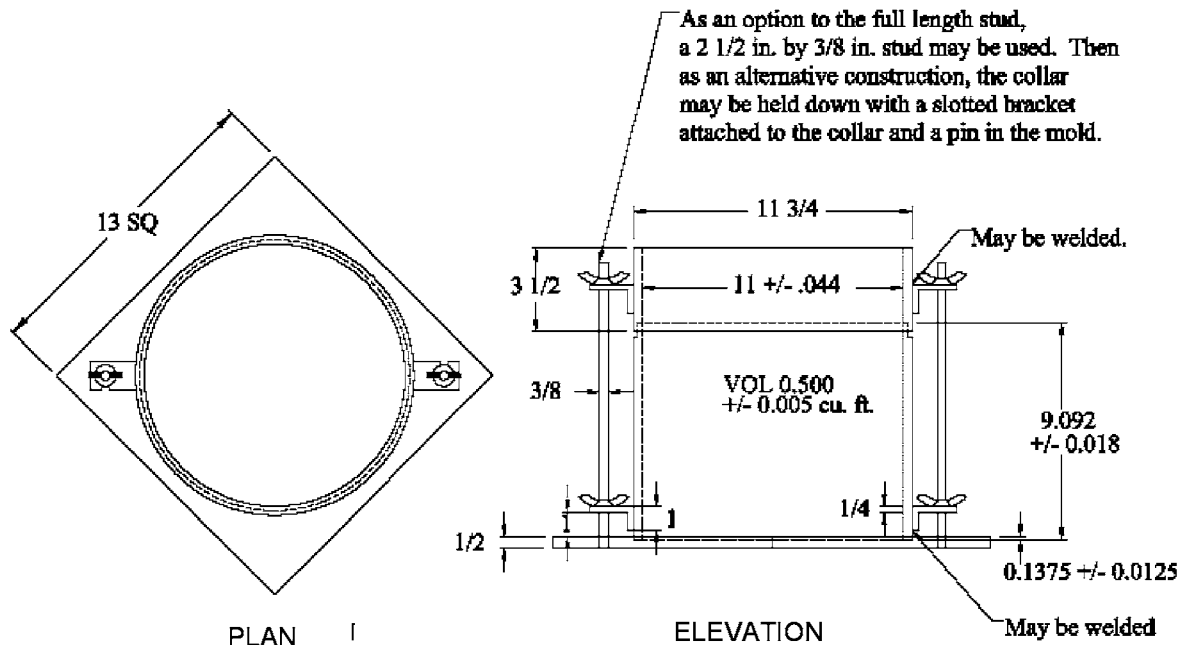


FIG. 1 6.0-in. Cylindrical Mold (see Table 2 for SI equivalent dimensions)



NOTE—All dimensions are in inches.

FIG. 2 11.0-in. Cylindrical Mold (see Table 2 for SI equivalent dimensions)

sections, or a section of pipe split along one element, which can be securely locked together to form a cylinder meeting the requirements of this section. The "tapered" type shall have an internal diameter taper that is uniform and not more than 0.200 in. per ft (16.7 mm per m) of mold height. Each mold shall have a base plate and an extension collar assembly, both made

of rigid metal and constructed so they can be securely attached and easily detached from the mold. The extension collar assembly shall have a height extending above the top of the mold of at least 2.0 in. (50.8 mm) which may include an upper section that flares out to form a funnel provided there is at least a 0.75 in. (19.0-mm) straight cylindrical section beneath it. The