INTERNATIONAL

Designation: D7382 – 20

Standard Test Methods for Determination of Maximum Dry Unit Weight of Granular Soils Using a Vibrating Hammer[1]

This standard is issued under the fixed designation D7382; 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 of granular soils. A vibrating hammer is used to impart a surcharge and compactive effort to the soil specimen. Further, an optional calculation is presented to determine the approximate water content range for effective compaction of granular soils based on the measured maximum dry density and specific gravity.

1.2 These test methods apply to primarily granular, free-draining soils for which impact compaction does not yield a clear optimum water content. Specifically, these test methods apply to soils:

1.2.1 with up to 35 %, by dry mass, passing a No. 200 (75-µm) sieve if the portion passing the No. 40 (425-µm) sieve is nonplastic;

1.2.2 with up to 15 %, by dry mass, passing a No. 200 (75-µm) sieve if the portion passing the No. 40 (425-µm) sieve exhibits plastic behavior.

1.3 Further, due to limitations of the testing equipment, and the available oversize correction procedures these test methods apply to soils in which:

1.3.1 less than 30 %, by dry mass, is retained on the ¾-in. (19.0-mm) sieve, or in which

1.3.2 100 %, by dry mass, passes the 2-in. (50-mm) sieve.

1.4 These test methods will typically produce a higher maximum dry unit weight for the soils specified in 1.2.1 and 1.2.2 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 D698 or D1557) may be useful in evaluating what is an appropriate maximum index unit weight.

1.5 Four alternative test methods are provided, with the variation being in saturated versus dry specimens and 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.

1.5.1 *Method 1A*—Using saturated material and a 6-in. (152.4-mm) diameter mold; applicable for materials with maximum particle size of ¾-in. (19-mm) or less, or with 30 % or less, by dry mass, retained on the ¾-in. (19-mm) sieve.

1.5.2 *Method 1B*—Using saturated material and an 11-in. (279.4-mm) diameter mold; applicable for materials with maximum particle size of 2-in. (50-mm) or less

1.5.3 *Method 2A*—Using oven-dry material and a 6-in. (152.4-mm) diameter mold; applicable for materials with maximum particle size of ¾-in. (19-mm) or less, or with 30 % or less, by dry mass, retained on the ¾-in. (19-mm) sieve.

1.5.4 *Method 2B*—Using oven-dry material and an 11-in. (279.4-mm) diameter mold; applicable for materials with maximum particle size of 2-in. (50-mm) or less.

1.5.5 It is recommended that both the saturated and dry methods (Methods 1A and 2A, or 1B and 2B) be performed when beginning a new job or encountering a change in soil type, as one method or the other may result in a higher value for the maximum dry unit weight. While the dry method is often preferred for convenience and because results can be obtained more quickly, as a general rule, the saturated method should be used if it proves to produce a significantly higher value for maximum dry unit weight.

NOTE 1—Results have been found to vary slightly when a material is tested at the same compaction effort in different size molds.

1.6 If the test specimen contains more than 5 % by mass of oversize material (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 D4718.

NOTE 2—Methods 1A and 2A (with the correction procedure of Practice D4718, if appropriate), have been shown to provide consistent results with Methods 1B and 2B for materials with 30 % or less, by dry mass retained on the ¾-in. (19-mm) sieve. Therefore, for ease of operations, it is recommended to use Method 1A or 2A, unless Method 1B or 2B is required due to soil gradations having in excess of 30 %, by dry mass, retained on the ¾-in. (19-mm) sieve.

[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 July 1, 2020. Published July 2020. Originally approved in 2007. Last previous edition approved in 2008 as D7382 – 08, which was withdrawn in February 2017 and reinstated July 2020. DOI: 10.1520/D7382-20.

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

1.7 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.

1.8 *Units*—The values stated in inch-pound units are to be regarded as standard. The SI units given in parentheses are mathematical conversions, which are provided for information purposes only and are not considered standard. Reporting of test results in units other than inch-pound units shall not be regarded as nonconformance with this test method.

1.8.1 The gravitational system of inch-pound units is used. In this system, the pound (lbf) represents a unit of force (weight), while the unit for mass is slugs. The slug unit is not given, unless dynamic (F = ma) calculations are involved.

1.8.2 The slug unit of mass is almost never used in commercial practice; for example as related to density, balances, and the like. 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/presented in parentheses.

1.8.3 It is common practice in the engineering/construction profession, in the United States, 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, 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.

1.8.4 The terms density and unit weight are often used interchangeably. Density is mass per unit volume whereas unit weight is force per unit volume. In this standard, density is given only in SI units. After the density has been determined, the unit weight is calculated in inch-pound or SI units, or both.

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

1.9.1 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, 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 this standard to consider significant digits used in analytical methods for engineering design.

1.10 *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.*

1.11 *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]

C127 Test Method for Relative Density (Specific Gravity) and Absorption of Coarse Aggregate
C136 Test Method for Sieve Analysis of Fine and Coarse Aggregates
C702 Practice for Reducing Samples of Aggregate to Testing Size
C778 Specification for Standard Sand
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
D1557 Test Methods for Laboratory Compaction Characteristics of Soil Using Modified Effort (56,000 ft-lbf/ft^3 (2,700 kN-m/m^3))
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)
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
D4220/D4220M Practices for Preserving and Transporting Soil Samples
D4318 Test Methods for Liquid Limit, Plastic Limit, and Plasticity Index of Soils
D4718 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
D6026 Practice for Using Significant Digits in Geotechnical Data
D6913 Test Methods for Particle-Size Distribution (Gradation) of Soils Using Sieve Analysis

[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.

E11 Specification for Woven Wire Test Sieve Cloth and Test Sieves

E145 Specification for Gravity-Convection and Forced-Ventilation Ovens

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 common technical terms used in this test method, refer to Terminology D653.

3.2 *Definitions of Terms Specific to This Standard:*

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

3.2.2 *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.

3.2.3 *oversize fraction (coarse fraction), P_c (%), n*—the portion of total sample not used in performing the compaction test; for Methods 1A and 2A for example, it is the portion of total sample retained on the ¾-in. (19.0-mm) sieve.

4. Summary of Test Method

4.1 The maximum dry unit weight and optionally, the approximate water content range for effective compaction, of a given free-draining soil is determined using either oven-dried or saturated soil, and either a 6-in. (152.4-mm) or 11-in. (279.4-mm) compaction mold. 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 approximate water content range for effective compaction is optionally 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 ensure 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. Subsections 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 increases[4] 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 3—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 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,

[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] 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.

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 4—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, and the like. 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.

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 vibrating 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 5—At the time of last revision, it was found that DeWalt models and D25501K and D25553K 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. At the time of last revision, several hammers were identified that had lower than specified impact energy and weight, but that could prove suitable if additional mass were added to the hammer frame apparatus (see 6.3 and Annex A2). Possible examples include Hilti model TE 50 and Bosch model 11240. Subcommittee D18.03 is actively seeking 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 1. The walls of the mold may be solid, split, or tapered. The "split" type may consist of two half-round 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 extension collar shall align with the inside of the mold. The bottom of the base plate and bottom of the centrally recessed area that accepts the cylindrical mold shall be planar.

6.2.1 *Mold, 6 in.*—A mold having a 6.000 ± 0.026-in. (152.4 ± 0.7-mm) average inside diameter, a height of 4.584 ± 0.018 in. (116.4 ± 0.5 mm), and a volume of 0.075 ± 0.0009 ft^3 (2124 ± 25 cm^3). A mold assembly having the minimum required features is shown in Fig. 1.

6.2.2 *Mold, 11 in.*—A mold having a 11.000 ± 0.044-in. (279.4 ± 1.1-mm) average inside diameter, a height of 9.092 ± 0.018 in. (230.9 ± 0.5 mm), and a volume of 0.500 ± 0.005 ft^3 (14 200 ± 142 cm^3). A mold assembly having the minimum required features is shown in Fig. 2.

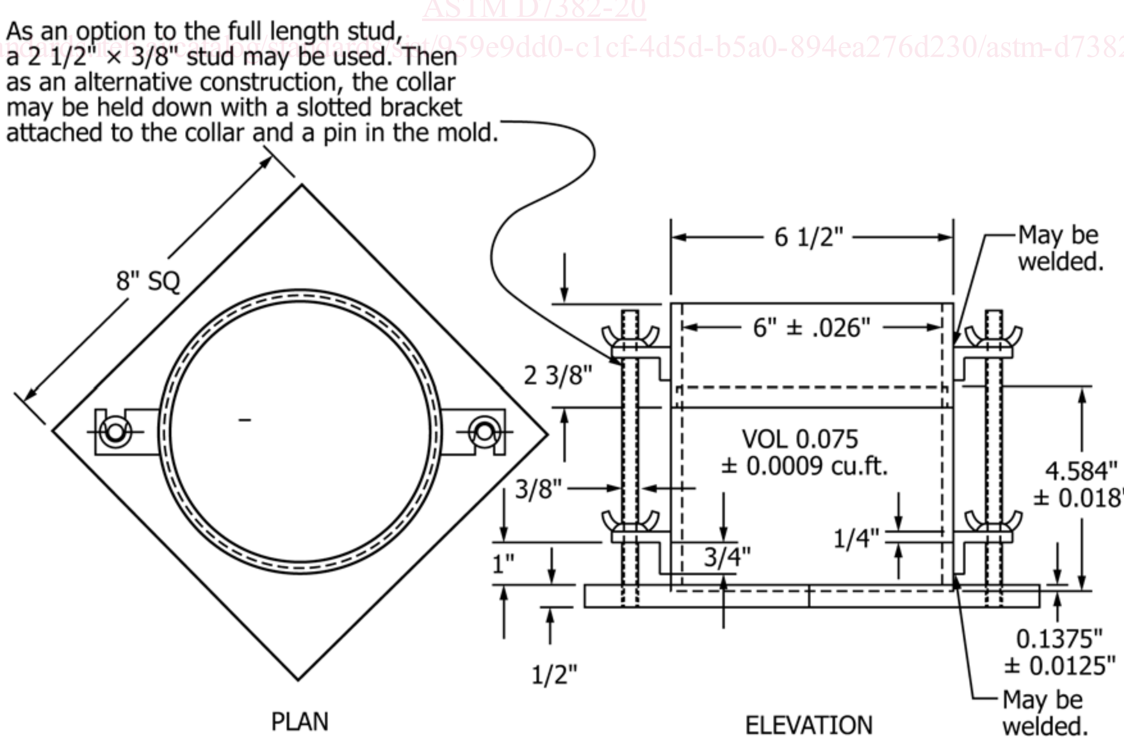
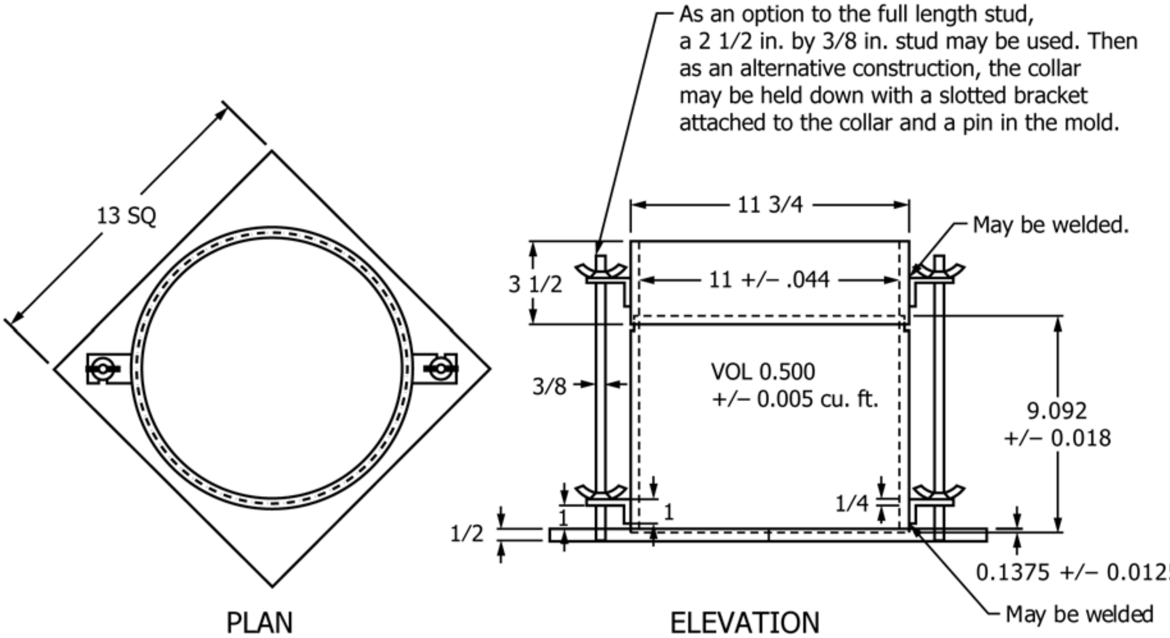


FIG. 1 6.0-in. Cylindrical Mold (see Table 1 for SI equivalent dimensions)



NOTE 1—All dimensions are in inches.

FIG. 2 11.0-in. Cylindrical Mold (see Table 1 for SI equivalent dimensions)

TABLE 1 SI Equivalents for Figs. 1-3

in.	mm	in.	mm	ft³	cm³
0.005	0.13	2⅜	60.33	0.0009	25
0.0125	0.32	3½	88.90	0.005	142
0.018	0.46	4.584	116.43	0.075	2124
0.026	0.66	5.750	146.05	0.500	14 200
0.044	1.12	6	152.40		
0.1375	3.49	6½	165.10		
¼	6.35	8	203.20		
⅜ and 0.375	9.53	9.092	230.94		
½	12.70	11	279.40		
¾	19.05	11¾	298.45		
1	25.40	13	330.20		

6.3 *Hammer Frame*—The hammer frame shall consist of a metal clamp assembly to firmly hold the vibrating hammer that moves on guide rods that allow for free vertical movement of the vibrating hammer and clamp assembly. The guide rods are fastened to a metal base in a manner to keep them vertical and parallel to each other. The frame shall be designed to securely hold the vibrating hammer and clamp assembly in an elevated position during insertion and removal of molds. Guides may be placed on the base of the frame to allow for proper alignment of molds underneath the tamper. The mass of the clamp assembly, vibrating hammer (6.1), and tamper (Fig. 3) shall be such to impart a surcharge of 2.5 to 5.0 psi (17 to 34 kPa) from the base of the tamper. The metal base dimensions in Fig. 4 provide sufficient mass and stiffness to support the compaction molds. This plate may be mounted on heavy duty casters or on a rigid table. A suitable design is shown in Figs. 4 and 5. See also Table 2.

6.4 *Sample Extruder (optional)*—A jack, frame, or other device adapted for the purpose of extruding compacted specimens from the mold.

6.5 *Balance(s)*—Balances of sufficient capacity to determine the total mass of the specimen and mold, having sufficient readability that the mass of the soil is determined to the nearest 0.1 %. Examples of balances capable of satisfying these requirements for most conditions have specifications as follows:

6.5.1 For Method 1A or 2A (6-in. (152.4-mm) diameter molds), use a class GP5 balance of at least 30-lbm (15-kg) capacity and meeting the requirements of Guide D4753 for a balance of 1-g readability.

6.5.2 For Method 1B or 2B (11-in. (279.4-mm) diameter molds), use a class GP100 balance having a minimum capacity of 125 lbm (60 kg) and meeting the requirements of Guide D4753 for a balance of 50-g readability.

6.6 *Drying Oven*—Thermostatically controlled oven, capable of maintaining a uniform temperature of 230 ± 9°F (110 ± 5°C) throughout the drying chamber. These requirements typically require the use of a forced-draft type oven. Preferably the oven should be vented outside the building.

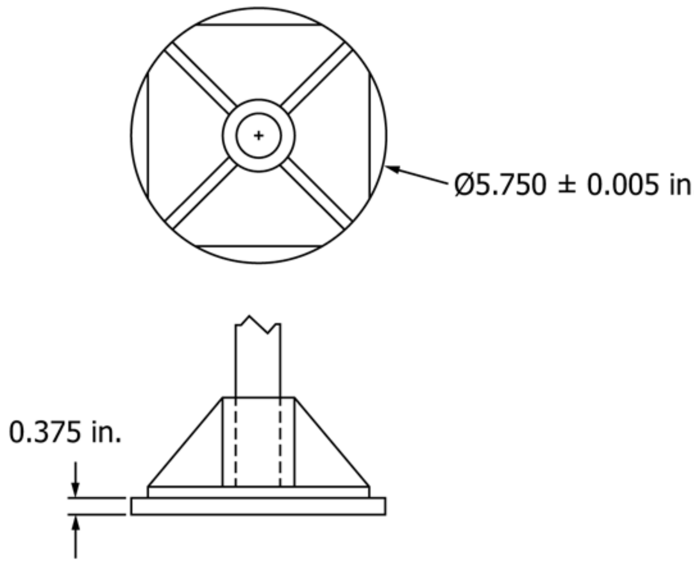
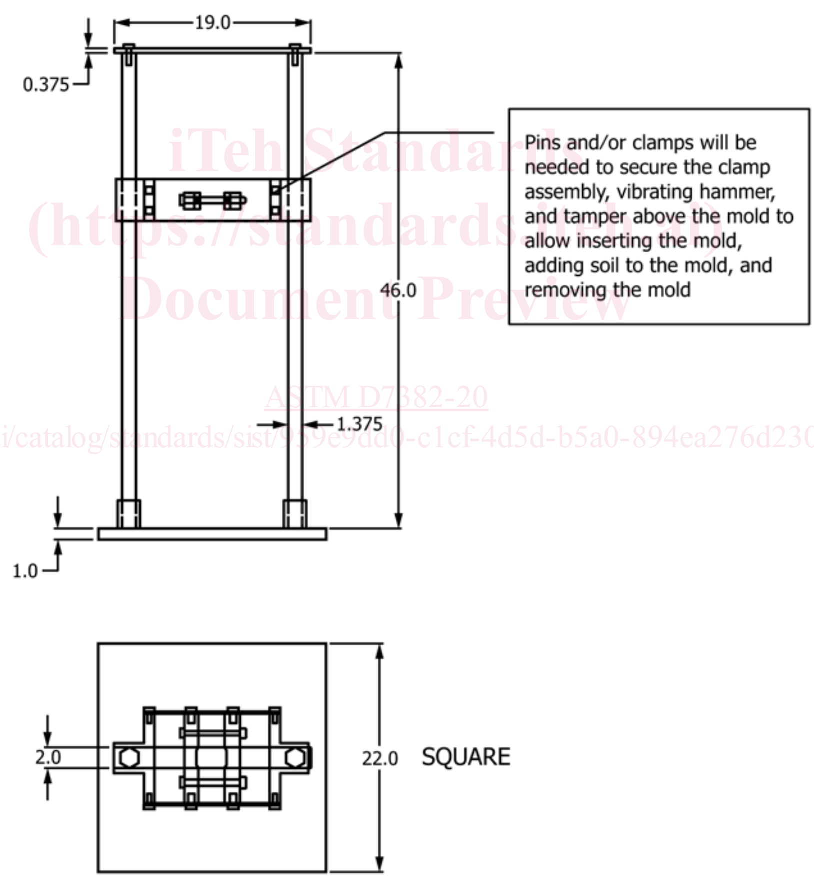


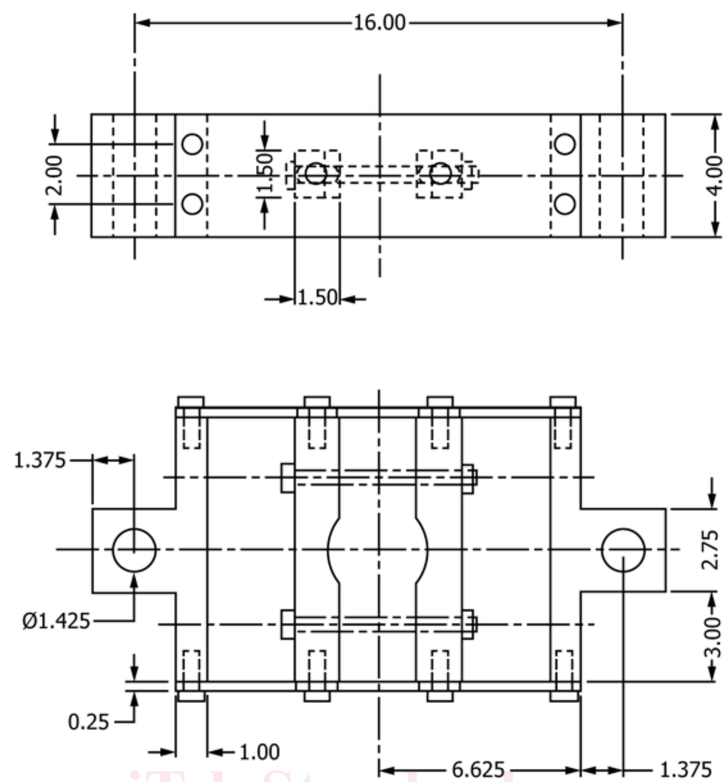
FIG. 3 6-in. Tamper (see Table 1 for SI equivalent dimensions)



NOTE 1—All dimensions are in inches.

FIG. 4 Hammer Frame

6.7 *Straightedge*—A stiff metal straightedge of any convenient length, but not less than 4 in. (101.6 mm) longer than the diameter of the mold used. 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).



NOTE 1—All dimensions are in inches.

FIG. 5 Hammer Clamp Assembly

TABLE 2 SI Equivalents for Figs. 4 and 5

in.	mm
0.250	6.35
0.375	9.53
1.000	25.40
1.375	19.05
1.425	34.93
1.500	38.10
2.000	50.80
2.750	69.85
3.000	76.20
4.000	101.60
6.625	168.28
16.000	406.40
19.000	482.60
22.000	558.80
46.000	1168.40

6.8 *Sieves*—2-in. (50-mm), ¾-in. (19-mm), and No. 200 (75-µm) sieves conforming to the requirements of Specification E11.

6.9 Other equipment such as mixing pans, a large metal scoop, a hair-bristled dusting brush, and a timing device indicating minutes and seconds.

NOTE 6—Modifications may be made to the vibrating hammer such as a mechanical device using pneumatic or electrical power to lift the vibrating hammer up and down as long as the device does not impede the free movement of the hammer during compaction. In addition, a timing device to directly control the vibrating hammer may be used; however, a power relay is usually needed to provide the power required to supply to the hammer.

7. Hazards

7.1 **Warning—**Use of vibrating hammers in certain acoustic environments may produce noise levels above those considered acceptable. Suitable hearing-protection devices shall be used in areas where such conditions are known to exist or where acoustic monitoring surveys have not been conducted. In addition, testing personnel should also adhere to any additional personal safety requirements in accordance with individual laboratory policies.

8. Sampling and Test Specimens

8.1 *General*—This test method does not address, in any detail, procurement of the sample. It is assumed the sample is obtained using appropriate methods and is representative of the material under evaluation. However, the testing agency shall preserve all samples in accordance with Practice D4220/D4220M, Group B, except if the as-received sample does not meet those requirements. In which case, the water content of the material does not have to be maintained.

8.2 Do not reuse soil that has been previously compacted in the laboratory.

8.3 The required dry specimen mass is approximately 7 kg for Method 1A or 2A, and approximately 45 kg for Methods 1B and 2B. Field samples should have a moist mass of at least three (and preferably six) times these values to allow for drying and splitting/quartering, and since normally the saturated and dry methods are both performed and more than one trial is completed. Greater masses could be required if the oversize fraction is large or if the field sample is very wet.