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# Standard Test Methods for Laboratory Determination of Density and Unit Weight of Soil Specimens[1]

This standard is issued under the fixed designation D7263; 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 describe two ways of determining the total/moist/bulk density, dry density, and dry unit weight of intact, disturbed, remolded, and reconstituted (compacted) soil specimens (Note 1). Intact specimens may be obtained from thin-walled sampling tubes, block samples, or clods. Specimens that are remolded by dynamic or static compaction procedures are also measured by these methods. These methods apply to soils that will retain their shape during the measurement process and may also apply to other materials such as soil-cement, soil-lime, soil-bentonite or solidified soil-bentonite-cement slurries. It is common for the density to be less than the value based on tube or mold volumes, or of in situ conditions after removal of the specimen from sampling tubes and compaction molds. This change is due to the specimen swelling after removal of lateral pressures.

NOTE 1—The adjectives total, moist, wet or bulk are used to represent the density condition. In some professions, such as Soil Science and Geology, the term "bulk density" usually has the same meaning as dry density. In the Geotechnical and Civil Engineering professions, the preferred adjective is total over moist and bulk when referring to the total mass of partially saturated or saturated soil or rock per unit total volume. For more detailed information regarding the term density, refer to Terminology D653.

1.1.1 *Method A (Water Displacement)*—A specimen is coated in wax and then placed in water to measure the volume by determining the quantity of water displaced. The density and unit weight are then calculated based on the mass and volume measurements. Do not use this method if the specimen is susceptible to surface wax intrusion.

1.1.2 *Method B (Direct Measurement)*—The dimensions and mass of a specimen are measured. The density and unit weight are then calculated using these direct measurements. Usually, the specimen has a cylindrical or cuboid shape. Intact and reconstituted/remolded specimens may be tested by this method in conjunction with strength, permeability/hydraulic conductivity (air/water) and compressibility determinations.

1.2 *Units*—The values stated in SI units are to be regarded as standard. The values given in parentheses are provided for information only and are not considered standard. Reporting of test results in units other than SI shall not be regarded as nonconformance with this standard.

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

1.2.2 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 practice implicitly combines two separate systems of units; the absolute and the gravitational systems. 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 of mass. However, the use of balances and scales recording pounds of mass (lbm) or recording density in $lbm/ft^3$ shall not be regarded as nonconformance with this standard.

1.2.3 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 SI or inch-pound units, or both.

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 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 analysis methods for engineering design.

1.4 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the*

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

*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.*

1.5 *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]

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$^3$))

D1587/D1587M Practice for Thin-Walled Tube Sampling of Fine-Grained Soils for Geotechnical Purposes

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

D4753 Guide for Evaluating, Selecting, and Specifying Balances and Standard Masses for Use in Soil, Rock, and Construction Materials Testing

D4943 Test Method for Shrinkage Factors of Cohesive Soils by the Water Submersion Method

D6026 Practice for Using Significant Digits in Geotechnical Data

D7015/D7015M Practices for Obtaining Intact Block (Cubical and Cylindrical) Samples of Soils

## 3. Terminology

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

## 4. Summary of Test Methods

4.1 *Test Method A (Water Displacement)*—A test specimen is obtained from a sample, then its mass in air is measured. It is then coated in wax and its mass is measured. The wax-coated specimen is then placed in a wire basket that is attached to a balance and fully submerged in a container (water tank) of water. Its mass in water is measured. The quantity of water displaced measures the volume of the specimen. The density and unit weight are then calculated. This method must not be used for specimens that allow wax to penetrate the outer surface of the specimen

4.2 *Test Method B (Direct Measurement)*—A test specimen is obtained from a sample. The test specimen can have a cylindrical or cuboidal shape. If the test specimen is cylindrical in shape, its mass, height, and diameter are measured. If it is cuboidal in shape, its mass, height, width, and length are measured. The density and unit weight are then calculated based on the physical dimensions and mass of the specimen.

## 5. Significance and Use

5.1 Density is a key element in the phase relations, phase relationships, or mass-volume relationships of soil and rock (Appendix X1). When particle density, that is, specific gravity (Test Methods D854) is also known, dry density can be used to calculate porosity and void ratio (see Appendix X1). Dry density measurements are also useful for determining degree of soil compaction. Since water content is variable, total/moist soil density provides little useful information except to estimate the weight of soil per unit volume, for example, grams per cubic centimeter, at the time of sampling. Since soil volume shrinks with drying of swelling soils, total density will vary with water content. Hence, the water content of the soil should be determined at the time of sampling.

5.2 Densities and unit weights of remolded/reconstituted specimens are commonly used to evaluate the degree of compaction of earthen fills, embankments, and the like. Dry density values are used to calculate dry unit weight values to create a compaction curve (Test Methods D698 and D1557).

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 several factors; Practice D3740 provides a means of evaluating some of these factors.

## 6. Apparatus

6.1 *Balance*—Balances must conform to the requirements of Guide D4753.

6.1.1 To measure the mass of the specimen, the balance shall have readability without estimation of 0.01 g. For Method A, the capacity of this balance will need to exceed the mass of the specimen suspended in water. A balance having a below-balance port using a weighing hook or a yoke assemblage for top loading balances is typically used to make this measurement. For Method B, the capacity of this balance will need to exceed the mass of the specimen plus mold, if applicable. In general, a balance with a minimum capacity of 1000 g is sufficient. A higher capacity balance may be needed when determining the mass of an un-extruded specimen.

[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.

6.2 *Drying Oven*—A vented, thermostatically controlled, preferably of the forced-draft type, oven capable of maintaining a uniform temperature of 110 ± 5°C (230 ± 9°F) throughout the drying chamber.

6.3 *Wax (Method A)*—Non-shrinking paraffin, microcrystalline, or other suitable wax mixture that does not become brittle when dry and does not shrink during solidification. The density of the wax must be known to three significant digits and have a relatively constant density, $\rho_x$, (Note 3). The density must not appreciably change after repeated melting and solidification cycles. Determine the density of the wax following the procedure given in Test Method D4943, Annex A2.

6.3.1 The density of the wax can often be obtained from the manufacturer, but shall be determined in accordance with the procedure given in Test Method D4943, Annex A2 before initial use and after replenishment of stock. To verify the density of the wax is not changing by more than 0.0025 g/cm$^3$ after repeated cycles, perform the procedure three times in a row to determine the density of each heating and cooling cycle. The density values should not vary more than 0.0025 g/cm$^3$.

NOTE 3—A 50/50 mixture of paraffin wax and petroleum jelly by mass has been demonstrated to provide an adequate alternative. Paraffin wax is commercially available and has a typical density of 900 kg/m$^3$ (0.900 g/cm$^3$).

6.4 *Wax-Melting Container (Method A)*—Any container or device capable of melting the wax without overheating the wax. Heating using hot water and a container/device that is thermostatically controlled is preferred.

6.5 *Wire Basket (Method A)*—A wire basket of 3.35 mm (0.132 in.) or finer mesh of approximately equal width and height of sufficient size to contain the specimen. The basket shall be constructed to prevent trapping air when it is submerged. A hairnet may also be used in lieu of the basket for smaller soil specimens.

6.6 *Water Tank (Method A)*—A watertight container or tank of sufficient size to contain the submerged basket and specimen.

6.7 *Thermometric Device (Method A)*—A thermometric device capable of measuring the temperature range within which the test is being performed readable to 0.1°C or better and having an accuracy of at least ±0.5°C.

6.8 *Specimen-Size Measurement Devices (Method B)*—Devices used to measure the physical dimensions, such as height, width, length, and diameter, of the specimen to four significant digits. The devices shall be constructed such that their use will not disturb/deform, indent, or penetrate the specimen.

NOTE 4—Circumferential measuring tapes are recommended over calipers for measuring the diameter of cylindrical specimens.

6.9 *Miscellaneous*—Items such as, a paintbrush, trimming and carving tools (such as a wire saw, steel straightedge, miter box and vertical trimming lathe), apparatus for preparing remolded or reconstituted specimens, sample extruder, specimen containers for water contents, plastic wrap, aluminum foil, plastic bags, gloves, and tongs, may be necessary or useful, or both.

## 7. Samples and Test Specimens

7.1 *Samples*—Intact samples shall be preserved and transported in accordance with Practice D4220/D4220M Groups C and D, except if the as-received sample does not meet those requirements. Reconstituted or remolded specimens shall be preserved in accordance with Practice D4220/D4220M Group B, except if the as-received sample does not meet those requirements. Maintain stored samples prior to testing in non-corrodible airtight containers at a temperature between approximately 3°C and 30°C (37.4°F and 86°F) in an area that prevents direct contact with sunlight. Preserve the sample at its original moisture condition unless excluded above, and at no time shall the sample be allowed to undergo undesirable temperature changes such as freezing or heating.

7.2 *Specimens Size*—Cylindrical specimens must have a minimum diameter of 33 mm (1.3 in.) and be sufficiently cohesive and able to maintain shape during the measuring procedure. The average height to average diameter ratio should, but is not required to, be between 2 and 2.5. The largest particle size must be smaller than ⅙ the specimen diameter. Cubical/Cuboidal specimens must have minimum dimensions (height, width, and length) of 33 mm (1.3 in.) and the largest particle size must be smaller than 1/10 of the specimen's smallest dimension. If, after completion of a test on an intact specimen, it is found based on visual observation that oversize particles are present, indicate this information in the remarks section of the data sheet. Irregular shaped (clods) specimens must be of sufficient size to adequately represent the soil under evaluation. Avoid selecting a specimen that is too small since it would not be representative.

7.3 *Intact Specimens*—Prepare intact specimens from large intact samples (Practice D7015/D7015M), from samples secured in accordance with Practice D1587/D1587M, or other acceptable intact tube sampling procedures. Specimens obtained by tube sampling may be tested without extrusion or trimming except for cutting the end surfaces plane and perpendicular to the longitudinal axis of the specimen, provided soil characteristics are such that no significant disturbance results from sampling. Specimens can also be obtained from intact block samples using a sharp cutting ring. Handle specimens carefully to reduce the potential for disturbance, changes in cross section, or changes in water content. If compression or any type of noticeable disturbance would be caused by the extrusion device, split the sample tube lengthwise or cut the tube in suitable sections to facilitate removal of the specimen with minimum disturbance. Prepare trimmed specimens, in an environment such as a controlled high-humidity room where soil water content change is avoided. Where removal of pebbles or crumbling resulting from trimming causes voids on the surface of the specimen, carefully fill the voids with remolded soil obtained from the trimmings. When the sample condition permits, a vertical trimming lathe may be used to reduce the specimen to a smaller diameter if desired. After obtaining the desired diameter, place the specimen in a miter box, and cut the specimen to the final height with a wire saw

or other suitable device. Trim the surfaces with the straightedge. Perform and record one or more water content determinations to the nearest 0.1 % on material trimmed from the specimen in accordance with Test Methods D2216.

NOTE 5—Core sampling might be difficult or impossible in gravelly or hard dry soils. Wet soils tend to be more plastic and subject to compression.

NOTE 6—Some soils may expand into the sampling tube with a resultant change in volume from the original in situ condition.

7.3.1 Cubical/Cuboidal specimens must be prepared such that the sides are relatively flat and even. Trimming devices that assist in creating a smooth, flat surface should be used.

7.4 *Reconstituted (Compacted) Specimens*—Soil needed for reconstituted specimens shall be thoroughly mixed with sufficient water to produce the desired water content. If water is added to the soil, store the material in a covered container for at least 16 h prior to compaction. Reconstituted specimens may be prepared by compacting material in at least six layers using a split mold of circular cross section having dimensions meeting the requirements enumerated in 7.2 for cylindrical specimens. Specimens may be reconstituted to the desired density by either: (*1*) kneading or tamping each layer until the accumulative mass of the soil placed in the mold is reconstituted to a known volume; or (*2*) by adjusting the number of layers, the number of tamps per layer, and the force per tamp. The top of each layer shall be scarified prior to the addition of material for the next layer. The tamper used to compact the material shall have a diameter equal to or less than one half the diameter of the mold. After a specimen is formed, with the ends perpendicular to the longitudinal axis, remove the mold. Perform and record one or more water content determinations to the nearest 0.1 % on excess material used to prepare the specimen in accordance with Test Methods D2216.

7.5 *Remolded Specimens*—Specimens may be prepared either from a failed intact specimen or from a disturbed sample, providing it is representative of the failed intact specimen. In the case of failed intact specimens, wrap the material in a thin rubber membrane and work the material thoroughly with the fingers to make sure of complete remolding. Avoid entrapping air in the specimen. Exercise care to obtain a uniform density, to remold to the same void ratio as the intact specimen, and to preserve the water content of the soil. Form the disturbed material into a mold of circular cross section having dimensions meeting the requirements of 7.2. After a specimen is formed, with the ends perpendicular to the longitudinal axis, remove the mold. Perform and record one or more water content determinations to the nearest 0.1 % on excess material used to prepare the specimen in accordance with Test Methods D2216.

7.6 *Irregularly Shaped Specimens*—Select a specimen that does not have re-entrant angles and adequately represents the soil under evaluation.

7.7 If testing is not immediately performed, wrap the specimen in plastic wrap and then, either wrap with aluminum foil or place in a plastic bag to prevent changes in water content. Take care to avoid deforming the specimen during wrapping. It is recommended to immediately test the specimen after trimming/preparing.

## 8. Safety Hazards

8.1 Wax melting equipment and hot wax may burn unprotected skin. Overheated wax may burst into flames; therefore, extreme care should be exercised when working with hot wax.

8.2 **Warning—**Vapors given off by molten wax ignite spontaneously above 205°C (400°F) and wax can ignite if allowed to come in contact with the heating element or open flame. Do not use an open flame device to heat wax.

## 9. Procedure

9.1 *Method A—Water Displacement:*

9.1.1 Determine and record the density of the wax being used to coat the specimen to three significant digits (6.3.1).

9.1.2 Obtain the test specimen as described in Section 7. The specimen must meet the minimum size requirements given in 7.2. Cylindrical and cuboid specimens must have a fairly regular shape. Re-entrant angles should be avoided for irregular shaped (clod) specimens.

9.1.3 Measure and record the moist mass of the soil specimen ($M_t$) to four significant digits in g.

9.1.4 Melt the wax to only slightly above its melting point to avoid flashing of the wax vapors and to permit quick forming of a uniform surface coating of the wax.

9.1.5 Cover the specimen with a thin coat of melted wax, either with a paintbrush or by dipping the specimen in a container of melted wax. Apply a second coat of wax after the first coat has hardened. The wax should be sufficiently warm to flow when brushed on the specimen, yet not so hot that it dries the soil.

NOTE 7—If overheated wax comes in contact with the soil specimen, it may cause the moisture to vaporize and form air bubbles under the wax. Bubbles may be trimmed out and filled with wax.

9.1.6 Measure and record the mass of the wax-coated specimen in air ($M_c$) to four significant digits in g.

9.1.7 Attach the wire basket to the below-balance port or to the yoke assemblage of the balance and submerge it in the water tank. Then zero/tare the balance. Make sure the basket is fully submerged and not touching the sides or the bottom of the water tank while submerged. The wire basket must also be at the same depth for both zeroing/taring the balance and taking the measurement with the specimen. Before removing the wire basket, measure and record the temperature of the water to the nearest 0.1°C. The temperature of the water must remain within ±3°C of this temperature between zeroing the balance and submerging the specimen in the basket.

9.1.8 Lift the wire basket out of the water and place the wax-coated specimen in the wire basket and submerge it in the water tank. Make sure the basket plus specimen is fully submerged and not touching the sides or the bottom of the water tank while submerged. Measure and record the mass of the wax-coated specimen submerged in water ($M_{sub}$) to four significant digits in g. Measure and record the temperature of the water to the nearest 0.1°C to confirm the temperature has not changed more than ±3°C since the balance was zeroed/tared.

9.1.9 Remove the specimen from the wire basket and remove the wax from the specimen. It can be peeled off after