



Designation: D7263 – 21

Standard Test Methods for Laboratory Determination of Density and Unit Weight of Soil Specimens¹

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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 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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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/ft³ 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*

*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/ft³ (600 kN-m/m³))
- 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/ft³ (2,700 kN-m/m³))
- 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 $110 \pm 5^{\circ}\text{C}$ ($230 \pm 9^{\circ}\text{F}$) 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, ρ_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 $\pm 0.5^{\circ}\text{C}$.

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 $\frac{1}{6}$ 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 $\frac{1}{10}$ 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