Designation: D5030/D5030M – 21

Standard Test Methods for
Density of In-Place Soil and Rock Materials by the Water Replacement Method in a Test Pit[1]

1. Scope*

1.1 These test methods cover the determination of the in-place density of soil and rock materials using water to fill a lined test pit to determine the volume of the test pit. The use of the word "rock" in these test methods is used to imply that the material being tested will typically only contain particles larger than 3 in. [75 mm].

1.2 These test methods are best suited for test pits with a volume between approximately 3 and 100 ft^3 [0.08 and 3 m^3]. In general, the materials tested would have maximum particle sizes over 5 in. [125 mm]. These test methods may be used for larger sized excavations if desirable.

1.2.1 This procedure is usually performed using circular metal templates with inside diameters of 3 ft [0.9 m] or more. Other shapes or materials may be used providing they meet the requirements of these test methods and the guidelines given in Annex A1 for the minimum volume of the test pit.

1.2.2 Test Method D4914 may be used as an alternative method. Its use, however, is usually only practical for volume determination of test pits between approximately 1 and 6 ft^3 [0.03 and 0.2 m^3].

1.2.3 Test Method D1556 or Test Method D2167 is usually used to determine the volume of test holes smaller than 1 ft^3 [0.03 m^3].

1.3 The two procedures are described as follows:

1.3.1 *Procedure A*—In-Place Density and Density of Total Material (Section 12).

1.3.2 *Procedure B*—In-Place Density and Density of Control Fraction (Section 13).

1.4 *Selection of Procedure:*

1.4.1 Procedure A is used when the in-place density of the total material is to be determined. Procedure A can also be used to determine percent compaction or percent relative density when the maximum particle size present in the in-place material being tested does not exceed the maximum particle size allowed in the laboratory compaction test (Test Methods D698, D1557, D4253, D4254, and D7382). For Test Methods D698 and D1557 only, the density determined in the laboratory compaction test may be corrected for larger particle sizes in accordance with, and subject to the limitations of, Practice D4718.

1.4.2 Procedure B is used when percent compaction or percent relative density is to be determined and the in-place material contains particles larger than the maximum particle size allowed in the laboratory compaction test methods previously described or when Practice D4718 is not applicable for the laboratory compaction test method. Then, the material is considered to consist of two fractions, or portions. The material obtained from the in-place density test is physically divided into a control fraction and an oversize fraction based on a designated sieve size. The density of the control fraction is calculated and compared with the density(ies) established by the laboratory compaction test method(s).

1.4.3 Often, the control fraction is the minus No. 4 [4.75-mm] sieve size material for cohesive or nonfree-draining materials and the minus 3-in. [75-mm] sieve size material for cohesionless, free-draining materials. While other sizes may be used for the control fraction such as ⅜, ¾-in. [9.5, 19-mm], these test methods have been prepared using only the No. 4 [4.75-mm] and the 3-in. [75-mm] sieve sizes for clarity.

1.5 Any soil and rock material can be tested, provided that the material being tested has sufficient cohesion or particle attraction to maintain stable side walls during excavation of the test pit and through completion of this test. It should also be firm enough not to deform or slough due to the minor pressures exerted while digging the hole and filling it with water.

1.6 These test methods are generally limited to material in an unsaturated or partially saturated condition above the ground water table and is not recommended for materials that are soft or friable (crumble easily) or in a moisture condition such that water seeps into the excavated hole. The accuracy of the test may be affected for materials that deform easily or that may undergo volume change in the excavated hole from standing or walking near the hole while performing the test.

1.7 *Units*—The values stated in either inch-pound units or SI units [presented in brackets] are to be regarded separately as standard. The values stated in each system may not be exact

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[1] These test methods are under the jurisdiction of ASTM Committee D18 on Soil and Rock and is the direct responsibility of Subcommittee D18.08 on Special and Construction Control Tests.

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

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.

1.7.1 The gravitational system of inch-pound units is used when dealing with inch-pound units. 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.

1.7.2 In the engineering profession, it is customary practice to use, interchangeably, units representing both mass and force, unless dynamic calculations ($F = ma$) are involved. This implicitly combines two separate systems of units, that is, the absolute system and the gravimetric system. It is scientifically undesirable to combine the use of two separate systems within a single standard. These test methods have been written using inch-pound units (absolute system) where the pound (lbm) represents a unit of mass; however, conversions are given in the SI system. The use of balances or scales recording pounds of weight (lbf), or the recording of density in lbf/ft^3 should not be regarded as nonconformance with this standard.

1.8 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.

1.8.1 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; 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 data.

1.9 *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.* For a specific hazard statement, see Section 9.

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:*[2]

C127 Test Method for Relative Density (Specific Gravity) and Absorption of Coarse Aggregate
C138/C138M Test Method for Density (Unit Weight), Yield, and Air Content (Gravimetric) of Concrete
C566 Test Method for Total Evaporable Moisture Content of Aggregate by Drying
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))
D1556 Test Method for Density and Unit Weight of Soil in Place by Sand-Cone Method
D1557 Test Methods for Laboratory Compaction Characteristics of Soil Using Modified Effort (56,000 ft-lbf/ft^3 (2,700 kN-m/m^3))
D2167 Test Method for Density and Unit Weight of Soil in Place by the Rubber Balloon Method
D2216 Test Methods for Laboratory Determination of Water (Moisture) Content of Soil and Rock by Mass
D3740 Practice for Minimum Requirements for Agencies Engaged in Testing and/or Inspection of Soil and Rock as Used in Engineering Design and Construction
D4253 Test Methods for Maximum Index Density and Unit Weight of Soils Using a Vibratory Table
D4254 Test Methods for Minimum Index Density and Unit Weight of Soils and Calculation of Relative Density
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
D4914 Test Methods for Density of Soil and Rock in Place by the Sand Replacement Method in a Test Pit
D6026 Practice for Using Significant Digits in Geotechnical Data
D7382 Test Methods for Determination of Maximum Dry Unit Weight of Granular Soils Using a Vibrating Hammer
E11 Specification for Woven Wire Test Sieve Cloth and Test Sieves
F2362 Specification for Temperature Monitoring Equipment

3. Terminology

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

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *control fraction, n*—the portion of a soil sample consisting of particles smaller than a designated sieve size.

3.2.1.1 *Discussion*—This fraction is used to compare in-place densities with densities obtained from standard laboratory compaction test methods. The control sieve size depends on the laboratory test used.

3.2.2 *oversize particles, n*—the portion of a soil sample consisting of the particles larger than a designated sieve size.

3.2.2.1 *Discussion*—This designated sieve size is often the same sieve size used to determine the control fraction.

4. Summary of Test Method

4.1 The ground surface at the test location is prepared and a template (metal ring) is placed and fixed into position. A liner is laid in the template and the volume of the space between a selected level within the template and the ground surface is

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[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.

determined by filling the space with water. The mass or the volume of the water required to fill the template to the selected level is determined and the water and liner removed. Material from within the boundaries of the template is excavated, forming a pit. A liner is placed in the test pit and template, water is poured into the pit and template up to the selected level; the mass or volume of the water within the pit and template and, subsequently, the volume of the hole are determined. The wet density of the in-place material is calculated from the mass of material removed and the measured volume of the test pit. The water content of the material is determined, and the dry density of the in-place material is calculated.

4.2 The density of a control fraction of the material can be determined by subtracting the mass and volume of any oversize particles from the initial values and recalculating the density.

5. Significance and Use

5.1 These test methods can be used to determine the in-place density of compacted soil and rock materials in construction of earth embankments, road fills, and structure backfill. For construction control, the test methods can be used as the basis for acceptance of material compacted to a specified density or to a percentage of a maximum density determined by a standard laboratory compaction test method such as determined from Test Methods D698 or D1557, subject to the limitations discussed in 1.4.

5.2 These test methods can be used to determine in-place density of natural soil deposits, aggregates, soil mixtures, or other similar material.

NOTE 1—The quality of the result produced by these test methods are dependent on the competence of the personnel performing them 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 these test methods are cautioned that compliance with Practice D3740 does not in itself assure reliable results. Reliable results depend on many factors; Practice D3740 provides a means of evaluating some of those factors.

6. Interferences

6.1 Because it is possible to observe lower densities in soil and rock materials created by particle interference (see Practice D4718), the percent compaction of the control fraction should not be assumed to represent the percent compaction of the total material in the field.

6.2 A very careful assessment must be made as to whether or not the volume determined is representative of the in-place condition when this test method is used for clean, relatively uniform-sized particles 3 in. [75 mm] and larger. The disturbance during excavation, due to lack of cohesion, and the void spaces between particles spanned by the liner may affect the measurement of the volume of the test pit.

7. Apparatus

7.1 *Balance or Scale,* having a capacity and readability appropriate to the mass and procedural techniques for the specific test pit dimensions within the range of 3 to 100 ft^3 [0.08 to 3 m^3] volume and meeting the requirements of Specification D4753.

7.2 *Balance or Scale,* a balance (or scale) to determine water content of minus No. 4 material having a minimum capacity of about 2 lbm [1000 g] and meeting the requirements of Specification D4753 for a balance of 0.001 lb [0.1 g] readability.

7.3 *Drying Oven,* thermostatically controlled, preferably of the forced-draft type, and capable of maintaining a uniform temperature of 110 ± 5°C throughout the drying chamber, in accordance with Test Methods D2216.

7.4 *Sieves,* No. 4 sieve [4.75-mm] and 3-in. [75-mm], conforming to the requirements of Specification E11.

7.5 *Thermometer,* use of electrical thermocouples or thermoresistive devices (Specification F2362) are required with readability to four significant digits.

7.6 *Metal Template,* a circular template to serve as a pattern for the excavation. Template dimensions, shapes, and material may vary according to the size of the test pit to be excavated. The template must be rigid enough not to deflect or bend.

NOTE 2—The template shown in Fig. 1 represents a design that has been found suitable for this purpose.

7.6.1 Since it may be difficult to place the template exactly level on the soil surface, particularly with 6-ft [1.8-m] and larger diameter rings, the height of the template should accommodate a slope of approximately 5 %. Since the water level is kept below the top of the template during testing, it is not necessary that the template be level. The top of the ring must be high enough to prevent any loss of water due to wave action caused by wind.

7.7 *Liners*—Material used to line the excavation and retain the test water should be approximately 4 to 6 mil [100 to 150 µm] thick. Two pieces, each large enough to line the test pit prior to and after excavation, with about 3 ft [1 m] extending beyond the outside of the template in both cases. Any type of

FIG. 1 A 6-ft [1.8-m] Diameter Metal Ring for Determining In-Place Density

material, plastic sheeting, etc. can be used as long as it is impervious and flexible enough to conform to the ground surface. A transparent liner will help facilitate the detection of leaks during the test.

7.8 *Water-Measuring Device*—A system including a storage container, delivery hoses or piping, and a water meter, scale, or other suitable device used for the measurement of the test water. Water may be measured by mass or by volume. The equipment must be capable of controlling the delivery of the water so that any inaccuracies in filling and measuring do not exceed ±1 % of the total mass or volume of water delivered.

7.9 *Water-Level Reference Indicator*—A water-level reference must be established so that the water level in the template is the same for the two volume determinations. A hook gage may be the simplest and most practical, although any device such as a rod with a pointed end that can be fastened to the template, a carpenter's level and scale, a carpenter's scale on a beam across the template, or other similar arrangement or device may be used. Whichever method is employed, the device must be able to be removed and replaced so that the reference water level is measured at the exact same location.

7.10 *Siphon Hose, Pump, Buckets, Hoses,* or other suitable equipment to move water to and from the template or pit, or both, and any storage container or reservoir.

7.11 *Miscellaneous Equipment,* sandbags used to prevent movement of the template during the test; shovels, picks, chisels, bars, knives, and spoons for digging test pit; buckets or seamless cans with lids, drums, barrels, or other suitable containers for retaining the test specimen without water change; cloth for collecting excess/dropped soil; assorted pans and porcelain dishes suitable for drying water content specimens; boards, planks, to serve as a work platform when testing soils that may flow or deform; hoists, slings, chains, and other suitable equipment that may be required to handle heavy loads; surveyor's level and rod or other suitable equipment for checking the slope on the template in place; duct tape or mortar, or both, used to prevent tearing of the plastic sheeting by sharp rock fragments.

8. Reagents and Water

8.1 Use clean potable water.

9. Safety Hazards

9.1 These test methods involve handling heavy loads, which may introduce pinching or crushing hazards.

10. Technical Hazards

10.1 Materials that may flow or deform during the test must be identified and appropriate precautions taken.

10.2 Errors may arise in the computed density of material due to the influence of excessive moisture in the material. These errors may be significant in materials with high permeability such as sands and gravels where the bottom of the test hole is close to or below the water table. The buoyant forces of free water beneath or behind the liner may adversely affect the volume determination.

10.3 The test area and equipment must be suitably protected during periods of inclement weather such as rain, snowfall, or high wind. If the in-place water content value is required, it may be necessary to protect the area from direct sunlight.

10.4 Numerous containers may be required during performance of these test methods. All containers must be properly labeled.

10.5 The total mass of the water, or soil sample, or both, may exceed the capacity of the scale used, requiring cumulative determinations of mass. Care must be taken to make sure that the total mass is properly determined.

11. Calibration and Standardization

11.1 If the volume of water used is determined with a water-measuring device containing a water meter, the device must be calibrated to meet the requirements of 7.8.

12. Procedure A—In-Place Density of Total Material

12.1 Procedure A is used to determine a total density (see 1.4). Practice D6026 requires that all measurements and calculations must be recorded to a minimum of four significant digits.

12.2 Determine the recommended sample volume and select the appropriate template for the anticipated soil gradation in accordance with information in Annex A1. Assemble the remainder of the required equipment.

12.3 Determine the mass of each combination of empty container, lid, and container liner (if used) that will contain the excavated material. Number the containers and mark as to use. Write the mass on the container or prepare a separate list.

12.4 Determine the quantity of water to be used. The volume of the excavated test pit is determined by filling the test pit with water and either the mass or volume of the water is measured. Measuring the mass of water used is usually only practical for 3 to 4-ft [1 to 1.3-m] diameter rings. If the mass of water is measured, follow 12.4.1. If the volume of water is measured, follow 12.4.2.

12.4.1 If the mass of water used is measured, containers of water must be prepared with the mass of water determined before and after the test. For test pits with volumes of 3 to 6 ft^3, [0.08 to 0.2 m^3], use containers such as hand-held buckets so the mass can be determined on a balance or scale of the type normally found in a laboratory. Larger test pit volumes can be measured using water contained in tanks or large drums if equipment, such as a hoist and a suitable scale, is available to determine the mass.

12.4.1.1 Two sets of water and containers are necessary. Determining the volume of the test pit requires two separate determinations of the mass of water to: (*a*) measure the mass of water used to fill the space between the soil surface (before the test pit is excavated) and a water-level reference in the template; and (*b*) measure the mass of water used to fill the test pit up to the same water-level reference. The difference between the two masses gives the mass of water in the test pit.

12.4.1.2 Estimate the mass of water (and the number of containers) required to fill the template. The estimated mass may be calculated by multiplying the template volume by the density of water. Number the containers to be used and mark as to use, for example "template correction." Fill the containers with water, and determine and record the mass of the containers and water.

12.4.1.3 From the anticipated volume of the test pit, estimate the mass of water required to fill the test pit. The estimated mass of water to be used for the test pit may be calculated by multiplying the anticipated volume of the test pit by the density of water and then adding to it the mass of water calculated in 12.4.1.2. Increase this amount by about 25 % to make sure that a sufficient supply of water is available at the site. Determine the number of containers required, number them, and mark as to use, for example, "test pit." Fill the containers with water, and determine and record the mass of the containers and water. Proceed to 12.5.

12.4.2 If the volume of water used is measured, use a water-measuring device to measure the volume of water used from a water truck, a large water reservoir, or large containers of water. The water-measuring device must meet the requirements of 7.8.

12.4.2.1 Two separate determinations of volume are necessary to: (*a*) measure the volume of water to fill the space between the soil surface (before the test pit is excavated) and a water-level reference in the template; and (*b*) measure the volume of water used to fill the test pit up to the same water-level reference in the template. The difference between the two volumes gives the volume of water in the test pit.

12.4.2.2 The approximate volume of water required equals the anticipated volume of the test pit plus twice the calculated volume of the template. Increase this amount by about 25 % to make sure that a sufficient supply of water is available at the site. If containers are used, determine the number required and fill the containers with water; otherwise, fill the water truck or water reservoir with sufficient water.

12.5 Select a representative area for the test, avoiding locations where removal of large particles would undermine the template.

12.6 *Preparation of the Surface Area to be Tested:*

12.6.1 Remove all loose material from an area large enough on which to place the template. Prepare the exposed surface so that it is a firm, reasonably level plane.

12.6.2 Personnel should not step on or around the area selected for testing. Provide a working platform when testing materials which may flow or deform.

12.7 *Placing and Seating the Template on the Prepared Surface:*

12.7.1 Firmly seat the template to avoid movement of the template while the test is performed. The use of nails, weights, or other means may be necessary to maintain the position. Check the elevation at several locations on the template. Since the water-level reference is kept below the top of the template, it is not necessary that the template be exactly level, but the slope of the template should not exceed 5 %.

12.7.2 Remove any material loosened while placing and seating the template, taking care to minimize any void space under the template. If necessary, voids under the template may be filled using plastic soil, molding clay, mortar, or other suitable material, provided that this material is not subsequently excavated as part of the material removed from the test pit.

12.7.3 Inspect the surface within the template. If necessary, cover any sharp edges with duct tape or other suitable material to prevent tearing or puncturing of the liner.

12.8 Determine the volume of the space between the soil surface and the water-level reference.

12.8.1 Irregularities of the soil surface within the template must be taken into account. To do this, determine the volume of water required to fill the space between the soil surface and the water-level reference.

12.8.2 Place the liner over the template, and shape it by hand to conform to the irregular in-place material surface and the template. The liner should extend approximately 3 ft [1 m] outside the template. The liner should not be stretched too taut or contain excessive folds or wrinkles (see Fig. 2).

12.8.3 Assemble the equipment for the water-level reference indicator. The water-level reference may be set after the water in the template reaches a practical level.

12.8.4 If the volume of water is being measured, set the water-measuring device indicator to zero or record the initial reading of the indicator. Pour the water from the containers or discharge the water from the water reservoir into the template until the water level reaches a practical level. The slope of the template and any possible wave action must be considered to prevent losing any water. Set the water-level reference indicator (see Fig. 3). If the volume of water is being measured, record the final reading of the water-measuring device. If the mass of water is being measured, save the remaining water for a subsequent determination of mass.

12.8.4.1 Inspect for water leakage by looking for bubbles, observing the water level over an appropriate time. If the liner is transparent, look for darker areas in the in-place material surface indicating saturation from the test water. If water leakage is present, quickly vacate water from the template to

FIG. 2 Plastic Liner Placed in Preparation for the Initial Volume Determination

FIG. 3 Measuring the Water-Level Reference with a Carpenter's Square

avoid artificial saturation of the in-place materials. If leakage is excessive, the test area shall be abandoned.

12.8.5 Make appropriate markings so that the water-level indicator can be placed in the identical position and at the same elevation following excavation of the test pit. Disassemble the water-level reference indicator.

12.8.6 Remove the water in the template, and remove the liner. Care must be taken to prevent any test water from reaching the in-place material being tested.

12.9 *Excavating the Test Pit:*

12.9.1 Using hand tools (shovel, chisel, knife, bar), excavate the center portion of the test pit. Use of heavy equipment, such as a backhoe or a mechanical or hydraulic hoist, may be required to remove large particles.

12.9.1.1 Do not permit the movement of heavy equipment in the area of the test if deformation of the material within the test pit may occur.

12.9.2 Place all material removed from the test pit in the container(s). Care must be taken to prevent losing any material.

NOTE 3—For the smaller size templates where the containers for the material may be outside the template, a cloth or plastic sheet may be placed under the containers to facilitate locating and collecting any loose material that needs to be retained.

12.9.3 Keep container(s) covered when not in use to avoid loss of water from the excavated material. A sealable plastic bag may be used inside the container to hold the material.

12.9.4 Carefully trim the sides of the excavation so the dimensions of the test pit at the soil-template contact are as close as practical to the dimensions of the template diameter. Avoid undercutting the in-place materials below the template, disturbing the template or the materials beneath or outside the template.

12.9.5 Continue the excavation to the required depth as outlined in Annex A1, carefully removing any material that has been compacted or loosened in the process.

12.9.5.1 If during excavation of material from within the test pit, a particle (or particles) is found that is about 1½ times, or more, larger than the maximum particle size used to establish the dimensions and minimum volume of the test pit (see Annex A1), set the particle(s) aside and mark appropriately. The mass and volume of the particle(s) must be determined and subtracted from the mass and volume of the material removed from the test pit. Consider the larger particle(s) as "oversize," and follow the procedure outlined in Section 13 except that the "total" density, which would include the larger particle(s), need not be calculated. The "control fraction" values determined then become the values for the total material from the test pit.

12.9.5.2 If enough of these particles are found so that their mass is determined to be about 5 % or more of the total mass of the excavated material, repeat the test with a larger test pit in accordance with the guidelines in Annex A1.

12.9.6 The sides of the pit should be as close to vertical as practical but will, out of necessity, slope inward (see Fig. 4). Materials that do not exhibit much cohesion will result in a more conically shaped test pit.

12.9.7 The profile of the finished pit must be such that the water will completely fill the excavation. The sides of the test pit should be as smooth as possible and free of pockets or overhangs.

12.9.8 The bottom of the test pit must be cleaned of all loosened material.

12.9.9 Inspect the surface of the material within the template. Cover any sharp edges with duct tape or other suitable material to prevent tearing or puncture of the liner. Mortar, or other suitable material, may be used to fill recesses to eliminate sharp edges, overhangs, or pockets that cannot be smoothed or eliminated. The volume of the material used must be able to be determined and provisions to do this made accordingly.

FIG. 4 Test Pit Excavation

12.9.9.1 If mortar is used, measure the mass of mortar and calculate the volume in cubic feet in accordance with Test Method C138/C138M.

12.10 *Determine the Volume of the Test Pit:*

12.10.1 Equations for calculations are shown in Section 14.

12.10.2 Place the liner into the test pit. The liner should be large enough to extend approximately 3 ft [1 m] outside the template boundaries after having been carefully placed and shaped within the pit. Make allowances for slack. The liner should not be stretched too taut nor contain excessive folds or wrinkles. Inspect the liner for punctures before use.

12.10.3 If the volume of water is being measured, set the water-measuring device indicator to zero or record the initial reading of the indicator. Pour the water from the containers or discharge the water from the water reservoir into the test pit until the water reaches the water-level reference indicator. When the filling is complete, record the final reading of the water-measuring device indicator. If the mass of water is being measured, set aside the remaining water for a subsequent determination of mass.

12.10.3.1 Inspect for water leakage by looking for bubbles and observing the water level over an appropriate time. If the liner is transparent, look for darker areas in the in-place material surface indicating saturation from the test water. If water leakage is present, vacate the water from the test pit and restart the test pit volume procedure with a new liner.

12.10.4 If the mass of the water is being measured, determine and record the temperature of the water in the test pit.

12.10.5 Remove the water from the test pit, and remove the liner. Inspect the liner for any holes that may have allowed water to escape during the test. Loss of water will require another determination of the volume.

12.11 *Calculating the Volume of the Test Pit:*

12.11.1 Calculate and record all volume and mass measurements to four significant digits. Equations for calculations are shown in Section 14.

12.11.2 If the mass of water is being measured, determine the mass as follows:

12.11.2.1 Determine and record the mass of the container(s) and remaining water after filling the template (the space between the soil surface and the water-level reference).

12.11.2.2 Calculate and record the total mass of water used to fill the template to the water-level reference.

12.11.2.3 Determine and record the mass of the container(s) and remaining water after filling the test pit and template to the water-level reference.

12.11.2.4 Calculate and record the total mass of water used to fill the test pit and template to the water-level reference.

12.11.2.5 Calculate and record the mass of water used to fill the test pit.

12.11.2.6 Using a density of water of 62.43 lbm/ft^3 [1.00 g/cm^3] (this assumes a water temperature between 18 and 24°C), calculate and record the volume of water used to fill the test pit. If mortar or other material was not used, this value is the volume of the test pit. If mortar was used, add the calculated volume of mortar to the volume of water used to determine the volume of the test pit.

12.11.3 If the volume of the water is being measured, determine the volume as follows:

12.11.3.1 Calculate and record the volume of water used to fill the template (the space between the soil surface and the water-level reference).

12.11.3.2 Calculate and record the volume of water used to fill the test pit and template.

12.11.3.3 Calculate and record the volume of water used to fill the test pit.

12.11.3.4 If mortar was not used, this value is the volume of the test pit. If mortar was used, add the calculated volume of mortar (see 12.9.9.1) to the volume of water used to determine the volume of the test pit.

12.12 *Determine the Dry Density:*

12.12.1 Equations for calculations are shown in Section 14.

12.12.2 Determine the total mass of the excavated material and containers.

12.12.3 Calculate and record the total mass of the containers used to hold the excavated material. Record the container numbers.

12.12.4 Calculate and record the mass of excavated material.

12.12.5 Calculate the wet density of the excavated material.

12.12.6 Obtain a water content specimen representative of the excavated in-place material and place in an airtight, sealed container; determine the water content in accordance with Test Method D2216 or Test Method C566 and record.

12.12.7 Calculate and record the dry density of the total material.

13. Procedure B—In-Place Density of Control Fraction

13.1 This procedure is used when percent compaction or percent relative density of the control fraction is required (see 1.4). Practice D6026 requires that all measurements and calculations must be recorded to a minimum of four significant digits

13.2 Obtain the in-place wet density of the total material by following the procedure for Procedure A, as stated in 12.2 – 12.12.5.

13.3 Equations for calculations are shown in Section 15.

13.4 To obtain the wet density of the control fraction, determine the mass and volume of the oversize particles and subtract from the total mass and total volume to get the mass and volume of the control fraction. Calculate and record the wet density of the control fraction from the mass and volume of the control fraction.

13.4.1 Often, the wet density of the control fraction is determined and the dry density is calculated using the water content of the control fraction.

13.4.2 In addition, the water content of the oversize particles, the water content of the total material, and the percentage of oversize particles may be determined.

13.5 After obtaining the wet mass of total material removed from the test pit, separate the material into the control fraction and the oversize particles using the designated sieve. Do this rapidly to minimize loss of water contained in the excavated material. If the test is for construction control, place the control fraction in an airtight sealed container for further tests.

13.6 Wash the oversize particles if they have smaller fractions adhered to them. After washing, reduce the free water on the surface of the particles by blotting, draining, or using a similar method.

13.7 Determine the wet mass of the oversize particles plus the container of predetermined mass and record.

13.8 Calculate the wet mass of the oversize particles and record.

13.9 Calculate the wet mass of the control fraction and record.

13.10 Calculate and record the volume of the oversize particles by using a bulk specific gravity value of the oversize particles. If previous tests for bulk specific gravity of the oversize particles from a particular source have been performed and the value is relatively constant, a specific gravity may be assumed. Otherwise, obtain a representative sample and determine the bulk specific gravity in accordance with Test Method C127 except that oven drying and the 24-h soaking period are not performed. The bulk specific gravity used must correspond to the moisture condition of the oversize particles when their mass is determined. As used in these test methods, the bulk specific gravity must have been determined on the oversize particles in the moisture condition as stated in 13.6 – 13.8. If an oven dry or saturated surface dry (SSD) bulk specific gravity is used, then determine the mass of the oversize particles for this procedure on oven dry or SSD material, respectively.

13.11 Calculate the volume of the control fraction and record.

13.12 Calculate the wet density of the control fraction and record.

13.13 Determine the water content of the control fraction in accordance with Test Method C566 or Method D2216 and record.

13.14 Calculate the dry density of the control fraction and record.

13.15 If desired, determine and record the water content of the oversize particles in accordance with Test Method C566 or Method D2216. If previous tests for water content of the oversize particles from a particular source have been performed and the value is relatively constant, a water content may be assumed.

13.16 If desired, determine the percentage of oversize particles:

13.16.1 Calculate the dry mass of the control fraction and record.

13.16.2 Calculate the dry mass of the oversize particles and record.

13.16.3 Calculate the dry mass of the total sample and record.

13.16.4 Calculate the percentage of oversize particles and record.

13.17 If desired, calculate the water content of the total material and record.

13.18 If desired, calculate the dry density of the total material and record.

14. Calculation—Procedure A

14.1 If volume determinations are based on the mass of water used, calculate the mass of the water used to fill the test pit and template as follows:

$$m_5 = m_1 - m_3 \tag{1}$$

where:

m_5 = mass of water used for template and test pit volume, lbm [kg],
m_1 = initial mass of water and containers for template and test pit volume (before test), lbm [kg], and
m_3 = final mass of water and containers for template and test pit volume (after test), lbm [kg].

14.1.1 Calculate the mass of the water used to fill the template as follows:

$$m_6 = m_2 - m_4 \tag{2}$$

where:

m_6 = mass of water used for template volume, lbm [kg],
m_2 = initial mass of water and containers for template volume (before test), lbm [kg], and
m_4 = final mass of water and containers for template volume (after test), lbm [kg].

14.1.2 Calculate the mass of the water used to fill the test pit as follows:

$$m_7 = m_5 - m_6 \tag{3}$$

where:

m_7 = mass of water used in test pit, lbm [kg],

14.1.3 Calculate the volume of water used to fill the test pit as follows:

Measured mass of water:

$$V_4 = m_7/\rho_w \qquad (\text{inch} - \text{pound}) \tag{4}$$

$$V_4 = (m_7/\rho_w) \times \frac{1}{10^3} \quad (\text{SI}) \tag{5}$$

where:

V_4 = volume of water in test pit, ft^3 [m^3], and
ρ_w = density of water, 62.43 lbm/ft^3 [1.0 g/cm^3].

NOTE 4—The density of water above is for room temperature. For better accuracy the density of water used can be adjusted based on the temperature of the water used during testing using know relationships between water temperature and density of water.

14.1.4 Calculate the volume of mortar, if used, as follows:

$$V_5 = \frac{m_{11}}{\rho_m} \tag{6}$$

where:

V_5 = volume of mortar in test pit, ft^3 [m^3],
m_{11} = mass of mortar in test pit, lbm [kg], and
ρ_m = density of mortar, lbm/ft^3 [Mg/m^3].

14.1.5 Calculate the volume of the test pit as follows:

$$V_6 = V_4 + V_5 \tag{7}$$

or if no mortar has been used:

$$V_6 = V_4 \tag{8}$$

where:

V_6 = volume of test pit, ft^3 [m^3].

14.2 If volume determinations were made with a water-measuring device containing a water meter, calculate the volume of the test pit as follows:

$$V_6 = V_7 - V_8 \tag{9}$$

or if mortar has been used:

$$V_6 = V_7 - V_8 + V_5 \tag{10}$$

where:

V_7 = volume of water used to fill the test pit and template, ft^3 [m^3], and

V_8 = volume of water used to fill the template, ft^3 [m^3].

14.3 Calculate the mass of wet (total) material removed from the test pit, as follows:

$$m_{10} = m_8 - m_9 \tag{11}$$

where:

m_{10} = mass of wet material removed from test pit, lbm [kg],

m_8 = mass of wet material removed from test pit and containers, lbm [kg], and

m_9 = mass of containers for m_8, lbm [kg].

14.4 Calculate the wet density of material excavated from the test pit as follows:

$$\rho_{wet} = m_{10}/V_6 \qquad (\text{inch} - \text{pound}) \tag{12}$$

$$\rho_{wet} = (m_{10}/V_6)\,\frac{1}{10^3} \qquad (\text{SI}) \tag{13}$$

where:

ρ_{wet} = wet density of material excavated from test pit, lbm/ft^3 [Mg/m^3].

14.5 Calculate the dry density of material excavated from the test pit as follows:

$$\rho_d = \frac{\rho_{wet}}{1 + (w/100)} \tag{14}$$

where:

ρ_d = dry density of material excavated from test pit, lbm/ft^3 [Mg/m^3], and

w = water content of material excavated from test pit, %.

15. Calculation—Procedure B

15.1 Calculate the wet mass of oversize particles, as follows:

$$m_{14} = m_{12} - m_{13} \tag{15}$$

where:

m_{14} = wet mass of oversize particles, lbm [kg],

m_{12} = wet mass of oversize particles and containers, lbm [kg], and

m_{13} = mass of containers, lbm [kg].

15.2 Calculate the wet mass of the control fraction as follows:

$$m_{18} = m_{10} - m_{14} \tag{16}$$

where:

m_{18} = wet mass of control fraction, lbm [kg],

m_{10} = mass of wet material removed from test pit (from 14.3), lbm [kg].

15.3 Calculate the volume of the oversize particles based on a known bulk specific gravity as follows:

$$V_{os} = \frac{m_{14}}{G_m\,(62.43\ \text{lbm/ft}^3)} \qquad (\text{inch} - \text{pound}) \tag{17}$$

$$V_{os} = \frac{m_{14}}{G_m\,(1\ \text{g/cm}^3)} \times \frac{1}{10^3} \qquad (\text{SI}) \tag{18}$$

where:

V_{os} = volume of oversize particles, ft^3 [m^3],

G_m = bulk specific gravity of oversize particles,

62.43 = density of water, lbm/ft^3,

1.00 = density of water, g/m^3, and

$1/10^3$ = constant to convert g/cm^3 to kg/m^3.

15.4 Calculate the volume of the control fraction as follows:

$$V_c = V_6 - V_{os} \tag{19}$$

where:

V_c = volume of control fraction, ft^3 [m^3].

15.5 Calculate the wet density of the control fraction as follows:

$$\rho_{wet}(c) = \frac{m_{18}}{V_c} \qquad (\text{inch} - \text{pound}) \tag{20}$$

$$\rho_{wet}(c) = (m_{18}/V_c) \times \frac{1}{10^3}\ (\text{SI}) \tag{21}$$

where:

$\rho_{wet}(c)$ = wet density of control fraction, lbm/ft^3 [Mg/m^3].

15.6 Calculate the dry density of the control fraction as follows:

$$\rho_d(c) = \frac{\rho_{wet}(c)}{1 + (w_f/100)} \tag{22}$$

where:

$\rho_d(c)$ = dry density of control fraction, lbm/ft^3 [Mg/m^3], and

w_f = water content of control fraction, %.

15.7 Calculate the dry mass of the control fraction as follows:

$$m_{19} = \frac{m_{18}}{1 + w_f/100} \tag{23}$$

where:

m_{19} = dry mass of control fraction, lbm [kg].

15.8 Calculate the dry mass of the oversize particles using one of the following expressions as appropriate:

$$m_{17} = m_{15} - m_{13} \tag{24}$$

or:

$$m_{17} = \frac{m_{14}}{1 + (w_{os}/100)} \tag{25}$$

where:

m_{17} = dry mass of oversize particles, lbm [kg],
m_{15} = dry mass of oversize particles and containers, lbm [kg], and
w_{os} = water content of oversize particles, %.

15.9 Calculate the dry mass of the total sample as follows:

$$m_{20} = m_{19} + m_{17} \tag{26}$$

where:

m_{20} = dry mass of total material (control fraction plus oversize), lbm [kg].

15.10 Calculate the percent oversize particles by mass as follows:

$$\text{Percent oversize} = \frac{m_{17} \times 100}{m_{20}} \tag{27}$$

15.11 If the water content of the total material was not directly measured from a representative specimen, calculate the water content of the total material as follows:

$$w = \frac{m_{10} - m_{20}}{m_{20}} \tag{28}$$

15.12 Calculate the dry density of the total material by using Eq 12-14.

16. Report: Test Data Sheet(s)/Form(s)

16.1 The methodology used to specify how data are recorded is covered in 1.8 and in Practice D6026.

16.2 Record as a minimum the following general information (data):

16.2.1 Project and Feature information;

16.2.2 Test Location and depth (including coordinates or stationing, and elevation if available at the time of the test);

16.2.3 Procedure performed (A or B);

16.2.4 Site conditions that may influence the test, including surface conditions and weather conditions;

16.2.5 Visual description of the material; and

16.2.6 Comments on conduct of the test including any test conditions or difficulties that may affect test results. Examples may include cobbles and boulders with angular edges and method of treatment, large inclusions left in the excavation, movement of the ring, or deformation of the excavation. Photographs of the test are helpful to document conditions but not required to be reported.

16.3 Record as a minimum the following apparatus information:

16.3.1 Dimensions of the ring used;

16.3.2 Apparatus and methods for determining the mass or volume of water, including the scales or water meters used and their sensitivity or readability, including the methods and results of calibrations;

16.3.3 Apparatus and methods for determining the mass of soil excavated including scales used and their readability;

16.3.4 Apparatus and methods for determining the water content(s), of the total or control and oversize fractions, or both including ovens and scales; and

16.3.5 Apparatus and methods for processing and weighing and determining the bulk specific gravity oversize particles, if performing Procedure B.

16.4 Record as a minimum the following test data/results:

16.4.1 Test hole volume;

16.4.2 Maximum particle size encountered;

16.4.3 In-place wet density, total, or control fraction, or both;

16.4.4 In-place dry density, total, or control fraction, or both;

16.4.5 In-place dry unit weight, total, or control fraction, or both;

16.4.6 In-place water content(s), and total, or control fraction, or both, and test method(s) used; and

16.4.7 Bulk specific gravity and percentage of oversize particles.

17. Precision and Bias

17.1 *Precision*—Test data on precision is not presented due to the nature of this test method. It is either not feasible or too costly at this time to have ten or more agencies participate in an interlaboratory testing program at a given site.

17.1.1 Subcommittee D18.08 is seeking any data from the users of this test method that might be used to make a limited statement on precision.

17.2 *Bias*—There is no accepted reference value for this test method, therefore, bias cannot be determined.

18. Keywords

18.1 acceptance tests; degrees of compaction; densities; density tests; field tests; in-place densities; pit tests; quality controls; test pit densities; water pits; water replacement methods

ANNEX

(Mandatory Information)

A1. GUIDELINES FOR TEST HOLE OR TEST DIMENSIONS AND SELECTION OF EQUIPMENT

A1.1 This annex covers guidelines for selecting the excavation dimensions and the type of equipment to use based on the maximum particle size present in the material (or control fraction) being tested. These guidelines apply to both these test methods and to Test Method D4914. The guidelines are given in Tables A1.1-A1.3.

A1.2 These guidelines are based on providing a representative sample of the material being tested and on practical working conditions. For a discussion of the shape and dimensions of the test pits and for the minimum volumes for the excavation, see Appendix X1.

A1.3 The guidelines shown in Table A1.1 apply to test pit Types A and B (Fig. A1.1). These test pits generally are for non free-draining materials and for cohesionless materials whose gradation and particle angularity will allow near-vertical side walls to be excavated.

A1.4 The guidelines shown in Table A1.2 apply to test pit Type C (Fig. A1.1). This type of test pit can be excavated when Type A or B cannot. For this case, the slope of the side walls will be much flatter, approximately the angle of repose of the material.

A1.5 These guidelines are only applicable when the limitations stated in 1.5 and 1.6 for unstable or soft materials are followed.

TABLE A1.1 Test Pit Types A and B (see Fig. A1.1)—Test Apparatus and Minimum Excavation Volume and Depth

Maximum Particle Size, in.[A]	Minimum Required Volume, ft^3	Suggested Apparatus and Template Opening	Required Minimum Depth, in.[B]
3	1.0	24-in. square frame	18
5	2	30-in. square frame	12
8	8	4-ft diameter ring	24
12	27	6-ft diameter ring	24
18	90	9-ft diameter ring	36
More than 18 in. maximum particle size should be determined on a case-by-case basis.			

[A] Maximum particle size present in total material or the maximum particle size of control fraction if the total in-place density is not of concern.

[B] This depth is necessary to obtain the minimum required volume of material when using the suggested apparatus and template opening.

TABLE A1.2 Test Pit Type C (see Fig. A1.1)—Test Apparatus and Minimum Excavation Volume and Depth

Maximum Particle Size, in.[A]	Minimum Required Volume, ft^3	Suggested Apparatus and Template Opening	Required Minimum Depth, in.[B]	Approximate Diameter of Excavated Hole, in.
3	1.0	33-in. square frame	10	30
5	2	40-in. square frame	12	35
8	8	62-in. diameter ring	18	54
More than 8 in. maximum particle size should be determined on a case-by-case basis.				

[A] Maximum particle size present in total material or the maximum particle size of control fraction if the total in-place density is not of concern.

[B] This depth is necessary to obtain the minimum required volume of material when using the suggested apparatus and template opening.

TABLE A1.3 Metric Equivalents for Table A1.1 and Table A1.2

Inches	Millimetres
3	75
5	125
8	200
10	250
12	300
18	450
24	600
30	750
33	825
35	875
36	900
40	1000
54	1350
62	1550
Feet	Metres
4.0	1.2
6.0	1.8
9.0	2.7
Cubic Feet	Cubic Metres
1.0	0.03
2.0	0.06
8.0	0.23
27.0	0.76
90.0	2.55

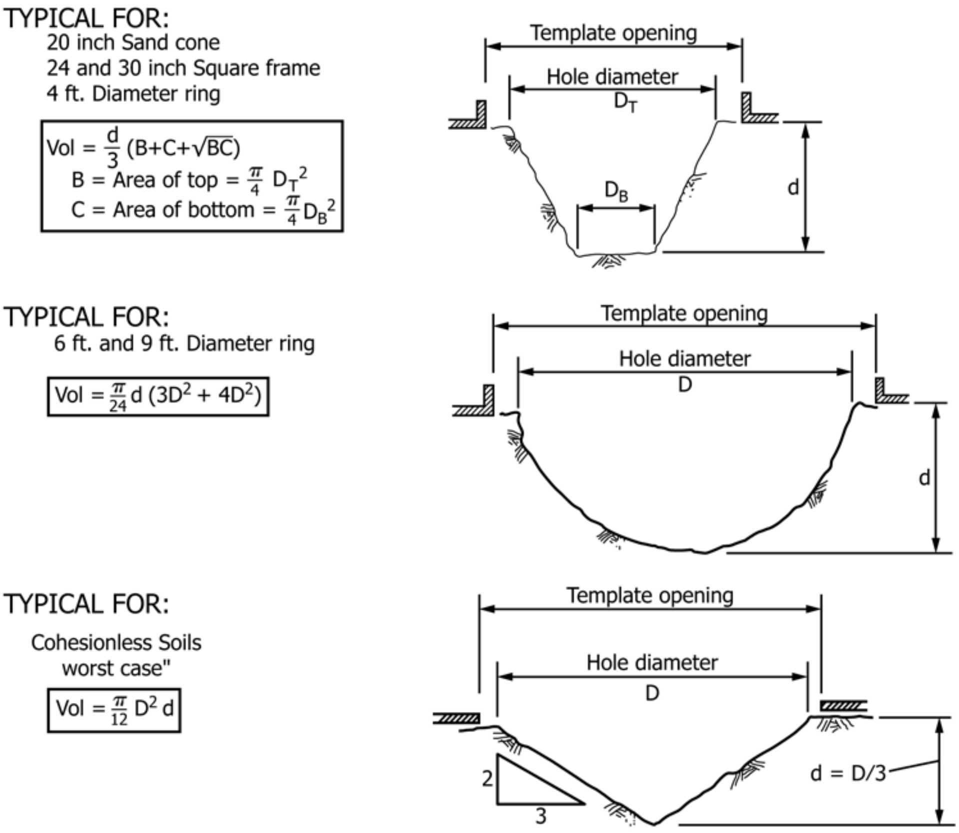

FIG. A1.1 Test Pit Configurations

APPENDIX

(Nonmandatory Information)

X1. RATIONALE

X1.1 Required Excavation Volume

X1.1.1 The minimum excavation volumes shown in Table A1.1 and Table A1.2 are required to provide a representative sample of the material being tested. For this test method, a representative sample is based on the mass required to provide a gradation analysis of the soil within certain limits of accuracy. For soils with a maximum particle size of 3 in. [75 mm], the required mass (and volume) is based on a sample 100 times the mass of the maximum particle size. This results in gradation percentages with an accuracy of ±1.0 %. For soils with a maximum particle size larger than 3 in. [75 mm], the required mass is based on a sample 40 times the mass of the maximum particle size. This results in gradation percentages with an accuracy of ±2.5 %. The volumes recommended are also typical of volumes used in practice.

X1.2 Type and Size of Equipment

X1.2.1 The basic types of apparatus used to determine in-place density are the sand-cone device, the rubber balloon, the square metal frame, and the metal ring. Each type is practical only for specific excavation sizes. The sand-cone device is practical only up to about a 20-in. [500-mm] test hole diameter because of the physical difficulty in handling anything larger. The square frame is practical from about 18 in. [450 mm] square to about 36 in. [900 mm] square. Square frames are easier to fabricate than circular templates. Rings are preferred as templates for excavating test pits about 3 ft [0.9 m] in diameter and larger because square frames need to be stiffened and can be heavier and more awkward to handle than circular templates. In addition, it is difficult to trim the excavation with corners because of the larger particle sizes present in the material when a square frame larger than 33 in. [825 mm] is required. The liner for the sand replacement method should be about ½ mil thick while the liner for the water replacement method should be about 4 to 6 mils thick. Bunching of a liner 4 to 6 mils thick in the corners of a square frame may result in errors in the volume measurement.

X1.2.2 The apparatus and template sizes shown in Table A1.1 and Table A1.2 were selected to provide a volume about equal to the required volume. Other sizes may be used (for example, 27-in. square frame) as long as the minimum volume of excavated material can be obtained.

X1.3 Minimum Volume of Test

X1.3.1 In Table A1.2, the minimum volume obtained from excavating a test pit using the template shown and the required minimum depth is based on the following assumptions:

X1.3.1.1 The material being excavated contains a significant amount of the maximum particle size, not just a random, isolated particle of that size.

X1.3.1.2 No matter whether the template is square or round, the excavation will be basically circular in plan view because the presence of the maximum particle size will probably prevent excavating corners.

X1.3.1.3 The side walls will be sloped. Encountering the maximum particle in the side wall while excavating will necessitate reducing the excavation diameter. For a maximum particle size of 3 in. [75 mm], most materials can be excavated at a slope of 1 horizontal to 3 vertical or steeper; while for the 5 and 8-in. [125 and 200-mm] maximum particle sizes, the side walls can be excavated at a slope of 1 horizontal to 2 vertical or steeper.

X1.3.1.4 The diameter of the excavation will be smaller than the template opening because a large particle may be just beneath the template. To prevent an overhang in the excavation, these particles should not be removed unless they are protruding into the excavation more than about two-thirds their diameter.

X1.3.1.5 For excavation of materials with maximum particle size up to 8 in. [200 mm], the volume of the excavation is assumed to be a frustrum of a cone as shown in Fig. A1.1. The diameter of the excavation is assumed to be the template diameter minus the maximum particle size.

X1.3.1.6 For excavation of materials with maximum particle sizes of 12 in. and larger, the volume of the excavation is assumed to be a spherical segment. The diameter of the excavation is assumed to be the template diameter minus two thirds of the maximum particle size.

X1.3.2 In Table A1.2, the minimum volume is assumed to be conical, as shown on Fig. A1.1, with the depth of the excavation equal to about one-third the hole diameter. For cohesionless materials, with relatively uniform gradation, the "worst case" is assumed where the slope of the side walls could not exceed the angle of repose of the material.

X1.3.3 Based on these assumptions, the minimum volume of excavations shown in Table A1.1 and Table A1.2 is thus conservative. Steeper side walls or larger test hole diameters will result in larger volumes. In some cases, a smaller apparatus than that indicated in Table A1.1 and Table A1.2 may be used if a trial test pit is excavated and it can be shown that the smaller apparatus can provide the minimum required volume. However, the depth of excavation should never be less than one-third the hole diameter, the volume of the excavation must be 50 times larger than the volume of the maximum particle size, and the hole diameter must be at least 4 times larger than the maximum particle diameter.

X1.4 Replacement Medium

X1.4.1 For the templates shown in Table A1.1 and Table A1.2, sand replacement using a sand-pouring device is felt to be practical for square frames up to 33-in. [875-mm] and water replacement for 40-in. [1000-mm] and larger diameter rings.

X1.4.2 If other sizes are used, the sand replacement method is probably practical up through 36-in. [900-mm] square frames, while water replacement is more practical for 36-in. [900-mm] diameter rings and larger. A 36-in. [900-mm] opening is about the size limit where sand can be poured into the excavation uniformly and consistently while standing outside the template.

X1.5 Depth of Excavation

X1.5.1 For materials with a maximum particle size of 5 in. [125 mm] or less, the depth of excavation in Table A1.1 is shown in 6-in. [150-mm] increments since cohesive soils are normally compacted in layers of 6 in. [150 mm] maximum thickness. The minimum depth is 12 in. [300 mm] so that at least two lifts are included in the determination. If the in-place density determination is for in situ materials, the minimum depth shown is that required to obtain the minimum volume. Greater depths, not necessarily in 6-in. [150-mm] increments, may be used.

X1.5.2 Shallower depths may be used for in situ materials but only if the diameter of the excavation is larger so that the minimum volume of material is obtained. This may be necessary to test deposits of material of limited thickness.

X1.5.3 For the materials in Table A1.1 with maximum particles sizes of 8 and 12 in. [200 and 300 mm] the desired minimum excavation depth is shown as 24 in. [600 mm] since these soils would normally be placed in 12-in. [900-mm] lifts. For materials with an 18-in. [450-mm] maximum particle size, a 36-in. [900-mm] minimum depth is necessary to obtain the required volume.

X1.5.4 In Table A1.2, the minimum depths of excavation are equal to about one-third the hole diameter as discussed previously. The elevation of the top of the excavation should be such that the test will be representative of the lift being tested.

SUMMARY OF CHANGES

Committee D18 has identified the location of selected changes to this standard since the last issue (D5030 – 13a) that may impact the use of this standard. (Approved May 15, 2021.)

(1) Term "materials" was added to the title and throughout standard for clarification.
(2) Significant digits on SI equivalents were updated throughout.
(3) Term "moisture" replaced with "water" throughout.
(4) Updated Subsection 1.7.2 to reflect absolute inch-pound unit system.
(5) Subsection 1.10 was added.
(6) Section 2 was updated for current standards and titles.
(7) Significant Digits statement removed from Section 7, Apparatus. Other general language added to section 7 to add clarity and additional information.
(8) Section 9 updated to reflect what safety hazards could be encountered.
(9) Added significant digits statement to Procedure, Section 12 and changed all significant digits to 4.
(10) Updated Figures 1 through 4 for better clarity.
(11) Removed Note 4.
(12) Updated Calculations Sections 14 and 15 to remove redundant equation variable definitions
(13) Removed Equations 6 and 7.
(14) Added Equations 9 and 10 (based on new numbering).
(15) Corrected error in Equation 24.
(16) Added general requirements for reporting section 16 and removed significant digit comments.

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