Designation: D 5030 – 04

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

This standard is issued under the fixed designation D 5030; 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 This test method covers the determination of the in-place density and unit weight of soil and rock using water to fill a lined test pit to determine the volume of the test pit. The use of the word "rock" in this test method is used to imply that the material being tested will typically contain particles larger than 3 in. (75 mm).

1.2 This test method is best suited for test pits with a volume between approximately 3 and 100 ft^3 (0.08 and 2.83 m^3). In general, the materials tested would have maximum particle sizes over 5 in. (125 mm). This test method 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 this test method and the guidelines given in Annex A1 for the minimum volume of the test pit.

1.2.2 Test Method D 4914 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 0.17 m^3).

1.2.3 Test Method D 1556 or Test Method D 2167 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 Unit Weight of Total Material (Section 10).

1.3.2 *Procedure B*—In-Place Density and Unit Weight of Control Fraction (Section 11).

1.4 *Selection of Procedure*:

1.4.1 Procedure A is used when the in-place unit weight of 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 D 698, D 1557, D 4253, D 4254, D 4564). For Test Methods D 698 and D 1557 only, the unit weight determined in the laboratory compaction test may be corrected for larger particle sizes in accordance with, and subject to the limitations of, Practice D 4718.

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 or when Practice D 4718 is not applicable for the laboratory compaction test. Then the material is considered to consist of two fractions, or portions. The material from the in-place unit weight test is physically divided into a control fraction and an oversize fraction based on a designated sieve size. The unit weight of the control fraction is calculated and compared with the unit weight(s) established by the laboratory compaction test(s).

1.4.2.1 Because of possible lower densities created when there is particle interference (see Practice D 4718), the percent compaction of the control fraction should not be assumed to represent the percent compaction of the total material in the field.

1.4.3 Normally, the control fraction is the minus No. 4 sieve size material for cohesive or nonfree-draining materials and the minus 3-in. sieve size material for cohesionless, free-draining materials. While other sizes are used for the control fraction (⅜, ¾-in.), this test method has been prepared using only the No. 4 and the 3-in. sieve sizes for clarity.

1.5 Any material can be tested, provided the material being tested has sufficient cohesion or particle attraction to maintain stable sides 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 in digging the hole and filling with water.

1.5.1 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.

1.6 This test method is generally limited to material in an unsaturated condition and is not recommended for materials that are soft or friable (crumble easily) or in a moisture

[1] This test method is 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.

Current edition approved March. 1, 2004. Published April 2004. Originally approved in 1989. Last previous edition approved in 1994 as D 5030–89(1994)$^{\epsilon 1}$

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 during the test.

1.7 The values stated in inch-pound units are to be regarded as the standard. The values given in parentheses are for information only.

1.7.1 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. This test method has been written using inch-pound units (gravimetric system) where the pound (lbf) represents a unit of force (weight); however, conversions are given in the SI system. The use of balances or scales recording pounds of mass (lbm), or the recording of density in lbm/ft^3 should not be regarded as nonconformance with this standard.

1.8 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.* For a specific hazard statement, see Section 7.

2. Referenced Documents

2.1 *ASTM Standards:* [2]

C 127 Test Method for Specific Gravity and Absorption of Coarse Aggregate

C 138 Test Method for Unit Weight, Yield, and Air Content (Gravimetric) of Concrete

C 566 Test Method for Total Moisture Content of Aggregate by Drying

D 653 Terminology Relating to Soil, Rock, and Contained Fluids

D 698 Test Methods for Moisture-Density Relations of Soils and Soil-Aggregate Mixtures Using 5.5-lb (2.49-kg) Rammer and 12-in. (305-mm) Drop

D 1556 Test Method for Density of Soil in Place by the Sand-Cone Method

D 1557 Test Methods for Moisture-Density Relations of Soils and Soil Aggregate Mixtures Using 10-lb (4.54-kg) Rammer and 18-in. (457-mm) Drop

D 2167 Test Method for Density and Unit Weight of Soil In-Place by the Rubber Balloon Method

D 2216 Method for Laboratory Determination of Water (Moisture) Content of Soil, Rock, and Soil-Aggregate Mixtures

D 4253 Test Methods for Maximum Index Density of Soils Using a Vibratory Table

D 4254 Test Methods for Minimum Index Density of Soils and Calculation of Relative Density

D 4564 Test Method for Density of Soil in Place by the Sleeve Method

D 4718 Practice for Correction of Unit Weight and Water Content for Soils Containing Oversize Particles

D 4753 Specification for Evaluating, Selecting, and Specifying Balances and Scales for Use in Soil and Rock Testing

D 4914 Test Method for Density of Soils in Place by Sand Replacement Method in a Test Pit

E 1 Specification for ASTM Thermometers

E 11 Specification for Wire-Cloth Sieves for Testing Purposes

3. Terminology

3.1 *Definitions*—Except as follows in 3.2, all definitions are in accordance with Terminology D 653.

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *control fraction*—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 unit weights with unit weights obtained from standard laboratory tests. The control sieve size depends on the laboratory test used.

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

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 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 moisture content is determined and the dry unit weight of the in-place material is calculated.

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

5. Significance and Use

5.1 This test method is used to determine the in-place unit weight of compacted materials in construction of earth embankments, road fills, and structure backfill. For construction control, it can be used as the basis for acceptance of material compacted to a specified unit weight or to a percentage of a maximum unit weight determined by a standard laboratory test method such as determined from Test Methods D 698 or D 1557, subject to the limitations discussed in 1.4.

[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.

5.2 This test method can be used to determine in-place unit weight of natural soil deposits, aggregates, soil mixtures, or other similar material.

6. Apparatus

6.1 *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 2.83 m^3) volume and meeting the requirements of Specification D 4753.

6.2 *Balance or Scale*—a balance (or scale) to determine moisture content of minus No. 4 material having a minimum capacity of about 1000 g and meeting the requirements of Specification D 4753 for a balance of 0.1 g readability.

6.3 *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.

6.4 *Sieves*, No. 4 sieve (4.75-mm) and 3-in. (75-mm), conforming to the requirements of Specification E 11.

6.5 *Thermometer*, 0 to 50°C range, 0.5° graduations, conforming to the requirements of Specification E 1.

6.6 *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 1—The template shown in Fig. 1 represents a design that has been found suitable for this purpose.

6.6.1 Since it may be difficult to place the template exactly level, 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 has to be below the top of the template, it is not necessary that the template be level. The larger rings should be high enough to prevent any loss of water due to wave action caused by wind.

6.7 *Liners*, approximately 4 to 6 mil thick. Two pieces, each large enough to line the test pit, with about 3 ft (1 m) extending beyond the outside of the template. Any type of material, plastic sheeting, etc. can be used as long as it is flexible enough to conform to the ground surface.

FIG. 1 A 6-ft (1.8-m) Diameter Metal Ring for Determining In-Place Unit Weight

6.8 *Water-Measuring Device*, including a storage container, delivery hoses or piping, and a water meter, scale, or other suitable measurement device. 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 delivered.

6.9 *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 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. Some type of protection around the device may be necessary if the water surface inside the template is not smooth.

6.10 *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.

6.11 *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 moisture change; cloth for collecting excess soil; assorted pans and porcelain dishes suitable for drying moisture content specimens; boards, planks, etc., 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.

7. Safety Hazards

7.1 This test method involves handling heavy loads.

8. Technical Hazards

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

8.2 Errors may arise in the computed unit weight 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.

8.3 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 moisture content value is required, it may be necessary to protect the area from direct sunlight.

8.4 Numerous containers may be required during performance of this test method. All containers must be properly labeled to avoid a possible mixup.

8.5 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 ensure that the total mass is properly determined.

9. Calibration and Standardization

9.1 If the volume of water used is determined with a water-measuring device, the device must be calibrated to meet the requirements of 6.8.

10. Procedure A—In-Place Density and Unit Weight of Total Material

10.1 Procedure A is used to determine a total unit weight (see 1.4).

10.2 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.

10.3 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.

10.4 Prepare 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 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 10.4.1. If the volume of water is measured, follow 10.4.2.

10.4.1 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 0.17 m^3), use containers such as 5-gal 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 55-gal drums if equipment, such as a hoist and a suitable scale, is available to determine the mass.

10.4.1.1 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.

10.4.1.2 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.

10.4.1.3 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 10.4.1.2. Increase this amount by about 25 % to ensure 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 10.5.

10.4.2 If the volume of water used is measured, use a water-measuring device to measure the gallons (litres) of water used from a water truck, a large water reservoir, or large containers of water such as 55-gal drums. The water-measuring device must meet the requirements of 6.8.

10.4.2.1 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.

10.4.2.2 The approximate volume of water required equals the anticipated volume of the test pit plus twice the calculated volume of the template. If appropriate, multiply the required volume in cubic feet by 7.48 to determine the volume in gallons. Increase this amount by about 25 % to ensure 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.

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

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

10.6.1 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.

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

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

10.7.1 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 %.

10.7.2 Remove any material loosened while placing and seating the template, taking care to avoid leaving 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.

10.7.3 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 plastic lining.

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

10.8.1 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.

10.8.2 Place a liner 4 to 6 mil thick over the template, and shape it by hand to conform to the irregular soil 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).

10.8.3 Assemble the equipment for the water-level reference indicator. Normally, the water-level reference is set after the water in the template reaches a practical level.

10.8.4 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.

10.8.4.1 Inspect for water leakage by looking for bubbles, observing the water level over an appropriate time, etc.

10.8.5 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.

10.8.6 Remove the water in the template, and remove the liner.

10.9 *Excavating the Test Pit*:

10.9.1 Using handtools (shovel, chisel, knife, bar, etc.), 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.

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

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

10.9.1.1 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.

10.9.2 Place all material removed from the test pit in the container(s). Take care to avoid losing any material.

NOTE 2—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.

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

10.9.4 Carefully trim the sides of the excavation so the dimensions of the test pit at the soil-template contact are as close as possible to the dimensions of the template hole. Avoid disturbing the template or the material beneath or outside the template.

10.9.5 Continue the excavation to the required depth, carefully removing any material that has been compacted or loosened in the process.

10.9.5.1 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 11 except that the "total" unit weight, 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.

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

10.9.6 The sides of the pit should be as close to vertical as possible 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.

10.9.7 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.

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

10.9.9 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 plastic lining. 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.

10.9.9.1 If mortar is used, measure the mass of mortar and calculate the volume in cubic feet in accordance with Test Method C 138.

10.10 *Determine the Volume of the Test Pit*:

10.10.1 Place the liner into the test pit. The liner, approximately 4 to 6 mil thick, 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.

10.10.2 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. If necessary, calculate the gallons (litres) of water used.

FIG. 4 Test Pit During Excavation

10.10.2.1 Inspect for water leakage by looking for bubbles, observing the water level over an appropriate time, etc.

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

10.10.4 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.

10.11 *Calculating the Volume of the Test Pit*:

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

10.11.1.1 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).

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

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

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

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

10.11.1.6 Using a density of water of 62.3 lbm/ft^3 (this assumes a 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.

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

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

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

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

10.11.2.4 Calculate and record the cubic feet of water used to fill the test pit. 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 10.9.9.1) to the volume of water used to determine the volume of the test pit.

10.12 *Determine the Dry Unit Weight*:

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

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

10.12.3 Calculate and record the mass of excavated material.

10.12.4 Calculate the wet density of the excavated material.

10.12.5 If percent compaction or percent relative density of the control fraction is required, separate the material using the appropriate size sieve and follow the procedures in Procedure B.

10.12.6 If Procedure B is not used, obtain a moisture content specimen representative of the excavated material; determine the moisture content in accordance with Method D 2216 or Test Method C 566 and record.

NOTE 3—For rapid moisture content determination of soils containing less than 15 % fines (minus No. 200 sieve), a suitable source of heat such as an electric or gas hotplate may be used. If a source of heat other than the controlled temperature oven is used, stir the test specimen to accelerate drying and avoid localized overheating. The material may be considered dry when further heating causes, or would cause, less than 0.1 % additional loss of mass.

10.12.7 Calculate and record the dry density and dry unit weight of the material.

11. Procedure B—In-Place Density and Unit Weight of Control Fraction

11.1 This procedure is used when percent compaction or percent relative density of the control fraction is required (see 1.4).

11.2 Obtain the in-place wet density of the total material by following the procedure for Procedure A, as stated in 10.2-10.12.4.

11.3 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 the density of the control fraction from the mass and volume of the control fraction.

11.3.1 Normally, the wet density of the control fraction is determined and the dry density is calculated using the moisture content of the control fraction.

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

11.4 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 moisture. If the test is for construction control, place the control fraction in an airtight container for further tests.

11.5 Wash the oversize particles and reduce the free water on the surface of the particles by blotting, draining, or using a similar method.

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

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

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

11.9 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 C 127 except that oven drying and the 24-h soaking period are not used. The bulk specific gravity used must correspond to the moisture condition of the oversize particles when their mass is determined. As used in this test method, the bulk specific gravity must have been determined on the oversize particles in the moisture condition as stated in 11.5-11.7. 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.

11.10 Calculate the volume of the control fraction and record.

11.11 Calculate the wet density of the control fraction.

11.12 Determine the moisture content of the control fraction in accordance with Test Method C 566 or Method D 2216 (see Note 2) and record.

11.13 Calculate the dry density and dry unit weight of the control fraction and record.

11.14 If desired, determine and record the moisture content of the oversize particles in accordance with Test Method C 566 or Method D 2216 (see Note 2). If previous tests for moisture content of the oversize particles from a particular source have been performed and the value is relatively constant, a moisture content may be assumed.

11.15 If desired, determine the percentage of oversize particles:

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

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

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

11.15.4 Calculate the percentage of oversize particles and record.

11.16 If desired, calculate the moisture content of the total material and record.

11.17 If desired, calculate the dry density and dry unit weight of the total material and record.

12. Calculation—Procedure A

12.1 Calculate the mass of the water used to fill the test pit and template as follows:

$$m_5 = m_1 - m_3 \quad (1)$$

where:

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

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

$$m_6 = m_2 - m_4 \quad (2)$$

where:

m_6 = mass of water for template volume, lbm (kg),

m_2 = mass of water and containers for template volume (before test), lbm (kg), and
m_4 = mass of water and containers for template volume (after test), lbm (kg).

12.3 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 in test pit, lbm (kg),
m_5 = mass of water used for template and test pit volume, lbm (kg), and
m_6 = mass of water for template volume, lbm (kg).

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

Measured mass of water:

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

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

where:
V_4 = volume of water in test pit, ft^3 (m^3),
m_7 = mass of water in test pit, lbm (kg), and
ρ_w = density of water, lbm/ft^3 (g/cm^3).

or:

Measured volume of water:

$$V_4 = V_3 \times 0.13368 \quad \text{(inch-pound)} \tag{6}$$

$$V_4 = V_3 \times \frac{1}{10^3} \quad \text{(SI)} \tag{7}$$

where:
V_4 = volume of water in test pit, ft^3 (m^3),
V_3 = volume of water in the test pit, gal (L) = $V_1 - V_2$,
V_1 = volume of water used to fill test pit and template, gal (L),
V_2 = volume of water used to fill template, gal (L),
0.13368 = constant to convert gallons to ft^3, and
10^3 = constant to convert litres to m^3.

12.5 Calculate the volume of mortar as follows:

$$V_5 = \frac{m_{11}}{\rho_m} \tag{8}$$

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).

12.6 Calculate the volume of the test pit as follows:

$$V_6 = V_4 + V_5 \tag{9}$$

or if no mortar has been used:

$$V_6 = V_4 \tag{10}$$

where:
V_6 = volume of test pit, ft^3 (m^3),
V_4 = volume of water in test pit, ft^3 (m^3), and
V_5 = volume of mortar in test pit, ft^3 (m^3).

12.7 Calculate the mass of wet 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 plus mass of the containers, lbm (kg), and
m_9 = mass of containers for m_8, lbm (kg).

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

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

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

where:
ρ_{wet} = wet density of material excavated from test pit, lbm/ft^3 (Mg/m^3),
m_{10} = mass of wet material removed from test pit, lbm (kg), and
V_6 = volume of test pit, ft^3 (m^3).

12.9 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),
ρ_{wet} = wet density of material excavated from test pit, lbm/ft^3 (Mg/m^3), and
w = moisture content of material excavated from test pit, %.

12.10 Calculate the dry unit weight of the material excavated from the test pit as follows:

$$\gamma_d = \rho_d \times \frac{1\ \text{lbf}}{1\ \text{lbm}} \quad \text{(inch-pound)} \tag{15}$$

where:
γ_d = dry unit weight of material excavated from test pit, lbf/ft^3 (kN/m^3), and
ρ_d = dry density of material excavated from test pit, lbm/ft^3 (Mg/m^3).

Assume that in the inch-pound system 1 lbm = 1 lbf.

$$\gamma_d = \rho_d \times 9.807 \quad \text{(SI)} \tag{16}$$

where:
9.807 = the constant to convert Mg to kN.

12.11 If desired, convert the dry unit weight in inch-pound units to SI units as follows:

$$\text{unit weight in kN/m}^3 = \text{unit weight in lbf/ft}^3 \times 0.1571 \tag{17}$$

where:
0.1571 = the constant to convert lbf/ft^3 to kN/m^3.

13. Calculation—Procedure B

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

$$m_{14} = m_{12} - m_{13} \tag{18}$$

where:

m_{14} = wet mass of oversize particles, lbm (kg),
m_{12} = wet mass of oversize particles and container, lbm (kg), and
m_{13} = mass of container, lbm (kg).

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

$$m_{18} = m_{10} - m_{14} \tag{19}$$

where:

m_{18} = wet mass of control fraction, lbm (kg),
m_{10} = mass of wet material removed from test pit, lbm (kg), and
m_{14} = wet mass of oversize particles lbm (kg).

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

$$V_{os} = \frac{m_{14}}{G_m\,(62.4\ \text{lbm/ft}^3)} \quad \text{(inch-pound)} \tag{20}$$

$$V_{os} = \frac{m_{14}}{G_m\,(1\ \text{g/cm}^3)} \times \frac{1}{10^3} \quad \text{(SI)} \tag{21}$$

where:

V_{os} = volume of oversize particles, ft^3 (m^3),
m_{14} = wet mass of oversize particles, lbm (kg),
G_m = bulk specific gravity of oversize particles,
62.4 lbm/ft^3 = density of water,
1 g/cm^3 = density of water, and
$1/10^3$ = constant to convert g/cm^3 to kg/m^3.

13.4 Calculate the volume of the control fraction as follows:

$$V_c = V_6 - V_{os} \tag{22}$$

where:

V_c = volume of control fraction, ft^3 (m^3),
V_6 = volume of test pit, ft^3 (m^3), and
V_{os} = volume of oversize particles, ft^3 (m^3).

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

$$\rho_{wet}(c) = \frac{m_{18}}{V_c} \quad \text{(inch-pound)} \tag{23}$$

$$\rho_{wet}(c) = (m_{18}/V_c) \times \frac{1}{10^3} \quad \text{(SI)} \tag{24}$$

where:

$\rho_{wet}(c)$ = wet density of control fraction, lbm/ft^3 (Mg/m^3),
m_{18} = wet mass of control fraction, lbm (kg), and
V_c = volume of control fraction, ft^3 (m^3).

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

$$\rho_d(c) = \frac{\rho_{wet}(c)}{1 + (w_f/100)} \tag{25}$$

where:

$\rho_d(c)$ = dry density of control fraction, lbm/ft^3 (Mg/m^3),
$\rho_{wet}(c)$ = wet density of control fraction, lbm/ft^3 (Mg/m^3), and
w_f = moisture content of control fraction, %.

13.7 Calculate the dry unit weight of the control fraction as follows:

$$\gamma_d(c) = \rho_d(c) \times \frac{1\ \text{lbf}}{1\ \text{lbm}} \quad \text{(inch-pound)} \tag{26}$$

Assume that in the inch-pound system 1 lbm = 1 lbf.

$$\gamma_d(c) = \rho_d(c) \times 9.807\ \text{(SI)} \tag{27}$$

where:

9.807 = the constant to convert mg to kN,
$\gamma_d(c)$ = dry unit weight of control fraction, lbf/ft^3 (kN/m^3), and
$\rho_d(c)$ = dry density of control fraction, lbm/ft^3 (Mg/m^3).

13.8 If desired, convert dry unit weight in inch-pound units to SI units, using Eq 17.

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

$$m_{19} = \frac{m_{18}}{1 + w_f/100} \tag{28}$$

where:

m_{19} = dry mass of control fraction, lbm (kg),
m_{18} = wet mass of control fraction, lbm (kg), and
w_f = moisture content of control fraction, %.

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

$$m_{17} = m_{15} - m_{10} \tag{29}$$

or:

$$m_{17} = \frac{m_{14}}{1 + (w_{os}/100)} \tag{30}$$

where:

m_{17} = dry mass of oversize particles, lbm (kg),
m_{10} = mass of wet material removed from test pit, lbm (kg),
m_{14} = wet mass of oversize particles, lbm (kg),
m_{15} = dry mass of oversize particles and container, lbm (kg), and
w_{os} = moisture content of oversize particles, %.

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

$$m_{20} = m_{19} + m_{17} \tag{31}$$

where:

m_{20} = dry mass of total sample (control fraction plus oversize), lbm (kg),
m_{19} = dry mass of control fraction, lbm (kg), and
m_{17} = dry mass of oversize particles, lbm (kg).

13.12 Calculate the percent oversize particles as follows:

$$\text{Percent oversize} = \frac{m_{17} \times 100}{m_{20}} \tag{32}$$

where:

m_{17} = dry mass of oversize particles, lbm (kg), and
m_{20} = dry mass of total sample (control fraction plus oversize particles), lbm (kg).

13.13 Calculate the moisture content of the total material as follows:

$$w = \frac{m_{10} - m_{20}}{m_{20}} \tag{33}$$

where:

w = moisture content of material excavated from test pit, %,
m_{10} = mass of wet material removed from test pit, lbm (kg), and
m_{20} = dry mass of total sample (control fraction plus oversize particles), lbm (kg).

13.14 Calculate the dry density and the dry unit weight of the total material by using Eq 12-16.

13.15 If required, convert dry unit weight in inch-pound units to SI units, using Eq 17.

14. Report

14.1 Report the following information:

14.1.1 Test location,

14.1.2 Test location elevation,

14.1.3 Test hole volume,

14.1.4 In-place wet density, total, or control fraction, or both,

14.1.5 In-place dry density, total, or control fraction, or both,

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

14.1.7 In-place moisture content(s), and total, or control fraction, or both, and test method(s) used,

14.1.8 Test apparatus description,

14.1.9 Comments on test, as applicable,

14.1.10 Visual description of the material,

14.1.11 Bulk specific gravity and test method used, and

14.1.12 If required, percentage of oversize particles.

15. Precision and Bias

15.1 The precision and bias of this test method have not yet been determined. No available methods provide absolute values for the density or unit weight of material in place against which these test methods can be compared. The variability of the material and the destructive nature of these test methods do not allow for the repetitive duplication of test results required to obtain a meaningful statistical evaluation of bias.

16. Keywords

16.1 acceptance test; degree of compaction; density tests; field test; In-place density; pit test; quality control; test pit density; unit weight; water pit; water replacement method

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 D 4914. The guidelines are given in Tables A1.1-A1.3.

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

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 unit weight 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.

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.

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

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 unit weight 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.

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.

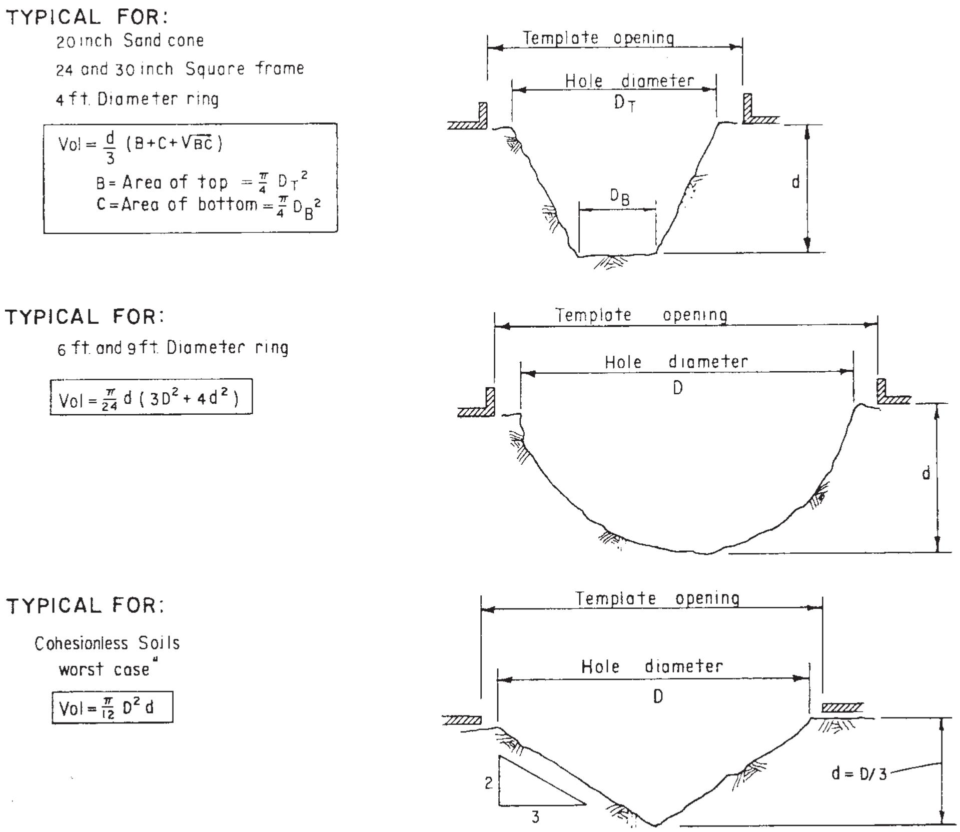

FIG. A1.1 Test Pit Configurations

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	1.2
6	1.8
9	2.7
Cubic Feet	Cubic Metres
1.0	0.03
2	0.06
8	0.23
27	0.76
90	2.55

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., 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 unit weight 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., 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. A36-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 unit weight 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.