Designation: D 2167 – 94 (Reapproved 2001)

Standard Test Method for Density and Unit Weight of Soil in Place by the Rubber Balloon Method[1]

This standard is issued under the fixed designation D 2167; 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.

This standard has been approved for use by agencies of the Department of Defense.

1. Scope

1.1 This test method covers the determination of the in-place density and unit weight of compacted or firmly bonded soil using a rubber balloon apparatus.

1.2 This test method is suitable for use as a means of acceptance for compacted fill or embankments constructed of fine-grained soils or granular soils without appreciable amounts of rock or coarse material.

1.3 This test method also may be used for the determination of the in-place density and unit weight of undisturbed or in situ soils, provided the soil will not deform under the pressures imposed during the test.

1.4 This test method is not suitable for use in organic, saturated, or highly plastic soils that would deform under the pressures applied during this test. This test method may require special care for use on (*1*) soils consisting of unbonded granular materials that will not maintain stable sides in a small hole, (*2*) soils containing appreciable amounts of coarse material in excess of 1½ in. (37.5 mm), (*3*) granular soils having high void ratios, or (*4*) fill materials containing particles with sharp edges. For soils containing appreciable amounts of particles in excess of 1½ in. (37.5 mm), Test Methods D 4914 or D 5030 should be used.

1.5 It is common practice in the engineering profession to concurrently use pounds to represent both a unit of mass (lbm) and a unit of force (lbf). This implicitly combines two separate systems of units; that is, the absolute system and the gravitational system. It is scientifically undesirable to combine the use of two separate sets of inch-pound units within a single standard. This standard has been written using the gravitational system of units when dealing with the inch-pound system. In this system the pound (lbf) represents a unit of force (weight). However, the use of balances or scales recording pounds of mass lbm/ft ^{3} should not be regarded as nonconforming with this test method.

1.6 *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.*

2. Referenced Documents

2.1 *ASTM Standards:*

D 653 Terminology Relating to Soil, Rock, and Contained Fluids[2]

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[2]

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[2]

D 2216 Method for Laboratory Determination of Water (Moisture) Content of Soil, Rock, and Soil-Aggregate Mixtures[2]

D 3740 Practice for the Evaluation of Agencies Engaged in Testing and/or Inspection of Soil and Rock as Used in Engineering Design and Construction[2]

D 4643 Test Method for Determination of Water (Moisture) Content of Soils by the Microwave Oven Method[2]

D 4718 Practice for the Correction of Unit Weight and Water Content for Soils Containing Oversize Particles[2]

D 4753 Specification for Evaluating, Selecting, and Specifying Balances and Scales for Use in Testing Soil, Rock, and Related Construction Materials[2]

D 4914 Test Method for Density of Soil and Rock in Place by the Sand Replacement Method in a Test Pit[2]

D 4944 Test Method for Field Determination of Water (Moisture) Content of Soil by the Calcium Carbide Gas Pressure Tester[2]

D 4959 Test Method for Determination of Water (Moisture) Content of Soils by the Direct Heating Method[2]

D 5030 Test Method for Density and Unit Weight of Soil and Rock in Place by the Water Replacement Method in a Test Pit[2]

[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 Nov. 10, 2001. Published April 1994. Originally published as D 2167 – 63 T. Last previous edition D 2167 – 66 (1990).

[2] *Annual Book of ASTM Standards*, Vol 04.08.

3. Summary of Test Method

3.1 The volume of an excavated hole in a given soil is determined using a liquid-filled calibrated vessel for filling a thin flexible rubber membrane; this membrane is displaced to fill the hole. The in-place wet density is determined by dividing the wet mass of the soil removed by the volume of the hole. The water (moisture) content and the in-place wet density are used to calculate the dry in-place density and dry unit weight.

4. Significance and Use

4.1 This test method can be used to determine the in-place density and unit weight of natural inorganic soil deposits, soil-aggregate mixtures, or other similar firm materials.

4.2 This test method may be used to determine the density and unit weight of compacted soils used in construction of earth embankments, road fill, and structural backfill. This test method often is used as a basis of acceptance for soils compacted to a specified density or a percentage of maximum density or unit weight, as determined by a standard test method.

4.3 The use of this test method is generally limited to soil in an unsaturated condition and is not recommended for soils that are soft or that deform easily. Such soils may undergo a volume change during the application of pressure during testing. This test method may not be suitable for soils containing crushed rock fragments or sharp edge materials which may puncture the rubber membrane.

NOTE 1—Notwithstanding the statements on precision and bias contained in this test method, the precision of this test method is dependent on the competence of the personnel performing it and the suitability of the equipment and the facilities used. Agencies that meet the criteria of Practice D 3740 are generally considered capable of competent and objective testing. Users of this test method are cautioned that compliance with Practice D 3740 does not in itself ensure reliable testing. Reliable testing depends on many factors; Practice D 3740 provides a means of evaluating some of those factors.

5. Apparatus

5.1 *Balloon Apparatus*—This is a calibrated vessel containing a liquid within a relatively thin, flexible, elastic membrane (rubber balloon) designed for measuring the volume of the test hole under the conditions of this test method. An example of the essential elements for this apparatus is shown in Fig. 1. The apparatus shall be equipped so that an externally controlled pressure or partial vacuum can be applied to the contained liquid. It shall be of such weight and size that will not cause distortion of the excavated test hole and adjacent test area during the performance of the test. The apparatus shall provide for the use of an integral pressure gage or other means for controlling the applied pressure during calibration and testing. Provision shall be made for placing loads (surcharge) on the apparatus. There shall be an indicator for determining the volume of the test hole to the nearest 1 %. The flexible membrane shall be of such size and shape as to fill the test hole completely without wrinkles or folds when inflated within the test hole, and the membrane strength shall be sufficient to withstand such pressure as is necessary to ensure complete filling of the test hole without loss of liquid. Withdrawal of the membrane from the test hole shall be accomplished by the application of a partial vacuum to the liquid or by other means.

5.1.1 The description and requirements given are intended to be nonrestrictive. Any apparatus using a flexible (rubber) membrane and liquid that can be used to measure within an accuracy of 1 % the volume of a test hole in soil under the conditions of this test method is satisfactory. Larger apparatus and test hole volumes are required when particles over 1 1/2 in. (37.5 mm) are prevalent in the material being tested.

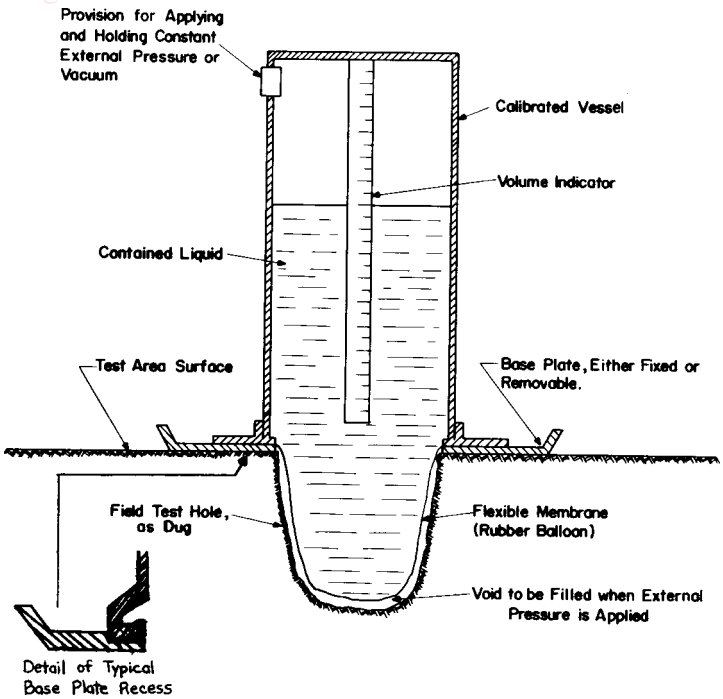

FIG. 1 Schematic Drawing of Calibrated Vessel Indicating Principle (Not to Scale)

5.2 *Base Plate*—A rigid metal plate machined to fit the base of the balloon apparatus. The base plate shall have a minimum dimension of at least twice the test hole diameter to prevent deformation of the test hole while supporting the apparatus and surcharge loads (if used).

5.3 *Balances or Scales*—A balance or scale having a minimum capacity of 20 kg meeting the requirements of Specification D 4753 for a balance of 5.0 g readability. Balances or scales required for moisture determination or oversize correction are contained in those standards.

5.4 *Drying Apparatus*—Equipment or ovens, or both, for the determination of moisture content in accordance with Test Methods D 2216, D 4643, D 4959, or D 4944.

5.5 *Miscellaneous Equipment*—Equipment including: small picks, chisels, spoons, brushes, and screwdrivers for digging test holes; plastic bags, buckets with lids, or other suitable moisture proof containers with snug fitting lids for retaining the soil taken from the test hole; shovels or spades and a straight edge for leveling and preparing test location; calculator or slide rule for calculations; and surcharge weights, if required, for apparatus.

6. Calibration

6.1 Prior to first use, verify the procedure to be used and the accuracy of the volume indicator by using the apparatus to measure containers or molds of known volume in accordance with Annex A1.

6.2 Apparatus calibration checks should be periodically performed. These should be performed annually, as a minimum, and whenever damage, repair, or change of membrane that may affect the pressure or volume indicating portions of the apparatus occurs.

7. Procedure

7.1 Prepare the surface at the test location so that it is reasonably plane and level. Dependent on the water (moisture) content and texture of the soil, the surface may be leveled using a bulldozer or other heavy equipment blades, provided the test area is not deformed, compressed, torn, or otherwise disturbed.

7.2 Assemble the base plate and rubber balloon apparatus on the test location. Using the same pressure and surcharge determined during the calibration of the apparatus, take an initial reading on the volume indicator and record. The base plate shall remain in place through completion of the test.

7.3 Remove the apparatus from the test hole location. Using spoons, trowels, and other tools necessary, dig a hole within the base plate. Exercise care in digging the test hole so that soil around the top edge of the hole is not disturbed. The test hole shall be of the minimum volume shown in Table 1 based on the maximum particle size in the soil being tested. When material being tested contains a small amount of oversize, and isolated large particles are encountered, the test can be moved to a new location or the changing to another test method, such as Test Method D 4914 or D 5030. When particles larger than 1½ in. (37.5 mm) are prevalent, larger test apparatus and test volumes are required. Larger test-hole volumes will provide improved accuracy and shall be used where practical. The optimum dimensions of the test hole are related to the design of the apparatus and the pressure used. In general, the dimensions shall approximate those used in the calibration check procedure. The test hole shall be kept as free of pockets and sharp obtrusions as possible, since they may affect accuracy or may puncture the rubber membrane. Place all soil removed from the test hole in a moisture tight container for later mass and water (moisture) content determination.

TABLE 1 Minimum Test Hole Volumes Based on Maximum Size of Included Particles

Maximum Particle Size		Minimum Test Hole Volumes	
in.	(mm)	cm^3	ft^3
1/2	(12.5)	1420	0.05
1	(25.0)	2120	0.075
1 1/2	(37.5)	2840	0.1

7.4 After the test hole has been dug, place the apparatus over the base plate in the same position as used for the initial reading. Applying the same pressure and surcharge load as used in the calibration check, take and record the reading on the volume indicator. The difference between the initial and final readings is the volume of the test hole, V_h.

7.5 Determine the mass of all the moist soil removed from the test hole to the nearest 5 g. Mix all the soil thoroughly and select a representative water (moisture) content sample and determine the water (moisture) content in accordance with Test Methods D 2216, D 4643, D 4959, or D 4944. If oversize particles are present in the, perform field corrections in accordance with Test Method D 4718.

8. Calculation

8.1 Calculate the in-place wet density, ρ_{wet}, of the soil removed from the test hole as follows:

$$\rho_{wet} = \frac{M_{wet}}{V_h\,(1 \times 10^3)} \tag{1}$$

where:

ρ_{wet} = in-place wet density, mg/m^3,
M_{wet} = mass of the moist soil removed from the test hole, kg, and
V_h = volume of the test hole, m^3.

NOTE 2—$m^3 = ft^3(0.02832)$.

NOTE 3—Calculations shown are for using units in grams and cubic metres. Other units are permissible provided the appropriate conversion factors are used to maintain consistency of units throughout the calculations.

8.2 Calculate the in-place dry density, ρ_d, of the soil as follows:

$$\rho_d = \frac{\rho_{wet}}{\left(1 + \frac{w}{100}\right)} \tag{2}$$

where:

ρ_d = in-place dry density, mg/m^3,
ρ_{wet} = in-place wet density, mg/m^3, and
w = water (moisture) content of the soil removed from the test hole, expressed as a percentage of the dry mass of the soil to the nearest 1 %.

8.3 Calculate the in-place dry unit weight, δ_d, as follows:

$$\delta_d = \rho_d\,(9.807)\ in\ kN/m^3 \tag{3}$$