INTERNATIONAL

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Standard Test Method for Density of Soil in Place by the Drive-Cylinder Method[1]

This standard is issued under the fixed designation D2937; 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 in-place density of soil by the drive-cylinder method. The test method involves obtaining a relatively ~~undisturbed~~intact soil sample by driving a thin-walled cylinder and the subsequent activities for the determination of in-place density. When sampling or in-place density is required at depth, Test Method D1587 should be used.

1.2 This test method is not appropriate for sampling organic soils which can compress upon sampling, very hard natural soils and heavily compacted soils which cannot be easily penetrated by the drive sampler, soils of low plasticity which will not be readily retained in the cylinder, or soils which contain appreciable amounts of gravel (particles coarser than 4.75 mm (3⁄16 in.)). The presence of particles coarser than 4.75 mm (3⁄16 in.) may introduce significant errors in density measurements by causing voids along the wall of the cylinder during driving, and when coarse materials have to be dislodged by the trimming of the sample obtained by the cylinder.

1.3 This test method is limited to the procedures necessary for obtaining specimens suitable for determining the in-place density and water content of certain soils. The procedures and precautions necessary for selecting locations and obtaining ~~undisturbed~~intact samples suitable for laboratory testing or otherwise determining engineering properties is beyond the scope of this test method.

1.4 The values stated in SI units are to be regarded as standard. The inch-pound units given in parentheses are mathematical conversions, which are provided for information purposes only and are not considered standard.

1.4.1 It is common practice in the engineering/construction 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,~~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 test method has been written using~~ As stated, this standard includes the gravitational system of ~~units when dealing with the~~ inch-pound ~~system. In this system~~ units and does not use/present the ~~pound (lbf) represents a~~ slug unit ~~of force (weight).~~ for mass. However, the use of balances or scales recording pounds of mass ~~(lbm),~~(lbm) or the recording of density in lbm/ft^3 ~~should~~shall not be regarded as nonconformance with this ~~test method.~~ standard.

~~1.5All~~1.5 All observed and calculated values shall conform to the guidelines for significant digits and rounding established in Practice D6026~~.~~

~~1.6The standard values stated in SI units are to be regarded as the standard. The values in parentheses are provided for information purposes only.~~

~~1.7~~*, unless superseded by this standard.*

1.5.1 The procedures used to specify how data are collected/recorded or calculated in this standard are regarded as the industry standard. In addition, they are representative of the significant digits that generally should be retained. The procedures used do not consider material variation, purpose for obtaining the data, special purpose studies, or any considerations for the user's objectives; and it is common practice to increase or reduce significant digits of reported data to be commensurate with these considerations. It is beyond the scope of this standard to consider significant digits used in analysis methods for engineering design.

1.6 *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.*

[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.

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

2. Referenced Documents

2.1 *ASTM Standards:*[2]

D653 Terminology Relating to Soil, Rock, and Contained Fluids

D698 Test Methods for Laboratory Compaction Characteristics of Soil Using Standard Effort (12 400 ft-lbf/ft³(600 kN-m/m³))

D1557

D1557 Test Methods for Laboratory Compaction Characteristics of Soil Using Modified Effort (56,000 ft-lbf/ft³(2,700 kN-m/m³))

D1587 Practice for Thin-Walled Tube Sampling of Soils for Geotechnical Purposes

D2216 Test Methods for Laboratory Determination of Water (Moisture) Content of Soil and Rock by Mass

D2488 Practice for Description and Identification of Soils (Visual-Manual Procedure)

D3740 Practice for Minimum Requirements for Agencies Engaged in Testing and/or Inspection of Soil and Rock as Used in Engineering Design and Construction

D4643 Test Method for Determination of Water (Moisture) Content of Soil by Microwave Oven Heating

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

D4944 Test Method for Field Determination of Water (Moisture) Content of Soil by the Calcium Carbide Gas Pressure Tester

D4959 Test Method for Determination of Water (Moisture) Content of Soil By Direct Heating

D6026 Practice for Using Significant Digits in Geotechnical Data

3. Terminology

3.1 *Definitions*—All definitions are in accordance with Terminology D653.

4. Significance and Use

4.1 This test method can be used to determine the in-place density of natural, inorganic soils which do not contain significant amounts of particles coarser than 4.75 mm (3⁄16 in.), and which can be readily retained in the drive cylinder. This test method may also be used to determine the in-place density of compacted soils used in construction of structural fill, highway embankments, or earth dams. When the in-place density is to be used as a basis for acceptance, the drive cylinder volumes must be as large as practical and not less than 850 cm³ (.03 ft(0.030 ft³).

4.2 This test method is not recommended for use in organic or friable soils. This test method may not be applicable for soft, highly plastic, noncohesive, saturated or other soils which are easily deformed, compress during sampling, or which may not be retained in the drive cylinder. The use of this test method in soils containing particles coarser than 4.75 mm (3⁄16 in.) may result in damage to the drive cylinder equipment. Soils containing particles coarser than 4.75 mm (3⁄16 in.) may not yield valid results if voids are created along the wall of cylinder during driving, or if particles are dislodged from the sample ends during trimming.

4.3 The general principles of this test method have been successfully used to obtain samples of some field compacted fine-grained soils having a maximum particle size of 4.75 mm (3⁄16 in.) for purposes other than density determinations, such as the testing for engineering properties.

NOTE 1—Notwithstanding the statements on precision and bias contained in this standard: The precision of this test method is dependent on the competence of the personnel performing it and the suitability of the equipment and facilities used. Agencies which meet the criteria of Practice D3740 are generally considered capable of competent and objective testing. Users of this method are cautioned that compliance with Practice D3740 does not in itself assure reliable testing. Reliable testing depends on many factors; Practice D3740 provides a means of evaluating some of those factors.

5. Apparatus

5.1 *Drive Cylinders*, of approximately 102 to 152 mm (4.00 to 6.00 in.) diameter or larger. Typical details of drive cylinders with outside diameters of 102 mm (4.00 in.) are shown in Fig. 1 (see also Table 1). Drive cylinders of other diameters will require proportional changes in the drive-cylinder tube and drive-head dimensions. The volume of the cylinders with the dimensions shown in Fig. 1 is approximately 942940 cm³ (0.033 ft³). The apparatus shown in Fig. 1 is of a design suitable for use at or near the surface.

5.1.1 When the in-place density is to be used as a basis for acceptance of compacted fill, the cylinders shall be as large as practical to minimize the effects of errors and shall in no case be smaller than 850 cm³(0.03 ft (0.030 ft³).

5.1.2 The number of cylinders required depends on the number of samples to be taken and the anticipated rapidity by which the cylinders can be returned to service after weighing, cleaning, etc.

5.1.3 The cylinders shown in Fig. 1 meet the clearance ratio, wall thickness and area-ratio requirements as set forth by Hvorslev[3] for drive samplers, and should preferably not exceed 10 to 15 %, as defined by the following:

(1) $Ar = [(Dw2 - De2)/De2] \times 100$

[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.

[3] Hvorslev, M. J., "Surface Exploration and Sampling of Soils for Engineering Purposes," Engineering Foundation, 345 E. 47th St., New York, NY 10017.

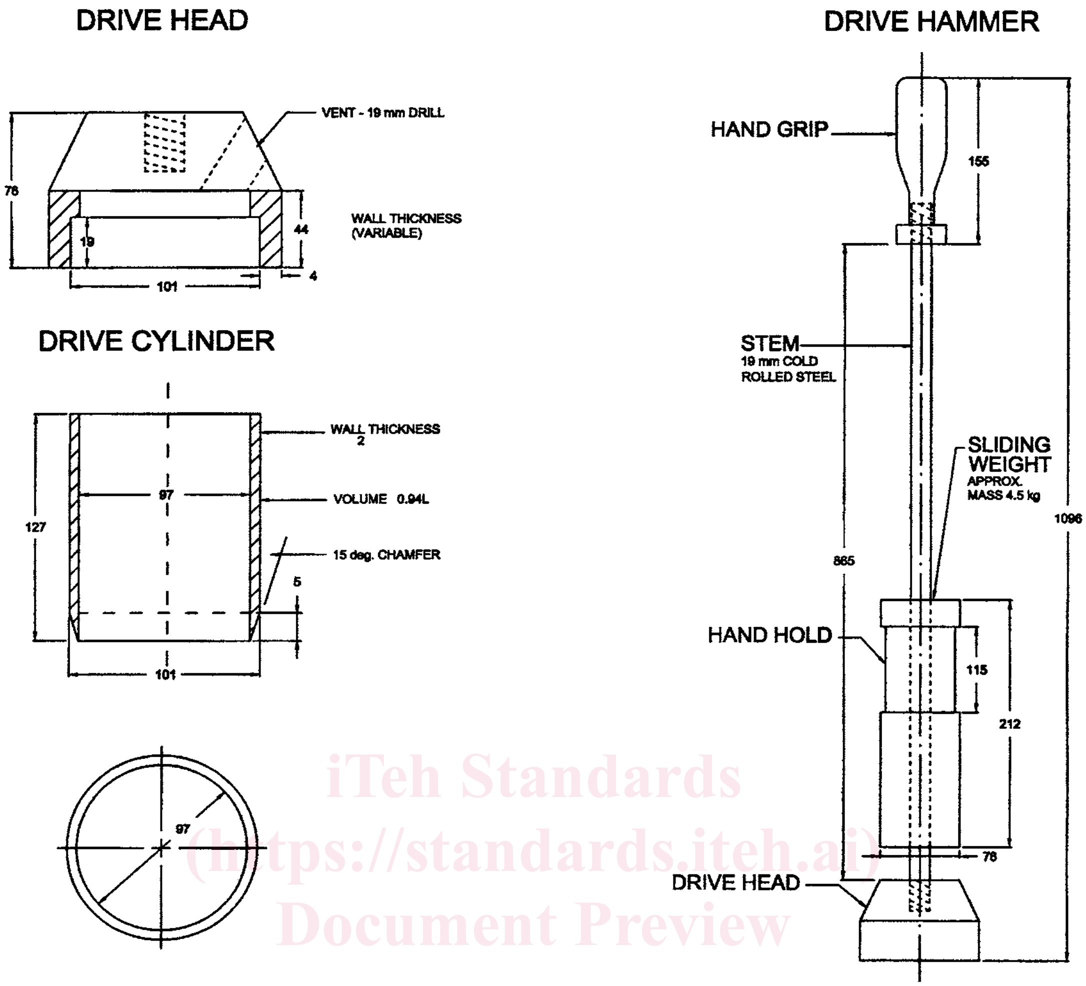

FIG. 1 Typical Design for a Surface Soil Sampler

TABLE 1 Dimensional Equivalent for Fig. 1

mm	in.	mm	in.
~~2~~	~~5⁄64~~	~~101.2~~	~~4 1⁄16~~
2	5⁄64	103	4 1⁄16
~~3.3~~	~~0.13~~5⁄32	~~114.3~~	~~4½~~
4	5⁄32	115	4½
~~4.8~~	~~3⁄16~~	~~127.0~~	~~5~~
5	3⁄16	127	5.00
~~19~~	~~3⁄4~~	~~152.4~~	~~6~~
19	3⁄4	155	6.00
~~44.4~~	~~1¾~~	~~212.0~~	~~8~~
44	1¾	212	8.00
~~76~~	~~3~~	~~863.6~~	~~34~~
76	3.0	865	36.00
~~97.2~~	~~3⅞~~	~~1117.6~~	~~45.00~~
98	3⅞	1096	45.00
102	4.00		

~~(1) $A_r = [(D_w 2 - D_e 2)/D_e 2] \times 100$~~

Dw

where:

A_r = area ratio, %,

~~D_e~~ Dw= maximum external diameter of the drive ~~sampler,~~ cylinder, and

~~D_i~~ De= ~~minimum internal diameter of the drive sampler at the cutting edge.~~ effective (minimum) internal diameter of the drive sampler at the cutting edge after swaging.

5.1.4 Except for very short samplers with no clearance, the inside clearance ratio of the cylinders should ~~be 1% or greater,~~ from

0.5 to 3.0 %, with increasing ratios withas the increase in plasticity ofincreases in the soil being sampled. Inside clearance ratio is defined by the following:

$$C_r = \quad (2)$$

$$C_r = \quad (2)$$

Di − DeDe × 100

where:

C_r = inside clearance ratio, %

D_eDe = effective (minimum) insideinternal diameter of the sampler at the cutting edge,edge after swaging, and

D_iDi = internal diameter of the sampler.

5.1.5 Cylinders of other diameters should conform to these requirements.

5.2 *Drive Head*—The typical details of the drive heads and appurtenances are shown in Fig. 1. The drive head has a sliding weight for driving the cylinder.

5.3 *Straightedge*, steel, approximately 3 mm (⅛ —steel, approximately 3 mm (⅛ in.) by 38 mm (1½ in.) by 305 mm (12.0 in.) with one edge sharpened at approximately a 45° angle for trimming the ends of the sample flush with the cylinder.

5.4 *Shovel*—Any one of several types of shovels or spades is satisfactory in shallow sampling for digging the cylinders out after they have been driven into the soil.

5.5 *Balances*—A balance having a minimum capacity of 10 kg (22 lbs) and meeting the requirements of Specification D4753 for a balance of 1 g (0.002 lbs) readability is required for the cylinders shown in Fig. 1. Larger cylinders will require a balance of 20 kg capacity with readability of 0.1%. . Larger cylinders will require a balance of 25 kg (55 lbs) capacity with readability of 1 gm (0.002 lbs).

5.6 *Drying Equipment*—Equipment or ovens, or both, to determine water (moisture) content in compliance with Test Methods D2216, D4643, D4944, or D4959.

5.7 *Miscellaneous Equipment*—Brushes, sledgehammers, plastic bags, metal cans with lids, or other suitable containers for retaining the drive cylinder and sample until determination of mass and drying, spoons, inside/outside vernier caliper, or the equivalent accurate to 0.002250.25 mm (0.01 in.) for calibration, gloves, and safety glasses.

6. Sampling

6.1*Sampling at or Near the Surface*:

6.1.1Brush all loose particles from the surface. For near-surface sampling (not more than 1 m (36 in.) in depth), sample through a hole bored with an auger or dug by a shovel from which loosened material has been removed. Obtain a fairly level surface before any cylinder is driven. Depending on the soil texture and moisture, the surface may be prepared utilizing a bulldozer blade or other heavy equipment blades provided the sample area and vicinity are not deformed, compressed, torn, or otherwise disturbed.

6.1.2Assemble the cylinder and drive apparatus with the sharpened edge on the surface to be sampled. Drive the cylinder by raising the drop hammer and allowing it to fall, or alternatively by applying a uniform force via a jack or similar device, while keeping the drive rod steady and in a vertical position. Continue driving until the top of the cylinder is approximately 13 mm (½ in.) below the original surface. Overdriving may result in deforming or compressing the sample and may provide erroneous results. Care should be taken to prevent overdriving, particularly when sampling below the surface. If overdriving occurs or is suspected, the sample should be discarded and the soil resampled. Remove the drive head and dig the cylinder from the ground with a shovel, digging the soil from around the sides of the cylinder and undercutting several inches below the bottom of the cylinder before lifting the cylinder out. When sampling near, but below, the surface, use the same procedure, but more soil will necessarily have to be dug from around the sides of the cylinder to properly undercut the cylinder.

6.1.3After the cylinder has been removed from the ground, trim any excess soil from the sides of the cylinder. Using the straightedge, trim the ends of the sample flush and plane with the ends of the cylinder. A satisfactory sample is composed of relatively undisturbed soil representative of the soil in place and shall not contain rocks, roots, or other foreign material. If the cylinder is not full or is not representative, discard the sample and take another sample. If the cylinder is deformed or otherwise damaged while driving it into or removing it from the ground, discard the sample and repair or replace the cylinder. Immediately determine the mass of the sample and determine the water content or place the drive cylinder and sample in a container which will prevent soil or water loss until mass and water determinations can be made.

7.Calibration

7.1Before testing begins and periodically thereafter, or when damage is suspected, check the cutting edge of the drive cylinders (dulled or damaged cylinders may be resharpened and reswaged or discarded).

7.1.1Before testing and periodically thereafter, determine the mass and volume of each cylinder. Determine and record the mass accurately to the nearest 1 g. Determine the volume of each cylinder by measuring the height and the swaged-end diameter at four equally spaced points to 0.254 mm (0.01 in.) and average the respective dimensions. Calculate and record the volume to the nearest 0.16 mm^3(0.01 $in.^3$).

7.2Permanently identify each cylinder by a number or symbol traceable to the calibration data. It may be desirable in some cases to show the mass and volume on the cylinder along with the identification.

8.Procedure

8.1Determine the mass of the drive cylinder and soil sample to the nearest 1 g and record.

8.2Remove the soil from the cylinder. Obtain a representative specimen for water content determination, or use the entire sample. Specimens for determining water content are to be as large as practical but in no case smaller than 100 g and selected in such a way so as to represent all the material from the cylinder. Determine the water content of the soil in accordance with either Test Methods

6.1 Brush all loose particles from the surface. For near-surface sampling (not more than 1 m (3 ft) in depth), sample through a hole bored with an auger or dug by a shovel from which loosened material has been removed. Obtain a fairly level ground surface before the cylinder is driven. Depending on the soil texture and moisture, the surface may be prepared utilizing a bulldozer blade or other heavy equipment blades provided the sample area and vicinity are not deformed, compressed, torn, or otherwise disturbed.

6.2 Assemble the cylinder and drive apparatus with the sharpened edge on the surface to be sampled. Drive the cylinder by raising the drop hammer and allowing it to fall, or alternatively by applying a uniform force via a jack or similar device, while keeping the drive rod steady and in a vertical position. Continue driving until the top of the cylinder is approximately 13 mm (1/2 in.) below the original surface as shown in Fig. 2. Overdriving may result in deforming or compressing the sample and may provide erroneous results. Care should be taken to prevent overdriving, particularly when sampling below the surface. If overdriving occurs or is suspected, the sample should be discarded and the soil resampled. Remove the drive head and dig the cylinder from the ground with a shovel; dig the soil from around the sides of the cylinder, undercutting several inches below the bottom of the cylinder before lifting the cylinder out. When sampling near the surface, more soil may have to be dug from around the sides of the cylinder to properly undercut the cylinder.

6.3 After the cylinder has been removed from the ground, remove any excess soil from the sides of the cylinder. Using the straightedge, trim the ends of the sample flush and plane with the ends of the cylinder. A satisfactory sample is composed of an intact soil and shall not contain rocks, roots, or other foreign material. If the cylinder is not full or does not properly represent the in-situ soil, discard and take another sample. If the cylinder is deformed or otherwise damaged while driving it into or removing it from the ground, discard and repair or replace the cylinder. Immediately determine the mass and water content of the sample or place the drive cylinder and sample in a container which will prevent soil or water loss until mass and water determinations can be made.

6.4 Record the mass of the drive cylinder and soil sample to the nearest 1 g (0.002 lbm).

6.5 Remove the soil from the cylinder. Obtain a representative specimen for water content determination. Specimens for determining water content are to be as large as practical but in no case smaller than 100 g (0.200 lbs) and selected to represent all the material from the cylinder. Determine the water content of the soil in accordance with Test Methods D2216, D4643, D4944, or D4959.

9.

7. Calculation

9.1The in-place dry density of the soil is expressed as the mass of the dry soil divided by the volume of soil, and is usually reported in kilograms per cubic meter or pounds per cubic foot.

9.2Calculate the dry mass of the drive-cylinder sample, *M*

7.1 The density of the soil is expressed as the mass of the soil divided by the volume of soil, and is usually reported in grams per cubic centimeter (g/cm^3, in grams, as follows:) or pounds per cubic foot (lb/ft^3).

7.2 Calculate the wet density, ρ_{wet}, of the drive-cylinder sample in g/cm^3 as follows:

$$\rho_{wet} = (M_1 - M \quad (3)$$

$$\rho_{wet} = (M_1 - M \quad (3)$$

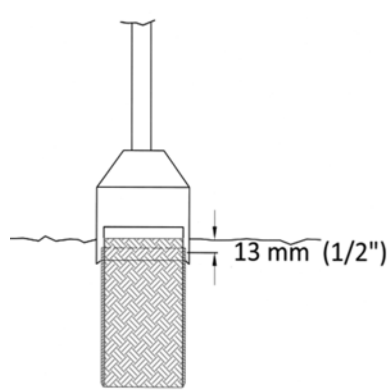

FIG. 2 Relationship of Driven Cylinder to Ground Surface

2)V
V

where:

M_1 = mass of the cylinder and wet soil sample, g, g
M_2 = mass of the cylinder, g, and
w = water content, %, dry mass basis.volume of the drive cylinder, cm^3
V

97.3 Calculate the in-place dry density, ρ_d, of the drive-cylinder samplesoil in g/cm^3 as follows:

$$\rho_d \quad (4)$$

$$\rho_d \quad (4)$$

= ρwet(1 + (w/100))

ρd

where:

$V\rho_d$ = volume of the drive cylinder, cm in-place dry density, g/cm^3 (to the nearest 0.01 cm
ρ^{wet} = in-place wet density, g/cm^3), and
w = water content, %, dry mass basis.

7.3.1 *Dry Unit Weight*:

$$\gamma_d = K_1 \times \rho_d \ (in\ kN/m^3) \quad (5)$$

or

$$\gamma_d = K_2 \times \rho_d \ (in\ lbf/ft^3) \quad (6)$$

where:

ρ_d = in-place dry density, g/cm^3,
K_1 = 9.81 for density in g/cm^3, and
K_2 = 62.4 for density in lb/ft^3.

NOTE 2—It may be desired to express the in-place density as a percentage of some other density, for example, the laboratory maximum density, determined in accordance with Test Methods D698 or D1557. This relation can be determined by dividing the in-place density by the maximum density and multiplying by 100.

10.Data Sheet(s)/Form(s)

10.1Report the following information:
10.1.1Location,
10.1.2Depth below ground surface or elevation of surface, or both,
10.1.3Dry density,
10.1.4Water content and the test method used,
10.1.5Dimensions and volume of the sampler,
10.1.6Visual description of the soil sample, and
10.1.7Comments on soil sample disturbance.
10.2If the in-place dry density or unit weight is expressed as a percentage of another value, or used as a basis for acceptance of compacted fill, include the following:
10.2.1Volume of the drive cylinder used,
10.2.2The comparative dry density or unit weight value and water content used,
10.2.3The method used to determine the comparative values,
10.2.4The comparative percentage of the in-place material to the comparison value, and
10.2.5The acceptance criteria applicable to the test.

11.

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

8.1 Record as a minimum the following general information (data):
8.1.1 Project No., Location, Date Test(s) Performed, Tests Performed By,
8.1.2 Sample/specimen identifying information, such as, Test No., depth below surface or elevation (cm).
8.2 Record as a minimum the following test specimen data:
8.2.1 The mass and dimensions (length and diameter) and volume of the drive cylinder, to either three or four significant digits, see Annex A1.
8.2.2 The water content (nearest 0.1 percent) and test method used, and dry unit weight (three or four significant digits, see Section 7.2) of the test sample.