



Standard Test Method for Density of Soil in Place by the Drive-Cylinder Method¹

This standard is issued under the fixed designation D 2937; 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} NOTE—Figure 1 was editorially corrected in July 2002.

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 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 D 1587 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 ($\frac{3}{16}$ in.)). The presence of particles coarser than 4.75 mm ($\frac{3}{16}$ 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 samples suitable for laboratory testing or otherwise determining engineering properties is beyond the scope of this test method.

1.4 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 test method 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), or the recording of density in lbm/ft³

should not be regarded as nonconformance with this test method.

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

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 Fluids²
- D 698 Test Method for Laboratory Compaction Characteristics of Soil Using Standard Effort (12,000 ft-lbf/ft (600 kN-m/m))²
- D 1557 Test Method for Laboratory Compaction Characteristics of Soil Using Modified Effort (56,000 ft-lbf/ft (2700 kN-m/m))²
- D 1587 Practice for Thin-Walled Tube Sampling of Soils²
- D 2216 Test Method for Laboratory Determination of Water (Moisture) Content of Soil and Rock²
- D 2488 Practice for Description and Identification of Soils for Engineering Practices (Visual-Manual Procedure)²
- D 3740 Practice for the Evaluation of Agencies Engaged in the Testing and/or Inspection of Soil and Rock as Used in Engineering Design and Construction²
- D 4643 Test Method for Determination of Water (Moisture) Content of Soil by the Microwave Oven Method²
- D 4753 Specification for Evaluating Selecting, and Specifying Balances and Scales for Use in Soil, Rock, and Construction Materials Testing²
- D 4944 Test Method for Field Determination of Water (Moisture) Content of Soil by the Calcium Carbide Gas Pressure Tester Method³
- D 4959 Test Method for Determination of Water (Moisture) Content of Soil by Direct Heating Method²

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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² Annual Book of ASTM Standards, Vol 04.08.

³ Annual Book of ASTM Standards, Vol 04.09.

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

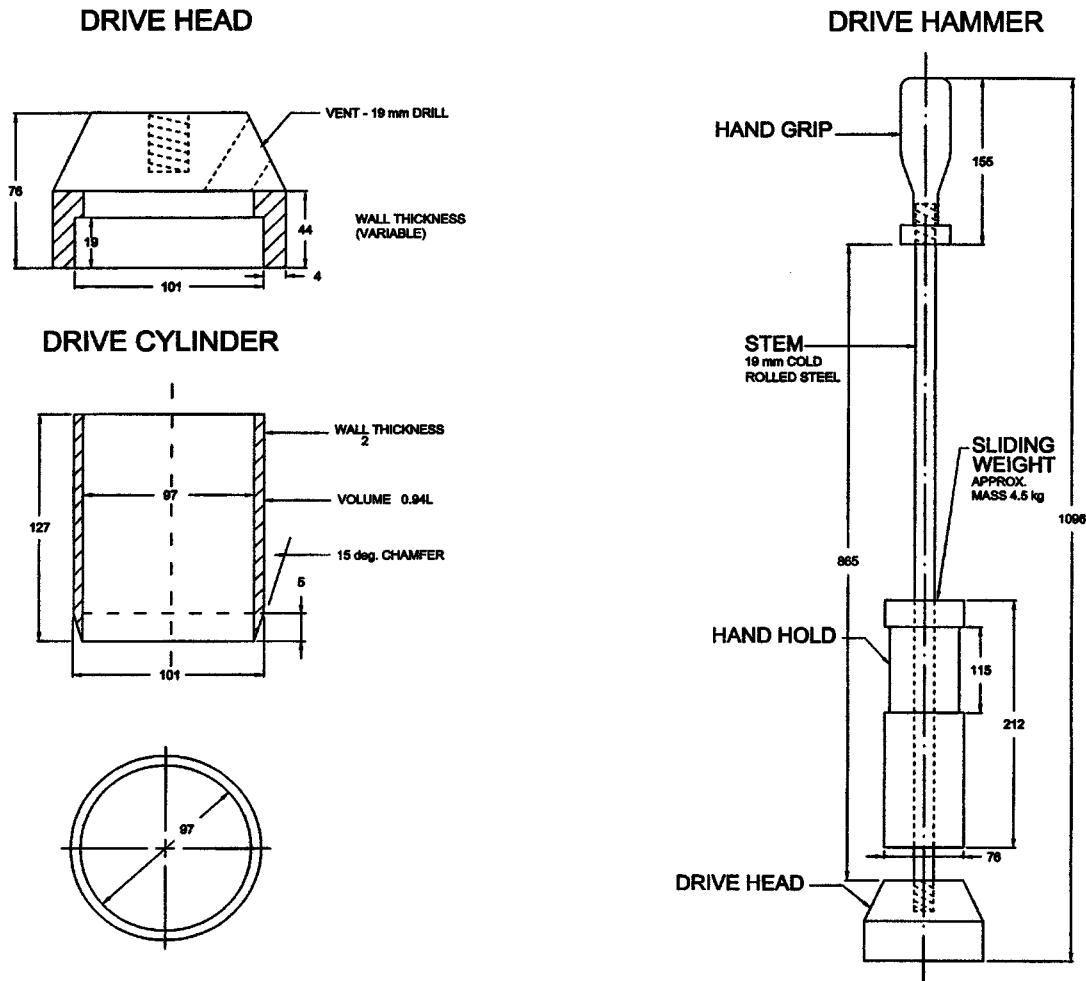


FIG. 1 Typical Design for a Surface Soil Sampler

TABLE 1 Dimensional Equivalent for Fig. 1

mm	in.	mm	in.
2	$\frac{5}{64}$	101.2	4
3.3	0.13	114.3	$4\frac{1}{2}$
4.8	$\frac{3}{16}$	127.0	5
19	$\frac{3}{4}$	152.4	6
44.4	$1\frac{3}{4}$	212.0	$8\frac{11}{32}$
76	3	863.6	34
97.2	$3\frac{13}{16}$	1117.6	44

3. Terminology

3.1 *Definitions*—All definitions are in accordance with Terminology D 653.

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 ($\frac{3}{16}$ 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 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 ($\frac{3}{16}$ in.) may result in damage to the drive cylinder equipment. Soils containing particles coarser than 4.75 mm ($\frac{3}{16}$ 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 ($\frac{3}{16}$ 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 D 3740 are generally considered capable of competent and objective testing. Users of this method are cautioned that compliance with Practice D 3740 does not in itself assure reliable testing. Reliable testing depends on many factors; Practice D 3740 provides a means of evaluating some of those factors.

5. Apparatus

5.1 *Drive Cylinders*, of approximately 102 to 152 mm (4 to 6 in.) diameter or larger. Typical details of drive cylinders with outside diameters of 102 mm (4.0 in.) are shown in Fig. 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 942 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 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 Hvorslev⁴ for drive samplers, and should preferably not exceed 10 to 15 %, as defined by the following:

$$A_r = [(D_e^2 - D_i^2)/D_i^2] \times 100 \quad (1)$$

where:

A_r = area ratio, %,

D_e = maximum external diameter of the drive sampler, and

D_i = minimum internal diameter of the drive sampler at the cutting edge.

5.1.4 Except for very short samplers with no clearance, the inside clearance ratio of the cylinders should be 1 % or greater, with increasing ratios with the increase in plasticity of the soil being sampled. Inside clearance ratio is defined by the following:

$$C_r = \frac{D_i - D_e}{D_e} \quad (2)$$

where:

C_r = inside clearance ratio, %

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

D_i = 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 3.18 mm (1/8 in.) by 38 mm (1 1/2 in.) by 305 mm (12 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 1 kg and meeting the requirements of Specification D 4753 for a balance of 1 g 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 %.

5.6 *Drying Equipment*—Equipment or ovens, or both, to determine water (moisture) content in compliance with Test Methods D 2216, D 4643, D 4944, or D 4959.

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 0.0025 mm (0.01 in.) for calibration, gloves, and safety glasses.

6. Sampling

6.1 Sampling at or Near the Surface:

6.1.1 Brush 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.

6.1.2 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. 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.

6.1.3 After 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

⁴ Hvorslev, M. J., "Surface Exploration and Sampling of Soils for Engineering Purposes," Engineering Foundation, 345 E. 47th St., New York, NY 10017.

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

7.1 Before 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).

7.1.1 Before 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 mm³ (0.01 in.³).

7.2 Permanently 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

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

8.2 Remove 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 D 2216, D 4643, D 4944, or D 4959.

9. Calculation

9.1 The 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 metre or pounds per cubic foot.

9.2 Calculate the dry mass of the drive-cylinder sample, M_3 , in grams, as follows:

$$M_3 = [(M_1 - M_2)/(100 + w)] \times 100 \quad (3)$$

where:

M_1 = mass of the cylinder and wet soil sample, g,

M_2 = mass of the cylinder, g, and

w = water content, %, dry mass basis.

9.3 Calculate the dry density, ρ_d , of the drive-cylinder sample in g/cm³ as follows:

$$\rho_d = (M_3/V) \quad (4)$$

where:

V = volume of the drive cylinder, cm³ (to the nearest 0.01 cm³)

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 Method D 698. This relation can be determined by dividing the in-place density by the maximum density and multiplying by 100.

10. Report

10.1 Report the following information:

10.1.1 Location,

10.1.2 Depth below ground surface or elevation of surface, or both,

10.1.3 Dry density,

10.1.4 Water content and the test method used,

10.1.5 Dimensions and volume of the sampler,

10.1.6 Visual description of the soil sample, and

10.1.7 Comments on soil sample disturbance.

10.2 If 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:

10.2.1 Volume of the drive cylinder used,

10.2.2 The comparative dry density or unit weight value and water content used,

10.2.3 The method used to determine the comparative values,

10.2.4 The comparative percentage of the in-place material to the comparison value, and

10.2.5 The acceptance criteria applicable to the test.

11. Precision and Bias

11.1 The precision of this test method is operator dependent and a function of the care exercised in performing the steps of the procedure, giving particular attention to careful control and systematic repetition of the procedure used. While no standard soils exist, limited studies running repetitive adjacent tests on the same soil using 7.3 cm (2 $\frac{7}{8}$ in.) inside diameter cylinders, have indicated standard deviations of 32 kg/m³ (2.00 lb/ft³) to 46.4 kg/m³ (2.90 lb/ft³) for soils with a compacted wet density ranging from 2022 kg/m³ (126.2 lb/ft³) to 2154 kg/m³ (134.5 lb/ft³).⁵

In another study, running repetitive adjacent tests on the same soil using a 13.0 cm (5 $\frac{1}{8}$ in.) inside diameter cylinder, a standard deviation of 31 kg/m³ (1.93 lb/ft³) was obtained for soil with a compacted wet density of about 2000 kg/m³ (125 lb/ft³).⁶ In general, a lower standard deviation should be expected with a larger diameter drive cylinder.

11.2 There are no absolute values of in-place density for soils against which this test method can be compared. Therefore this test method has no determinable bias since the values obtained can only be defined in terms of the test method.

11.3 Subcommittee D18.08 is seeking pertinent data from users of this test method on precision.

12. Keywords

12.1 compaction control; density testing; drive cylinder;

⁵ Noorany, I., Gardener, W.S., Corley, D.J., and Brown, J.L., "Variability in Field Density Tests," *Constructing and Controlling Compaction of Earth Fills*, ASTM STP 1384, March 2000.

⁶ McCook, D. K., and Shanklin, D., "Nuclear Density Testing and Comparisons with Sand Cone and Calibrated Cylinder Methods," *Constructing and Controlling Compaction of Earth Fills*, ASTM STP 1384, March 2000.

drive cylinder test; field density; in-place density; plug sampler; quality control; subsurface sampler; surface sampler; unit weight

SUMMARY OF CHANGES

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|---|--|
| (1) SI units were made standard. | numbering and placement. |
| (2) Added Section 1.5 and renumbered. | (8) Renumbered formulae 2 & 3 to correct for error in numbering. |
| (3) Added D 2488 to Referenced Section. | (9) Updated Section 11.1. |
| (4) Added footnote 3 and renumbered. | (10) Updated footnotes 5 & 6. |
| (5) Added Section 3 Terminology and renumbered Sections. | (11) Added Summary of Changes. |
| (6) Replaced Fig. 1. | |
| (7) Renumbered footnotes 4, 5, & 6 to correct for errors in | |

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