Designation: F3013 – 13

Standard Test Method for Density of Topsoil and Blended Soils In-place by the Core Displacement Method[1]

This standard is issued under the fixed designation F3013; 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 may be used to determine the undisturbed (in-situ) in-place bulk-density, moisture content and unit weight of topsoil and blended soil growing mediums using the Core Displacement Method.

1.2 This test method is applicable for soils without appreciable amounts of rock or coarse material exceeding 1 inch in size. Further it is only suitable for soils in-which the natural void or pore openings in the soil are small enough to prevent the sand used in the test from entering the voids and impacting the test results. Unlike Test Method D1556, this test method is suitable for organic and plastic soils due to the use of a core apparatus, and not hand excavation methods. The material shall have adequate cohesive material or particle attraction to provide a stable core (core hole) for the duration of the test without deforming or sloughing. Therefore this method is not suitable for unbound granular soils that cannot maintain stable sides. This test method is applicable for assessing compaction of surface layers of topsoil (or blended soils) using a soil small core unlike Test Methods D4914, which uses a large volume soil pit excavation.

1.3 This test method is intended for soil typical of growing mediums suitable for sports fields, golf courses and lawn areas that may include organic material, silts, clays and sand.

1.4 This test method is not applicable for soil conditions in-which the root mass is excessive or in-which the root mass includes woody roots.

1.5 *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 F08 on Sports Equipment, Playing Surfaces, and Facilities and is the direct responsibility of Subcommittee F08.64 on Natural Playing Surfaces.

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2. Referenced Documents

2.1 *ASTM Standards:*[2]

D1556 Test Method for Density and Unit Weight of Soil in Place by Sand-Cone Method

D4914 Test Methods for Density and Unit Weight of Soil and Rock in Place by the Sand Replacement Method in a Test Pit

F1815 Test Methods for Saturated Hydraulic Conductivity, Water Retention, Porosity, and Bulk Density of Athletic Field Rootzones

3. Terminology

3.1 *Definitions:*

3.1.1 *bulk density of soil, D_b*—mass of dry soil per unit bulk volume, (Mg m^{-3}).

3.1.2 *density, D*—mass per unit volume, (Mg m^{-3}).

3.1.3 *density of water, D_w*—mass per volume of water, (Mg m^{-3}).

3.1.4 *particle density of soil, D_p*—density of the soil particles, the dry mass of the particles being divided by the solid (not bulk) volume of the particles, in contrast with bulk density, (Mg m^{-3}).

4. Summary of Test Method

4.1 A test hole is cored using a hole-cutter into the soil to be tested and the hole-cutter is retracted to remove all soil and saved in a container. The depth of the hole is measured at four points around the diameter of the core. Points shall be at approximately 90° apart. The hole is then filled with a free flowing sand of know volume to determine the volume of the soil removed. The volume of the soil removed is adjusted to account for the volume of the hole-cutter. The removed soil is weight in the laboratory and the in-place wet density of the sample is calculated by dividing the initial moist sample mass

[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.

divided by the volume of hole (adjusted for the volume of the coring apparatus) from which the sample is removed as determined by the volume of free flowing sand. The sample is then dried and weight to determine the in-place dry bulk-density of the soil.

5. Significance and Use

5.1 This test method can be used to determine in-place density of topsoil and blended soils prior to planting or in the development of a maintenance programs for natural turf sports fields, planting areas, lawns and golf courses.

5.2 This test method can provide builders and maintenance staff with a quick assessment of the turf growing medium density without the delays associated with formal lab testing programs. During construction and prior to seeding or sodding having a method to quantify in-place soil density will assist the builder in providing an appropriate soil density at the time of planting thus improving overall turf establishment.

5.3 The use of this test method is generally limited to soil in an unsaturated condition. This test method is not recommended for soils that are soft or friable (crumble easily) or in a moisture condition such that water seeps into the hand excavated hole. The accuracy of this test can be affected by stones or other material that can create grooves or loose material along the side walls or bottom of the test core. Test core locations within areas subject to vehicle travel may result in higher densities and such locations should be noted in the report.

6. Apparatus

6.1 The testing apparatus consists of a coring device (Hole Corer or Hole cutter), a uniform (free flowing) testing sand, graduated cylinder, and a rule. A drying oven capable of maintaining a temperature of 100°C (212°F) 12 h for preparation of an oven-dried sample.

6.1.1 *Hole-Cutter*—A 10.8 cm diameter (4-¼ in.) hot-rolled steel tubing with steel shaft and sturdy handle. Tubing shall consist of a non-scalloped shell sharpened outsides to allow clean uniform coring into soil. Tubing shall be capable of coring to depths of approximately 20 cm (8 in.). Hole-cutter shall be equipped with a core removal plate that will allow clean uniform removal of core sample.

6.1.1.1 A steel sharpened core cutting device with an outside diameter of 10.8 cm (4.25 in.) and an inside diameter, d_i, of 10.16 cm (4.00 in.).

6.1.1.2 A handle positioned at approximately waist level suitable for twisting the core into the soil while maintaining vertical alignment.

6.1.1.3 A core with a depth, h_c, of at least 10.16 cm (4 in.) and not more than 20.32 cm (8 in.). The core shall be marked on the outside to indicate a 10 cm depth.

6.1.1.4 A soil removal piston or other device that allows complete removal of the cored sample.

6.1.1.5 Details of the apparatus are shown in Fig. 1.

6.1.2 *Free Flowing Sand*—Clean, dry sand, uniform in density and grading, uncemented, durable, and free-flowing. Any gradation may be used that has a uniformity coefficient (Cu 5 D60/D10) less than 2.0, a maximum particle size smaller than 2.0 mm (No. 10 sieve), and less than 3 % by weight passing 250 µm (No. 60 sieve).). Sand shall be uniformly graded to prevent segregation during handling, storage and use. Sand must be free flowing and therefore non-compacting.

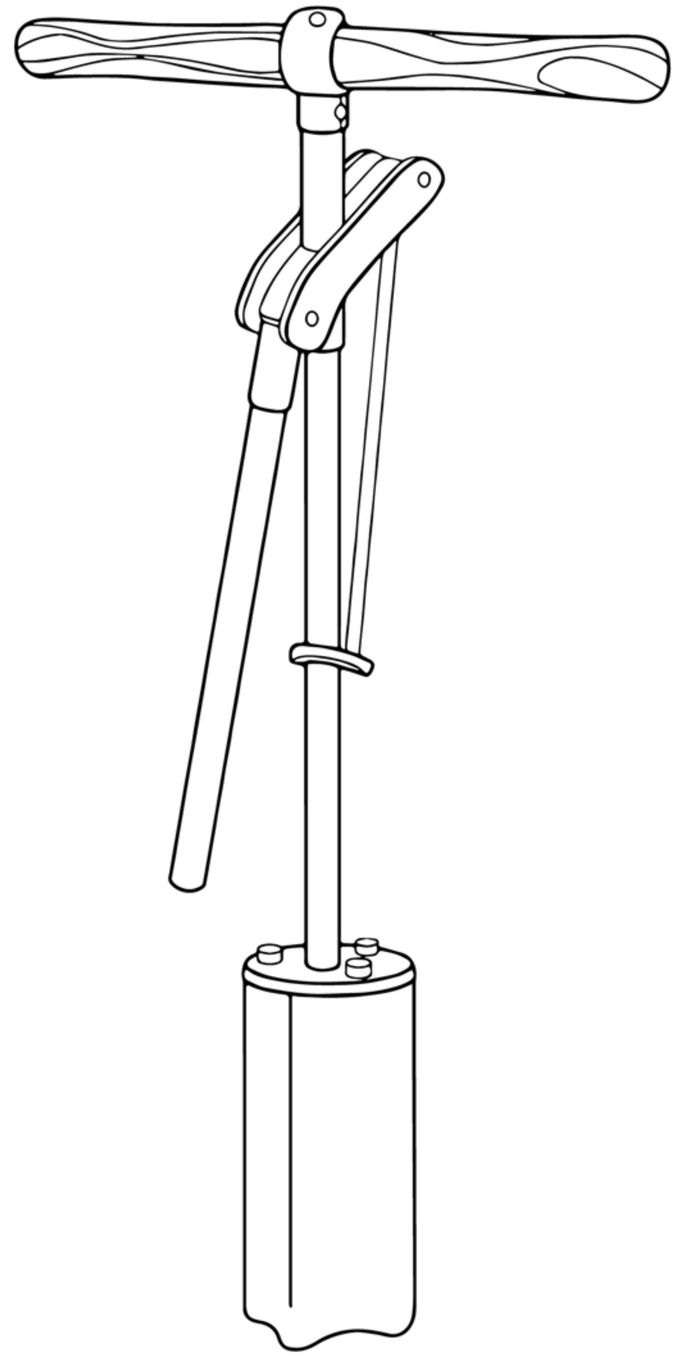

FIG. 1 Hole Cutter

NOTE 1—Uniformly graded sand is needed to prevent segregation during handling, storage, and use. Sand free of fines (and fine sand particles) is required to avoid significant bulk-density changes which can occur due to normal daily changes in atmospheric humidity. Sand comprised of durable, natural sub-angular, sub-rounded, or rounded particles is desirable. Crushed sand or sand having angular particles may not be free-flowing, a condition that can cause bridging resulting in inaccurate density determinations. Likewise, sands containing significant amounts of micaceous grains (which tend to be plate-shaped) should be avoided. In selecting sand from a potential source, bulk-density variation between any one determination shall not be greater than 1 % of the average.

6.1.3 *Graduated Cylinder,* meeting the following parameters:

6.1.3.1 Minimum volume of 1000 mL. Where test cores are to exceed 10 cm (4 in.) in depth 2000 mL volume is recommended.

6.1.3.2 Measurement increments allowing reading to 10 mL.

6.1.3.3 Accurate to ±3 mL.

6.1.4 *Standard Rule,* meeting the following parameters:

6.1.4.1 A rule of 30 cm (12 in.) length with increments of measure in centimetres (cm) marked with scale divisions of 1 mm per division.

6.1.4.2 Alternatively, a 30 cm Vernier caliper can be utilized, using the depth probe, which is capable of measurements in increments of 1 mm or finer. The Vernier caliper is also ideally used to measure the coring tube for wall thickness, inside diameter, and outside diameter.

7. Procedure

7.1 Select a location/elevation that is representative of the area to be tested, and determine the density of the soil in-place as follows:

7.1.1 Inspect the core apparatus for damage, free movement of the core removal piston. Verify dimensions of core tubing using a Vernier caliper.

7.1.2 Fill the graduated cylinder with 1000 mL of free flowing sand. This volume is suitable for a core depth not to exceed 10 cm (4 in.) in depth.

7.1.3 Prepare the surface of the location to be tested so that it is a level plain. This must be accomplished without deformation of the soil to be tested. In creating a level plain at the top consideration should be given to removal the thatch layer. A shovel with a clean straight flat cutting edge shall be used to level the surface. In the case where the tested strata is below the surface of the soil a hole shall be hand excavated adjacent to the test location and a shelf shall be cut using a shovel with a clean straight flat cutting edge. The shelf shall be of adequate surface area to prevent deformation of side wall of the excavation and also of adequate surface area extract the core, make the necessary sidewall depth measurements, and to accurately fill the void with a level volume of free flowing sand flush with the top of the test core void. If stones are encountered during the preparation of the sample location or during the sidewalls of the actual coring, a new test site should be selected.

7.1.4 The hole-cutter shall be placed in the general center of the prepared area with the shaft upright and vertical. Uniform pressure shall be applied to the handle and the cutter shall be twisted into the soil to a depth between 7.5 and 10.0 cm (3 and 4 in.). The 10 cm (4 in.) depth mark shall be used as the maximum depth of penetration for the test core. During coring the shaft shall be kept as close to vertical as possible. Once the test depth is reached, the core shall be twisted one quarter turn in the direction of the coring and then one quarter turn again in the opposite direction to shear the sample from the surrounding soil. During this procedure the apparatus shall be kept vertical to prevent deformation of the sidewalls of the core.

7.1.5 The core sample shall be extracted from the test location using a smooth uniform motion. Slight twisting back and forth may be required. The sample shall be extracted from the apparatus into a sample bag. The bag shall be labeled with the date, site location and a suitable reference numbering or labeling system to identify the sample. Any loose soil in the bottom of the sample void should be removed and added to the sample bag.

7.1.6 The depth of the void shall be measured at four locations spaced approximately 90° apart. Each depth shall be recorded,(h_s1, h_s2, h_s3, h_s4) , and the depths shall be averaged (ha) and used as a check to assure the volume of the void is consistent with the fill volume of free flowing sand. The average depth shall be used to calculate the volume of the core (V_o) contained within the cutting wall of the test apparatus. This volume shall be calculated using the following equation and recorded:

$$V_o = h_a \times ((r_o)^2 \times \pi) \tag{1}$$

where:

r_o = the outside radius of the core apparatus.

7.1.6.1 Calculating the volume of a particular sample (V_s) necessitates obtaining the volume using the inside diameter of the coring tube by the equation:

$$V_i = h_a \times ((r_i)^2 \times \pi) \tag{2}$$

where:

r_i = the inside radius of the core apparatus.

7.1.6.2 The outside volume of the core (V_o) shall be used as an approximate volume check compared to the sand volume (V_h) used to fill the cored hole.

7.1.6.3 The volume of the sample, V_s, is calculated by determining the volume difference when accounting for the wall thickness of the coring tube. This can be calculated by the following formula:

$$V_s = V_h - (V_o - V_i) \tag{3}$$

7.1.7 The free flowing sand in the graduated cylinder shall be leveled by lightly tapping the cylinder on a firm, uniform surface for an accurate reading of the initial volume of sand, V_i. The volume of sand in the graduated cylinder shall be read and recorded. Sand shall be poured from the graduated cylinder into the void left by the apparatus. Care must be taken to avoid over filling the void. Sand in the void shall be carefully spread to create a uniform level surface to the bottom of the thatch layer. Additional sand shall be added until the void is full and level with the top edge of the test void. Care shall be taken not to compact the sand into the void. The free flowing sand in the graduated cylinder shall again be lighting tapped on a firm, uniform suface for an accurate reading of the remaining (final) sand volume, V_f. The final volume of sand in the graduated cylinder shall be read and recorded. The difference between the initial graduated cylinder volume reading and the volume after the sand is added to the void shall be calculated and recorded. This calculated volume shall represent the volume of the test hole, V_h:

$$V_h = V_i - V_f \quad (4)$$

7.1.8 The core sample extracted from the test location shall be weighed and the mass recorded to the nearest 0.001 g. This shall represent the in place moist sample weight, m_{wet}.

7.1.9 The core sample extracted from the test location shall then be oven-dried, weighed to the nearest 0.001 g and the mass recorded. This shall represent the in place dry sample weight, m_{dry}.

8. Calculation or Interpretation of Results

8.1 The volume of the test hole (soil volume), V_h shall be compared to the volume of the cutting tube, V_{tube}.

8.2 Using the in-place sample weight (m_{wet}) as determined from 7.1.8 and the dry sample weight from 7.1.9 (m_{dry}), determine a gravimetric (mass) soil water content, θ_m, by the formula:

$$\theta_m = (m_{wet} - m_{dry})/m_{dry} \quad (5)$$

8.3 Calculation of volumetric soil moisture content, θ_v, shall be calculated by multiplying the in-place mass soil water content by the soil bulk density according to the formula:

$$\theta_v = \theta_m \times (D_b / D_w) \quad (6)$$

NOTE 2—For the purpose of this standard, the density of water can be assumed to be 1.0 Mg m^{-3} such that Eq 6 can be rewritten as:

$$\theta_v = \theta_m \times D_b \quad (7)$$

8.4 Calculation of the soil bulk density, D_b, shall be calculated by dividing the in place oven-dry sample weight by the soil volume:

$$D_b = m_{dry}/V_h \quad (8)$$

NOTE 3—Using bulk density, the total porosity may be calculated if a particle density is known (as per Test Methods F1815). Or, if the soil is relatively low in organic matter content and primarily composed or quartz, the total porosity can be estimated by assuming a particle density (D_p) value of 2.65 Mg m^{-3}. The formula for determining the percent total porosity (TP):

$$TP = 1 - (D_b / D_p) \times 100 \quad (9)$$

9. Report

9.1 Record the following information on the field report:

9.1.1 For the overall project site:

9.1.1.1 Project name.

9.1.1.2 Project location and address.

9.1.1.3 Weather and air temperature.

9.1.1.4 An overall site sketch map.

9.1.2 For each test location:

9.1.2.1 Mark on the Sketch Map depicting location within site.

9.1.2.2 Surface Condition: Soil, Turf, Other ____________________

9.1.2.3 General Soil Condition: Wet, Moist, Dry

9.1.2.4 Height of core sidewall (four locations), h_s, 1) ______, 2) ______,3) ______,4) ______.

9.1.2.5 Average height of core, h_a, ($h_a = (\Sigma h_s)/4$) = _____________.

9.1.2.6 Initial volume of sand in graduated cylinder (Vi) = ______________.

9.1.2.7 Volume of sand remaining in cylinder after filling hole (V_f) = _____________.

9.2 Record the following information after laboratory determinations/calculations:

9.2.1 Sample weight wet, m_{wet} = ______________.

9.2.2 Sample weight dry, m_{dry} = ______________.

9.2.3 Gravimetric soil moisture content using Eq 5 is ________________.

9.2.4 Outside volume of Core (V_o) using Eq 1 is __________________.

9.2.5 Inside volume of Core (V_i) using Eq 2 is ___________________.

9.2.6 Volume of test sample (V_s) using Eq 3 is __________________.

9.2.7 Volume Comparison: ($V_h/V_o \times 100$) = ______________ (if value is greater than 100 %, use formula $V_o/V_h \times 100$ = ____________.

9.2.8 Soil bulk density (D_b) using Eq 8 is _____________.

9.2.9 In-place (as sampled) volumetric soil moisture using Eq 7 is ____________.

9.2.10 Optional; estimated total porosity (TP) using Eq 9 is ______________.

10. Keywords

10.1 core; density; in-place; in-situ; sand; soil