Designation: D7830/D7830M − 14 (Reapproved 2021)$^{\varepsilon 1}$

Standard Test Method for In-Place Density (Unit Weight) and Water Content of Soil Using an Electromagnetic Soil Density Gauge[1]

This standard is issued under the fixed designation D7830/D7830M; 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.

ε^1 NOTE—Referenced Documents section was updated editorially in July 2021.

1. Scope

1.1 This test method covers the procedures for determining in-place properties of non-frozen, unbound soil and soil aggregate mixtures such as total density, gravimetric water content and relative compaction by measuring the intrinsic impedance of the compacted soil.

1.1.1 The method and device described in this test method are intended for in-process quality control of earthwork projects. Site or material characterization is not an intended result.

1.2 *Units*—The values stated in either SI units or inch-pound units are to be regarded separately as standard. The values stated in each system may not be exact equivalents; therefore, each system shall be used independently of the other. Combining values from the two systems may result in nonconformance with the standard.

1.2.1 The gravitational system of inch-pound units is used when dealing with inch-pound units. In this system, the pound (lbf) represents a unit of force (weight) while the unit for mass is slugs. The rationalized slug unit is not given in this standard.

1.2.2 In the engineering profession, it is customary practice to use, interchangeably, units representing both mass and force, unless dynamic calculations are involved. This implicitly combines two separate systems of units, that is, the absolute system and the gravimetric system. It is undesirable to combine the use of two separate systems within a single standard. 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.

1.3 All observed and calculated values shall conform to the Guide for Significant Digits and Rounding established in Practice D6026.

1.3.1 The procedures used to specify how data is collected, recorded, and calculated in this standard are regarded as industry standard. In addition, they are representative of the significant digits that should generally 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 decrease the number of significant digits of reported data commensurate with these considerations. It is beyond the scope of this standard to consider significant digits used in the analysis methods for engineering design.

1.4 *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, health, and environmental practices and determine the applicability of regulatory limitations prior to use.*

NOTE 1—ASTM International takes no position respecting the validity of any patent rights asserted in connection with any item mentioned in this standard. Users of this standard are expressly advised that determination of the validity of any such patent rights, and the risk of infringement of such rights, are entirely their own responsibility.

1.5 *This international standard was developed in accordance with internationally recognized principles on standardization established in the Decision on Principles for the Development of International Standards, Guides and Recommendations issued by the World Trade Organization Technical Barriers to Trade (TBT) Committee.*

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/ft^3 (600 kN-m/m^3))

D1556/D1556M Test Method for Density and Unit Weight of Soil in Place by Sand-Cone Method

[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] 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.

D1557 Test Methods for Laboratory Compaction Characteristics of Soil Using Modified Effort (56,000 ft-lbf/ft^3 (2,700 kN-m/m^3))
D2167 Test Method for Density and Unit Weight of Soil in Place by the Rubber Balloon Method
D2216 Test Methods for Laboratory Determination of Water (Moisture) Content of Soil and Rock by Mass
D2937 Test Method for Density of Soil in Place by the Drive-Cylinder Method
D3740 Practice for Minimum Requirements for Agencies Engaged in Testing and/or Inspection of Soil and Rock as Used in Engineering Design and Construction
D4253 Test Methods for Maximum Index Density and Unit Weight of Soils Using a Vibratory Table
D4254 Test Methods for Minimum Index Density and Unit Weight of Soils and Calculation of Relative Density
D4318 Test Methods for Liquid Limit, Plastic Limit, and Plasticity Index of Soils
D4643 Test Method for Determination of Water Content of Soil and Rock by Microwave Oven Heating
D4718/D4718M Practice for Correction of Unit Weight and Water Content for Soils Containing Oversize Particles
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 Content of Soil By Direct Heating
D6026 Practice for Using Significant Digits and Data Records in Geotechnical Data
D6913/D6913M Test Methods for Particle-Size Distribution (Gradation) of Soils Using Sieve Analysis
D6938 Test Methods for In-Place Density and Water Content of Soil and Soil-Aggregate by Nuclear Methods (Shallow Depth)
D7382 Test Methods for Determination of Maximum Dry Unit Weight of Granular Soils Using a Vibrating Hammer
E691 Practice for Conducting an Interlaboratory Study to Determine the Precision of a Test Method

2.2 *Other Referenced Documents:*

"Development of a Non-Nuclear Soil Density Gauge to Eliminate the Need for Nuclear Density Gauges"[3]

3. Terminology

3.1 *Definitions:*

3.1.1 See Terminology D653 for general definitions.

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *impedance, n*—a measure of opposition to alternating current (AC).

3.2.2 *impedance spectroscopy, n*—a method that measures the electromagnetic properties of a medium as a function of frequency.

4. Summary of Test Method

4.1 The total or wet density and gravimetric water content of soil and soil-aggregate are correlated to empirical data using an electromagnetic impedance spectroscopy device. Electromagnetic properties of the soil are determined at specific frequencies by measuring the changes in the electromagnetic field. A function is generated that describes the relationship between electrical properties over a range of frequencies. That function is compared to an empirical model and other calibration checks to determine water content and density.

4.2 This method employs electromagnetic impedance spectroscopy to determine the volumetric water content and wet density. The measurement spectrum is made up of frequencies ranging from 30 kHz to 50 MHz.

4.3 Properties such as dry density, gravimetric water content and relative compaction are calculated from the total density and the volumetric water content.

5. Significance and Use

5.1 The method described determines wet density and gravimetric water content by correlating complex impedance measurement data to an empirically developed model. The empirical model is generated by comparing the electrical properties of typical soils encountered in civil construction projects to their wet densities and gravimetric water contents determined by other accepted methods.

5.2 The test method described is useful as a rapid, non-destructive technique for determining the in-place total density and gravimetric water content of soil and soil-aggregate mixtures and the determination of dry density.

5.3 This method may be used for quality control and acceptance of compacted soil and soil-aggregate mixtures as used in construction and also for research and development. The non-destructive nature allows for repetitive measurements at a single test location and statistical analysis of the results.

NOTE 2—The quality of the result produced by this standard test method is dependent on the competence of the personnel performing it, and the suitability of the equipment and facilities used. Agencies that meet the requirements of Practice D3740 are generally considered capable of competent and objective sampling/testing/inspection, and the like. Users of this standard are cautioned that compliance with Practice D3740 does not in itself assure reliable results. Reliable results depend on many factors; Practice D3740 provides a means of evaluation some of those factors.

6. Interferences

6.1 Anomalies in the test material with electrical impedance properties significantly different from construction soils and aggregate evaluated during soil model development, such as metal objects or organic material, may affect the accuracy of the test method.

6.2 Chemical and mineralogical composition may affect the results of a test. Examples of materials that may impact the results include but are not limited to, quarried materials containing higher concentrations of iron, volcanic rock, and materials that have significant fractions of cemented particles, organic soils, recycled materials or materials containing asphalt, portland cement, lime, fly ash, or other stabilizing modifiers. In most cases the effect may be satisfactorily addressed by following the Calibration Procedure in Section 7.

[3] Prepared for The Department of Homeland Security under contract No. HSHQDC-07-C-00080. Dated October 31, 2008. Available from the U.S. Department of Homeland Security, Washington, D.C. 20528, http://www.dhs.gov.

6.3 A significant increase in the conductivity of the pore water such as from ground water that may contain significant salt deposits or contaminants. In most cases the effect may be satisfactorily addressed by following the Calibration Procedure in Section 7.

6.4 This test method applies only to non-frozen soil. The electrical properties of soil change with temperature. Generally, testing should be limited to soil temperatures above 10°C [50°F] and below 40°C [104°F]. Effects of temperature on electrical properties of soils also depend on soil type. Clayey soils are more temperature sensitive than sandy soils. Accuracy of measurements improves when the temperature of soil is close to the temperature used in the model calibration. Calibration for temperature effects should be done when soil temperatures differ by more than 10°C [18°F] from model calibration temperatures. Calibration Procedures are given in Section 7.

6.5 The accuracy of the results obtained by this test method may be influenced by poor or incorrect placement of the device on the soil being tested. Non-homogeneous soils, non-uniform surface texture, large air voids that may be present may decrease the precision of the results. Correct placement of the soil gauge is important to the quality of the electrical measurements collected by the device.

6.6 Oversized particles in the measurement volume may cause an error in water content and/or density results. Where lack of uniformity in the soil is suspected due to layering, aggregates, or voids, the test site should be excavated and visually examined to determine if the material is representative of the in-situ material in general and if an oversize correction is required in accordance with Practice D4718/D4718M.

6.7 Variation from actual values may increase for soil material that is significantly drier or wetter than optimum water content as determined using Test Methods D698 or D1557. Variation from actual values may increase for soil material that is compacted to less than 80 % of the maximum dry density as determined using Test Methods D698 or D1557.

6.8 Attempts to measure unknown in-place soils with a soil model that was generated from a limited range of density or water content values, or both, may result in density and water content errors.

6.9 Strong electromagnetic fields such as those generated by high tension power lines may interfere with the device operation.

6.10 For a circular sensor 280 mm [11 in.] in diameter, the typical maximum measured volume is approximately 0.0034 m^3 [0.12 ft^3]. The actual measured volume is indeterminate and varies with the plate diameter, sensor configuration, and material being tested. Results are typically influenced more by the density and water content of the material near the surface.

7. Apparatus[4,5]

7.1 *Electromagnetic Soil Density Gauge*—A device capable of generating an electromagnetic field and measuring the differential voltage change between two electrodes. An example of the device is shown in Fig. 1 and a sensor schematic section and approximate electrical fields that sense the soil is shown in Fig. 2. While the exact details of construction of the apparatus may vary, the system shall consist of:

7.1.1 Electronic circuitry to provide power and signal conditioning to the sensor and to provide the data acquisition and display functions. The circuitry shall be designed to perform a calibration of the unit over a range of conditions and materials expected in the field.

7.1.2 Internal circuitry suitable for displaying individual measurements to allow operators to record the results.

[4] The sole source of supply of the TransTech Soil Density Gauge (SDG) apparatus known to the committee at this time is TransTech Systems, Inc. 1594 State Street, Schenectady, NY. If you are aware of alternative suppliers, please provide this information to ASTM International Headquarters. Your comments will receive careful consideration at a meeting of the responsible technical committee, which you may attend.

[5] The Electromagnetic Soil Density Gauge is covered by a patent (patent no.: US 7,219,024 B2). Interested parties are invited to submit information regarding the identification of an alternative(s) to this patented item to the ASTM International Headquarters. Your comments will receive careful consideration at a meeting of the responsible technical committee, which you may attend.

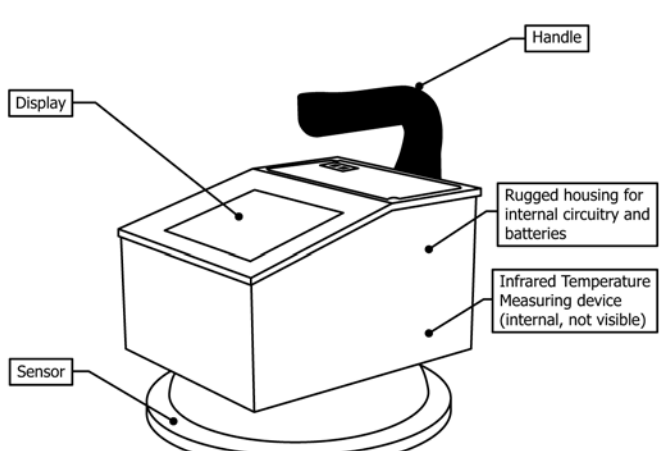

FIG. 1 Electromagnetic Soil Density Gauge

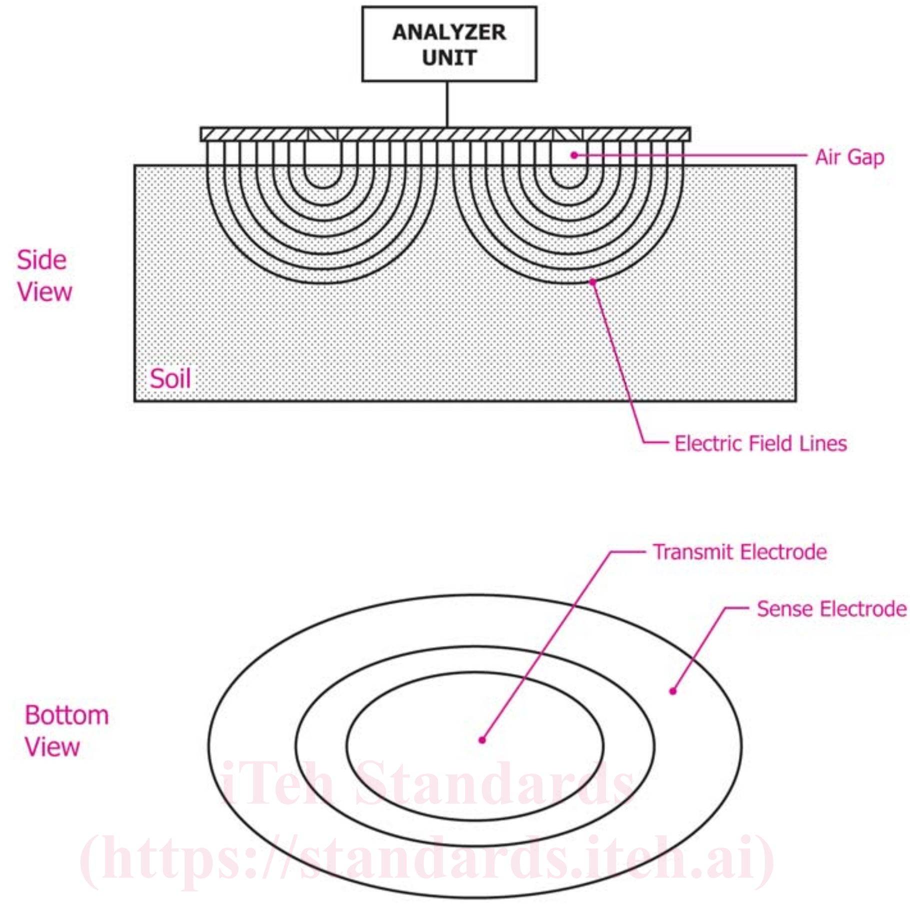

FIG. 2 Sensor Section and Schematic

7.1.3 A rugged housing designed for taking in-situ density and water content measurements of soil and soil-aggregate mixtures during routine earthwork operations.

7.1.4 *Infrared Temperature Measuring Device,* shall be capable of measuring the surface temperature of the material being tested to ± 0.5°C [± 1°F] throughout a range of 0° to 50°C [30° to 120°F].

7.2 *Soil Calibration Container*—Containers for calibration of the gauge as described in section 8.5.1, Container Calibration.

8. Calibration

8.1 For Factory Calibration information and requirements please refer to Annex A1.

8.2 The *soil density gauge* has been designed to determine the moisture and density in a compacted soil sample without the need for special field generated soil models. The ability to measure moisture and density is based on multiple soil models that were developed by studying various soil types. As the soil density gauge's measurement performance is based on these models, there will be occasions where the soil being measured is so different from one that has been studied previously that an adjustment may be required to enable the soil density gauge to produce acceptable results.[6]

8.3 Determine the test parameters that will be used to calibrate the device. For example, selection of a pre-existing soil model or manual entry of soil model parameters for calibration.

8.3.1 Obtain a representative sample of soil from the site where in-place testing is conducted or from the borrow source.

8.3.2 Determine the laboratory compaction characteristics of the material to be tested. Test Methods D698 or D1557 for fine grained soils and soil rock mixtures that exhibit a clear maximum dry density or Test Methods D4253 or Test Methods D7382 for predominately granular material.

8.3.3 Information required by the device to associate the soil to the correct predetermined soil model may include but not be limited to: maximum dry density; optimum water content as determined by Test Methods D698 or D1557; percent of sample larger than 75 mm [3 in.]; percentage of sample between 75 mm [3 in.] and 19 mm [0.75 in.]; percent gravel;

[6] A comparison to other accepted test methods is recommended on a regular frequency to verify the validity and appropriateness of the calibration.

percent sand; percent fines; coefficient of uniformity; and coefficient of curvature in accordance with Test Method D6913/D6913M, Plastic Limit, and Test Methods D4318, Liquid Limit.

8.4 Prior to using the gauge derived water content on any new material, the value for water content should be verified by comparison to another accepted test method such as Test Methods D2216, D4643, D4944, or D4959. Prior to using the gauge derived density on any new material, the value should be verified by comparison to another accepted test method such as Test Methods D1556/D1556M, D2167, D2937, or D6938. As part of a user developed procedure, occasional tests should be taken beneath the gauge and from samples taken beneath the gauge and comparison test be done to confirm the gauge derived water content values. Following the manufacturer procedures for correcting the gauge derived water content and density values.

8.5 The calibration should be checked prior to performing tests on materials that are distinctly different from material types previously used in obtaining or adjusting the calibration. If a field calibration is necessary follow the procedures below.

8.5.1 *Container Calibration*—Prepare containers of compacted material with a known water content as determined by Test Methods D2216, D4643, D4944, or D4959 and a wet density calculated by dividing the mass of the material by the inside volume of the container.

8.5.1.1 Containers used for preparing compacted samples shall have minimum dimensions of 0.66 m [2 ft] wide, 0.66 m [2 ft] long, and 0.33 m [1 ft] deep and be constructed of a non-conductive material capable of retaining its shape during the compaction process.

8.5.1.2 Material used for calibration shall be representative of the material to be tested and should be compacted at optimum moisture content ±2 % and should be compacted to 95 % ± 2 %.

8.5.1.3 Calibration shall be performed on soil at or near temperatures expected in the field during routine testing.

8.5.2 *Onsite Calibration*—Where prepared containers of compacted samples are not available, the gauge may be correlated by using a minimum of three sets of test results taken in an area of a compaction project where material has been placed at different water contents. The test sites shall represent the range of water contents and densities, over which the correlation is to be used. At least three gauge readings shall be made at each test site. The density at each site shall be verified by tests performed in accordance with Test Methods D1556/D1556M, D2167, D2937, or D6938. The water content at each site shall be determined in accordance with Test Methods D2216, D4643, D4944, or D4959. Use the mean value of the replicate readings as the correlation point value for each test site.

8.5.2.1 Calibration shall be performed on material that is at or near material temperatures expected during routine testing.

8.5.3 The mean value of the difference between the water content as determined in 8.5.2 and the values measured with the gauge shall be used as a correction to those measurements made in the field.

8.5.3.1 The water content correction can be applied manually, or can be entered into the device if the device is equipped with an offset or correction feature.

8.5.4 The mean value of the difference between the wet density as determined in 8.5.2 and the values measured with the gauge shall be used as a correction to those measurements made in the field.

8.5.4.1 The wet density correction can be applied manually, or can be entered into the device if the device is equipped with an offset or correction feature.

8.6 The method and test procedures used to obtain the electrical measurements must be the same as those used during routine testing.

9. Procedure

9.1 *Preparation of Test Site:*

9.1.1 Select a test location in accordance with the contract documents, located to be representative of the total material being placed and to minimize potential interferences.

9.1.2 Remove all loose and disturbed material, or overlying material, as necessary to expose the true surface of the material to be tested.

9.2 Place the device on the surface of the material to be tested.

9.3 Secure and record one or more density and water content measurements.

9.4 Measure the soil temperature to the nearest 1°C [0.5°F]. (The temperature of the material during testing should be representative of the material temperature during calibration.)

9.5 For proper use of the gauge and accurate values of both water content and density corrections to density (8.5.4), to water content (8.5.3) and for oversize particles (Practice D4718/D4718M) should be applied when applicable.

9.5.1 When there is any uncertainty as to the presence of oversize particles, it is advisable to sample the material beneath the gauge to verify the presence and relative proportion of the oversize particles. A rock correction can then be made for both the water content and the density by the method in Practice D4718/D4718M.

10. Calculation of Results

10.1 *Determine the Wet Density, ρ_t:*

10.1.1 Read the value directly in kg/m^3 [lbm/ft^3].

10.1.2 Record the density to the nearest 1 kg/m^3 [0.1 lbm/ft^3].

10.1.2.1 If desired, calculate the wet unit weight, γ_t, as follows:

$$\gamma_t = 9.8066 \times \rho_t, \text{ N/m}^3 \quad (1)$$

or

$$\gamma_t = 62.428 \times \rho_t, \text{ lbf/ft}^3 \quad (2)$$

10.2 *Determine the Water Content, w:*

10.2.1 Read the value directly in percent.

10.2.2 If the gauge determines water mass per unit volume, M_w in kg/m^3 [lbm /ft^3], calculate *w* using the equation:

$$w = \frac{M_w \times 100}{\rho_t - M_w} \quad (3)$$

or, if the gauge determines water weight per unit volume, W_w in N/m^3 [lbf /ft^3], calculate w using the formula:

$$w = \frac{W_w \times 100}{\gamma_t - W_w} \quad (4)$$

10.2.3 Record water content to the nearest 0.1 %.

10.3 *Determine the Dry Density by One of the Following Methods:*

10.3.1 If the water content is obtained by electromagnetic methods, use the gauge readings directly for dry density in kg/m^3 [lbm/ft^3]. The value can also be calculated from:

$$\rho_d = \rho_t - M_w = \text{dry density, kg/m}^3 \ [\text{lbm/ft}^3] \quad (5)$$

$$\gamma_d = \gamma_t - W_w = \text{dry unit weight, N/m}^3 \ [\text{lbf/ft}^3] \quad (6)$$

10.3.2 If the water content is to be determined manually from a sample of soil, follow the procedures and perform the calculations of the chosen test method (Test Methods D2216, D4643, D4944, or D4959).

10.3.3 With a water content value from 10.3.2 calculate the dry density from:

$$\rho_d = \frac{\rho_t}{1 + \frac{w}{100}} \quad (7)$$

10.3.4 Report the dry density to the nearest 1 kg/m^3 [0.1 lbm/ft^3].

10.3.4.1 If desired, calculate the dry unit weight, γ_d, as follows:

$$\gamma_d \ (\text{kN/m}^3) = 0.0098066 \times \rho_d \ (\text{kg/m}^3) \quad (8)$$

or

$$\gamma_d \ (\text{lbf/ft}^3) = 0.062428 \times \rho_d \ (\text{kg/m}^3) \quad (9)$$

10.4 *Determine the Percent Compaction:*

10.4.1 It may be desired to express the in-place dry density as a percentage of a laboratory density such as Test Methods D698, D1557, D4253, or D4254. This relationship can be calculated by dividing the *in-place dry density* by the *laboratory maximum dry density* and multiplying by 100. Procedures for calculating relative density are provided in Test Method D4254 which requires that Test Method D4253 also be performed. Corrections for oversize material, if required, shall be performed in accordance with Practice D4718/D4718M.

11. Report: Test Data Sheet(s)/Form(s)/Final Report(s)

11.1 *The Field Data Records Shall Include, as a Minimum, the Following:*

11.1.1 Test number or test identification.

11.1.2 Location of test (for example, station number or global positioning system (GPS) number or coordinates or other identifiable information).

11.1.3 Visual description of material tested.

11.1.4 Lift number or elevation or depth.

11.1.5 Name of the operator(s).

11.1.6 Make, model, and serial number of the test gauge.

11.1.7 Standardization and adjustment data for the date of the tests.

11.1.8 Any corrections made in the reported values and reasons for these corrections (that is, over-sized particles, water content).

11.1.9 Maximum laboratory density value in kg/m^3 [lbm/ft^3].

11.1.10 Dry density in kg/m^3 [lbm/ft^3].

11.1.11 Wet density in kg/m^3 [lbm/ft^3].

11.1.12 Gravimetric water content in percent.

11.1.13 Percent compaction.

11.1.14 Soil temperature.

11.1.15 Observation made during testing including but not limited to: site conditions, weather, material being tested, equipment used to achieve compaction.

11.2 *Final Report (Minimum Required Information):*

11.2.1 Test number.

11.2.2 Gauge serial number.

11.2.3 Location of test (for example, station number or GPS number or coordinates or other identifiable information).

11.2.4 Lift number or elevation or depth.

11.2.5 Water content as a percent.

11.2.6 Maximum laboratory density value in kg/m^3 [lbm/ft^3].

11.2.7 Dry density result in kg/m^3 [lbm/ft^3].

11.2.8 Percent compaction.

11.2.9 Name of operator(s).

12. Precision and Bias

12.1 *Precision*—Complete test data on precision in accordance with Practice E691 is not presented due to the nature of this test method. It is either not feasible or too costly at this time to have ten or more agencies participate in an in-situ testing program at a given site. The Subcommittee (D18.08) is seeking any data from the users of this test method that might be used to make a limited statement on precision. Task group D18.08.03 is looking into an ASTM sponsored interlaboratory study (ILS) to generate data on a variety of soils for a precision statement.

12.1.1 In lieu of a Practice E691 precision study, the following information from "Development of a Non-Nuclear Soil Density Gauge to Eliminate the Need for Nuclear Density Gauges" is provided in Tables 1 and 2. A description of the materials tested is given in Table 3.

12.2 *Density Bias*—Due to the variability in materials and construction practices, there is no consensus as to the most accurate test method for measurement of density against which this test can be compared. Accordingly, a statement of method bias cannot be made.

12.3 *Water Content Bias*—There is no accepted reference value for this test method; therefore, bias cannot be determined. Deviations from Test Method D2216 can be determined from comparison results.

13. Keywords

13.1 acceptance testing; compaction test; construction control; dry density; electromagnetic density gauge; field density;

TABLE 1 Single Operator Precision

NOTE 1—One instrument with one operator, each at one location.

USCS	SP	GP-GM	CL	GP-GM	GW-GM	CL-ML
Wet Density kg/m^3 [lbm/ft^3]	2077 ± 0.9 [129.7 ± 1.9]	2228 ± 17 139.1 ± 1.1]	2040 ± 4.6 [127.4 ± 0.3]	2246 ± 12 [140.2 ± 0.8]	1868 ± 21.2 [116.6 ± 1.3]	1920 ± 15.8 [119.8 ± 1.0]
Vol Water kg/m^3 [lbm/ft^3]	133 ± 8.0 [8.3 ± 0.5]	167 ± 3.2 [10.4 ± 0.2]	373 ± 1.6 [23.3 ± 0.1]	151 ± 4.8 [9.4 ± 0.3]	86 ± 4.8 [5.4 ± 0.3]	181 ± 3.2 [11.3 ± 0.2]
Dry Density kg/m^3 [lbm/ft^3]	1945 ± 23.2 [121.4 ± 1.4]	2061 ± 13.6 [128.7 ± 0.8]	1667 ± 3.3 [104.1 ± 0.2]	2096 ± 6.9 [130.8 ± 0.4]	1781 ± 16.4 [111.2 ± 1.0]	1723 ± 12.3 [107.6 ± 0.8]
Water (%)	6.8 ± 0.3	8.0 ± 0.1	22.4 ± 0.03	7.2 ± 0.2	4.9 ± 0.2	11.4 ± 0.1

TABLE 2 Multi-Operator Precision

NOTE 1—Four instruments with four operators at six locations.

USCS	SP	GP-GM	CL	GP-GM	GW-GM	CL-ML
Wet Density kg/m^3 [lbm/ft^3]	2052 ± 84.9 [128.1 ± 5.3]	2185 ± 104.1 [136.4 ± 6.5]	2041 ± 9.6 [127.4 ± 0.6]	2235 ± 14.4 [139.5 ± 0.9]	1863 ± 30.4 [116.3 ± 1.9]	1869 ± 64.1 [116.7 ± 4.0]
Vol. Water kg/m^3 [lbm/ft^3]	127 ± 22.4 [7.9 ± 1.4]	159 ± 24 [9.9 ± 1.5]	373 ± 3.2 [23.3 ± 0.2]	146 ± 8 [9.1 ± 0.5]	86 ± 6.4 [5.4 ± 0.4]	184 ± 16 [11.5 ± 1.0]
Dry Density kg/m^3 [lbm/ft^3]	1925 ± 62.5 [120.2 ± 3.9]	2026 ± 80.1 [126.5 ± 5.0]	1669 ± 6.4 [104.2 ± 0.4]	2089 ± 8.0 [130.4 ± 0.5]	1776 ± 24.0 [110.9 ± 1.5]	1685 ± 48.1 [105.2 ± 3.0]
Water (%)	6.6 ± 1.0	7.8 ± 0.9	22.4 ± 0.1	7.0 ± 0.3	4.8 ± 0.3	10.9 ± 0.7

TABLE 3 Description of Materials Tested

	USCS	Common Name
1	*SP* (Poorly graded sand with gravel)	100 mm [4 in.] Gravel Borrow
2	*GP-GM* (Poorly graded gravel with silt and sand)	31.5 mm [1¼ in.] Crushed Base Course
3	*CL* (Lean clay)	Red Silty Clay
4	*GP-GM* (Poorly graded gravel with silt and sand)	Graded Aggregate Base
5	*GW-GM* (Well graded gravel with silt and sand)	Red Sand with Rock
6	*CL-ML* (Silty clay)	Red Sandy Clay

impedance spectroscopy; in-place density; nondestructive testing; non-nuclear test method; quality control; soil density; wet density

ANNEXES

(Mandatory Information)

A1. FACTORY CALIBRATION

A1.1 *Calibration*—Gauges shall be calibrated initially, after any repairs and at intervals not exceeding 12 months.

A1.1.1 Gauge calibration response shall be within ±16 kg/m^3 [±1.0 lbm/ft^3] on blocks on which the gauge was calibrated. This calibration shall be performed by the manufacturer, or a manufacturer certified repair and calibration facility. Impedance is influenced by chemical and mineralogical composition of measured materials. This response must be considered when establishing the calibration block density. The materials used for calibration shall represent densities and water contents common in earthwork projects. The density of the blocks shall be determined in such a manner that the estimated standard deviation of the blocks shall not exceed 1.0 % of the measured block density.

A1.1.2 Re-establish or verify the density of the block(s) used to calibrate or verify calibrations at a period not to exceed five years.

A1.1.3 Sufficient data shall be taken on each calibration block to ensure a gauge precision of at least one-half the gauge precision required for field use. The data may be presented in the form of a graph, table, equation or coefficients or stored in the gauge to allow for corrected measurements.