Designation: D8153 – 22

Standard Test Method for Determination of Soil Water Contents Using a Dielectric Permittivity Probe[1]

This standard is issued under the fixed designation D8153; 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 describes the procedures for measuring the water mass per unit volume of soil and soil-aggregate by use of an in situ permittivity probe. Measurements are taken at a depth beneath the surface of the soil determined by the design of the probe.

1.1.1 For limitations see Section 6 on Interferences.

1.2 The permittivity probe is inserted into a hole drilled or punched into the soil being measured. As its name indicates, the probe measures the dielectric permittivity of the soil into which it is placed. Two electrodes, connected to an oscillating circuit, are mounted a predetermined distance apart. These electrodes act as the plates of a capacitor, with the soil between the plates forming the capacitor dielectric.

1.2.1 The probe circuit creates an oscillating electric field in the soil. Changes in the dielectric permittivity of the soil are indicated by changes in the circuit's operating frequency. Since water has a much higher dielectric constant (80) than the surrounding soil (typically around 4), the water content can be related by a mathematical function to the change in dielectric permittivity, and, consequently, the changes in the circuit's operating frequency.

1.2.2 The construction, deployment, and operating principle of the device described in this test method differ from other methods that measure the dielectric constant, bulk electrical conductivity, complex impedance, or electromagnetic impedance (see Test Methods D6780/D6780M, D7698, and D7830/D7830M) of the soil and relate the results to water mass per unit volume and/or water content.

1.2.3 The water content of the soil measured by the permittivity probe is the volumetric water content, expressed as the ratio of the volume of water to the total volume occupied by the soil. This quantity is often converted, and displayed, by the probe in units of mass of water per volume of soil, or water mass per unit volume. This conversion is performed by multiplying the water content (in volume of water per volume of soil) by the density of water.

1.3 Water content most prevalent in engineering and construction activities is known as the gravimetric water content, ω, and is the ratio of the mass of the water in pore spaces to the total mass of solids, expressed as a percentage. To determine this quantity, the bulk density of the soil under measurement must also be determined.

1.4 *Units*—The values stated in SI units are to be regarded as the standard. Reporting the test results in units other than SI shall not be regarded as nonconformance with this standard.

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

1.5.1 For purposes of comparing, a measured or calculated value(s) with specified limits, the measured or calculated value(s) shall be rounded to the nearest decimal or significant digits in the specified limits.

1.5.2 The procedures used to specify how data are collected/recorded and calculated in this standard are regarded as the 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 reduce significant digits of reported data to 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, health, and environmental practices and determine the applicability of regulatory limitations prior to use.*

1.7 *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.*

[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. Referenced Documents

2.1 *ASTM Standards:*[2]

C231/C231M Test Method for Air Content of Freshly Mixed Concrete by the Pressure Method

D653 Terminology Relating to Soil, Rock, and Contained Fluids

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

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

D2487 Practice for Classification of Soils for Engineering Purposes (Unified Soil Classification System)

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

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

D4718/D4718M Practice for Correction of Unit Weight and Water Content for Soils Containing Oversize Particles

D6026 Practice for Using Significant Digits and Data Records in Geotechnical Data

D6780/D6780M Test Methods for Water Content and Density of Soil In situ by Time Domain Reflectometry (TDR)

D6938 Test Methods for In-Place Density and Water Content of Soil and Soil-Aggregate by Nuclear Methods (Shallow Depth)

D7698 Test Method for In-Place Estimation of Density and Water Content of Soil and Aggregate by Correlation with Complex Impedance Method

D7830/D7830M Test Method for In-Place Density (Unit Weight) and Water Content of Soil Using an Electromagnetic Soil Density Gauge

D8167/D8167M Test Method for In-Place Bulk Density of Soil and Soil-Aggregate by a Low-Activity Nuclear Method (Shallow Depth)

E177 Practice for Use of the Terms Precision and Bias in ASTM Test Methods

E691 Practice for Conducting an Interlaboratory Study to Determine the Precision of a Test Method

3. Terminology

3.1 *Definitions:*

3.1.1 For definitions of common technical terms used in this standard, refer to Terminology D653.

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *permittivity probe, n*—an in situ electronic probe that utilizes the measurement of the dielectric permittivity of the surrounding soil to determine the water mass per unit volume of the soil.

3.2.2 *capacitance standard, n*—a reference material or object prepared of soil, soil and rock, or engineered materials that has a stated dielectric permittivity value and an associated measurement uncertainty.

NOTE 1—The term "bulk density" is used throughout this standard. This term has different definitions in ASTM D653, depending on the context of its use. For this standard, however, "bulk density" refers to, as defined in ASTM D653, "the total mass of partially saturated or saturated soil or rock per unit total volume."

4. Summary of Test Method

4.1 The surface of an in situ test site where the water content is to be determined is scraped to a smooth, coplanar surface.

4.2 An access hole, with a nominal diameter of 19 mm, is punched, drilled, or augured into the soil. The hole shall extend a minimum of 25 mm below the end of the probe.

4.3 The probe is inserted into the access hole in such a manner as to minimize any disturbance to the integrity of the hole.

4.4 A measurement of the soil with the permittivity probe is acquired. The measurement consists of a series of readings of the oscillator frequency of the circuit associated with the dielectric permittivity. The readings are averaged to obtain a final result.

4.5 The resulting circuit reading, along with the calibration equation that relates this reading with the water mass per unit volume of the soil, are used to compute the water mass per unit volume of the soil.

4.6 If the data are available, then this calculated water mass per unit volume, in conjunction with the independently determined bulk density of the soil, may be used to determine the (gravimetric) water content of the soil. Bulk density may be determined by test methods such as the ones described in , Test Methods D1556/D1556M, D2167, D2937, D6938, and D8167/D8167M, as examples.

5. Significance and Use

5.1 The soil permittivity probe is used for the following purposes:

5.1.1 The test method described is useful as a rapid, nondestructive technique for bulk measurements of the water mass per unit volume of soil and soil-aggregate which may, in conjunction with an independent bulk density determination, be used in the determination of dry density.

5.1.2 The test method is used for quality control and acceptance testing of compacted soil and soil-aggregate mixtures as used in construction and also for research and development. The nondestructive nature allows repetitive measurements at a single test location and statistical analysis of the results.

5.1.3 *Volumetric Water Content*—The fundamental assumptions inherent in the test method are that the dielectric constants value measured by the system in a given test site composed of soil or soil-aggregate are directly correlated to the volumetric water content of the soil or soil-aggregate, and that the material is homogeneous. (See 6, "Interferences.")

NOTE 2—The quality of the result produced by this standard is

[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.