Designation: D6031/D6031M – 24

Standard Test Method for Logging In Situ Moisture Content and Density of Soil and Rock by the Nuclear Method in Horizontal, Slanted, and Vertical Access Tubes[1]

This standard is issued under the fixed designation D6031/D6031M; 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 covers collection and comparison of logs of thermalized-neutron counts and back-scattered gamma counts along horizontal or vertical air-filled access tubes.

1.2 For limitations, see Section 6, "Interferences."

1.3 The in situ water content in mass per unit volume and the density in mass per unit volume of soil and rock at positions or in intervals along the length of an access tube are calculated by comparing the thermal neutron count rate and gamma count rates respectively to previously established calibration data.

1.4 *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 are not necessarily exact equivalents; therefore, to ensure conformance with the standard, each system shall be used independently of the other, and values from the two systems shall not be combined. Within the text of this standard, SI units appear first followed by the inch-pound (or other non-SI) units in brackets

1.4.1 Reporting the test results in units other than SI shall not be regarded as nonconformance with the standard.

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

1.5.1 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 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, health, and environmental practices and determine the applicability of regulatory limitations prior to use.* For specific hazards, see Section 8.

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.*

2. Referenced Documents

2.1 *ASTM Standards:*[2]

D653 Terminology Relating to Soil, Rock, and Contained Fluids

D1452/D1452M Practice for Soil Exploration and Sampling by Auger Borings

D1586/D1586M Test Method for Standard Penetration Test (SPT) and Split-Barrel Sampling of Soils

D1587/D1587M Practice for Thin-Walled Tube Sampling of Fine-Grained Soils for Geotechnical Purposes (Withdrawn 2024)[3]

D2113 Practice for Rock Core Drilling and Sampling of Rock for Site Exploration (Withdrawn 2023)[3]

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

D3550/D3550M Practice for Thick Wall, Ring-Lined, Split Barrel, Drive Sampling of Soils

[1] This test method is under the jurisdiction of ASTM Committee D18 on Soil and Rock and is the direct responsibility of Subcommittee D18.21 on Groundwater and Vadose Zone Investigations.

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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.

[3] The last approved version of this historical standard is referenced on www.astm.org.

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

D4428/D4428M Test Methods for Crosshole Seismic Testing (Withdrawn 2023)[3]
D4564 Test Method for Density and Unit Weight of Soil in Place by the Sleeve Method (Withdrawn 2013)[3]
D5195 Test Method for Density of Soil and Rock In-Place at Depths Below Surface by Nuclear Methods
D5220/D5220M Test Method for Water Mass per Unit Volume of Soil and Rock In-Place by the Neutron Depth Probe Method
D6026 Practice for Using Significant Digits and Data Records in Geotechnical Data

3. Terminology

3.1 *Definitions*—For definitions of common technical terms in this standard, refer to Terminology D653.

4. Summary of the Test Method

4.1 The test method is as follows:

4.1.1 A horizontal, slanted, or vertical hole is bored or driven into the site where the test is to be performed. The depth of the hole shall be at least 300 mm [1 ft] lower than the bottom of the probe when it is in its deepest measurement position.

4.1.2 An access tube is installed in the hole, with any soil or rock falling back into the hole removed.

4.1.3 The probe containing the source(s) and detector(s) are positioned at the desired measurement depth, and a measurement is taken.

5. Significance and Use

5.1 This test method is useful as a repeatable, nondestructive technique to monitor in-place density and moisture of soil and rock along lengthy sections of horizontal, slanted, and vertical access holes or tubes. With proper calibration in accordance with Annex A1, this test method can be used to quantify changes in density and moisture content of soil and rock.

5.2 This test method is used in vadose zone monitoring, for performance assessment of engineered barriers at waste facilities, and for research related to monitoring the movement of liquids (water solutions and hydrocarbons) through soil and rock. The nondestructive nature of the test allows repetitive measurements at a site and statistical analysis of results.

5.3 The fundamental assumptions inherent in the density measurement portion of this test method are that Compton scattering and photoelectric absorption are the dominant interactions of the gamma rays with the material under test.

5.4 The probe response, in counts, can be converted to wet density by comparing the detected rate of gamma radiation with previously established calibration data (see Annex A1).

5.5 The probe count response may also be utilized directly for unitless, relative comparison with other probe readings.

5.5.1 For materials of densities higher than that of about the density of water, higher count rates within the same soil type relate to lower densities and, conversely, lower count rates within the same soil type relate to higher densities.

5.5.2 For materials of densities lower than the density of water, higher count rates within the same soil type relate to higher densities and, conversely, lower count rates within the same soil type relate to lower densities.

5.5.3 Because of the functional inflection of probe response for densities near the density of water, exercise great care when drawing conclusions from probe response in this density range.

5.6 The fundamental assumption inherent in the moisture measurement portion of this test is that the hydrogen contained in the water molecules within the soil and rock is the dominant neutron thermalizing media, so increased water content of the soil and rock results in higher count rates of the moisture content system of the instrument.

6. Interferences

6.1 The sample heterogeneity and elemental composition of the material under test may affect the measurement of water content, density, or both. The apparatus should be calibrated to the material under test at a similar density of dry soil or rock and in the similar type and orientation of access tube, or adjustments must be made in accordance with Annex A2.

6.2 Hydrogen, in forms other than water, as defined by Test Method D2216, will cause measurements in excess of the true moisture content. Some elements such as boron, chlorine, and minute quantities of cadmium, if present in the material under test, will cause measurements lower than the true moisture content. Some elements with atomic numbers greater than 20 such as iron (Fe) or other heavy metals may cause measurements higher than the true density value.

6.3 The measurement of moisture and density using this test method exhibits spatial bias in that it is more sensitive to the material closest to the access tube. The density and moisture measurements are necessarily an average of the total sample involved.

6.4 The sample volume for a moisture measurement is approximately 0.11 m^3 [3.8 ft^3] at a water mass per unit volume of 200 kg/m^3 [12.5 lbm/ft^3]. The actual sample volume for moisture is indeterminate and varies with the apparatus and the moisture content of the material. In general the greater the moisture content of the material, the smaller the measurement volume.

6.5 A density measurement has a sample volume of approximately 0.003 m^3 [0.8 ft^3]. The actual sample volume for density is indeterminate and varies with the apparatus and the density of the material. In general, the greater the density of the material, the smaller the measurement volume.

6.6 Air gaps between the probe and the access tube or voids around the access tube may cause the indicated moisture content and density to be less than the calibrated values.

6.7 Condensed moisture inside the access tube may cause the indicated moisture content to be greater than the true moisture content of material outside the access tube.

7. Apparatus

7.1 While exact details of construction of the apparatus may vary, the system shall consist of:

7.1.1 *Fast Neutron Source*—A sealed mixture of a radioactive material such as americium or radium and a target material