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Standard Test Methods for Laboratory Determination of Water (Moisture) Content of Soil and Rock by Mass[1]

This standard is issued under the fixed designation D2216; 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.

This standard has been approved for use by agencies of the U.S. Department of Defense.

1. Scope*

1.1 These test methods cover the laboratory determination of the water (moisture) content by mass of soil, rock, and similar materials where the reduction in mass by drying is due to loss of water except as noted in 1.4, 1.5, and ~~1.7~~1.8. For simplicity, the word "material" shall refer to soil, rock or aggregate whichever is most applicable.

1.2 Some disciplines, such as soil science, need to determine water content on the basis of volume. Such determinations are beyond the scope of this test method.

1.3 The water content of a material is ~~defined~~ the ratio of the mass of water contained in ~~3.2.1.~~the pore spaces of soil or rock material, to the solid mass of particles, expressed as a percentage.

1.4 The term "solid material" as used in geotechnical engineering is typically assumed to mean naturally occurring mineral particles of soil and rock that are not readily soluble in water. Therefore, the water content of materials containing extraneous matter (such as cement etc.) may require special treatment or a qualified definition of water content. In addition, some organic materials may be decomposed by oven drying at the standard drying temperature for this method ~~(110°C).~~(110 ± 5°C). Materials containing gypsum (calcium sulfate dihydrate) or other compounds having significant amounts of hydrated water, may present a special problem as this material slowly dehydrates at the standard drying temperature ~~(110°C)~~(110 ± 5°C) and at very low relative humidity, forming a compound (such as calcium sulfate hemihydrate) that is not normally present in natural materials except in some desert soils. In order to reduce the degree of dehydration of gypsum in those materials containing gypsum or to reduce decomposition in highly/fibrous organic soils, it may be desirable to dry the materials at 60°C or in a desiccator at room temperature. ~~Thus, when~~ When a drying temperature is used which is different from the standard drying temperature as defined by this test method, the resulting water content may be different from the standard water content determined at the standard drying temperature of ~~110°C.~~110 ± 5°C.

NOTE 1—Test Method D2974 provides an alternate procedure for determining water content of peat materials.

1.5 Materials containing water with substantial amounts of soluble solids (such as salt in the case of marine sediments) when tested by this method will give a mass of solids that includes the previously soluble dissolved solids. These materials require special treatment to remove or account for the presence of precipitated solids in the dry mass of the specimen, or a qualified definition of water content must be used. For example, see Test Method D4542 regarding information on marine sediments.

1.6 This test standard requires several hours for proper drying of the water content specimen. Test Methods D4643, D4944 and D4959 provide less time-consuming processes for determining water content. See Gilbert[2] for details on the background of Test Method D4643.

1.7 Two test methods are provided in this standard. The methods differ in the significant digits reported and the size of the specimen (mass) required. The method to be used may be specified by the requesting authority; otherwise Method A shall be performed.

1.7.1 *Method A*—The water content by mass is recorded to the nearest 1 %. For cases of dispute, Method A is the referee method.

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[1] This test method is under the jurisdiction of ASTM Committee D18 on Soil and Rock and is the direct responsibility of Subcommittee D18.03 on Texture, Plasticity and Density Characteristics of Soils.

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[2] Gilbert, P.A., "~~"Computer~~Computer Controlled Microwave Oven System for Rapid Water Content ~~Determination,"~~Determination," Tech. Report GL-88–21, Department of the Army, Waterways Experiment Station, Corps of Engineers, Vicksburg, MS, November 1988.

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

1.7.2 *Method B*—The water content by mass is recorded to the nearest 0.1 %.

1.8 This standard requires the drying of material in an oven. If the material being dried is contaminated with certain ~~chemicals,~~ chemicals that may react violently or emit hazardous gases when heated, health and safety hazards ~~can~~may exist. Therefore, this standard should not be used in determining the water content of contaminated soils unless adequate health and safety precautions are ~~taken.~~exercised.

1.9 *Units*—The values stated in SI units shall be regarded as standard ~~excluding~~except the Alternative Sieve Sizes listed in Table 1.~~ are~~ are used. No other units of measurement are included in this test method.

1.10 ~~Refer to~~ All observed and calculated values shall conform to the guidelines for significant digits and rounding established in Practice D6026 ~~for guidance concerning the use of significant figures that shall determine whether Method, A or B is required. This is especially important if the water content will be used to calculate other relationships such as moist mass to dry mass or vice versa, wet unit weight to dry unit weight or vice versa, and total density to dry density or vice versa. For example, if four significant digits are required in any of the above calculations, then the water content must be recorded to the nearest 0.1 %. This occurs since 1 plus the water content (not in percent) will have four significant digits regardless of what the value of the water content is; that is, 1 plus 0.1/100 = 1.001, a value with four significant digits. While, if three significant digits are acceptable, then the water content can be recorded to the nearest 1 %.~~, unless superseded by this test method.

1.10.1 This is especially important if the water content will be used to calculate other relationships such as moist mass to dry mass or vice versa, wet unit weight to dry unit weight or vice versa, and total density to dry density or vice versa. For example, if four significant digits are required in any of the above calculations, then the water content must be recorded to the nearest 0.1 %. This occurs since 1 plus the water content (not in percent) will have four significant digits regardless of what the value of the water content is; that is, 1 plus 0.1/100 = 1.001, a value with four significant digits. While, if three significant digits are acceptable, then the water content can be recorded to the nearest 1 %.

1.10.2 If water content data is to be used to calculate other relationships, such as moist or dry mass, wet or dry unit weight or total or dry density, then the specimen mass up to 200 g must be determined using a balance accurate to 0.01 g.

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

1.12 *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.*

TABLE 1 Minimum Requirements for Mass of Test ~~Specimen,~~ and Balance Readability[A]

Maximum Particle Size (100 % Passing)		Method A Water Content Recorded to ±1 %		Method B Water Content Recorded to ±0.1 %	
~~SI Unit~~ Sieve Size	Alternative Sieve Size	Specimen Mass	Balance Readability (g)	Specimen Mass (g)	Balance Readability (g)
~~75.0 mm~~	~~3 in~~	~~5 kg~~	~~10~~	~~50 kg~~	~~10~~
~~37.5 mm~~	~~1-½ in.~~	~~1 kg~~	~~10~~	~~10 kg~~	~~10~~
~~19.0 mm~~	~~¾ in.~~	~~250 g~~	~~1~~	~~2.5 kg~~	~~1~~
~~9.5 mm~~	~~⅜ in.~~	~~50 g~~	~~0.1~~	~~500 g~~	~~0.1~~
~~4.75 mm~~	~~No. 4~~	~~20 g~~	~~0.1~~	~~100 g~~	~~0.1~~
~~2.00 mm~~	~~No. 10~~	~~20 g~~	~~0.1~~	~~20 g~~	~~0.01~~

TABLE 1 Minimum Requirements for Mass of Test Specimens, and Balance Readability[A]

Maximum Particle Size (100 % Passing)		Method A Water Content Recorded to ±1 %		Method B Water Content Recorded to ±0.1 %	
Sieve Size	Alternative Sieve Size	Minimum Specimen Mass	Balance Readability (g)	Minimum Specimen Mass (g)	Balance Readability (g)
75.0 mm	3 in.	5 kg	10	50 kg	10
37.5 mm	1-½ in.	1 kg	10	10 kg	10
19.0 mm	¾ in.	250 g	0.1	2.5 kg	0.1
9.5 mm	⅜ in.	50 g	0.1	500 g	0.1
4.75 mm	No. 4			100 g	0.01
2.00 mm	No. 10			20 g	0.01

[A] ~~If~~See 1.10.2~~water content data is to be used to calculate other relationships, such as moist or dry mass, wet or dry unit weight or total or dry density, then specimen mass up to 200 g must be determined using a balance accurate to 0.01 g.~~.

2. Referenced Documents

2.1 *ASTM Standards:*[3]

D653 Terminology Relating to Soil, Rock, and Contained Fluids
D2974 Test Methods for Moisture, Ash, and Organic Matter of Peat and Other Organic Soils
D3740 Practice for Minimum Requirements for Agencies Engaged in Testing and/or Inspection of Soil and Rock as Used in Engineering Design and Construction
D4220 Practices for Preserving and Transporting Soil Samples
D4318 Test Methods for Liquid Limit, Plastic Limit, and Plasticity Index of Soils
D4542 Test Methods for Pore Water Extraction and Determination of the Soluble Salt Content of Soils by Refractometer
D4643 Test Method for Determination of Water Content of Soil and Rock by Microwave Oven Heating
D4753 Guide for Evaluating, Selecting, and Specifying Balances and Standard Masses for Use in Soil, Rock, and Construction Materials Testing
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
D5079 Practices for Preserving and Transporting Rock Core Samples (Withdrawn 2017)[4]
D6026 Practice for Using Significant Digits in Geotechnical Data
D7263 Test Methods for Laboratory Determination of Density (Unit Weight) of Soil Specimens
~~E145 Specification for Gravity-Convection and Forced-Ventilation Ovens~~

3. Terminology

3.1 ~~Refer to Terminology D653 for standard definitions of terms.~~*Definitions:*

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

~~3.2 *Definitions:*~~

~~3.2.1 *water content by mass (of a material)*—the ratio of the mass of water contained in the pore spaces of soil or rock material, to the solid mass of particles in that material, expressed as a percentage. A standard temperature of 110 ± 5°C is used to determine these masses.~~

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *constant dry mass (of a solid material)*—the state that a water content specimen has attained when further heating ~~causes, or would cause,~~ results in less than 1 % or 0.1 % additional loss in mass for Method A or B respectively. The time ~~required~~necessary to obtain constant dry mass will vary depending on numerous ~~factors.~~ factors such as the type of material being tested, the size of the specimen and type of oven being used (forced draft or gravity type). The influence of these factors generally can be established by good ~~judgement.~~judgment, and experience with the materials being tested and the apparatus being used.

4. Summary of Test Method

4.1 ~~A~~ The mass of a moist test specimen is determined. The specimen is then dried in an oven at a temperature of 110 ± 5°C ~~to~~until a constant ~~mass.~~ mass is achieved. The loss of mass, due to drying, is considered to be water. The water content is calculated using the mass of water ~~and~~to the mass of the dry ~~specimen.~~specimen expressed in percent.

5. Significance and Use

5.1 For many materials, the water content is one of the most significant ~~index~~ properties used in establishing a correlation between soil behavior and its index properties.

5.2 The water content of a material is used in expressing the phase relationships of air, water, and solids in a given volume of material.

5.3 In fine-grained ~~(cohesive)~~ soils, the consistency of a given soil type depends on its water content. The water content of a soil, along with its liquid and plastic limits as determined by Test Method D4318, is used to express its relative consistency or liquidity index.

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

6. Apparatus

6.1 *Drying Oven*—Vented, thermostatically-controlled, preferably of the forced-draft ~~type, meeting the requirements of Specification~~ type ~~E145~~and capable of maintaining a uniform temperature of 110 ± 5°C throughout the drying chamber. The oven

[3] 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.

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

shall have a means of indicating the oven drying chamber temperature when in operation. This can be accomplished by such means as an electronic display, an analog thermometer, remote temperature recording device or any other means to determine the current drying chamber temperature while in operation.

6.1.1 Ovens in excess of 30 cubic feet shall have the temperature verified for adherence to the temperature requirements in the four quadrants and the center of the oven. Smaller ovens shall have the temperature verified in a single center location. Oven temperature verification shall follow the schedule as outlined in D3740 or following such things as repairs or questionable operation.

6.2 *Balances*—All balances must meet the requirements of Specification D4753 and this section. A Class GP1 balance of 0.01 g readability is required for specimens having a mass of up to 200 g (excluding mass of specimen container) and a Class GP2 balance of 0.1 g readability is required for specimens having a mass over 200 g. If desired, a Class GP1 balance may be used for specimens exceeding 200 g providing the specimen size is within the capacity of the balance. However, the balance used may be controlled by the number of significant digits needed (see 1.10).

6.3 *Specimen Containers*—Suitable containers made of material resistant to corrosion and change in mass upon repeated heating, cooling, exposure to materials of varying pH, and cleaning. Unless a ~~dessicator~~desiccator is used, containers with close-fitting lids shall be used for testing specimens having a mass of ~~less than about 200 g;~~ 200 g or less; while for specimens having a mass greater than ~~about~~ 200 g, containers without lids may be used (see Note 3). One uniquely numbered (identified) container or number-matched container and lid combination as required is needed for each water content determination.

NOTE 3—The purpose of close-fitting lids is to prevent loss of moisture from specimens before initial mass determination, and to prevent absorption of moisture from the atmosphere following drying and before final mass determination.

6.4 *Desiccator (Optional)*—A desiccator cabinet or large desiccator jar of suitable size containing silica gel or anhydrous calcium sulfate. It is preferable to use a desiccant that changes color when it needs to be ~~reconstituted.~~recharged.

NOTE 4—Anhydrous calcium sulfate is sold under the trade name Drierite.

6.5 *Container Handling Apparatus,* heat resistant gloves, tongs, or suitable holder for moving and handling hot containers after drying.

6.6 *Miscellaneous,* knives, spatulas, scoops, quartering cloth, wire saws, etc., as required.

7. Samples

7.1 Soil samples shall be preserved and transported in accordance with Practice D4220 Section 8 Groups B, C, or D soils. Rock samples shall be preserved and transported in accordance with Practice D5079 section ~~7.5.2,~~7.5.2.1, Special Care Rock. Keep the samples that are stored prior to testing in non-corrodible airtight containers at a temperature between ~~approximately~~ 3 and 30°C and in an area that ~~prevents direct contact with~~ is without direct sunlight. Disturbed samples in jars or other containers shall be stored in such a way as to minimize moisture condensation on the insides of the containers.

7.2 The water content determination should be done as soon as ~~practicable~~practical after sampling, especially if potentially corrodible containers (such as thin-walled steel tubes, paint cans, etc.) or plastic sample bags are used.

8. Test Specimen

8.1 For water contents being determined in conjunction with another ASTM method, the specimen mass requirement stated in that method shall be used if one is provided. If no minimum specimen mass is provided in that method then the values ~~given below~~outlined in Table 1 and 1.10.2 shall apply. See Howard[5] for background data for the values listed.

8.2 The minimum specimen mass of moist material selected to be representative of the total sample is based on visual maximum particle size in the sample and the Method (Method A or B) used to record the data. Minimum specimen mass and balance readability shall be in accordance with Table 1.

8.3 Using a test specimen smaller than the minimum indicated in Table 1 and 8.2 requires discretion, though it may be adequate for the purposes of the test. ~~Any specimen used not meeting these requirements~~ It shall be noted on the test data forms or test data ~~sheets.~~sheets of any specimen used not meeting these requirements.

8.4 When working with a ~~small (less~~ specimen weighing less than 200 ~~g) specimen~~g and containing a relatively large gravel particle, it is appropriate not to include ~~this~~ the gravel particle in the test specimen. However, any discarded material shall be described and noted on the test data form/sheet.

8.5 For those samples consisting entirely of intact rock or gravel-size aggregate, the minimum specimen mass shall be 500 g. Representative portions of the sample may be broken into smaller particles. The particle size is dictated by the specimen mass, the

[5] Howard, A. K., "~~"Minimum~~Minimum Test Specimen Mass for Moisture Content ~~Determination,"~~Determination," *Geotechnical Testing Journal,* ASTM., Vol. 12, No. 1, March 1989, pp. 39-44.