Designation: D4511 – 11

Standard Test Method for Hydraulic Conductivity of Essentially Saturated Peat [1]

This standard is issued under the fixed designation D4511; 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 the determination of the hydraulic conductivity (permeability) of essentially saturated, intact cylindrical specimens of peat when the hydraulic conductivity is greater than 1×10^{-7} m/s (1×10^{-5} cm/s). During the test, the specimens are contained in the core holder, or in right, regular cylindrical sections cut from the sampling tube in which they were originally obtained in the field.

1.2 Hydraulic conductivity is calculated on the basis of the measured constant flow rate through the specimen under constant head.[2] For verification, flow rate determinations may be made at two or more values of constant head with corresponding calculations of hydraulic conductivity.

1.3 *Units*—The values stated in SI units are to be regarded as the standard. The inch-pound units given in parentheses are mathematical conversions, which are provided for information purposes only and are not considered standard.

1.3.1 The converted inch-pound units use the gravitational system of units. In this system, the pound (lbf) represents a unit of force (weight), while the unit for mass is slugs. The converted slug unit is not given, unless dynamic (F = ma) calculations are involved.

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

1.4.1 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.

1.5 *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.*

2. Referenced Documents

2.1 *ASTM Standards:*[3]

D653 Terminology Relating to Soil, Rock, and Contained Fluids

D1587 Practice for Thin-Walled Tube Sampling of Soils for Geotechnical Purposes

D2434 Test Method for Permeability of Granular Soils (Constant Head)

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

D4753 Guide for Evaluating, Selecting, and Specifying Balances and Standard Masses for Use in Soil, Rock, and Construction Materials Testing

D6026 Practice for Using Significant Digits in Geotechnical Data

2.2 *NRC Document:*

Peat Testing Manual[4]

3. Terminology

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

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *deaerated (de-aired) water*—water in which the amount of dissolved gas (air) has been reduced.

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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 D18.04 on Hydrologic Properties and Hydraulic Barriers.

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[2] For further information, see "Methods for Measurement of Saturated Hydraulic Conductivity," *Peat Testing Manual*, Technical Memorandum No. 125, NRC Canada, pp. 80–84.

[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] National Research Council of Canada, Publications Section, Building R–88, Ottawa, Canada K1A 0R6. Out of print.

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

3.2.2 *flow rate*—the quantity of water flowing through the test specimen in a given period of time, when subjected to a certain constant head differential.

3.2.3 *soaking*—placement of a specimen in water for the purpose of removing gas contained in the pore space, through bouyancy, and replacement with water to cause saturation of the specimen. This method of saturation does not effectively remove all the gas contained in the specimen and does not prevent the continuous slow formation of gas from decomposition under anaerobic conditions.

4. Significance and Use

4.1 Values of hydraulic conductivity determined by this test method may be useful in making rough preliminary estimates of the initial rates of drainage and compression of peat deposits when the only effective stress increase on the deposit is that resulting from a moderate, gradual lowering of the water table.

4.2 Even under light, sustained loads, peat will undergo dramatic volume changes that influence (decrease) the hydraulic conductivity of the deposit by several orders of magnitude. This test method does not offer provisions for the determination of the relationship between hydraulic conductivity and the void ratios corresponding to increasing stress levels. Therefore, this test method is not suitable for applications involving grade increases, such as embankment construction or placement of access berms alongside drainage ditches.

4.3 Undisturbed specimens from apparently homogeneous peat deposits at the same location often exhibit significantly different hydraulic conductivity properties due to variations in material composition and sampling procedure.

NOTE 1—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 reliable results. Reliable results depend on many factors; Practice D3740 provides a means of evaluating some of those factors.

5. Interferences

5.1 Due to the generally fibrous texture and extremely high compressibility of peat, present sampling technologies may not be able to obtain samples truly representative of the in situ conditions. Disturbance caused by sampling and specimen preparation as well as heterogeneity existing in situ may cause the hydraulic conductivity determined using this method to be significantly different than the in situ hydraulic conductivity.

5.2 There are no provisions in this test method for verification of compliance with the fundamental test conditions listed in 6.1.1 and 6.1.2. The assumption is made that these conditions are satisfied if the flow rate, with time, is a linear relationship.

5.3 The result of the test may be influenced by flow through open passages between the specimen and the rigid wall of the specimen container. If such a condition is suspected or visually verified, notice thereof should be made in the test report.

6. Fundamental Test Conditions

6.1 The following ideal test conditions are prerequisite for laminar flow of water through porous media under constant-head conditions:

6.1.1 Continuity of flow with no volume change during a test,

6.1.2 Flow with the void space saturated with water and no air bubbles in the voids,

6.1.3 Flow in the steady state with no changes in hydraulic gradient, and

6.1.4 Direct proportionality of flow velocity with hydraulic gradients below certain values, after which flow becomes turbulent.

6.2 All other types of flow involving partial saturation of void space, turbulent flow, and unsteady state of flow are transient in character and yield variable and time-dependent values of hydraulic conductivity; therefore, they require special test conditions and procedures.

7. Apparatus

7.1 *Flow Device*—The flow device shall be as shown in Fig. 1, fitted with the following components:

7.1.1 *Constant-Head Filter Tank,* as shown in Fig. 1 of Test Method D2434, to supply water and to remove most of the air from the water. The tank shall be fitted with a suitable siphon.

NOTE 2—Alternatively, deaerated water may be used, supplied from a self-siphoning burette with attached inverted flask (minimum 750-mL capacity), filled with deaerated water, and closed with a rubber stopper holding a tube, 150 cm (6 in.) long with the end cut diagonally.

7.1.2 *Upper Reservoir,* of the same diameter as the sampling cylinder and approximately 150 cm (6 in.) high.

7.1.3 *Wire-Screen Support,* fabricated from a ring clamp, with an inside diameter greater than the specimen cylinder and covered with 425-µm (No. 40) wire mesh screening.

7.1.4 *Circular Disk,* cut from 425-µm (No. 40) wire mesh screening, with a diameter 1 mmm smaller than that of the specimen.

7.1.5 *Funnel,* with a head diameter at least 10 % larger than that of the specimen cylinder.

7.1.6 *Two 400-mL Beakers.*

7.2 *Balance*—A balance or scale conforming to the requirements of Specification D4753, readable (with no estimate) to 0.1 % of the test mass, or better.

7.3 *Miscellaneous Apparatus and Materials,* such as thermometers, timer reading to nearest second, soaking pan, pipe cutters, trimming knife, cheese cloth, rubber bands, vinyl electrical tape, and micro-crystalline wax.

8. Specimen Preparation and Set Up

8.1 Specimens shall have a minimum diameter of 73 mm (2.87 in.). The height-to-diameter ratio shall be between 1 and 2.

8.2 Prepare specimens from tube samples secured in accordance with Practice D1587, or other acceptable undisturbed sampling procedure, yielding cylindrical samples obtained in tight-fitting, rigid-metal core holders (Note 3). Preserve and

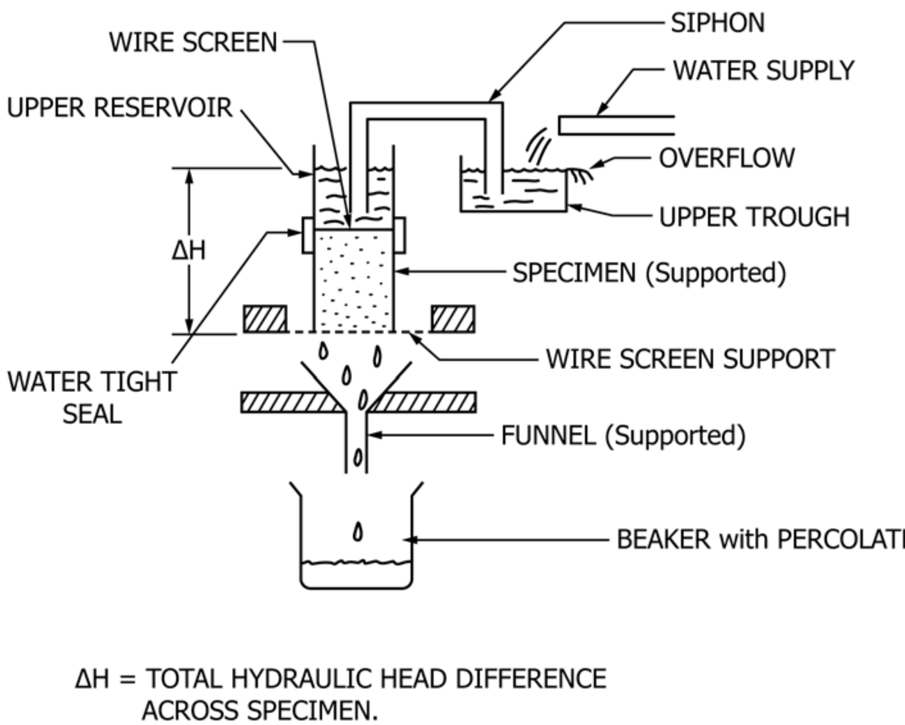

FIG. 1 Diagram for the Constant-Head System for Conductivity Measurement

transport the specimens in accordance with the practice for Group D samples in Practices D4220 (Note 4).

NOTE 3—Samples of fibrous peat from shallow depths can be secured with the least amount of disturbance using a rotary type sampling device equipped with a thin cutting edge, serrated with saw-teeth.[5]

NOTE 4—The integrity of a sample contained in a sampler liner or core holder is best preserved if the sample ends are trimmed flush with the ends of the liner and capped using tight-fitting, rigid-metal end caps, securely taped in place and dipped in micro-crystalline wax.

8.3 The specimen is tested in a section of the original sample container without extrusion. If the length of the sample container initially is not within the proper range for height-to-diameter ratio, secure the sample container firmly, without deformation, in a vertical position and cut off a suitable test section with a pipe cutter (Note 5). Trim the peat specimen flush with the cylinder at both ends. Determine and record the mass of the specimen and cylinder. Cover the bottom of the specimen with a piece of cheesecloth and secure the cheesecloth to the cylinder with a rubber band.

NOTE 5—A chain-type pipe cutter, such as those used for cutting automotive exhaust system pipe, is recommended.

8.4 Place the specimen inside a soaking pan with a depth greater than the specimen length. The cheesecloth covering the end of the specimen should rest on screening that is permeable enough to permit free flow of water to the specimen; separating the specimen from the bottom of the pan. Slowly fill the pan with water (Note 6) to a depth approximately 6 mm (0.25 in.) below the top of the specimen. Avoid the flow of water onto the top of the specimen cylinder. Soak the specimen for 72 h.

NOTE 6—Water used for soaking and subsequent permeation may be deaerated tap water, distilled water, or water obtained from the sample location in the field. In the latter case, the water must be filtered, prior to use in the laboratory, to remove suspended solids. The type of water used should be noted in the report under remarks (11.2), however; it should be recognized that hydraulic conductivity determined by this method is influenced by so many factors, that the results are not suitable for comparative study of the effects of different types of water on the hydraulic conductivity of peat.

NOTE 7—Continuing slow decomposition of peat is accompanied by the formation of gases. Total saturation may not be achieved by soaking alone.

8.5 Remove the specimen from the soaking pan, remove the cheesecloth, place the specimen on the pre-wetted wire screen support, and wipe excess water off the specimen cylinder.

8.6 Place the upper reservoir on top of the specimen cylinder and seal the joint with vinyl electrical tape, a wide rubber band, or a coat of micro-crystalline wax, to effect a watertight connection. Dip the cylindrical disk of 425-µm (No. 40) wire mesh screening in water, and place it on the top surface of the specimen.

8.7 Position a funnel and beaker beneath the specimen. Carefully add water (Note 6) to the upper reservoir to activate the siphoning system discussed in 7.1.1 (shown in principle in Fig. 1) and adjust to maintain the desired constant head. To minimize compression of the peat, limit the head of water above the specimen to 50 to 100 mm.

8.8 The ambient temperature during the test should not vary by more than ±3°C (±5.5°F).

9. Test Procedure

9.1 When it appears that a constant flow rate has been attained, set a convenient time to start the flow rate measurement. At the appointed time, replace the beaker with a dry,

[5] Such a device, the Peat Core Cutter, is described fully in *Peat Testing Manual*, Technical Memorandum No. 125, NRC Canada, Section 1.1.2, pp. 7–10.

clean beaker of known tare mass. After some suitable, convenient time interval, replace the beaker by a second dry, clean beaker of known tare mass, and weigh the first beaker. Exercise great care that water is not spilled or lost.

9.1.1 Determine the volume of flow in the first time interval as the difference between the mass of the beaker and water, and the tare mass of the beaker (using the assumption that 1 mL of water has a mass of 1 g) (Note 8).

NOTE 8—Graduated cylinders may be used in lieu of beakers as long as the accuracy of the flow rate determination is not impaired.

9.1.2 Repeat the flow measurements and prepare a plot of cumulative flow quantity at the respective times until a constant flow rate has been defined by a minimum of four points falling reasonably close to a straight line. A suitable minimum time interval between flow measurements is the time required for accumulation of a volume of water, corresponding to at least 10 % of the tare mass of the beaker.

9.2 Measure the value of the constant head applied during the flow rate determination as the elevation difference between the water level in the upper reservoir and the bottom of the specimen.

9.3 Measure and record the water temperature during the flow rate measurement.

9.4 Repeat flow rate determinations for at least two different values of constant head.

9.5 After the test, dismantle the apparatus and determine the moisture content of the specimen in accordance with Test Methods D2974. Determine the dry unit weight on the basis of the total dry mass of the specimen and the interior dimensions of the specimen cylinder, measured to the nearest 0.2 mm (0.01 in.).

10. Calculation

10.1 The flow rate, *Q/t*, is determined as the slope of the straight line portion of the flow-rate plot, for each respective value of established constant head.

10.2 Calculate the hydraulic conductivity, *k*, as follows:

$$k = \frac{L}{A(\Delta H)} \times Q/t \qquad (1)$$

where:

k = hydraulic conductivity, m/s,
Q/t = rate of water outflow, m^3/s,
A = cross-sectional area of specimen, m^2,
L = length of specimen, m, and
ΔH = value of constant head, m, required to maintain a sustained flow rate, Q/t.

NOTE 9—Units other than second (s), meter (m), etc. may be used provided an appropriate unit conversion factor is employed so that k is in m/s, or in other units, if requested or customary.

10.3 Correct values of hydraulic conductivity, *k*, at water temperature T°C to a reference temperature of 20°C (Note 10), as follows:

$$k_{20} = k_T \left(\frac{\mu_T}{\mu_{20}} \right) \qquad (2)$$

where:

k_{20} = hydraulic conductivity at 20°C,
k_T = hydraulic conductivity at T°C,
μ_T = viscosity of water at T°C, and
μ_{20} = viscosity of water at 20°C.[6]

NOTE 10—Considering the magnitude of influences from other factors, such as sample disturbance and gas content, on the accuracy of the result, this correction is of minor consequence and may, therefore, be considered optional.

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

11.1 The methodology used to specify how data are recorded on the test data sheet(s)/form(s), as given below, is covered in 1.4.

11.2 Record as a minimum the following general information (data):

11.2.1 Sample/specimen identifying information, such as Location, Project No., Boring No., Sample No., Depth, etc.

11.2.2 Visual description of the specimen, including peat classification.

11.2.3 Record any unusual conditions or other information, such as type of water used that may need to be considered necessary to properly interpret the results obtained.

11.3 Record as a minimum the following test specimen data:

11.3.1 The height and diameter of the specimen to three significant digits.

11.3.2 The dry unit weight (three significant digits) and the moisture content (nearest 0.1 %).

11.4 Record as a minimum the following permeation data:

11.4.1 The applied water temperature (nearest 0.1 °C), constant head, elapsed time, and flow volume. Applicable measurements/readings and any averages/differences calculated using measurements/readings obtained shall have two or more significant digits.

11.4.2 A graph of the relationship between cumulative flow volume and time and tabulation of flow rates and corresponding values of constant head applied to the specimen.

11.4.3 The calculated hydraulic gradient and hydraulic conductivity for the values meeting the applicable requirements in 9.1 and 9.2. Record these values to two or three significant digits.

11.4.4 A graph of hydraulic conductivity versus test gradient.

12. Precision and Bias

12.1 *Precision*—Test data on precision is not presented due to the nature of the peat and highly organic soil materials tested by this method. It is either not feasible or too costly at this time to have ten or more laboratories participate in a round–robin testing program. In addition, it is either not feasible or too costly to produce multible specimens that have uniform physical properties. Any variation observed in the data is just as likely to be due to specimen variation as to operator or laboratory testing variation.

[6] Values of the viscosity of water, μ, may be obtained from *International Critical Tables*, Vol 5, McGraw-Hill, New York, NY, 1929. Values of μ are also published in most laboratory testing manuals.

12.1.1 Subcommittee D18.04 is seeking any data from the users of this test method that might be used to make a limited statement of precision.

12.2 *Bias*—There is no accepted reference value for this test method, therefore, bias can not be determined.

13. Keywords

13.1 constant-head permeability; hydraulic conductivity; peat; permeability; rigid-wall permeameter; saturated peat

SUMMARY OF CHANGES

Committee D18 has identified the location of selected changes to this test method since the last issue, D4511–00(2006), that may impact the use of this test method. (Approved November 1, 2011)

(*1*) Revised the units statement in 1.3.

(*2*) Heavily revised Section 11.