Designation: D 5493 – 93 (Reapproved 2003)

Standard Test Method for Permittivity of Geotextiles Under Load[1]

This standard is issued under the fixed designation D 5493; 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 water permittivity behavior of geotextiles in a direction normal to the plane of the geotextile when subjected to specific normal compressive loads.

1.2 Use of this test method is limited to geotextiles. This test method is not intended for application with geotextile-related products such as geogrids, geonets, geomembranes, and other geocomposites.

1.3 The values stated in SI units are to be regarded as the standard. The inch-pound units given in parentheses are for information only.

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

2. Referenced Documents

2.1 *ASTM Standards:* [2]

D 123 Terminology Relating to Textile Materials
D 653 Terminology Relating to Soil, Rock, and Contained Fluids
D 4354 Practice for Sampling of Geosynthetics for Testing
D 4439 Terminology for Geosynthetics
D 4491 Test Method for Water Permeability of Geotextiles by Permittivity
D 4716 Test Method for Determining the (in-plane) Flow Rate per Unit Width and Hydraulic Transmissivity of a Geosynthetic Using a Constant Head

3. Terminology

3.1 *Definitions:*

3.1.1 *geotextile*, *n*—any permeable textile material used with foundation, soil, rock, earth, or any other geotechnical engineering related material as an integral part of a manmade project, structure, or system (see Terminology D 4439).

3.1.2 *hydraulic gradient*, *i*, *n*—the loss of hydraulic head per unit distance of flow, dh/dL (see Test Method D 4716).

3.1.3 *permittivity, (ψ), (T^{-1}), n*—of geotextiles, the volumetric flow rate of water per unit cross-sectional area per unit head under laminar flow conditions, in the normal direction through a geotextile (see Terminology D 4439).

3.1.4 *For the definitions of other terms relating to geotextiles, refer to Terminology D 4439. For the definitions of textile terms, refer to Terminology D 123. For the definitions of coefficient of permeability, refer to Terminology D 653.*

4. Summary of Test Method

4.1 This test method provides a procedure for measuring the water flow, in the normal direction through a known cross section of a single layer of a geotextile at predetermined constant hydraulic heads over a range of applied normal compressive stresses.

4.2 The permittivity of a geotextile, ψ, can be determined by measuring the flow rate of water, in the normal direction, through a known cross section of a geotextile at predetermined constant water heads.

4.3 Water flow through geotextiles can be laminar, transient, or turbulent, and therefore permittivity cannot be taken as a constant.

5. Significance and Use

5.1 The thickness of a geotextile decreases with increase in the normal compressive stress. This decrease in thickness may result in the partial closing or the opening of the voids of geotextile depending on its initial structure and the boundary conditions.

5.2 This test method measures the permittivity due to a change of void structure of a geotextile as a result of an applied compressive stress.

6. Apparatus

6.1 The apparatus used for the normal permeability under load test is shown in Fig. 1. The apparatus shall conform to one of the following arrangements:

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[1] This test method is under the jurisdiction of ASTM Committee D-35 on Geosynthetics and is the direct responsibility of Subcommittee D35.03 on Permeability and Filtration.

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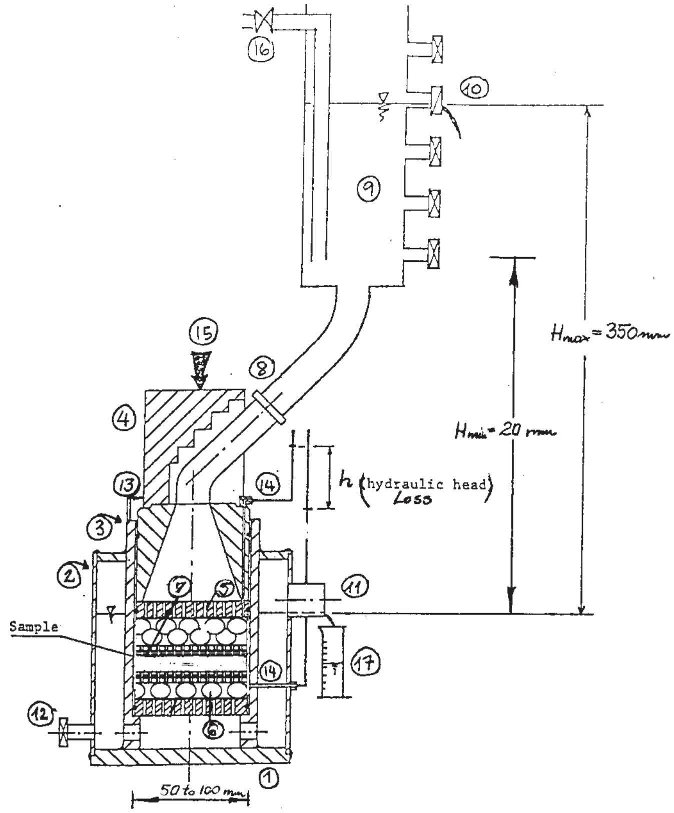
[2] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.



NOTE—Not at scale.

FIG. 1 Schematic View of the Apparatus

6.1.1 The apparatus must be capable of maintaining a constant head of water on the geotextile specimens being tested.

6.1.2 The apparatus must not be the controlling factor for flow during the test. It will be necessary to establish a calibration curve of flow rate versus hydraulic head for the apparatus alone in order to establish compliance with this requirement (see appendix).

6.2 The apparatus consists of a stand (*1*) and a water tank (*2*) on which sits a vertical cylinder (*3*), a piston (*4*) used for the application of the normal loads in the range from 2 to 200 kPa (0.28 to 28 psig) with an accuracy of ±2 μPa (±0.28 psig), two perforated plates used as water distributors (*5*), two glass or ceramic balls layers (*6*), two layers of wire mesh (*7*), a water inlet (*8*) connected to a reservoir containing deaired water (*9*), overflow outlets at both the upper reservoir (*10*) and lower water tank (*11*), a drainage or discharge valve (*12*), a scale to measure changes of thickness of test specimen (*13*) and piezometers (*14*).

6.3 The overflow (*11*) located in the water tank (*2*) must be located above the geotextile specimen installed in the cylinder (*3*). The recommended tubing diameter is 25 mm.

6.4 The reservoir (*9*) contains a number of overflow outlets to enable setting of different hydraulic heads. The range of possible hydraulic heads should be between 20 to 350 mm. The hydraulic head is defined as the difference between the water level at overflow (*10*) and the water level at the outlet overflow (*11*).

6.5 The geotextile specimen is installed in the cylinder (*3*) in between two wire meshes (*7*) and balls layers (*6*) and upper and lower perforated plates (*5*).

6.6 Once the specimen, the balls, and the plates are secured in the cylinder (*3*), remaining parts must be assembled on the apparatus, that is:

6.6.1 Piezometers (*14*) are used to measure hydraulic head losses at geotextile interfaces;

6.6.2 Part (*15*) allows setting of the load on the piston (*4*);

6.6.3 A valve (*16*) allows a constant flow of deaired water; and

6.6.4 A graduated collection vessel (*17*) allows collecting of the discharge water that flows through the specimen.

6.7 Certain required dimensions of the apparatus are shown in Fig. 1.

7. Sampling

7.1 *Lot Sample*—As a lot sample for acceptance testing, take at random the number of rolls of geotextile directed in an applicable material specification or other agreement between the purchaser and the supplier. Consider rolls of geotextile to be the primary sampling units. If the specification requires sampling during manufacture, select the rolls for the lot sample at uniformly spaced time intervals throughout the production period.

NOTE 1—An adequate specification or other agreement between the purchaser and the supplier requires taking into account the variability between rolls of geotextile and between specimens from a swatch from a roll of geotextile so as to provide a sampling plan with a meaningful producer's risk, consumer's risk, acceptable quality level, and limiting quality level.

7.2 *Laboratory Sample*—Consider the units in the lot sample as the units in the laboratory sample. Take a sample that will exclude material from the outer wrap of the roll or the inner wrap around the core unless the sample is taken at the production site, at which point the inner and outer wrap material may be used.

8. Test Water Preparation

8.1 De-air the test water to provide reproducible test results.

8.2 De-air the water used for saturation.

8.3 De-air the water under a vacuum of 710 mm (28 in.) of mercury (Hg) for the period of time to bring the dissolved oxygen content down to a maximum of 6 ppm.

8.4 Use dissolved oxygen meter or commercially available chemical kits to determine the dissolved oxygen content.

8.5 The deaired system may be a commercially available system, or one consisting of a vacuum pump capable of removing a minimum of 150 L/min of air in connection with a non-collapsible storage tank with a large enough storage capacity for the test series, or at least one specimen at a time. Allow the deaired water to stand in closed storage under a slight vacuum until room temperature is attained.

8.6 If water temperature other than 20°C is being used, make a temperature correction to the resulting value of permittivity.

8.7 Determine the temperature correction factor using the following equation:

$$Rt = ut/u20 \quad (1)$$

where:

ut = water viscosity at test temperature, mP, as determined from Table 1, and

$u20$ = water viscosity at 20°C, mP.

9. Specimen Preparation

9.1 Prepare four specimens of the geotextile to be tested avoiding sampling along the edges of the geotextile roll to ensure homogeneity of the specimens.

9.2 The minimum specimen diameter is 50 mm.

9.3 Referring to Fig. 2, select the specimens, A, B, C, and D, as follows:

9.3.1 Take Specimen A at the center of the sample, B at one corner (center located 200 mm from the corner), C midway between A and B, and D the same distance from A as C, located on a line with A, B, and C.

9.3.2 Cut specimens shall fit the testing apparatus.

10. Test Procedure

10.1 Soak the specimen in a vessel containing deaired water, at room conditions, for a period of at least 2 h to ensure saturation and wetting.

10.2 Soak the porous plates, wire meshes, and ceramic or glass balls to be used in a similar fashion as described in 10.1.

10.3 Maintain the test specimen, porous plates, wire meshes, and balls underwater at all times prior to and during the test.

10.4 Allow the deaired water to flow from the bottom of the apparatus to the predetermined overflow (*11*) located on the top of the upper section of the water tank (*2*) using the drain tube (*12*) as the water inlet.

TABLE 1 Viscosity of Water Versus Temperature

Temperature, °C	Viscosity (Poiseuille)[A]
0	1.7921×10^{-6}
1	1.7313×10^{-6}
2	1.6278×10^{-6}
3	1.6191×10^{-6}
4	1.5674×10^{-6}
5	1.5188×10^{-6}
6	1.4728×10^{-6}
7	1.4284×10^{-6}
8	1.3860×10^{-6}
9	1.3462×10^{-6}
10	1.3077×10^{-6}
11	1.2713×10^{-6}
12	1.2363×10^{-6}
13	1.2028×10^{-6}
14	1.1709×10^{-6}
15	1.1404×10^{-6}
16	1.1111×10^{-6}
17	1.0828×10^{-6}
18	1.0559×10^{-6}
19	1.0299×10^{-6}
20	1.0050×10^{-6}
21	0.9810×10^{-6}
22	0.9579×10^{-6}
23	0.9358×10^{-6}
24	0.9142×10^{-6}
25	0.8937×10^{-6}

[A] Poiseuille = kg s^{-1} m^{-1} = Nsm.

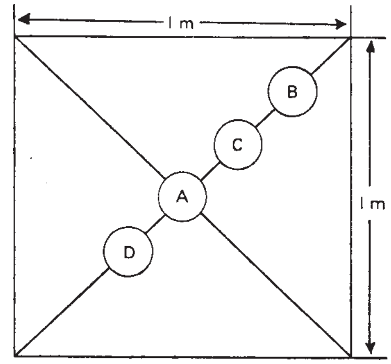


FIG. 2 Sampling Pattern

10.5 Place the plates (*5*), balls (*6*), wire meshes (*7*), and the single geotextile specimen in the cylinder (*3*) in sequence as shown in Fig. 1.

10.6 Lower the piston (*4*), until it reaches the upper porous plate (*6*).

10.7 Apply a load that, added to the initial load resulting from the piston weight, gives a load equal to 2 kPa.

10.8 Close the valve at the overflow (*11*) and continue to fill the tank (*2*) until water fills up the cylinder (*3*) and the reservoir (*9*) to the overflow (*10*). This step is needed to flush out any air bubbles located in the upper plate and the upper section of the cylinder. Air bubbles in the system will lead to erroneous and non-reproducible test results. Close the valve at drain (*12*).

10.9 Open the water inlet valve (*16*) located at the bottom section of the water reservoir (*9*) and adjust the water flow to maintain a constant water head after opening fully the overflow valve (*11*). The flow of water during the tests should be downward.

10.10 Take successive flow rate (*Q*) measurements using the collection vessel (*17*) to verify that the discharge flow of water is constant. Record the water volume collected, the time of flow, the water levels in the piezometers, and the piston position (or compressed thickness of the test specimens). The water heads are directly measured at the interface by piezometers in contact with the geotextile specimen. Measure the water temperature.

10.11 Increase the load on the test specimen to the next desired value of normal stress. The load increments applied should be 2, 10, 25, 50, 100, and 200 kPa.

10.12 Repeat 10.10 and 10.11 until the highest desired value of normal stress (200 kPa).

10.13 Open the valve at the next upward predetermined overflow (*10*) located on the water reservoir (*9*) and adjust the inlet water flow (*16*) to maintain a constant head of water.

10.14 Repeat 10.10, 10.11, 10.12, and 10.13 until the maximum constant head of 35 mm (14 in.) is achieved.

10.15 Close the water inlet valve (*16*) and drain the water out of the cylinder and the tank using the drain tube (*12*).

10.16 Remove the tested specimen.

10.17 Perform the calculations as directed in 11.1 and 11.4.

10.18 Repeat the procedure from 10.4 to 10.16 for each new specimen using the same constant heads and the same loads.

11. Calculation

11.1 Plot the curve of the hydraulic losses (*h*) versus the flow rate per unit area ($V = Q/A$) for all applied loads for each tested specimen.

11.2 The initial straight-line portion of the curve defines the region of laminar flow conditions.

11.3 The nonlinear portion of the curve defines the region of transient or turbulent flow conditions.

11.4 The permittivity for all type of flow conditions, for each compression level, can be calculated using the following equation:

$$\psi = QR_T/hAt \tag{2}$$

where:

ψ = permittivity, s^{-1},
Q = volume of water collected, m^3,
t = time for flow (Q), s,
A = area of the specimen perpendicular to the direction of flow, $m^2(ft^2)$, which is equal to the inside cross-section area of the vertical cylinder,
h = measured hydraulic head loss from piezometers, m, and
R_T = temperature correction factor.

11.5 The permittivity calculated for the region of transient or turbulent flow conditions is called permittivity under non-linear flow conditions.

12. Report

12.1 Report the following information:

12.1.1 Identification and description of geotextile, including the manufacturing process and polymer type, its nominal thickness, and the mass per unit area.

12.1.2 Test conditions, that is, cross-section area of flow, normal stress conditions, values of applied hydraulic heads, and condition of deaired water.

12.1.3 For each applied normal load present the following data in tabular form for each specimen: applied normal load, applied hydraulic heads, measured hydraulic losses, measured flow rates, measured thicknesses, water temperatures and temperature correction factors for 20°C, flow conditions (laminar, transient, or turbulent), and calculated permittivities under load at 20°C.

12.2 Graphs of the hydraulic losses (*h*) values plotted as a function of flow velocities (V = Q/A) for each applied load as shown in Fig. 3, and the thickness values as a function of applied loads as shown in Fig. 4.

13. Precision and Bias

13.1 The precision and bias of the procedure in this test method are being established.

13.2 The value of the permittivity can be defined in terms of geotextile and conditions used during testing. Because of the lack of a reference method there are no direct data to determine bias.

14. Keywords

14.1 geotextile; hydraulic gradient; permittivity

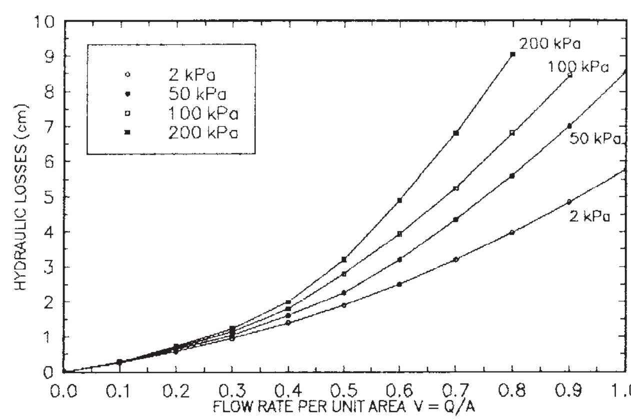


FIG. 3 Permittivity Behavior of Nonwoven Geotextile

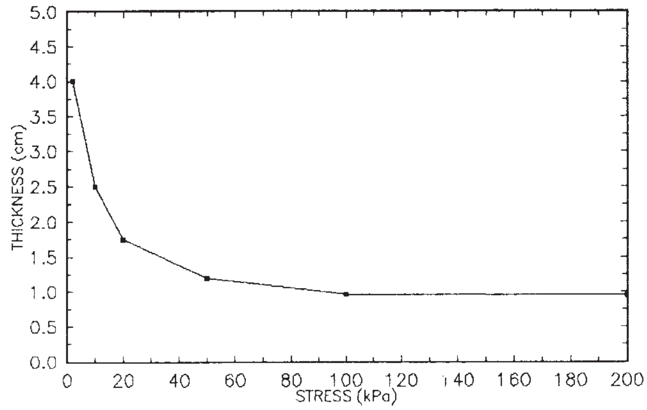


FIG. 4 Thickness in Function of Stress

APPENDIX

(Nonmandatory Information)

X1. CALIBRATION OF APPARATUS

X1.1 Calibrate the apparatus prior to its first use and when a modification has been made, and after each 100 experiments, to ensure that the apparatus is not the controlling agent for the water flow during a test.

X1.2 Lower the piston (*4*) inside the cylinder to compress the system (distributors and porous stones) prior to establishing a calibration curve.

X1.3 Establish a calibration curve by plotting the flow rate (*Q/A*) versus hydraulic head loss for the apparatus alone (with the wire meshes, the ball layers, and the perforated plates). The flow rate should be corrected using the temperature correction factor R_T. The permittivity of the porous stones must be at least ten times greater than the expected permittivity of geotextile.

X1.4 The calibration curve must be compared to the curve obtained with geotextile specimens installed in the apparatus at a compression level equal to 2 kPa to establish that the hydraulic head loss of the apparatus is not controlling the water flow.\