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

This standard is issued under the fixed designation D5493; 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]

D123 Terminology Relating to Textiles
D653 Terminology Relating to Soil, Rock, and Contained Fluids
D4354 Practice for Sampling of Geosynthetics and Rolled Erosion Control Products(RECPs) for Testing
D4439 Terminology for Geosynthetics
D4491/D4491M Test Methods for Water Permeability of Geotextiles by Permittivity
D4716/D4716M Test Method for Determining the (In-plane) Flow Rate per Unit Width and Hydraulic Transmissivity of a Geosynthetic Using a Constant Head
E11 Specification for Woven Wire Test Sieve Cloth and Test Sieves

## 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 D4439).

3.1.2 *hydraulic gradient, i, n*—the loss of hydraulic head per unit distance of flow, dh/dL (see Test Method D4716/D4716M).

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 D4439).

3.2 For the definitions of other terms relating to geotextiles, refer to Terminology D4439. For the definitions of textile terms, refer to Terminology D123. For the definitions of coefficient of permeability, refer to Terminology D653.

## 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.

[1] This test method is under the jurisdiction of ASTM Committee D35 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.

## 6. Apparatus

6.1 The apparatus is a constant head permeameter. General guidance on the hydraulic design of a constant head permeameter can be found in Test Methods D4491/D4491M.

6.2 The components installed around the test specimen are designed in such a way that a normal load can be applied uniformly on the entire flow surface without restraining significantly the flow rate. The permittivity of the apparatus, calculated using the calibration curve established in Section 10, shall be at least 10 times greater than the permittivity of the test specimen under the hydraulic conditions prevailing during a given test. However, the central deflection of the loading mechanism on the plane of the geotextile shall not exceed 0.025 mm while subjected to the maximum normal load applied during the test.

6.3 The recommended apparatus configuration is shown in Fig. 1:

6.3.1 An optimum flow diameter has been found to be 50 mm to minimize hydraulic side effects while ensuring an optimum rigidity of the loading mechanism.

6.3.2 A wire meshes, 1.0 mm in opening, complying with Specification E11 is installed as the contact surface on both sides of the test specimen.

6.3.3 Two rigid metallic plate with the geometry shown on Figure 2 act as a structural component on both sides of the wire meshes. The lower one is supported by the apparatus, while the upper one can move freely but is adjusted to the diameter of the flow channel.

6.3.4 The upper metallic plate is connected to a device capable of applying the requested normal load on the test specimen (dead loads, air piston or any suitable device). The mechanical connection between the upper metallic plate and the loading mechanism consists of four rods, 3 mm in diameter, distributed on a circle approximately 30 mm in diameter.

6.3.5 A dial indicator can be connected to the loading mechanism to monitor the specimen thickness during the test.

## 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 and the supplier (for example Practice D4354) 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.

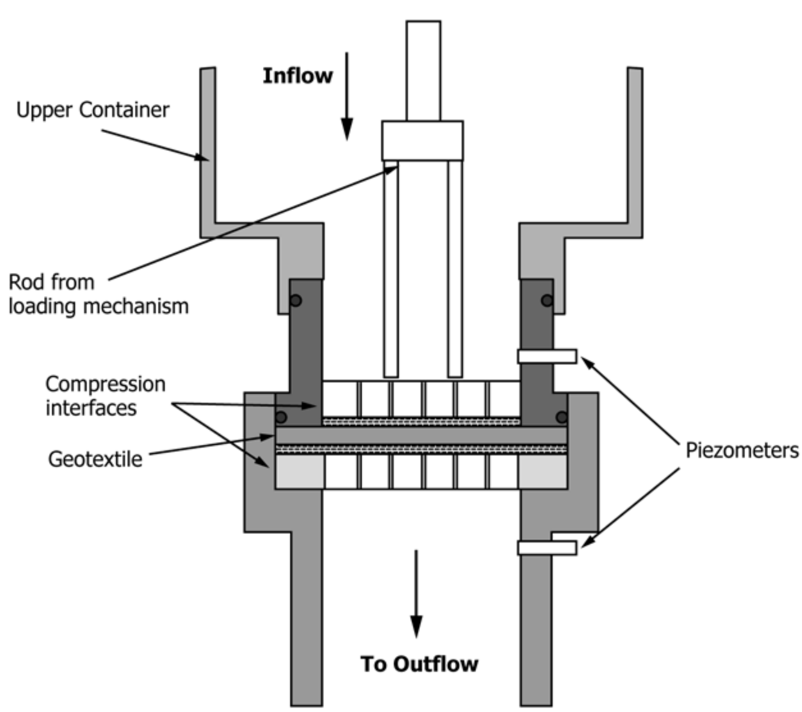


FIG. 1 Specimen Holder and Loading Mechanism

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.

**TABLE 1 Viscosity of Water Versus Temperature**

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

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

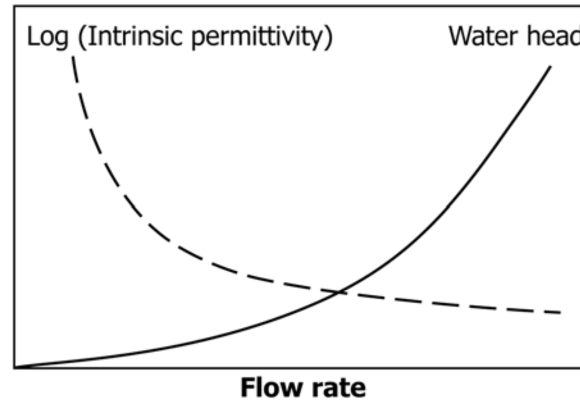


**FIG. 2 Hydraulic Calibration Curve**

9.3.2 Cut specimens shall fit the testing apparatus.

## 10. Calibrations

10.1 *Hydraulic Calibration:*

10.1.1 Run at least 3 tests without any geotextile specimen installed in the apparatus, each of them being ran with the system set to apply different normal loads spread over the equipment capability (that is, 2, 20, and 200 kPa). The specimen shall be replaced by a rigid material approximately 25 to 30 mm in diameter that will not restrain the flow (such as a 1 to 2 mm long section of a thick 25 mm PVC plastic pipe). For each test, measure the water heads corresponding to at least 10 different flow rates uniformly spread between 0 and the equipment capability.

10.1.2 Draw the 'Water Head versus Flow Rate' curve and calculate the intrinsic permittivity of the apparatus for each flow rate using Eq 2. Plot both curves on the same graph as shown on Fig. 2.

10.2 *Normal Load Calibration*—Use a convenient system to control the precision of the normal load applied on the geotextile. The normal load effectively applied shall be within 5 % of the targeted load.

10.3 *Thickness Measurement Calibration*—Although thickness measurement is not a mandatory requirement, if the thickness of the material is monitored, it shall be calibrated first. In that case, the central deflection requirement expressed in 6.2 shall be verified using the procedure presented below.

10.3.1 Install a metallic ring 50 mm in diameter (or the inner diameter of the flow channel), with a 1 mm wall and 10 mm thick in the sample holder in place of the geotextile.

10.3.2 Apply the minimum load that can be achieved with the equipment (that is, 2 kPa) and record the value provided by the dial indicator as the 'zero' for calibration purposes.

10.3.3 Apply by increments 10 different normal loads uniformly spread over the apparatus capability and record the corresponding values given by the dial indicator.

10.3.4 Plot the thickness versus load curve and verify that the deflection measured under 2, 20, and 200 kPa normal load are less than 0.025 mm.

## 11. Test Procedure

11.1 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.

11.2 Maintain the test specimen, underwater at all times prior to and during the test.

11.3 Allow the deaired water to flow from the bottom of the apparatus to the predetermined overflow located on the top of the upper section of the water tank using the drain tube as the water inlet.

11.4 Place the geotextile specimen in the apparatus in sequence as shown in Fig. 1.

11.5 Lower the piston until it reaches the upper metallic plate.

11.6 Apply a load equal to 2 kPa.

NOTE 2—Unless otherwise specified, the permittivity shall be measured under 2, 20, and 200 kPa. If a different normal load is required, the first applied normal load shall be the lightest one.

11.7 Continue to fill the tank from the outlet until the water level reaches the outlet level. 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 may lead to erroneous and non-reproducible test results.

11.8 Connect the water line to the inlet reservoir to run the test.

11.9 The seating period shall be long enough to reach a thickness variation of less than 0.0025 mm per minute.

11.10 Measure the flow rate under total (uncorrected) hydraulic heads of approximately 15, 25, 50, and 75 mm, or more in order to apply an actual (corrected) hydraulic head in the range of 10 to at least 50 mm. Conduct three flow rate measurements for each water head and verify that the difference between the lower and the higher value is less than 5 %.

11.11 Increase the normal load to reach the next requested normal load and repeat the flow measurements as described in 11.10.

11.12 Repeat steps 11.9 to 11.11 for three additional test specimens.

NOTE 3—If a reduction of permittivity is observed for a given product, it could be either caused by the product's behavior (sensitivity to the normal load) or by air clogging during the test. The following procedure can be used to assess whether air clogging has influenced the result or not: *(1)* apply a single normal load on the specimen; *(2)* measure its permittivity; *(3)* let the water flow through the specimen for a period of time equivalent to the total duration of the test, varying the water head in such a way that the hydraulic head history of the actual test will be reproduced; *(4)* repeat the permittivity measurement; and *(5)* compare the deviation between the two permittivity measurements.

## 12. Calculation

12.1 Use the calibration curve built in 10.1 to determine the water head correction DHQ to be considered for each individual flow rate measurement.

NOTE 4—A 'power' regression built with the values measured in 10.1 usually provides a very good tool to automate the water head correction.

12.2 Calculate the permittivity for each individual measurements using Eq 2.

$$\psi = Q \times R_t / [S(\Delta H - \Delta H_Q)] \tag{2}$$

where:

$Q$ = measured flow rate ($Q = V / t$, where $V$ = volume and $t$ = time),
$R_t$ = temperature correction factor,
$S$ = flow surface,
$\Delta H$ = measured water head, and
$\Delta H_Q$ = water head correction.

12.3 Plot the permittivity versus the corrected water head for each individual test specimen and determine the permittivity in the laminar region, which is constant up to a certain water head.

12.4 Determine the permittivity under a 50 mm water head using a best fit curve and reading the value corresponding to a 50 mm water head.

12.5 Calculate the averages and associated standard deviation (or coefficient of variation) for both values.

## 13. Report

13.1 Report the following information:

13.2 Report that the test was conducted according to Test Method D5493.

13.3 Report every relevant information available to describe the tested sample, including sample description, project name if applicable, nominal weight or thickness, structure and/or manufacturing process if available, etc.

13.4 Apparatus properties:
13.4.1 Flow surface,
13.4.2 Loading mechanism if different than the one described in 6.3, and
13.4.3 Dissolved oxygen content of the water.

13.5 Individual values, averages and standard deviations (or coefficients of variation) for each tested normal for both values:
13.5.1 Permittivity in the laminar region, and
13.5.2 Permittivity under a 50 mm water head.

13.6 Description of any departure from the above procedure.

## 14. Precision and Bias

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

14.2 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.

## 15. Keywords

15.1 geotextile; hydraulic gradient; normal load; permittivity; permittivity under load