Designation: D 4491 – 99a

Standard Test Methods for Water Permeability of Geotextiles by Permittivity[1]

This standard is issued under the fixed designation D 4491; 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 Department of Defense.

1. Scope

1.1 These test methods cover procedures for determining the hydraulic conductivity (water permeability) of geotextiles in terms of permittivity under standard testing conditions, in the uncompressed state. Included are two procedures: the constant head method and the falling head method.

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

1.3 *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:*

D 123 Terminology Relating to Textiles[2]

D 653 Terminology Relating to Soil, Rock, and Contained Fluids[3]

D 4439 Terminology for Geotextiles[4]

D 5199 Test Method for Measuring Nominal Thickness of Geotextiles and Geomembranes[4]

E 691 Practice for Conducting an Interlaboratory Study to Determine the Precision of a Test Method[5]

3. Terminology

3.1 *Definitions:*

3.1.1 *geotechnics, n*—the application of scientific methods and engineering principles to the acquisition, interpretation, and use of knowledge of materials of the earth's crust to the solution of engineering problems.

3.1.1.1 *Discussion*—Geotechnics embraces the fields of soil mechanics, rock mechanics, and many of the engineering aspects of geology, geophysics, hydrology, and related sciences.

3.1.2 *geotextile, n*—a permeable geosynthetic comprised solely of textiles.

3.1.3 *permeability, n*—the rate of flow of a liquid under a differential pressure through a material.

3.1.3.1 *Discussion*—The nominal thickness is used as it is difficult to evaluate the pressure on the geotextile during the test, thereby making it difficult to determine the thickness of the fabric under these test conditions.

3.1.4 *permeability, n—of geotextiles,* hydraulic conductivity.

3.1.5 *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.

3.1.6 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 definition of coefficient of permeability, refer to Terminology D 653.

4. Summary of Test Methods

4.1 These test methods describe procedures for determining the permittivity of geotextiles using constant head or falling head test procedures, as follows:

4.1.1 *Constant Head Test*—A head of 50 mm (2 in.) of water is maintained on the geotextile throughout the test. The quantity of flow is measured versus time. The constant head test is used when the flow rate of water through the geotextile is so large that it is difficult to obtain readings of head change versus time in the falling head test.

NOTE 1—Data has shown agreement between the falling and constant head methods of determining permittivity of geotextiles.[6] Selection of the test method, that is, constant or falling head, is left to the technician performing the test.

4.1.2 *Falling Head Test*—A column of water is allowed to flow through the geotextile and readings of head changes versus time are taken. The flow rate of water through the geotextile must be slow enough to obtain accurate readings.

5. Significance and Use

5.1 These test methods are considered satisfactory for acceptance testing of commercial shipments of geotextiles since

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

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[2] *Annual Book of ASTM Standards,* Vol 07.01.

[3] *Annual Book of ASTM Standards,* Vol 04.08.

[4] *Annual Book of ASTM Standards,* Vol 04.09.

[5] *Annual Book of ASTM Standards,* Vol 14.02.

[6] Data available from ASTM Headquarters. Request RR: D-35-1000.

the methods have been used extensively in the trade for acceptance testing.

5.1.1 In case of a dispute arising from differences in reported test results when using these test methods for acceptance testing of commercial shipments, the purchaser and the supplier should conduct comparative tests to determine if there is a statistical bias between their laboratories. Competent statistical assistance is recommended for the investigation of bias. As a minimum, the two parties should take a group of test specimens that are as homogeneous as possible and that are from a lot of material of the type in question. The test specimens should then be randomly assigned in numbers to each laboratory for testing. The average results from the two laboratories should be compared using Student's t-test for unpaired data and an acceptable probability level chosen by the two parties before the start of testing. If a bias is found, either its cause must be found and corrected, or the purchaser and the supplier must agree to interpret future test results in light of the known bias.

5.1.2 Permittivity is an indicator of the quantity of water that can pass through a geotextile in an isolated condition.

5.1.3 As there are many applications and environmental conditions under which a geotextile may be used, care should be taken when attempting to apply the results of these test methods to the field performance of a geotextile.

5.2 Since there are geotextiles of various thicknesses in use, evaluation in terms of their Darcy coefficient of permeabilities can be misleading. In many instances, it is more significant to evaluate the quantity of water that would pass through a geotextile under a given head over a particular cross-sectional area; this is expressed as permittivity.

5.3 If the permeability of an individual geotextile is of importance, a nominal coefficient of permeability, as related to geotechnical engineering, may be computed. By multiplying permittivity times the nominal thickness of the geotextile, as determined by Test Method D 5199, the nominal coefficient of permeability is obtained.

NOTE 2—The nominal thickness is used as it is difficult to evaluate the pressure on the geotextile during the test, thereby making it difficult to determine the thickness of the fabric under these test conditions.

6. Apparatus

6.1 The apparatus shall conform to one of the following arrangements:

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

6.1.2 The apparatus must be capable of being used as falling head apparatus.

6.2 In addition, the apparatus must not be the controlling agent for flow during the test. It will be necessary to establish a calibration curve of volumetric flow rate versus head for the apparatus alone in order to establish compliance with this requirement (see 11.7).

6.3 Refer to Fig. 1 for a schematic drawing of a device that conforms to all of the above requirements. The device consists of an upper and lower unit, which fasten together. The geotextile specimen is positioned in the bottom of the upper unit. There is a standpipe for measuring the constant head value. The rotating discharge pipe allows adjustment of the head of water at the bottom of the specimen.[7]

NOTE 3—The location of the manometer for measuring the headloss in either the constant head or falling head method shall be located directly beneath the specimen. For the device shown in Fig. 1, this may be accomplished by drilling a small (3mm; ⅛ in) diameter hole in the top plate of the bottom reservoir tank directly beneath the specimen, and attaching the manometer to this plate.

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 4—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*—Take for the laboratory sample a full roll width sample extending a minimum of 1 m along the selvage from each sample roll such that the requirements of Section 9 can be met. 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 inner and outer wrap material may be used.

8. Test Water Preparation

8.1 To provide reproducible test results, the test water shall be de-aired under a vacuum of 710 mm (28 in.) of mercury (Hg) for a period of time to bring the dissolved oxygen content down to a maximum of six parts per million. The dissolved oxygen content may be determined by either commercially available chemical kits or by a dissolved oxygen meter.

NOTE 5—The de-airing system may be either 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.

8.2 Allow the de-aired water to stand in a closed storage tank under a slight vacuum until room temperature is attained.

9. Specimen Preparation

9.1 To obtain a representative value of permittivity, take four specimens from each full width laboratory sample as described below.

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

9.2.1 Select four specimens equally spaced along a diagonal line extending from the lower left hand corner to the upper right hand corner of the laboratory sample. Neither specimen A or D shall be closer to the corner of the laboratory sample than 200 mm (8 in.).

[7] Detailed drawings and a materials list for construction are available at a nominal cost through ASTM Headquarters. Request adjunct No. ADJD4491.

FIG. 1 Constant and Falling Head Permeability Apparatus

9.2.2 Take specimen A at the center of the sample, B at one corner (center located 200 mm (8 in.) 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.

9.2.3 Cut specimens shall fit the testing apparatus, for example, 73 mm (2.87 in.) in diameter for the device illustrated in Fig. 1.

9.3 Condition the specimen by soaking in a closed container of de-aired water, at room conditions, for a period of 2 h. The minimum specimen diameter is to be 50 mm (2 in.).

NOTE 6—If the illustrated device is used, the specimens are attached to the specimen ring by contact cement.

10. Operator Process Control

10.1 Prepare four specimens of Standard U.S. Mesh Sieve to fit the test apparatus.

10.2 Following Section 11 or Section 13, depending on the method to be used for the geotextile specimens, perform testing on each mesh specimen.

10.3 Based on an interlaboratory test, involving seven

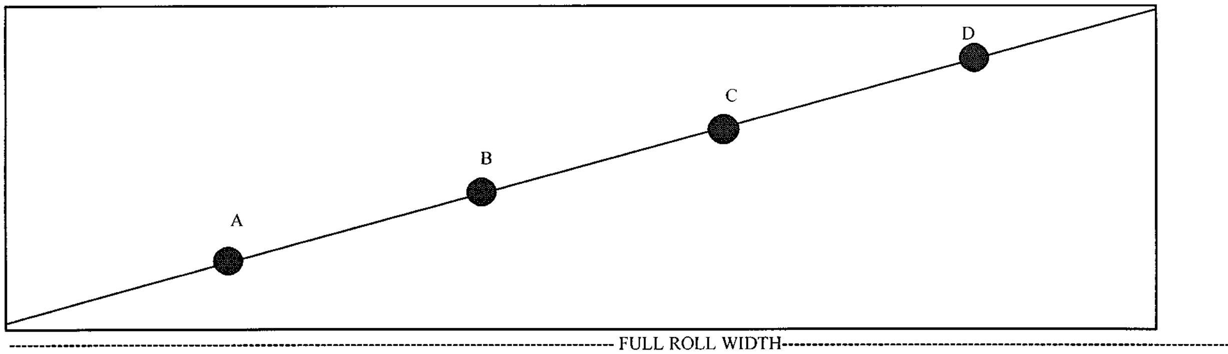

FIG. 2 Specimen Locations

laboratories, the permittivity of No 200 Standard US Mesh Sieve material has been determined to be 5.00 s^{-1}, with a standard deviation of 0.65.

10.3.1 New operator process control shall be performed until it is demonstrated that the operator is proficient in test performance as demonstrated by obtaining the value of permittivity stated in 10.3, plus or minus two standard deviations.

10.3.2 Following initial proficiency testing, the operator shall perform process control testing on a semi-annual basis.

CONSTANT HEAD TEST

11. Procedure

11.1 Assemble the apparatus with the specimen in place.

11.2 Open the bleed valve and backfill the system through the standpipe or discharge pipe, with de-aired water. Backfilling in this manner forces any trapped air out of the system and the geotextile.

NOTE 7—The water should be at the bottom level of the specimen at the time of specimen installation.

11.3 Close the bleed valve once water flows from it. Continue to fill the apparatus with de-aired water until the water level reaches the overflow.

11.4 With water flowing into the system through the water inlet, adjust the discharge pipe along with the rate of water flowing into the apparatus to obtain a 50-mm (2-in.) head of water on the geotextile. This is the head (h) under which the test will be performed initially.

11.5 Submerge a tube attached to a source of vacuum to just above (10 mm (0.5 in.)) the surface of the geotextile, moving the tube gently over the surface while applying a slight vacuum in order to remove any trapped air that may be in or on the specimen. If necessary, readjust the head to 50 mm (2 in.) after removing the vacuum.

11.6 Record the values of time (t), quantity of flow (Q) as collected from the discharge pipe, and water temperature (T), holding the head at 50 mm (2 in.). Make at least five readings per specimen and determine an average value of permittivity for the specimen.

NOTE 8—The quantity of flow may be measured in millilitres and then converted to cubic millimetres for the computation of permittivity (1 mL = 1000 mm^3).

11.7 After the first specimen has been tested under a 50-mm (2-in.) head, using the same specimen, start with a 10-mm (3⁄8-in.) head and repeat the procedure. Increase the head by 5 mm (3⁄16 in.) after every five readings. Increase the head until a 75-mm (3-in.) head is reached. Use this data to determine the region of laminar flow. Plot volumetric flow rate, v, (where v equals Q/At, values defined in 12.1) versus head. The quantity of flow (Q) should be corrected to 20°C (68°F). The initial straight line portion of the plot defines the region of laminar flow. If the 50-mm head is outside the region of laminar flow, repeat the test procedure using the head of water in the mid-region of laminar flow.

11.7.1 Compare the data from 10.7 with the apparatus calibration curve referred to in 6.2. The apparatus calibration plot of volumetric flow rate versus head should plot well above the same plot for the geotextile specimen (see Fig. 3). If the specimen curve intersects the calibration curve, the apparatus is controlling the flow through the geotextile rather than the structure of the geotextile itself. In such an instance, modify the apparatus by enlarging the discharge pipe so that the device does not control the flow.

11.8 Repeat 11.1-11.6 with the remaining specimens.

12. Calculation

12.1 Calculate the permittivity, ψ, as follows:

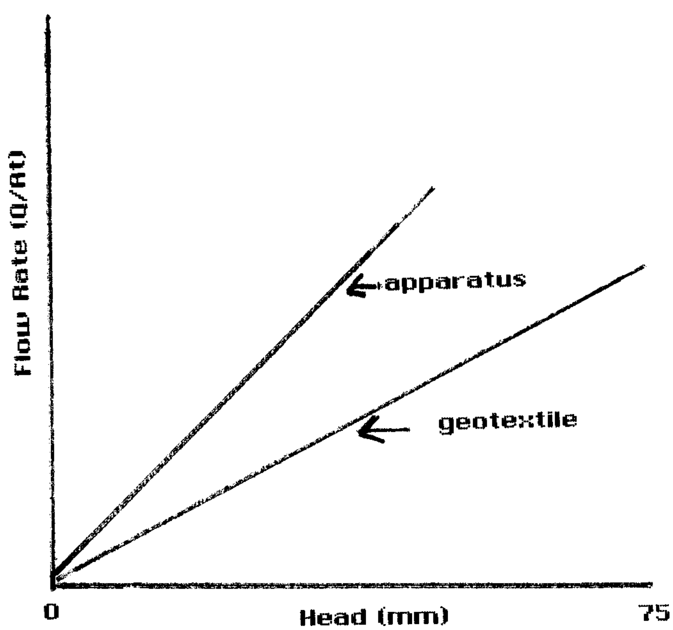

FIG. 3 Calibration Curve

$$\psi = QR_t/hAt \quad (1)$$

where:

ψ = permittivity, s^{-1},
Q = quantity of flow, mm^3,
h = head of water on the specimen, mm,
A = cross-sectional area of test area of specimen, mm^2,
t = time for flow (Q), s, and
R_t = temperature correction factor determined using Eq 2.

$$R_t = u_t/u20_c \quad (2)$$

where:

u_t = water viscosity at test temperature, millipoises, as determined from Table 1, and
$u20_c$ = water viscosity at 20°C, mP.

12.2 Calculate the permittivity for the five sets of readings per specimen at the 50 mm (2 in.) head.

12.3 Determine the average permittivity for the individual specimen tests.

12.4 Determine the average permittivity for the four specimens tested.

12.5 Determine the standard deviation and coefficient of variation for the four specimens tested.

FALLING HEAD TEST

13. Procedure

13.1 Proceed as in 11.1 through 11.5.

NOTE 9—**Caution:** The falling head procedure should not be performed for geotextiles with a permittivity greater than 0.05 sec^{-1} unless the system is equipped with an automated data acquisition system that would measure elapsed time for the drop in head from 80 to 20 mm on the manometer.

13.2 Adjust the discharge pipe so that its outlet is slightly above the level of the specimen.

TABLE 1 Viscosity of Water Versus Temperature

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

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

13.3 By increasing the flow from the water supply, adjust the water level to 150 mm (6 in.). Once the water is at this level, shut off the water supply and allow the water level to fall to 80 mm (3.2 in.). At this point, start the stop watch and determine the time for the water level to fall to the 20-mm (4⁄5-in.) level. Record the inside diameter (d) of the upper unit, the diameter (D) of the exposed portion of the specimen, and the water temperature (T). Make at least five readings per specimen. All measurements in 13.3 are in relation to the outlet water.

13.4 Repeat the procedure on the remaining specimens.

14. Calculation

14.1 Calculate the permittivity, ψ, as follows:

$$\psi = [(a/At)\ 1n\ (h_0/h_1)]R_t \quad (3)$$

where:

A = $\pi D^2/4$—cross-sectional test area of specimen, mm^2,
a = $\pi d^2/4$—cross-sectional area of standpipe above specimen,
t = time for head to drop from h_0 to h_1, s,
h_0 = initial head (80 mm),
h_1 = final head (20 mm), and
R_t = temperature correction factor determined from Eq 2.

14.2 Repeat calculations for the five sets of data per specimen. Determine the average permittivity for the individual specimens tested.

15. Report

15.1 The report shall include the following:

15.1.1 State that the specimens were tested in accordance with this standard. Describe the material or product sampled and the method of sampling used,

15.1.2 Procedure used,

15.1.3 Any deviations from the standard test method, such as a head other than 50 mm for the constant head procedure,

15.1.4 The following permittivity results for the four specimens from each swatch in the laboratory sample:

15.1.4.1 Observations on each individual specimen,

15.1.4.2 Average permittivity,

NOTE 10—To express permittivity in litres per unit area per unit head per time ($1/m^3$/min), multiply the results of 12.4 or 14.2 by 6 × 10^4.

15.1.4.3 Standard deviation for the individual observations, and

15.1.4.4 Coefficient of variation for the four observations, and

15.1.4.5 A plot of flow rate versus head for the laminar flow test in the constant head procedure.

16. Precision and Bias

16.1 *Precision*:

16.1.1 *Interlaboratory Test Program*—An interlaboratory study of this test method was performed in 1999. Three sets (four test specimen each) which were randomly drawn from each of two materials, one woven and one nonwoven, were tested for both permittity. Five laboratories performed the tests using the constant head procedure while three laboratories used the falling head procedure. The design of the experiment, similar to that of Practice E 691, and a within-between analysis of the data are given in ASTM Research Report No. D-35 1000.

16.1.2 *Test Result*—The precision information is given in Table 2. The precision values are for the permittivity test results and are in terms of coefficients of variation, CV%.

16.2 *Bias*—The procedure in this test method has no bias because the value of that property can only be defined in terms of a test method.

17. Keywords

17.1 constant head; falling head; geotextiles; permeability; permittivity

TABLE 2

Procedure → Statistic	Constant Head, Woven	Constant Head, Nonwoven	Falling Head, Woven	Falling Head, Nonwoven
Average Permittivity, s^{-1}	0.147	2.50	0.245	2.27
Within Laboratory Repeatability Limit, CV%Sr	13.8	7.6	36.7	4.1
Between Laboratory Reproducibility Limit, CV%SR	38.1	10.2	62.8	16.4
95 % Confidence Limit, Within Laboratory Repeatability, CV%r	38.5	21.2	62.7	11.4
95 % Confidence Limit, Between Laboratory Reproducibility, CV%R	107	28.6	176	46.0