Designation: D4716/D4716M – 22

Standard Test Method for Determining the (In-plane) Flow Rate per Unit Width and Hydraulic Transmissivity of a Geosynthetic Using a Constant Head[1]

This standard is issued under the fixed designation D4716/D4716M; 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 procedure for determining the flow rate per unit width within the manufactured plane of geosynthetics under varying normal compressive stresses and a constant head. The test is intended primarily as an index test but can be used also as a performance test when the hydraulic gradients and specimen contact surfaces are selected by the user to model anticipated field conditions.

1.2 This test method is limited to geosynthetics that allow continuous in-plane flow paths to occur parallel to the intended direction of flow.

1.3 The values stated in either SI units or inch-pound units are to be regarded separately as standard. The values stated in each system are not necessarily exact equivalents; therefore, to ensure conformance with the standard, each system shall be used independently of the other, and values from the two systems shall not be combined.

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

1.5 *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.*

2. Referenced Documents

2.1 *ASTM Standards:*[2]

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

D5092/D5092M Practice for Design and Installation of Groundwater Monitoring Wells

D5199 Test Method for Measuring the Nominal Thickness of Geosynthetics

D6574/D6574M Test Method for Determining the (In-Plane) Hydraulic Transmissivity of a Geosynthetic by Radial Flow

D7361 Test Method for Accelerated Compressive Creep of Geosynthetic Materials Based on Time-Temperature Superposition Using the Stepped Isothermal Method

E691 Practice for Conducting an Interlaboratory Study to Determine the Precision of a Test Method

3. Terminology

3.1 *Definitions:*

3.1.1 *geocomposite, n*—a product fabricated from any combination of geosynthetics with geotechnical materials or other synthetics which is used in a geotechnical application. **(D4439)**

3.1.2 *geonet, n*—a geosynthetic consisting of integrally connected parallel sets of ribs overlying similar sets at various angles for planar drainage of liquids or gases. **(D4439)**

3.1.3 *geosynthetic, n*—a planar product manufactured from polymeric material used with soil, rock, earth, or other geotechnical engineering related material as an integral part of a man-made project, structure, or system. **(D4439)**

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

[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.

3.1.4.1 *Discussion*—Geotechnics embraces the fields of soil mechanics, rock mechanics, and many of the engineering aspects of geology, geophysics, hydrology, and related sciences. **(D4439)**

3.1.5 *geotextile, n*—a permeable geosynthetic comprised solely of textiles. **(D4439)**

3.1.6 *gravity flow, n*—flow in a direction parallel to the plane of a geosynthetic driven predominantly by a difference in elevation between the inlet and outflow points of a specimen.

3.1.6.1 *Discussion*—The pressure at the outflow is considered to be atmospheric. **(D4439)**

3.1.7 *head (static), n*—the height above a standard datum of the surface of a column of water (or other liquid) that can be supported by a static pressure at a given point. The static head is the sum of the elevation head and the pressure head. **(D5092/D5092M)**

3.1.8 *hydraulic gradient, i, n*—the loss of hydraulic head per unit distance of flow, dh/dL. **(D4439)**

3.1.9 *hydraulic transmissivity, θ* (L^2 T^{-1}), *n*—for a geosynthetic, the volumetric flow rate per unit width of specimen per unit gradient in a direction parallel to the plane of the specimen.

3.1.9.1 *Discussion*—"Transmissivity" is technically applicable only to saturated, laminar hydraulic flow conditions. **(D4439)**

3.1.10 *index test, n*—a test procedure that may contain known bias but which may be used to establish an order for a set of specimens with respect to the property of interest. **(D4439)**

3.1.11 *in-plane flow, n*—fluid flow confined to a direction parallel to the plane of a geosynthetic. **(D4439)**

3.1.12 *laminar flow, n*—flow in which the head loss is proportional to the first power of the velocity. **(D4439)**

3.1.13 *normal stress* (FL^{-2}), *n*—the component of applied stress that is perpendicular to the surface on which the force acts. **(D4439)**

3.1.14 *performance test, n*—a test that simulates in the laboratory as closely as practical selected conditions experienced in the field and which can be used in design. **(D4439)**

3.1.15 *pressure flow, n*—flow in a direction parallel to the plane of a geosynthetic driven predominantly by a differential fluid pressure. **(D4439)**

3.1.16 *turbulent flow, n*—that type of flow in which any water particle may move in any direction with respect to any other particle, and in which the head loss is approximately proportional to the second power of the velocity. **(D4439)**

3.1.17 For definitions of terms relating to geosynthetics, refer to Terminology D4439.

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *steady flow, n*—flow conditions that do not vary with time.

3.2.2 *uniform flow, n*—conditions where the flow area and the mean velocity in the direction of flow are constant.

4. Summary of Test Method

4.1 The flow rate per unit width is determined by measuring the quantity of water that passes through a test specimen in a specific time interval under a specific normal stress and a specific hydraulic gradient. The hydraulic gradient(s) and specimen contact surfaces are selected by the user either as an index test or as a performance test to model a given set of field parameters as closely as possible. Measurements may be repeated under increasing normal stresses selected by the user.

4.1.1 The hydraulic transmissivity is the flow rate per unit width divided by the associated hydraulic gradient.

5. Significance and Use

5.1 This test method is intended either as an index test or as a performance test used to determine and compare the flow rate per unit width of one or several candidate geosynthetics under specific conditions.

5.2 This test method may be used as an index test for acceptance testing of commercial shipments of geosynthetics, but caution is advised since information on between-laboratory precision of this test method is incomplete. Comparative tests as directed in 5.2.1 may be advisable.

5.2.1 In case of a dispute arising from differences in reported test results when using this test method for acceptance testing of commercial shipments, the purchaser and the supplier should first confirm that the tests were conducted using comparable test parameters including specimen conditioning, normal stress, seating period, hydraulic gradient, test water temperature, etc., then 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 homogenous as possible and that are formed from a lot of the material of the type in question. The test specimens should then be randomly assigned in equal numbers to each laboratory for testing. The average results from the two laboratories should be compared using the Student's *t*-test for unpaired data and an acceptable probability level chosen by the two parties before the testing is begun. If bias is found, either its cause must be found and corrected or the purchaser and supplier must agree to interpret future test results in light of the known bias.

6. Apparatus

6.1 A schematic drawing of an assembly is shown in Fig. 1. The individual components and accessories are as follows:

6.1.1 *Base*—A sturdy metal base with smooth, flat bottom and sides capable of holding a test specimen of sufficient area and thickness. All seams between the bottom surface and sides of the base must be watertight and not inhibit in-plane flow of water through the specimen. For geotextile testing, all surfaces of the base in contact with the specimen shall be covered by a thin layer of rubber material of low compressibility in order to ensure a tight seal.

6.1.2 *Reservoir*—A plastic, glass, or metal water reservoir extending the full width of the base. The height of the reservoir shall be at least equal to the total length of the specimen. The

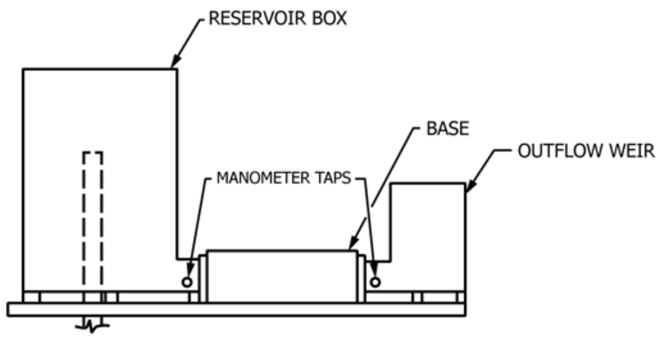

FIG. 1 A Constant Head (In-Plane) Flow Rate Testing Device

reservoir shall have provision for maintaining a constant water level at any of several elevations.

6.1.3 *Loading Mechanism*—Capable of sustaining a constant normal compressive stress on the specimen ranging from 10 kPa [1.45 psi] to at least 500 kPa [70 psi] on a 305 by 305 mm [12 by 12 in.] loaded area with an accuracy of ±1 %. The use of static weights, pneumatic bellows systems, or piston-applied stresses meeting the above conditions may be considered sufficient for use in this test.

6.1.4 *Outflow Weir*—A plastic, glass, or metal reservoir extending the full width of the base at the outlet side of the specimen having, at the opposite side, a rectangular weir at an elevation higher than the elevation of the upper surface of the specimen.

NOTE 1—The weir is used to sustain the steady, constant head condition on the outflow side of the specimen. For small discharge conditions, a narrow rectangular or triangular V-notch weir may be warranted.

6.1.5 *Outflow Collection*—A catch trough extending the entire width of the base is used for collection and measurement of the outflow from the specimen.

6.1.6 *Rubber Substrate/Superstrate (optional)*—Rubber sheets cut to fit the base may be used to model soil adjacent to the geosynthetic on one or both sides of the specimen if desired. The compressibility and thickness of the rubber layer should be selected such that it adequately represents the soil being modeled. The material selected should not allow continuous flow channels to exist through or around the rubber layer. These layers shall extend the entire length and width of the base. The thickness of the rubber layers shall be at least twice the thickness of the geosynthetic specimen to be tested.

6.1.6.1 Compare the uncompressed thickness measured prior to use with the thickness measured at least one hour after use. If the thickness decreases by 20 % or more, or if permanent indentations or damage are evident in the sheet, discard the sheet and retest using a new sheet.

6.1.7 *Thickness Monitoring Device (optional)*—In the form of a dial gauge and the like may be used to monitor the change in the thickness of the geosynthetic specimen in the testing device under various applied normal stresses.

6.1.8 *Manometers*—Open manometers are located at the inlet and outlet ends of the specimen in the reservoir box and outflow weir respectively (see Fig. 1). The manometer taps are placed at the same level as the base of the specimen as close to the specimen ends as practical. Extend the manometers with clear tubing to a height at least as high as the maximum water level in the reservoir box.

NOTE 2—The use of a pressure transducer(s) is recommended for measuring the pressure head when testing at hydraulic gradients less than 0.10. Use a transducer(s) with an accuracy of ±1 mm [±0.04 in.].

6.1.9 *Thermometer*—For measuring the water temperature to an accuracy of 0.2 °C.

6.1.10 *Calipers*—For measuring the width of test specimens that are narrower than the standard 300 mm [12 in.] width with an accuracy of 1 mm.

6.2 In addition, the apparatus must not be the controlling agent for flow during the test. It will be necessary to establish calibration curves of volumetric flow rate versus gradient for the apparatus alone using rigid, open channel substitutes (calibration blocks) representing the range of geosynthetic thicknesses to be tested in order to establish compliance with this requirement. (See Annex A1.)

7. Sampling

7.1 *Lot Sample*—Divide the product into lots, and for a lot to be tested take the lot sample as directed in Practice D4354.

7.2 *Laboratory Sample*—Consider the units in the lot sample as the units in the laboratory sample. For the laboratory sample, take a full-width swatch of sufficient length along the roll edge so that the requirements of 7.3 – 7.5.3 can be met.

7.3 *Test Specimens – Geotextiles*—Geotextiles should be tested in accordance with Test Method D6574/D6574M.

7.4 *Test Specimens – Geonets*—For acceptance testing, remove two specimens from each unit in the laboratory sample with the longer dimension parallel to the geonet direction (for example, machine or cross-machine direction) to be tested. The two test specimens are normally taken one third in from each edge of the roll width sample swatch, but may be taken at two other locations at the discretion of the user and noted in the report. For performance testing, the number of test specimens is selected by the user. If one test specimen is requested for performance testing, it is normally taken from the center of the sample swatch, but may be taken at two other locations at the discretion of the user and noted in the report.

7.4.1 Make the geonet specimen width 305 mm [12.0 in.]. Make the specimen length at least 350 mm [14 in.], or the length to allow the specimen to extend into the reservoir and weir a distance of 25 mm [1 in.], whichever is greater.

7.5 *Test Specimens – Geocomposites*—For acceptance testing, remove two specimens from each unit in the laboratory sample with the longer dimension parallel to the geocomposite direction (for example, machine or cross-machine direction) to be tested. The two test specimens are normally taken one third in from each edge of the roll width sample swatch, but may be taken at two other locations at the discretion of the user and noted in the report. For performance testing, the number of test specimens is selected by the user. If one test specimen is requested for performance testing, it is normally taken from the center of the sample swatch, but may be taken at two other locations at the discretion of the user and noted in the report.

7.5.1 For geocomposites manufactured with the full product width less than 305 mm [12.0 in.], the specimen width is equal to the manufactured product width. The specimen length is at least 350 mm [14 in.], or the length to allow the specimen to extend into the reservoir and weir a distance of 25 mm [1 in.], whichever is greater.

NOTE 3—The actual length of the geocomposite specimen may have an influence on the measured head losses and associated gradients; therefore, the specimen length of 350 mm [14 in.] will be considered standard. In any case, always report the actual specimen length used.

7.5.2 For geocomposites manufactured with a full product width 305 mm [12.0 in.] or greater, the specimen width is 300 mm [12 in.] unless the product cannot be cut to width without altering the product structure.

7.5.3 For geocomposites consisting of two or more different geosynthetic components, determine the specimen dimensions for each individual material in accordance with the applicable subsection, 7.3, 7.4, or 7.5.2. The minimum dimension of the specimens shall then be dictated by the component requiring the largest minimum size. This requirement does not apply for components sized per 7.5.1, which have manufactured widths less than 305 mm [12.0 in.].

8. Test Parameter Selection

8.1 *Selection of Substrate and Superstrate:*

8.1.1 *Index Testing*—For acceptance testing, the contact surfaces should be prescribed by the material specification. In the absence of a specification, use rigid sub and superstrates to minimize the variables impacting the test results.

8.1.2 For performance testing, the nature of the material in contact with the geosynthetic in the field should be modeled. A rigid platen on one or both sides of the specimen simulates similarly rigid surfaces (such as concrete walls or stiff geomembranes) where intrusion into the geosynthetic openings or pore spaces is not anticipated. Where intrusion is expected (as is the case for a geotextile in contact with soil or a geonet/geotextile/soil section) a layer of rubber membrane or representative soil may be placed between the platen and the geosynthetic specimen.

NOTE 4—Tests performed using site-specific soils are recommended when the end use of the material is known. The long-term effect of soil clogging should be considered when performing tests described in this test method.

8.2 *Gradient Selection:*

8.2.1 *Index Testing*—For acceptance testing, the test gradients should be prescribed by the material specification. In the absence of a specification, use three gradients selected from the following values: 0.05, 0.10, 0.25, 0.50, and 1.0.

8.2.2 *Performance Testing*—Select a test hydraulic gradient that is appropriate for the end use of the material and for specific field conditions. When specific field conditions are not known, use one of the following recommended gradients as well as at least two lesser gradients.

8.2.2.1 A maximum hydraulic gradient of 1.0 is suggested for tests intended to model gravity flow conditions.

8.2.2.2 A maximum hydraulic gradient of 0.1 is suggested for tests intended to model pressure flow conditions.

8.3 *Selection of the Applied Normal Compressive Stresses:*

8.3.1 *Index Testing*—For acceptance testing, the applied normal compressive stress(es) should be prescribed by the material specification. In the absence of a user or supplier specification, perform flow rate testing using a minimum of three applied normal stresses selected from the following values: 10, 25, 50, 100, 250, and 500 kPa [1.45, 3.63, 7.26, 14.51, 36.28, and 72.55 psi].

8.3.2 For performance testing, select the minimum and maximum normal stress to be applied as to model the specific field conditions. Perform the tests using a minimum of three applied normal stresses, selecting at least one value greater and one value less than the known design stress value.

8.3.2.1 Where the design or maximum normal compressive stress for a particular application is known, it may be sufficient to test the specimen under a single stress. This option should only be used when selected by the user or product specifier.

9. Procedure

9.1 Place the specimen substratum, if any, on the test device base. For test sections where the substratum consists of another geosynthetic, the interface between the substratum and the base should be sealed to prevent water from flowing under the substratum when this potential exists.

9.2 Trim the test specimen to the dimensions prescribed in 7.3 – 7.5 and then place the test specimen over the substratum, ensuring that all wrinkles, folds, etc., are removed.

9.2.1 Seal the sides of the specimen parallel to the direction of flow by wrapping the test specimen in a thin sheet of low compressibility plastic or rubber membrane, using a cast-in-place rubber or wax edge seal, or other measure (to prevent side leakage). This precaution may not be warranted for test specimens that are rectangular in profile, placed between rigid surfaces, and cut to fit snugly against the sides of the base.

NOTE 5—The elimination of leakage paths along the sides of the test specimen and along the loading tray adjacent to the upper surface of the specimen merits close attention when testing geotextile materials. The user is cautioned of the relatively high variability (see 12.1) in the test results that may be directly related to the laboratory's ability to address these fugative flows.

9.3 Place the desired superstratum, if any, over the test specimen in a similar manner. For test sections where the superstratum consists of another geosynthetic, the interface between the superstratum and the top plate should be sealed to prevent water from flowing over the superstratum when this potential exists.

9.4 Seat the top plate (platen) on the test assembly applying a small seating stress of 5 to 10 kPa [0.73 to 1.45 psi], and slowly fill the reservoir with water allowing water to flow through the test specimen. From this point forward, the specimen must be kept saturated at all times.

NOTE 6—For test devices or test sections, or both, where the test specimens are not placed into a loading tray that already contains water (which allows for expulsion of trapped air from the test specimen), a pre-flush is recommended to expel air from the test specimen. This step entails raising the water level in the reservoir to a gradient of approximately 0.5 and allowing the flow to continue until air bubbles no longer are visibly exiting the weir end of the test specimen.

9.4.1 The test water should be maintained at 21 ± 2 °C [70 ± 4 °F] throughout the test duration.

9.4.2 Visually check for preferential flow paths along the boundaries of the test specimen. If such flows are observed, re-seat or replace the test specimen as required.

NOTE 7—The use of deaired water is recommended for testing geotextiles and may be a consideration for test sections that include geotextiles where dissolved oxygen may influence the test results. Refer to Test Methods D4491/D4491M for details regarding deaired water.

9.5 Seat the specimen under the minimum normal compressive stress for a minimum period of 15 min.

9.5.1 The minimum seating period suggested may not be sufficient for acceptance testing of geosynthetics that exhibit time-dependent structural instability or other compressive response that significantly impacts the flow rate for stresses sustained longer than 15 min. The seating period selected should be based on long-term compression testing data at comparable stress levels.

9.5.2 For performance testing, seating periods may have to be extended for a considerable length of time in order to determine the minimum or "long-term" flow rate per unit width. This is especially true for geosynthetics and sections including soils that exhibit compression creep or other long-term deformation.

9.5.2.1 An optional, non-mandatory test method for accelerating the time required to perform long-term seating period tests, referred to as "thickness-controlled transmissivity," is detailed in Appendix X2.

9.6 After the seating period has elapsed, fill the reservoir to the level corresponding to the hydraulic gradient selected for the test.

9.6.1 Determine the system hydraulic gradient by computing the difference in water elevations between the reservoir and weir manometers and dividing this value by the length of the specimen subjected to the normal compressive stress. For most specimens this length will be 305 mm [12.0 in.]. Adjust the elevation of the water level in the reservoir box to change the system gradient.

9.7 Measure and record the water temperature to 0.2 °C.

9.8 Once steady flow through the specimen is observed, allow at least 0.5 L of water to flow through the specimen then measure the flow rate using Table 1 as a guide for the minimum collection volumes and maximum collection time. Obtain at least three flow rate measurements.

9.9 Increase the normal compressive stress and repeat the procedure outlined in 9.5 – 9.8 until the maximum desired stress is reached.

9.10 Compare flow rate data for each test to the flow rate data plotted on the appropriate calibration block curve for the device. For a given flow rate, if the hydraulic gradient value for the calibration block is more than 5 % of the corresponding gradient for the geosynthetic, then the test data is invalid and the device cannot be used to evaluate the test condition modeled.

9.11 Repeat the procedure 9.1 – 9.9 on the remaining test specimens.

10. Calculation

10.1 Calculate the flow rate per unit width or transmissivity values, or both, stipulated by the user for each test specimen per this section. The test result is the average of the results for the individual test specimens tested per the pertinent section in Section 7.

10.2 Calculate the flow rate per unit width, q_w, as follows:

$$q_w = R_t \ (Q_t / t \ W) \quad (1)$$

where:

q_w = flow rate per unit width, m^3/s-m [gpm/ft],
Q_t = measured quantity of water collected during collection time, t,
t = collection time, s,
W = width of specimen, 0.304 m [1.0 ft] or use the measured test specimen width for specimens that are narrower than the standard specimen width, and
R_t = temperature correction factor per Table 2.

10.2.1 Calculate the average of the three flow rate measurements obtained at each load and gradient.

10.2.2 Results can be expressed as a plot of flow rate per unit width versus hydraulic gradient (see Fig. 2) or versus normal compressive stress (see Fig. 3).

10.3 Calculate the hydraulic transmissivity, θ, as follows:

$$\theta = (R_t Q_t L)/W H \quad (2)$$

where:

θ = hydraulic transmissivity, m^2/s,
R_t = temperature correction factor per Table 2,
Q_t = measured average quantity of fluid discharged per unit time, m^3/s,
L = length of specimen subjected to the normal compressive stress. Do not consider the length of the specimen that extends into the reservoir or weir,
W = width of the specimen, m, and
H = difference in total head across the specimen, m.

10.3.1 Results can be presented as a plot of hydraulic transmissivity versus normal compressive stress (see Fig. 4).

TABLE 1 Flow Rate Measurement Criteria

Flow Rate LPM	Minimum Volume Litres	Minimum Time	Note
<0.03	NA	15 min	Confirm steady flow over weir for very low flow rates
0.03<FR<10	0.5	NA	
>10	NA	0.5 (30 s)	Apply apparatus head loss correction per 9.10

TABLE 2 Correction Factor R_t for the Viscosity of Water

Temperature °C	R_t
19	1.025
20	1.000
21	0.976
22	0.953
23	0.931

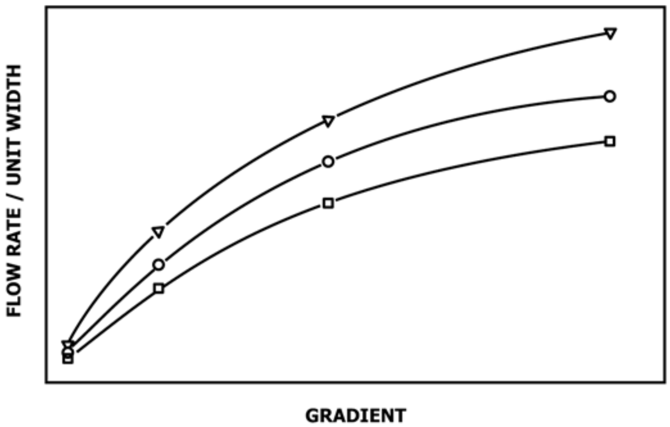

FIG. 2 Typical Plot of Flow Rate per Unit Width versus Hydraulic Gradient Under Several Normal Compressive Stresses

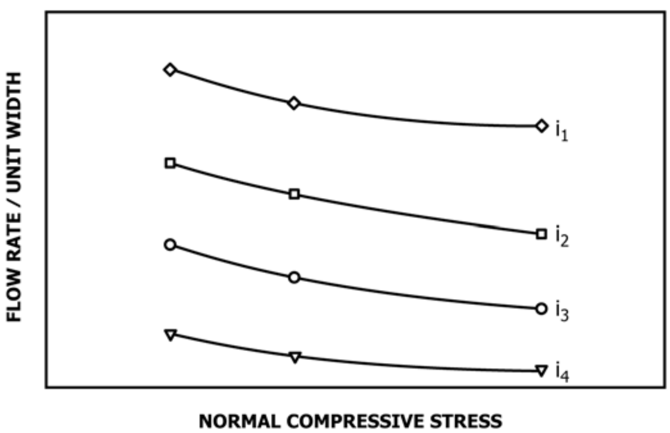

FIG. 3 Typical Plot of Flow Rate per Unit Width versus Normal Compressive Stress at Several Hydraulic Gradients

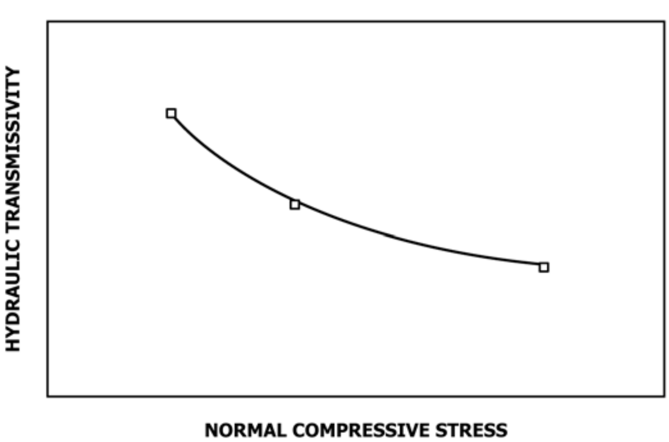

FIG. 4 Typical Plot of Hydraulic Transmissivity versus Normal Compressive Stress

11. Report

11.1 The report on the flow rate per unit width or hydraulic transmissivity test, or both, shall include the following information:

11.1.1 Project, type of geosynthetic(s) tested and included in sub and super stratum if applicable, method(s) of sampling, and directions tested.

11.1.2 Type of test performed and field conditions modeled (for example, contact sub and super stratum compositions, and the like).

11.1.3 Calibration curve(s) for the test device with the appropriate calibration block thickness(es), or a statement that a device calibration was conducted and that the equipment hydraulic losses are less than 5 % of the losses measured in the tests.

11.1.4 A statement of any departures from suggested testing procedure so the results can be evaluated and used.

11.1.5 Complete test data, including hydraulic head, quantity of flow collected, seating period for each stress, thickness (if monitored), temperature of test water, and specimen length and width.

11.1.6 Test plots expressing flow rate per unit width versus hydraulic gradient for each normal compressive stress or versus normal compressive stress for each hydraulic gradient and, when applicable, hydraulic transmissivity versus normal compressive stress.

11.1.7 If a rubber substrate was used as a superstrate or substrate, or both, report the thickness, type of rubber and durometer hardness, as well as the comparative test data generated for supporting the rubber selected.

11.1.8 Long-term creep/compression data for the geosynthetic, subject to comparable stress levels, which extend over a time interval that will provide insight into the long-term in-plane flow rate behavior relative to the seating period used and the long-term compressive creep behavior of the geosynthetic.

11.1.8.1 When used as an index test for acceptance of commercial shipments of qualified products, long-term creep/compression data is not required.

11.1.9 State with a footnote located on the same page as the test data that the transmissivity test was performed in accordance with Appendix X2, Optional Procedure for Performing Thickness Controlled Transmissivity Tests, when applicable.

12. Precision and Bias[3]

12.1 *Precision:*

12.1.1 *Interlaboratory Test Program*—Three separate interlaboratory testing programs (ILS) were performed in 1997 through 2001. The design of the experiments, similar to that of Practice E691, and a within-between analysis of the data, are given in ASTM Research Report No RR:D35-1008.[3] Program details are provided in Tables 3 and 4. The "geonet" and the geonet components of Composites I and II were strand HDPE

[3] Supporting data have been filed at ASTM International Headquarters and may be obtained by requesting Research Report RR:D35-1008. Contact ASTM Customer Service at service@astm.org.

TABLE 3 Interlaboratory Test Program

Material	No. Specimens Per Sample Set	No. Laboratories	Normal Load, kPa	Gradient	Seating Period
Geonet	2	8	250	1.0	15 min
Composite	2	8	250	1.0	15 min
Geotextile	3	8 (7)	250	1.0	15 min
Edge Drain	2	5	250	0.05	15 min

TABLE 4 Test Parameters

Material	Superstratum	Substratum	No. Laboratories	Normal Load, KPa	Gradient	Seating Period
Geonet	Rigid Plate	Rigid Plate	8	250	1.0	15 min
Composite I	Rigid Plate	Rigid Plate	8	250	1.0	15 min
Composite II	Sand	GM[A] /Rigid Plate	5	720	1.0	15 min
Composite III	Sand	GM[A] /Rigid Plate	5	720	1.0	15 min
Geotextile	Rigid Plate	Rigid Plate	5	250	1.0	15 min
Edge Drain	Rigid Plate	Rigid Plate	5	250	0.05	15 min

[A] 60 mil smooth HDPE geomembrane.

TABLE 5 Precision

Material	Average l/s·m [gpm/ft]	Repeatability Limit	Reproducibility Limit	95 % Confidence Repeatability Limit	95 % Confidence Reproducibility Limit
Geonet	2.18 [10.5]	7.0 %	7.3 %	19.8 %	20.5 %
Composite I	0.212 [1.02]	10.6 %	21.2 %	29.8 %	59.5 %
Composite II	0.92 [0.443]	15.2 %	42.6 %	44.8 %	125 %
Composite III	0.931 [4.48]	6.1 %	17.1 %	20.7 %	57.8 %
Geotextile	0.0108 [0.052]	53.4 %	93.3 %	150 %	261 %
Edge drain	3.55 [17.1]	3.9 %	8.0 %	10.9 %	22.3 %

geonets approximately 6 mm thick. The geonet component of Composite III was a three-strand HDPE geonet approximately 8 mm thick. The geotextile bonded to both sides of all three composites were approximately 270 g/m^2 [8 oz/sy] nonwovens. The "geotextile" was a 540 g/m^2 [16 oz/sy] needle-punched nonwoven. The "edge drain" was a core-type approximately 30 mm thick tested without the geotextile wrap.

12.1.2 *Test Result*—The precision information is given in Table 5 for the four materials. The test results are in units of l/s·m [gpm/ft].

12.2 *Bias*—The procedure in this test method for measuring the hydraulic transmissivity and flow rate per unit width of geosynthetics has no bias because the values of hydraulic transmissivity and flow rate per unit width can be defined only in terms of a test method.

13. Keywords

13.1 geosynthetics; hydraulic transmissivity; in-plane flow; index test; performance test

ANNEX

(Mandatory Information)

A1. TRANSMISSIVITY/FLOW RATE DEVICE CALIBRATION

A1.1 Calibration is conducted using an open channel (calibration block) or a similar object which allows flow to pass through the flow rate device unimpeded. Assemble the device with the calibration block in place of the geosynthetic specimen. The inside height of the calibration block opening shall be equal to or greater than the uncompressed thickness of the geosynthetic specimen (excluding adjacent soil or other components that are not intended to convey flow).

A1.2 Construct calibration blocks from rigid material such as steel, aluminum, or acrylic. The blocks are fabricated to provide an open channel for flow with a minimum of flow disruption across the width of the base. The upstream and downstream ends of the blocks are open. The blocks should fit tightly within the loading device specimen area. Fabricate a series of calibration blocks to simulate the thicknesses of the various geosynthetics to be tested in the device.

A1.3 Assemble the transmissivity device and conduct testing as outlined in the procedure section using the calibration block. Apply a nominal seating load (10 kPa is suggested) on the calibration block during testing. Conduct the calibration using at least five flow rates, ranging from the rate corresponding to the lowest measurable gradient (that is, head loss between the reservoir and weir) to a flow rate in excess of the maximum expected while testing geosynthetics of the block thickness used.

A1.4 No minimum seating period is required. At each flow rate, compute the hydraulic gradient values based on the head loss between the reservoir and weir manometers and a flow length equal to the calibration block length.

A1.5 Plot the measured flow rates versus the computed block gradients multiplied by 20. This curve is the calibration curve for the calibration block used Fig. A1.1.

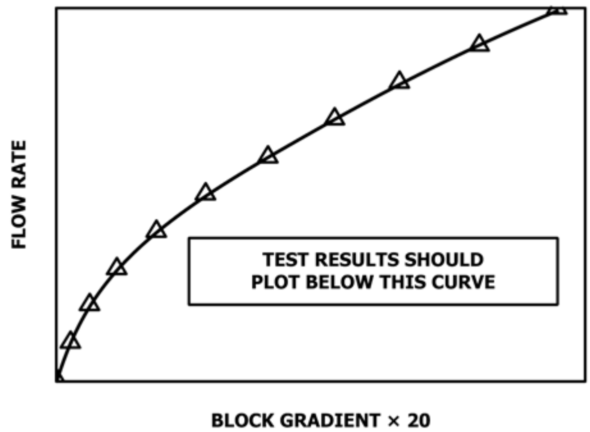

FIG. A1.1 A Typical Calibration Curve

APPENDIXES

(Nonmandatory Information)

X1. DISCUSSION REGARDING THE SELECTION OF SUITABLE SEATING CONDITIONS

X1.1 This appendix has been prepared to address the selection of the seating period for testing certain types of geosynthetics, which may be characterized by significant[4] time-dependent compression strains under constant loading. While all geosynthetic materials currently in use for drainage applications exhibit "creep" deformations under constant loading, the subject products can experience large deformations or collapse at some time after the initial application of a constant sustained load.

X1.2 Fig. X1.1 shows examples of the compression strain versus time behavior for a "nontime-dependent" (geonet) and a "time-dependent" (a core-type composite) material subject to three different compressive stress levels. Note the "spikes" in the deformation versus time curves where the core-type composite collapsed at some time after initial load application. This figure illustrates the unique compressive characteristic of materials addressed by this appendix, that is, materials which are subject to large compressive deformation at some time after initial application of a constant load.

X1.3 This time-dependent compression behavior merits consideration in conjunction with the use of this test method for the selection of the seating conditions, that is, compressive stress and seating period, which would produce compressive strain levels in a short-term test that are comparable to those expected under actual service conditions.

X1.3.1 For example, for a specific core-type composite, the estimated normal compressive load of 96 kPa [2000 psf] results in a compressive deformation approaching 10 % after 10 000 h; a compressive stress of 167 kPa [3500 psf] produces 10 % deformation after a seating period of 1 h. Based on this information, flow rate tests performed using a compressive stress of 167 kPa [3500 psf] and a seating period of 1 h may be suitable for product compliance, that is, commercial acceptance testing, and would be expeditious from a testing standpoint. Note that, for this example, if the 167 kPa [3500 psf] loading is sustained for an additional 10 h, the composite would collapse. The normal compressive loading may or may not be representative of actual field loading conditions.

NOTE X1.1—This appendix addresses the selection of a suitable seating period for any geosynthetic exhibiting time-dependent compressive behavior described herein. These may include products other than those which are currently in use.

[4] Significant in terms of the measured flow rate per unit width.

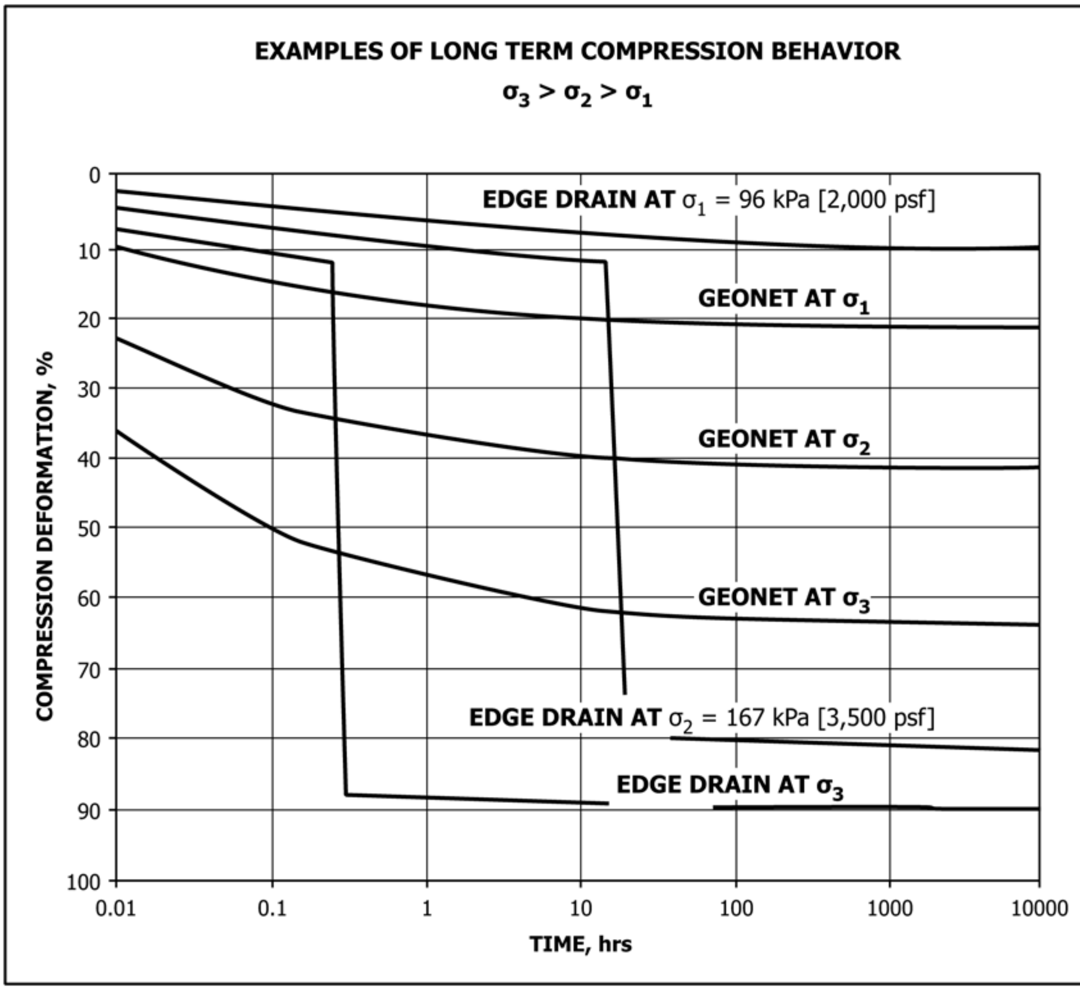

FIG. X1.1 Strain versus Time Curves for a Specific Core-Type Geocomposite

X2. OPTIONAL PROCEDURE FOR PERFORMING THICKNESS-CONTROLLED TRANSMISSIVITY TESTS

X2.1 This appendix describes an optional, non-mandatory accelerated procedure for determining the transmissivity of a test specimen when a long-term seating period is specified for several samples. The percent-reduced thickness of the drainage section is determined using Test Method D7361. This is a 150 mm by 150 mm test specimen between rigid platens. Then the sample is tested with the conventional ASTM D4716/D4716M test method with the geonet component of the section compressed to the target retained thickness determined with Test Method D7361.

X2.1.1 This procedure shows a generally good correlation with actual 100 h tests, for tests performed between rigid boundaries. Testing with soft boundaries (for example, closed-cell foam or soil) may sometimes generate conservative results as the procedure involves application of a larger normal load than the specified (target) normal load to affect a desired thickness, therefore possibly generating a larger intrusion of the geotextile into the drainage cavity. Comparative testing to actual 100 h test results shall be performed to confirm this potential bias.

X2.1.2 The procedure is intended for test sections where the primary flow element is a geonet, a single-sided geotextile/geonet geocomposite, or double-sided geotextile/geonet geocomposite.

X2.1.3 Any other drainage products that are demonstrated to be amenable to this test method may also be tested.

X2.1.4 In the case of a dispute arising from differences in reported test results when using this test appendix, the test performed using an actual 100 h seating time with the test section arranged normally, that is, "upright," is considered the referee method.

X2.2 *Apparatus for Testing Thickness-Controlled Transmissivity*—For testing using thickness-controlled transmissivity, the apparatus must be capable of monitoring the thickness of the specific drainage component under test.

X2.2.1 The following apparatus are required:

X2.2.1.1 Four or five length-measuring sensors for measuring the thickness of the geonet are required. Four are required for platen-mounted gauges, where the test section is placed in the loading tray "upside-down." The five-gauge setup is preferred, using base-mounted gauges and the test section placed "normally." Sketches of both arrangements are shown in Figs. X2.1 and X2.2.

NOTE X2.1—LDT devices with a range of 12.5 mm [0.5 in.] have been used successfully to test typical geonet products.

X2.2.2 The sensors shall be accurate to ±0.1 mm.

X2.2.3 The sensors shall have an external threaded section where the sensor can be attached to either the upper platen for plate-to-plate tests, or to a "floating" fixture where the sensor is threaded to a hollow tube that is also threaded into a circular plate placed on top of the component under test.

X2.2.4 The sensors typically are equipped with internal 4-48 threads where the contact tip is attached. A rod with a threaded end is connected to a circular bottom plate that is placed under the bottom of the component, that is, directly in contact with the geonet component under test.

X2.2.5 The circular plates that are placed on top and underneath the component test should be a maximum of 1.5 mm [1⁄16 in.] thickness. The plates should be placed the same way that the thicknesses were measured in the SIM test, in direct contact with the geonet. This involves cutting a small slit in the geotextile component(s) so that the plates can be slid into place against the geonet.

X2.2.6 The four or five length-measuring devices must be readable during the performance of the ASTM D4716/D4716M test.

X2.2.6.1 The devices' real-time thickness readings may be obtained visually and recorded manually, or may be connected to a digital readout device, where the readings may be recorded manually or automatically acquired via computer.

X2.2.7 Use a rigid template with four holes that accommodate a punch with a diameter slightly larger than the inner rods, locating the holes at the four corners of the loading platen, approximately 25 mm [1 in.] in from each side for top-mounted LDT tests and also at the center for base-mounted tests. These guide holes are used to punch holes through the test specimen (and any attached upper and lower geotextiles) so that the inner thickness rod can freely pass thru the geonet.

X2.2.8 The rigid loading platen must have holes that accommodate the hollow outer tubes.

X2.3 *Preparing the Test Specimen:*

X2.3.1 Mark the four (or five) corners of the test specimen, 1 through 4(5).

X2.3.2 If necessary, peel back the geotextile component(s) and measure the thickness of the test specimen at the four corners using the device described for geotextile thickness measurements in accordance with Test Method D5199.

X2.3.3 Using the guide hole template and a hole punch, make the holes at the corners of the test specimen for top-mounted LDT tests and make holes at the four corners and the center of the test specimen for base-mounted LDT tests.

X2.4 *Setting Up the Apparatus for Monitoring the Specimen Thickness During Testing:*

X2.4.1 Attach the four or five length-measuring devices during assembly of the test section including placement of the loading platen.

X2.4.2 Connect the four or five devices to the readout displays or to the data acquisition system as applicable.

X2.4.3 Apply a 50 lb seating load to the loading platen.

X2.4.4 Record the four initial drainage section thickness values to the nearest 0.1 mm. Calculate the average initial thickness by averaging these four or five values.

X2.5 *Performing the Stepped Isothermal Test:*

X2.5.1 Perform at least one compressive SIM test and two ramp and hold tests on one representative sample of the geonet or geocomposite for every project.

X2.5.2 Perform Test Method D7361 on a representative test specimen, immediately adjacent in the machine direction to the test specimen that will subsequently be used for the ASTM D4716/D4716M transmissivity test with geonet thickness measurements. The test must be performed at the target load specified for determination of the transmissivity.

X2.5.3 The thickness measurement shall be of the directly of the geonet component only, excluding the geotextile(s).

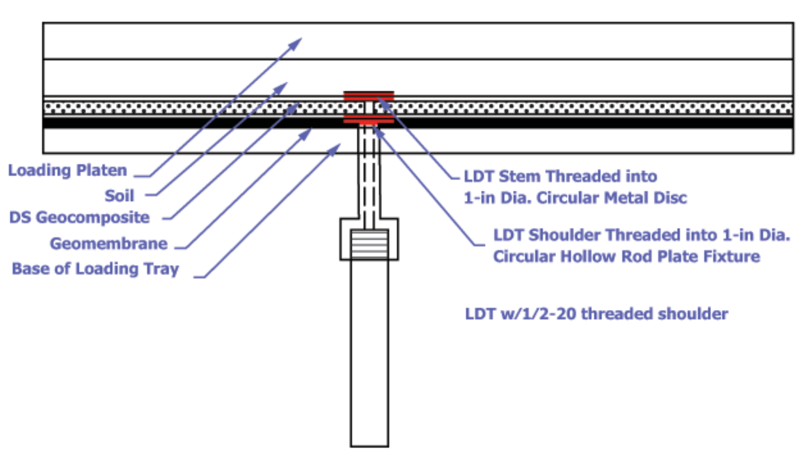

FIG. X2.1 Base-Mounted Thickness Measurement Setup

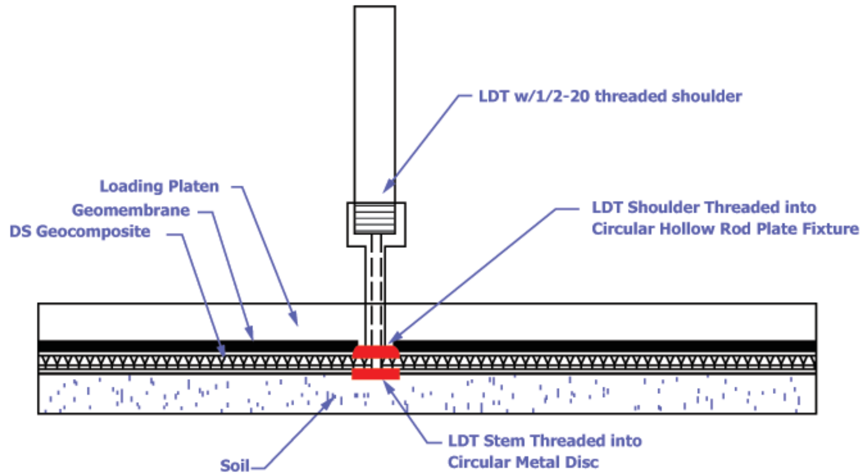

FIG. X2.2 Top-Mounted Thickness Measurement Setup

X2.5.4 Determine the retained thickness (in percent) at the desired loaded elapsed time value, for example, 100 h, 1000 h, 10 000 h, etc.

X2.5.5 Use the results of Test Method D7361 to determine the thickness at which the test must be performed.

X2.5.6 In X2.5.2, apply the specified target load to determine the initial thickness under the target load.

X2.5.7 The target thickness value used in X2.6.3 is calculated by multiplying the percent retained thickness determined in X2.5.4 by the average initial thickness determined in X2.4.4.

X2.6 *Performing the Thickness-Controlled Transmissivity Test:*

X2.6.1 Introduce the test water and fill the transmissivity apparatus to the weir elevation.

X2.6.2 Increase the compressive stress while monitoring the average of the four thickness values. Increase the force in increments, allowing time to average the four thickness values.

X2.6.3 Slowly approach the average drainage section target percent-reduced thickness value so that the target thickness value is achieved without overshooting.

X2.6.4 Lock off the hydraulic load line to hold the achieved thickness.

X2.6.5 Perform the hydraulic transmissivity test using the gradients in accordance with the project specifications. Purge any trapped air from the test section by either starting with a project-specified hydraulic gradient at or above 0.5, or by pre-flushing at a gradient of 0.5 before starting the testing. See Note 6.

X2.6.6 The thickness must be monitored throughout the flow measurement. Should it change by more than 1 % of the initial thickness over the duration of the test, multiple flow measurements may be performed with thicknesses greater and smaller than the target thickness, to permit extrapolation of the flow by numerical regression to the target thickness.