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Standard Test Method for Determining Performance Strength of Geomembranes by the Wide Strip Tensile Method[1]

This standard is issued under the fixed designation D4885; 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 performance strength of synthetic geomembranes by subjecting wide strips of material to tensile loading.

1.2 This test method covers the measurement of tensile strength and elongation of geomembranes and includes directions for calculating initial modulus, offset modulus, secant modulus, and breaking toughness.

1.3 The basic distinctions between this test method and other methods measuring tensile strength of geomembranes are the width of the specimens tested and the speed of applied force. The greater width of the specimens specified in this test method minimizes the contraction edge effect (necking) which occurs in many geosynthetics and provides a closer relationship to actual material behavior in service. The slower speed of applied strain also provides a closer relationship to actual material behavior in service.

1.4 As a performance test, this method will be used relatively infrequently, and to test large lots of material. This test method is not intended for routine quality control testing of geomembranes.

1.5 The values stated in SI units are to be regarded as standard. The values given in parentheses are for information only.

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

1.7 *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]
~~D76~~D76/D76M Specification for Tensile Testing Machines for Textiles
D123 Terminology Relating to Textiles
D751 Test Methods for Coated Fabrics
D882 Test Method for Tensile Properties of Thin Plastic Sheeting
D1593 Specification for Nonrigid Vinyl Chloride Plastic Film and Sheeting
D1909 Standard Tables of Commercial Moisture Regains and Commercial Allowances for Textile Fibers
D4354 Practice for Sampling of Geosynthetics and Rolled Erosion Control Products (RECPs) for Testing
D4439 Terminology for Geosynthetics

3. Terminology

3.1 *Definitions:*

3.1.1 *atmosphere for testing geomembranes, n*—air maintained at a relative humidity of 50 to 70 % and a temperature of 21 ± ~~2°C~~2 °C (70 ± ~~4°F).~~4 °F).

[1] This test method is under the jurisdiction of ASTM Committee D35 on Geosynthetics and is the direct responsibility of Subcommittee D35.10 on Geomembranes.

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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.

3.1.1.1 *Discussion—*

Within the range of 50 to 70 % relative humidity, moisture content is not expected to affect the tensile properties of geomembrane materials. In addition, geotextile standard test methods restrict the range of relative humidity to 65 ± 5 %, while geomembrane standard test methods restrict the range of relative humidity to 55 ± 5 %. The restricted range in this test method is made broader to reduce the need for testing laboratories to change laboratory conditions, and considering the lack of expected effect of moisture on geomembranes. The user should consult Table D1909 to resolve questions regarding moisture regains of textile fibers, especially if the user is testing a new or unknown material.

3.1.2 *breaking force, (F), J, n*—the force at failure.

3.1.3 *breaking toughness, T, (FL^{-1}), Jm^{-2}, n—for geosynthetics*, the actual work per unit volume of a material corresponding to the breaking force.

3.1.3.1 *Discussion—*

Breaking toughness is proportional to the area under the force-elongation curve from the origin to the breaking point (see also, ~~*work-to-break*).~~ *work-to-break*). Breaking toughness is calculated from work-to-break and width of a specimen. In geomembranes, breaking toughness is often expressed as force per unit width of material in inch-pound values. In other materials, breaking toughness is often expressed as work per unit mass of material.

3.1.4 *corresponding force, n*—synonym for *force at specified elongation*.

3.1.5 *elastic limit, n—in mechanics*, the stress intensity at which stress and deformation of a material subjected to an increasing force cease to be proportional; the limit of stress within which a material will return to its original size and shape when the force is removed, and hence, not a permanent set.

3.1.6 *failure, n*—an arbitrary point beyond which a material ceases to be functionally capable of its intended use.

3.1.6.1 *Discussion—*

In wide strip tensile testing of geosynthetics, failure occurs either at the rupture point or at the yield point in the force-elongation curve, whichever occurs first. For reinforced geomembranes, failure occurs at rupture of the reinforcing fabric. For nonreinforced geomembranes ~~which~~that exhibit a yield point, such as polyethylene materials, failure occurs at the yield point. Even though the geomembrane continues to elongate, the force-elongation relationship has been irreversibly altered. For nonreinforced geomembranes ~~which~~that do not exhibit a yield point, such as plasticized PVC materials, failure occurs at rupture of the geomembrane.

3.1.7 *force at specified elongation, FASE, n*—a force associated with a specific elongation on the force-elongation curve. (Synonym for *corresponding* ~~*force.)*~~*force.)*

3.1.8 *force-elongation curve, n—in a tensile test*, a graphical representation of the relationship between the magnitude of an externally applied force and the change in length of the specimen in the direction of the applied force. (Synonym for *stress-strain* ~~*curve.)*~~*curve.)*

3.1.9 *geomembrane, n*—~~An~~an essentially impermeable geosynthetic used with foundation soil, rock, earth, or any other geotechnical ~~engineering related~~ engineering-related material as an integral part of a ~~man-made~~manmade project, structure, or system.

3.1.9.1 *Discussion—*

Other names under which geomembranes are recognized include: flexible membrane liners ~~(fml's),~~(FMLs), liners, and membranes.

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

3.1.11 *inflection point, n*—the first point of the force-elongation curve at which the second derivative equals zero.

3.1.11.1 *Discussion—*

The inflection point occurs at the first point on the force-elongation curve at which the curve ceases to curve upward and begins to curve downward (or vice versa).

3.1.12 *initial tensile modulus, J_i,* ~~*(FL*~~ *(FL^{-1}),* ~~*Nm*~~ *Nm^{-1}, n—for geosynthetics*, the ratio of the change in force per unit width to the change in elongation of the initial portion of a force-elongation curve.

3.1.13 *offset modulus,* J_o, ~~*(FL*~~ *(FL*$^{-1}$*),* ~~*Nm*~~ *Nm*$^{-1}$*, n—for geosynthetics*, the ratio of the change in force per unit width to the change in elongation below an arbitrary offset point at which there is a proportional relationship between force and elongation, and above the inflection point on the force-elongation curve.

3.1.14 *performance test, n*—a test which simulates in the laboratory as closely as practicable selected conditions experienced in the field and which can be used in design. (Synonym for *design* ~~*test.)*~~*test.*)

3.1.15 *secant modulus,* J_{sec}, ~~*(FL*~~ *(FL*$^{-1}$*),* ~~*Nm*~~ *Nm*$^{-1}$*, n—for geosynthetics*, the ratio of change in force per unit width to the change in elongation between two points on a force-elongation curve.

3.1.16 *tensile, adj*—capable of tensions, or relating to tension of a material.

3.1.17 *tensile modulus, J, (FL*$^{-1}$*), Nm*$^{-1}$*, n—for geosynthetics*, the ratio of the change in tensile force per unit width to a corresponding change in elongation.

3.1.18 *tensile strength, n*—the maximum resistance to deformation developed by a specific material when subjected to tension by an external force.

3.1.19 *tensile test, n—for geosynthetics*, a test in which a material is stretched uniaxially to determine the force-elongation characteristics, the breaking force, or the breaking elongation.

3.1.20 *tension, n*—the force that produces a specified elongation.

3.1.21 *wide strip tensile test, n—for geosynthetics*, a tensile test in which the entire width of a ~~200 mm (8.0 in.)~~ 200-mm (8.0-in.) wide specimen is gripped in the clamps and the gauge length is 100 mm (4.0 in.).

3.1.22 *work-to-break, W, (LF), J, n—in tensile testing*, the total energy required to rupture a specimen.

3.1.22.1 *Discussion*—

For geomembranes, work-to-break is proportional to the area under the force-elongation curve from the origin to the breaking point.

3.1.23 *yield point, n—in geosynthetics*, the point on the force-elongation curve at which the first derivative equals zero (the first maximum).

3.1.24 For definitions of other terms used in this test method, refer to Terminologies D123 and D4439.

4. Summary of Test Method

4.1 A relatively wide specimen is gripped across its entire width in the clamps of a constant rate of extension type tensile testing machine operated at a prescribed rate of extension, applying a uniaxial load to the specimen until the specimen ruptures. Tensile strength, elongation, initial and secant modulus, and breaking toughness of the test specimen can be calculated from machine scales, dials, recording charts, or an interfaced computer.

5. Significance and Use

5.1 This test method is a performance test intended as a design aid used to determine the ability of geomembranes to withstand the stresses and strains imposed under design conditions. This test method assists the design engineer in comparing several candidate geomembranes under specific test conditions.

5.2 As a performance test, this method is not intended for routine acceptance testing of commercial shipments of geomembranes. Other more easily performed test methods, such as Test Methods D751 or Test Method D882, can be used for routine acceptance testing of geomembranes. This test method will be used relatively ~~infrequently,~~infrequently and to establish performance characteristics of geomembrane materials.

5.2.1 There is no known correlation between this test method and index test methods, such as Test Methods D751.

5.3 All geomembranes can be tested by this method. Some modification of techniques may be necessary for a given geomembrane depending upon its physical ~~make-up.~~makeup. Special adaptations may be necessary with strong geomembranes or geomembranes with extremely slick surfaces, to prevent them from slipping in the clamps or being damaged by the clamps.

6. Apparatus

6.1 *Clamps*—A gripping system that minimizes (with the goal of eliminating) slippage, damage to the specimen, and uneven stress distribution. The gripping system shall extend to or beyond the outer edge of the specimen to be tested.[3]

6.2 *Specimen Cutter*—An appropriate cutting device which does not create irregularities or imperfections in the edge of the specimen. For wide strip specimens, a jig may not be necessary provided that the actual cut dimensions of the specimen can be measured accurately to the nearest 1.0 mm (0.04 in.), and that the width of the specimen is constant to within 1.0 mm (0.04 in.).

[3] Examples of clamping and extensometer systems which have been successfully used are shown in Appendix X2~~Appendixes.~~ and Appendix X3.

6.3 *Tensile Testing Machine*—A testing machine of the constant rate of extension type as described in Specification ~~D76~~D76/D76M shall be used. The machine shall be equipped with a device for recording the tensile force and the amount of separation of the grips. Both of these measuring systems shall be accurate to ±2 % and, preferably, shall be external to the testing machine. The rate of separation shall be uniform and capable of adjustment within the range of the test.

7. Sampling

7.1 *Lot Sample*—Divide the product into lots and take the lot sample as directed in Practice D4354.

7.2 *Laboratory Sample—*For the laboratory sample, take a full-width swatch approximately 1 m (40 in.) long in the machine direction from each roll in the lot sample. The sample may be taken from the end portion of a roll, provided there is no evidence it is distorted or different from other portions of the roll.

7.3 *Test Specimens—*Take a total of twelve specimens from each swatch in the laboratory sample, with six specimens for tests in the machine direction and six specimens for tests in the cross-machine direction. Take the specimens from a diagonal on the swatch, with no specimen nearer the edge of the geomembrane than ~~1/10~~one-tenth of the width of the geomembrane. Cut each specimen 200 mm (8.0 in.) wide by at least ~~200 mm~~ 200 mm (8.0 in.) long, with the length precisely aligned with the direction in which the specimen is to be tested. The specimens must be long enough to extend completely through both clamps of the testing machine. Draw two parallel lines near the center of each specimen length ~~that (1)~~that: (*1*) are separated by 100 mm ~~(4.0 in.),~~(4.0 in.); (*2* ~~(2)~~) extend the full width of the ~~specimen,~~specimen; and ~~(3)~~(*3*) are exactly perpendicular to the length of the specimen. Exercise the utmost care in selecting, cutting, and preparing specimens to avoid nicks, tears, scratches, folds, or other imperfections that are likely to cause premature failure.

8. Conditioning

8.1 Expose the specimens to the standard atmosphere for testing geomembranes for a period long enough to allow the geomembrane to reach equilibrium with the standard atmosphere. Consider the specimen to be at moisture equilibrium when the change in mass of the specimen in successive weighings made at intervals of not less than 2 h does not exceed 0.1 % of the mass of the specimen. Consider the specimen to be at temperature equilibrium after 1 h of exposure to the standard atmosphere for testing.

9. Procedure

9.1 Test adequately conditioned specimens. Conduct tests at a temperature of 21 ± ~~2°C~~2 °C (70 ± ~~4°F)~~4 °F) and at a relative humidity of 50 to 70 %. The engineer may specify additional temperatures based upon expected service conditions for the installation.

9.2 Measure for the ~~specimens~~specimen's thickness at the four corners of the specimen. Select specimens used in this procedure so that thickness is uniform to within 5 %. Measure thickness using either Specification D1593 for nonreinforced geomembranes or Test Methods D751 for reinforced geomembranes.

9.3 Position the grips of the testing apparatus to a separation of 100 ± 3 mm (4 ± 0.1 in.). At least one clamp should be supported by a free swivel or universal joint, which will allow the clamp to rotate in the plane of the fabric. Select the force range of the testing machine so that the break occurs between 10 and 90 % of full scale load. Set the machine to a strain rate as directed in 9.6.

9.4 Mount the specimen centrally in the clamps. Do this by having the two ~~lines,~~lines which were previously drawn 100 ± 3 mm (4.0 ± 0.1 in.) apart across the width of the specimen as close as possible adjacent to the inside edges of the upper and lower jaw. The specimen length in the machine direction and the ~~cross machine~~ cross-machine direction tests, respectively, must be parallel to the direction of application of force.

9.5 Start the tensile testing machine and the area measuring device, if used, and continue running the test to rupture. Stop the machine and reset to the initial gauge position. Record and report the test results to three significant figures for each direction separately.

9.5.1 If a specimen slips in the jaws, or if for any reason attributed to faulty operation the result falls markedly below the average for the set of specimens, discard the result and test another specimen.

9.5.2 The decision to discard the results of a break shall be based upon observation of the specimen during the test and upon the inherent variability of the fabric. In the absence of other criteria for rejecting a so-called jaw break, any break occurring within 5 mm (0.25 in.) of the jaws which results in a value below 20 % of the average of all the other breaks shall be discarded. No other break shall be discarded unless the test is known to be faulty.

9.5.3 It is difficult to determine the precise reason why certain specimens break near the edge of the jaws. If a jaw break is caused by damage to the specimen by the jaws, then the results should be discarded. If, however, it is merely due to randomly distributed weak places, it is a perfectly legitimate result. In some cases, it may also be caused by a concentration of stress in the area adjacent to the jaws because they prevent the specimen from contracting in width as the load is applied. In these cases, a break near the edge of the jaws is inevitable and shall be accepted as a characteristic of the particular method of test.

9.5.4 If a geomembrane manifests any slippage in the jaws, or if more than 24 % of the specimens break at a point within 5 mm (0.25 in.) of the edge of the jaw, then the jaws may be padded, or the surface of the jaw face may be modified. The user should exercise the utmost care to select jaw modifications which will not damage the test specimens in any manner. If any modifications of the jaw faces are used, state the method of modification in the report.

9.6 Measure the elongation of the geomembrane to three significant figures at any stated load by means of a suitable recording device at the same time as the tensile strength is determined.

9.6.1 Extensometers are preferred for measurement of elongation in geomembranes. Other means of measuring elongation should be calibrated against extensometers whenever possible. In any case, the means of measuring elongation should be clearly indicated in the report.[3]

9.7 Crosshead speed shall be 10 mm/min (0.4 in./min) unless otherwise specified otherwise by the engineer.

10. Calculation

10.1 *Tensile Strength*—Calculate the tensile strength for individual specimens; that is, calculate the maximum force per unit width to cause a specimen to rupture or yield as read directly from the testing machine expressed in N/m (lbf/m) of width, using Eq 1:

$$\alpha_f = F_f/W_s \quad (1)$$

$$\alpha_f = F_f / W_s \quad (1)$$

where:

α_f = tensile strength of width, N/m (lbf/in.),
F_f = observed breaking force, N (lbf), and
W_s = specified specimen width, m (in.).

This value shall be reported to three significant figures.

NOTE 1—When tear or yield failure occurs, so indicate and calculate results based upon force and elongation at which tear or yield initiates, as reflected in the load-deformation curve.

10.2 *Percentage Elongation*—Calculate the percent elongation for individual specimens; that is, calculate the elongation of specimens, expressed as the percentage increase in length, based upon the initial gauge length of the specimen using Eq 2 for ~~XY~~X-Y type recorders, or Eq 3 for manual readings (ruler).

$$\varepsilon_p = (E \times R \times 100)/(C \times L_g) \quad (2)$$

$$\varepsilon_p = (\Delta L \times 100)/L_g \quad (3)$$

where:

~~ε_p = elongation, %,~~
ε_p = elongation, %,
~~E = distance along the zero load axis from the point the curve leaves the zero load axis to a point of corresponding force, mm (in.),~~
E = distance along the zero-load axis from the point the curve leaves the zero-load axis to a point of corresponding force, mm (in.),
R = testing speed rate, m/min (in./min),
C = recording chart speed, m/min (in./min),
L_g = initial nominal gauge length, mm (in.), and
ΔL = the unit change in length from a zero force to the corresponding measured force, mm (in.).

10.2.1 Gauge marks or extensometers are preferred to define a specific test section of the specimen; when these devices are used, only the length defined by the gauge marks or extensometers shall be used in the calculation. Gauge marks must not damage the geomembrane.

10.3 *Tensile Modulus:*

10.3.1 *Initial Tangent Modulus*—Determine the location and draw a line tangent to the first straight portion of the force-elongation curve. At any point on this tangent line, measure the force and the corresponding elongation with respect to the ~~zero load~~ zero-load axis. Calculate initial tensile modulus in N/m (lbf/in.) of width using Eq 4.

$$J_i = (F \times 100)/(\varepsilon_p \times W_s) \quad (4)$$

where:

J_i = initial tangent modulus, N (lbf), at corresponding elongation per metre (inch) of width,
F = determined force on the drawn tangent line, N (lbf),
ε_p = corresponding elongation, %, with respect to the drawn tangent line and determined force, and
W_s = specimen width, m (in.).

10.3.2 *Offset Modulus*—Determine the location and draw a line tangent to the force-elongation curve between the first point of inflection and the proportional limit and through the ~~zero load~~ zero-load axis. Measure the force and the corresponding elongation with respect to the load axis. Calculate offset tensile modulus using Eq 5.

$$J_o = (F \times 100)/(\varepsilon_p \times W_s) \quad (5)$$

where:

J_o = offset tensile modulus, N (lbf), at corresponding elongation per metre (inch) of width,
F = determined force on the drawn tangent line, N (lbf),
ε_p = corresponding elongation, %, with respect to the drawn tangent line and determined force, and
W_s = specimen width, m (in.).

10.3.3 *Secant Modulus*—Select a force for a specified elongation, ε_2, usually 10 %, and label the corresponding point on the force-elongation curve as P_2. Likewise, label a second point, P_1, at a specified elongation, ε_1, usually 0 % elongation. Draw a straight line (secant) through both points $P_{\not{2}1}$ and $P_{\not{1}2}$ intersecting the ~~zero load~~ zero-load axis. The preferred values are 0 and 10 % elongation, respectively, although other values may be substituted by the design engineer. Calculate secant tensile modulus using Eq 6.

$$J_{sec} = (F \times 100)/(\varepsilon_p \times W_s) \quad (6)$$

where:

J_{sec} = secant tensile modulus, N (lbf), between specified elongations per metre (inch) of width,
F = determined force on the constructed line, N (lbf),
ε_p = corresponding elongation, %, with respect to the constructed line and determined force, and
W_s = specimen width, m (in.).

10.4 *Breaking Toughness:*

10.4.1 When using the force-elongation curves, draw a line from the point of maximum force of each specimen perpendicular to the elongation axis. Measure the area bounded by the curve, the perpendicular, and the elongation axis by means of an integrator or a planimeter, or cut out the area of the chart under the force-elongation curve, weigh it, and calculate the area under the curve using the weight of the unit area.

10.4.2 When determining the breaking toughness of geomembranes using a manual gauge (steel rule or dial) to measure the amount of strain at a given force, record the change in specimen length for at least ten corresponding force intervals. Approximately equal force increments should be used throughout the application of force having the final measurement taken at specimen rupture.

10.4.3 Calculate the breaking toughness or work-to-break per unit surface area for each specimen when using ~~XY~~ X-Y recorders using Eq 7, or when using automatic area measuring equipment using Eq 8, or when using manually obtained strain measurements with a steel rule or dial gauge using Eq 9:

$$T_u = (A_c \times S \times R)/(W_c \times C \times A_s) \quad (7)$$

$$T_u = (V \times S \times R)/(I_c \times A_s) \quad (8)$$

$$T_u = \sum\nolimits^{F}{}_{f} 0 \; (pd\Delta L) \quad (9)$$

where:

T_u = breaking toughness,
A_c = area under force-elongation curve,
~~S = full scale force range,~~
S = full-scale force range,
R = testing speed rate,
W_c = recording chart width,
C = recording chart speed,
A_s = area of test specimen within the gauge length,
V = integrator reading,
I_c = integrator constant,
F_f = observed breaking force,
ΔL = unit change in length from a zero force to the corresponding measured force,
p = unit stress per area of test specimen within the gauge length, and
0 = zero force.

10.5 *Average Values*—Calculate the average values for tensile strength, elongation, initial tangent modulus, secant modulus, and breaking toughness to three significant figures.

10.6 *Standard Deviation (Estimated)*—Calculate the standard deviation using Eq 10 and report the value to two significant figures: