Standard Test Method for Multi-Axial Tension Test for Geosynthetics[1]

This standard is issued under the fixed designation D5617; 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 measurement of the out-of-plane response of geosynthetics to a force that is applied perpendicular to the initial plane of the sample.

1.2 When the geosynthetic deforms to a prescribed geometric shape (arc of a sphere or ellipsoid) formulations are provided to convert the test data to biaxial tensile stress-strain values. These formulations cannot be used for other geometric shapes. With other geometric shapes, comparative data on deformation versus pressure is obtained.

1.3 This test method is more commonly used to test geomembranes. Permeable materials may also be tested in conjunction with an impermeable material.

1.4 This test method requires a large diameter pressure vessel (600 mm). Information obtained from this test method may be more appropriate for design purposes than many small scale index tests such as Test Method D6693 or Test Method D7003/D7003M.

1.5 The values stated in SI units are to be regarded as standard. No other units of measurement are included in this standard.

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

2. Referenced Documents

2.1 *ASTM Standards:*[2]

D4439 Terminology for Geosynthetics

D6693 Test Method for Determining Tensile Properties of Nonreinforced Polyethylene and Nonreinforced Flexible Polypropylene Geomembranes

D7003/D7003M Test Method for Strip Tensile Properties of Reinforced Geomembranes

3. Terminology

3.1 *Definitions:*

3.1.1 *geosynthetic, n*—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.

3.1.2 *multi-axial tension, n*—stress in more than one direction.

3.1.3 For definitions of other terms used in this test method, refer to Terminology D4439.

4. Summary of Test Method

4.1 A pre-cut geosynthetic sample is secured at the edges of a large diameter (600 mm) pressure vessel. Pressure is applied to the sample to cause out-of-plane deformation and failure. This deformation with pressure information can then be analyzed to evaluate various materials.

5. Significance and Use

5.1 Installed geosynthetics are subjected to forces from more than one direction including forces perpendicular to the surfaces of the geosynthetic. Out of plane deformation of a geosynthetic may be useful in evaluating materials for caps where subsidence of the subsoil may be problematic.

5.2 Failure mechanisms on this test may be different compared to other relatively small scale index tests and may be beneficial for design purposes.

5.3 In applications where local subsidence is expected, this test can be considered a performance test.

NOTE 1—Although, this test specifies a vessel size of 600 mm, larger diameter vessels will better approximate field performance. However, the user is cautioned that different size vessels may yield different results and hence may not be comparable.

5.4 For applications where geosynthetics cannot be deformed in the fashion this test method prescribes, this test method should be considered an index test.

5.5 Due to the time involved to perform this test method, it is not considered practical as a quality control test.

[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.

Current edition approved May 1, 2015. Published June 2015. Originally approved in 1994. Last previous edition approved in 2010 as D5617–04(2010). DOI: 10.1520/D5617-04R15.

[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.

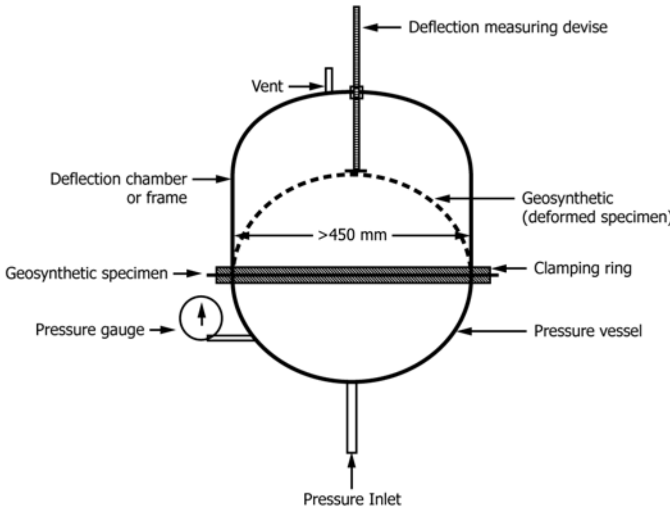


FIG. 1 Multi-Axial Burst Apparatus

6. Apparatus

6.1 Fig. 1 shows an example of the test apparatus that can be used in the performance of this test method. The apparatus requires a pressure vessel rated to a minimum of 690 kPa. The vessel diameter should be 600 mm.[3] Other size vessels may be used but it is up to the user to establish correlation to the standard size vessel.

6.2 If the vessel has a deflection chamber it should not inhibit the geosynthetic from freely deflecting during the test. The deflection chamber shall be vented.

6.2.1 Some materials will expand laterally beyond the diameter of the pressure vessel and may contact the sides of the deflection chamber. In these cases, the test is no longer valid and a different device must be used. Devices without deflection chambers have worked well in these situations.

6.3 The vessel will have a system to measure pressure and the magnitude of central deflection.

6.3.1 The system for measuring deflection shall be capable of being read to an accuracy of 5 mm.

6.3.2 The system for measuring pressure shall be capable of being read to an accuracy of 3.5 kPa.

6.4 All test shall be conducted at standard laboratory temperatures of 23 ± −2°C.

7. Test Specimen

7.1 Do not use test specimens with defects or any other abnormalities, unless this is the item of interest.

7.2 Cut the test specimen larger than the area of the main sealing force of the vessel.

7.3 If a permeable material such as a geotextile is being tested, an impermeable material such as a geomembrane or thin plastic sheet has to overlay the permeable material to maintain the pressure in the vessel during the test.

7.3.1 When testing permeable materials, the impermeable material shall be more elastic than the permeable material (unless the combination of the two materials is the desired test variable). This is required so that the permeable material fails first.

7.3.2 Test results on permeable materials will be affected by the impermeable material used in the test.

7.4 Test three replicate specimens on each sample unless otherwise noted.

8. Procedure

8.1 Cut the test specimen to the requirements of the test vessel to ensure a good seal. Place specimen across the opening of the vessel. Be sure the specimen is not sagging.

8.2 Be sure the specimen remains flat while the edge of the specimen is being securely clamped into place.

8.3 Either air or water can be used to pressurize the vessel. If a water system is used, introduce water into the vessel until it is completely filled.

8.4 Add water or air into the system so as to control the rate of centerpoint deflection at 20 mm/min in a continuous fashion.

8.4.1 Stepwise increments of center point deflection are not allowed.

8.5 Record the amount of centerpoint deflection and pressure at least every 10 s.

8.6 Continue with the test by maintaining a constant rate of centerpoint deflection at the specified rate until the specimen has ruptured (as noted by a sudden loss in pressure) or until some predetermined end point has been reached.

NOTE 2—The user is cautioned that the sudden release of pressure at rupture could potentially be dangerous and cause either personal injury or damage to the surroundings.

8.7 Repeat the above with two additional specimens from the same sample.

NOTE 3—If the specimen has deformed in a fashion so that the surface of the specimen approximates an arc of a sphere or an ellipsoid, stress-strain calculations are provided in Appendix X1.

9. Report

9.1 Report the following information:

9.1.1 Sample identification,

9.1.2 Size of vessel used (inside diameter), if other than standard,

9.1.3 Conditions under which the test was performed, if other than standard,

9.1.3.1 For permeable membranes, identify the impermeable material used during the test including the thickness.

NOTE 4—The impermeable material may have a significant impact on the data and must be considered when reviewing stress-strain results.

9.1.4 Description of the failure and the shape of the specimen after failure.

9.1.5 Plot the full pressure-deflection or stress-strain curves for all specimens.

[3] The sole source of supply of the apparatus known to the committee at this time is BT Technology, Inc., PO Box 49, 320 North Railroad St., Rushville, IL 62681. If you are aware of alternative suppliers, please provide this information to ASTM Headquarters. Your comments will receive careful consideration at a meeting of the responsible technical committee, which you may attend.

9.1.6 Average and individual specimen results for gauge, pressure at rupture and centerpoint deflection at rupture. Report stress and strain at rupture if calculations were made.

10. Precision and Bias

10.1 The precision and bias of this test method have not yet been established.

11. Keywords

11.1 deformation; geosynthetics; multi-axial

APPENDIXES

(Nonmandatory Information)

X1. DESCRIPTION OF SAMPLE FAILURES

X1.1 Materials will generally fail in a given manner that can be described by the following categories:

X1.2 Failure Location

X1.2.1 *Edge Tear (ET)*—Failure adjacent to the clamping ring. May not represent the performance of the sample material.

X1.2.2 *Non-edge Failure (N-EF)*—A rupture sufficiently far enough away from the edge of the device to assume that the device did not lead to the failure. The data is representative of the sample material.

X1.3 Failure Shape

X1.3.1 *Machine Direction Tear (MD-T)*—A tear in the machine direction.

X1.3.2 *Transverse Direction Tear (TD-T)*—A tear in the transverse direction.

X1.3.3 *Multi-Directional Tear (XD-T)*—A tear for several tears that do not follow any single direction.

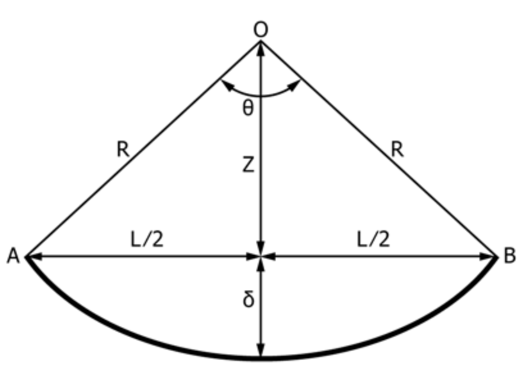
X1.3.4 *Hole*—Circular or elliptical hole in the specimen. Material may or may not have thinned over a broad region.

X1.3.5 *Hole in Cat Eye (H-Cat)*—Circular or elliptical hole in an area where the material has significantly necked down and thinned. The large thinned area resembles a pupil of a cat eye.

X2. STRESS-STRAIN CALCULATIONS FOR DEFINED SHAPES (ARC OF A SPHERE OR ELLIPSOID)

X2.1 Strain Calculations

X2.1.1 For $\delta < L/2$, assume the geomembrane test specimen to be deformed into arc of a circle as shown below:



$$R = Z^2 + (L/2)^2 \tag{X2.1}$$

$$R = Z + \delta \tag{X2.2}$$

X2.1.1.1 By squaring Eq X2.2 and substituting it into Eq X2.1:

$$Z = \frac{(L/2)^2 - \delta^2}{2\delta} \tag{X2.3}$$

$$Z = \frac{L^2 - 4\delta^2}{8\delta}$$

now:

$$R = Z + \delta = \frac{L^2 - 4\delta^2}{8\delta} + \delta \tag{X2.4}$$

$$R = \frac{L^2 + 4\delta^2}{8\delta}$$

X2.1.1.2 Working with the central angle "θ" and Eq X2.3:

$$\tan(\theta/2) = \frac{L/2}{Z} = \left(\frac{L}{2}\right)\left(\frac{8\delta}{L^2 - 4\delta^2}\right) = \frac{4L\delta}{L^2 - 4\delta^2} \tag{X2.5}$$

$$\theta = 2 \tan^{-1} \frac{4(L)\delta}{L^2 - 4\delta^2}$$

Also:

$$\hat{AB} = R\theta(\theta \text{ in radians}) \qquad (X2.6)$$

$$\hat{AB} = \frac{\theta}{360} \cdot 2\pi R = \frac{\theta}{180}\pi R \;(\theta \text{ in degrees})$$

$$\varepsilon = \frac{\hat{AB} - L}{L}(100)\;(\text{in percent}) \qquad (X2.7)$$

X2.1.1.3 Thus, the strain calculations proceed as follows:

$$\cdot R \frac{L^2 + 4\delta^2}{8\delta} \qquad (X2.8)$$

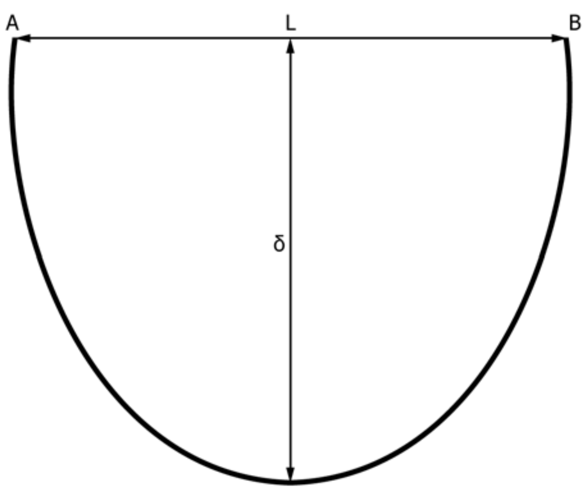
$$\cdot \theta = 2 \quad \tan^{-1}\frac{4(L)\delta}{L^2 - 4\delta^2}\;(\text{ in radians}) \qquad (X2.9)$$

$$\hat{AB}\cdot = R \cdot \theta\;(\theta \text{ in radians}) \qquad (X2.10)$$

$$\cdot \varepsilon = \frac{\hat{AB} - L}{L}(100), \text{ the desired value of strain in percent} \qquad (X2.11)$$

X2.1.1.4 Note that when $\delta = 0$, $R = \infty$, $\theta = 0°$ and $A\hat{B} = L$ which is to be expected.

X2.1.1.5 For $\delta \geq L/2$, assume the geomembrane test specimen to be deformed in an elliptic shape as shown below.



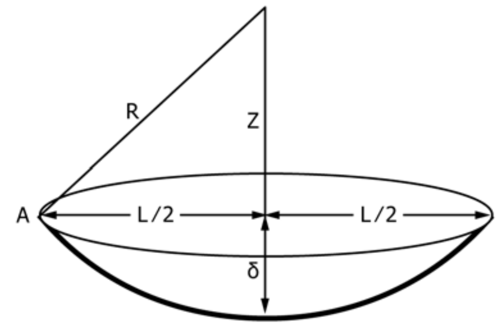
Here:

$$\hat{AB} = \pi\sqrt{\frac{(L/2)^2 + \delta^2}{2}} \qquad (X2.12)$$

$$\hat{AB} = \pi\sqrt{\frac{L^2 + 4\delta^2}{8}}$$

$$\varepsilon = \frac{\hat{AB} - L}{L}(100), \text{ the desired value of strain in percent}$$

X2.1.2 *Stress Calculations*—For $\delta < L/2$, the applied pressure acts over the original projection area, that is, original area of the geomembrane:



$$A_o = \pi(L/2)^2 \qquad (X2.13)$$

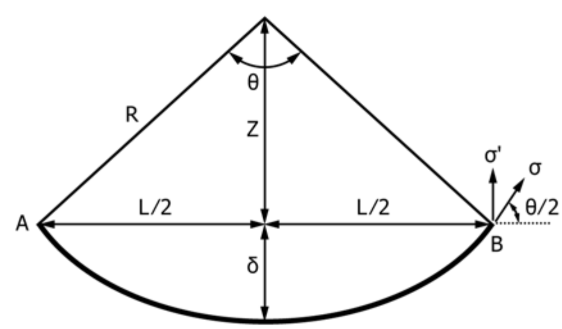
X2.1.2.1 Taking force summation in the vertical direction:

$$A_o p = C\sigma' t \qquad (X2.14)$$

where:

A_o = original area of geomembrane,
p = applied pressure,
C = circumference,
σ' = vertical component of geomembrane stress, and
t = geomembrane thickness,

which yields:



$$\frac{\pi}{4}(L^2)p = \pi L(\sigma')(t) \qquad (X2.15)$$

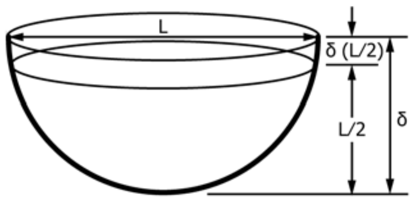
$$\sigma' = \frac{p(L^2)}{4(L)t} = \frac{pL}{4t}$$

but:

$$\sigma' = \sigma\sin(\theta/2) \qquad (X2.16)$$

$$\sigma = \frac{Lp}{4t\sin(\theta/2)}$$

X2.1.2.2 For $\delta \geq L/2$, assume σ' = σ, thus



$$A_o p = C(\sigma)t \quad \text{(X2.17)}$$

$$\sigma = \frac{[\pi L^2/4]p}{\pi(L)t}$$

$$\sigma = \frac{Lp}{4t}$$

NOTE X2.1—In performing stress and strain calculations for geomembrane materials with $\delta > L/2$, one must use the calculations of Eq X2.4-X2.7 and 11 up to $\delta = L/2$, and then use Eq X2.7 and X2.8 and 12 from $\delta > L/2$ until failure.

X2.1.3 For non-defined geometric shapes no calculations are necessary.