Designation: D 6693 – 013

Standard Test Method for Determining Tensile Properties of Nonreinforced Polyethylene and Nonreinforced Flexible Polypropylene Geomembranes[1]

This standard is issued under the fixed designation D 6693; 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 tensile properties of nonreinforced geomembranes in the form of standard dumbbell-shaped test specimens when tested under defined conditions of pretreatment, temperature and machine speed.

1.2 This test method can be used for testing materials thickness between 0.25 mm (0.0210 in) and 14 6.3 mm (0.525 in.).

NOTE 1—This test method is not intended to cover precise physical procedures. The constant rate of crosshead movement of this test lacks accuracy from a theoretical standpoint. A wide difference may exist between the rate of crosshead movement and the rate of strain of the specimen indicating that the testing speeds specified may disguise important effects or characteristics of these materials in the plastic state. Further, it is realized that variations in the thicknesses of test specimen, as permitted by this test standard, produce variations in the surface-volume ratios of such specimens, and that these variations may influence the test results. Hence, where directly comparable results are desired, all samples should be of equal thickness. Special additional tests should be used where more precise physical data are needed.

1.3 Test data obtained by this test method is relevant and may be appropriate for use in engineering design with consideration of test conditions as compared to in-service conditions.

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

1.5 *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.*

[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. Referenced Documents

2.1 *ASTM Standards:* [2]

D 4000 Classification System for Specifying Plastic Materials

D 4439 Terminology for Geosynthetics

D 5199 Test Method for Measuring Nominal Thickness of Geosynthetics

D 5994 Test Method for Measuring Core Thickness of Textured Geomembrane

E 4 Practices for Force Verification of Testing Machines

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

3. Terminology

3.1 *Definitions*—Definitions of terms applying to this test method appear in Terminology D 4439.

4. Significance and Use

4.1 This test method is designed to produce tensile property data for the control and specification of nonreinforced polyethylene and flexible nonreinforced polypropylene geomembranes. These data are also useful for qualitative characterization and for research and development. It may be necessary to modify this procedure for use in testing certain materials as recommended by the material specifications. Therefore, it is advisable to refer to that material's specification before using this test method. Table 1 in Classification D 4000 lists the ASTM materials standards that currently exist.

4.2 Tensile properties may vary with specimen preparation, test speed and environment of testing. Consequently, where precise comparative results are desired, these factors must be carefully monitored and controlled.

4.2.1 It is realized that a material cannot be tested without also testing the method of preparation of that material. Hence, when comparative tests of materials are desired, the care must be exercised to ensure that all samples are prepared in exactly the same way, unless the test is to include the effects of sample preparation. Similarly, for referee purposes or comparisons within any given series of specimens, care must be taken to secure the maximum degree of uniformity in details of preparation, treatment, and handling.

NOTE 2—Tensile properties may provide useful data for plastics engineering design purposes. However, because of the high degree of sensitivity exhibited by many plastics to rate of straining and environmental conditions, data obtained by this test method cannot be considered valid for applications involving load-time scales or environments widely different from those of this test method. In cases of such dissimilarity, no reliable estimation of the limit of usefulness can be made for most plastics. This sensitivity to rate of straining and environment necessitates testing over a broad load-time scale and range of environmental conditions if tensile properties are to suffice for engineering design purposes.

5. Apparatus

5.1 *Testing Machine*—A testing machine of the constant-rate-of-crosshead-movement type and comprising essentially the following:

5.1.1 *Fixed Member*—A fixed or essentially stationary member carrying one grip.

5.1.2 *Movable Member*—A movable member carrying a second grip.

5.1.3 *Grips*—Grips for holding the test specimen between the fixed member and the movable member of the test apparatus can be either a fixed or self-aligning type.

5.1.3.1 Fixed grips are rigidly attached to the fixed and movable members of the test apparatus. Extreme care should be taken when this type of grip is used to ensure that the test specimen is inserted and clamped so that the long axis of the test specimen coincides with the direction of pull through the centerline of the grip assembly.

5.1.3.2 Self-aligning grips are attached to the fixed and movable members of the test apparatus. This type of grip assembly is such that they will move freely into alignment as soon as any load is applied as long as the long axis of the test specimen will coincide with the direction of the applied pull through the centerline of the grip assembly. The specimens should be aligned as perfectly as possible with the direction of pull so that no rotary motion will occur in the grips thereby inducing slippage; there is a limit to the amount of misalignment self-aligning grips will accommodate.

5.1.3.3 The test specimen shall be held in such a way that slippage relative to the grips is prevented as much as possible. Grip surfaces that are deeply scored or serrated with a pattern similar to those of a coarse single-cut file, serrations about 2.4 mm (0.09 in) apart and about 1.6 mm (0.06 in.) deep, have been found satisfactory for most thermoplastics. Finer serrations have been found to be more satisfactory for harder plastics, such as the thermosetting materials. The serrations should be kept clean and sharp. Breaking in the grips may occur at times, even when deep serrations or abraded specimen surfaces are used; other techniques must be used in these cases. Other techniques that have been found useful, particularly with smooth-faced grips, are abrading that portion of the surface of the specimen that will be in the grips, and interposing thin pieces of abrasive cloth, abrasive paper, plastic, or rubber-coated fabric, commonly called hospital sheeting, between the specimen and the grip surface. No. 80 double-sided abrasive paper has been found effective in many cases. An open-mesh fabric, in which the threads are coated with abrasive, has also been

[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*, Vol 08.02. Standards volume information, refer to teh standard's Document Summary page on the ASTM website.

effective. Reducing the cross-sectional area of the specimen may also be effective. The use of special types of grips is sometimes necessary to eliminate slippage and breakage in the grips.

5.1.4 *Drive Mechanism*—A drive mechanism for imparting to the movable member a uniform, controlled velocity with respect to the stationary member, with this velocity to be regulated as specified in Section 9.

5.1.5 *Load Indicator*—A suitable load-indicating mechanism capable of showing the total tensile load carried by the test specimen when held by the grips. This mechanism shall be essentially free of inertia lag at the specified rate of testing and shall indicate the load with an accuracy of ±1 % of the indicated value, or better. The accuracy of the testing machine shall be verified in accordance with Practices E 4.

NOTE 3—Experience has shown that many testing machines now in use are incapable of maintaining accuracy for as long as the periods between inspection recommended in Practices in E 4. Hence, it is recommended that each machine be studied individually and verified as often as may be found necessary. It frequently will be necessary to perform this function daily.

6. Test Specimens

6.1 *Sheet, Plate, and Molded Plastics* :

6.1.1 The test specimens shall conform to the dimensions shown in Fig. 1. This specimen geometry was adopted from ASTM D 638 and is therefore equivalent to Type IV of said standard.

6.1.2 Test specimens shall be prepared by die cutting from materials in sheet, plate, slab, or similar form.

6.2 All surfaces of the specimen shall be free of visible flaws, scratches or imperfections. If the specimen exhibits such markings it should be discarded and replaced. If these flaws or imperfections are present in the new specimen the die should be inspected for flaws.

NOTE 4—Negative effects from imperfections on the edge of the specimens can severely impact the results of this test and should therefore be carefully monitored. In cases of dispute over the results, inspection of the die and specimen preparation should take place.

7. Conditioning

7.1 *Conditioning*—Specimens should be tested once the material has reached temperature equilibrium. The time required to

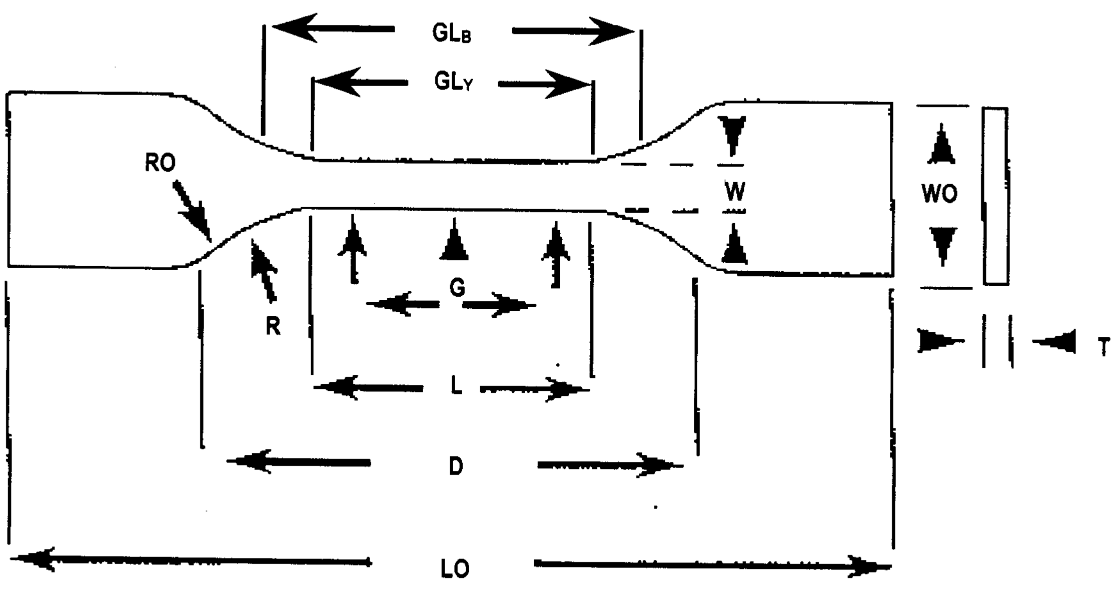

FIG. 1 Type IV Dog Bone Specimen

TABLE 1 Specimen Dimensions for Type IV Dog Bone of Thickness, T, mm (in.)

Description	Dimension, mm (in.)	Tolerances, mm (in.)
W–width of narrow section	6 (0.25)	±0.5 (±0.02)
L–length of narrow section	33 (1.30)	±0.5 (±0.02)
GL_Y–gage length for yield	33 (1.30)	±0.5 (±0.02)
GL_B–gage length for break	50 (2.0)	±0.5 (±0.02)
WO–width overall	19 (0.75)	±6.4 (±0.25)
LO–length overall	115 (4.5)	No max, No min
G–gage length	25 (1.00)	±0.5 (±0.02)
D–distance between grips	65 (2.5)	±0.13 (±0.005)
R–radius of fillet	14 (0.56)	±1 (±0.04)
RO–outer radius	25 (1.00)	±1 (±0.04)

reach a temperature equilibrium may vary according to the manufacturing process, material type and material thickness.

7.2 *Test Conditions*—Conduct tests in the Standard Laboratory Atmosphere of 21 ± 2°C (69.8 ± 3.6°F) unless otherwise specified in the test methods.

NOTE 5—A humidity requirement has intentionally been left out of the test conditions due to the fact that polyolefins are not significantly affected by large fluctuations in humidity thereby making such a restriction unnecessary.

NOTE 6—The tensile properties of some plastics change rapidly with small changes in temperature. Since heat may be generated as a result of straining the specimen at high rates, conduct tests without forced cooling to ensure uniformity of test conditions. Measure the temperature in the reduced section of the specimen and record it for materials where self-heating is suspected.

8. Number of Test Specimens

8.1 Test at least five specimens for each sample in the case of isotropic materials.

8.2 Test ten specimens, five normal to and five parallel with the principle axis of anisotropy, for each sample in the case of anisotropic materials.

8.3 Discard specimens that break at some obvious flaw and prepare new specimens for retest, unless such flaws constitute a variable to be studied.

9. Speed of Testing

9.1 Speed of testing shall be the relative rate of motion of the grips or test fixtures during the test. The rate of motion of the driven grip or fixture when the test apparatus is running idle may be used, if it can be shown that the resulting speed of testing is within the limits of variation allowed.

9.2 The test speed shall be 50 mm/min (2 in/min) for polyethylene geomembranes and 500 mm/min (20 in/min) for nonreinforced flexible polypropylene geomembranes.

NOTE 7—Some nonreinforced polyethylene materials approaching but less than a density of 0.940 g/cc exhibit less variation when tested at 2 ipm rather than 20 ipm. If a test speed other than that indicated in 9.2 is used this modification should be noted in the report.

10. Procedure

10.1 Measure the width and thickness of rigid flat specimens (Fig. 1) according to ASTM D 5199 for smooth geomembranes and ASTM D 5994 for textured (non-smooth) geomembranes.

10.2 Place the specimen in the grips of the test apparatus, taking care to align the long axis of the specimen and the grips with an imaginary line joining the points of attachment of the grips to the machine. The distance between the ends of the gripping surfaces, when using flat specimens, shall be as indicated in Fig. 1. Tighten the grips evenly and firmly to the degree necessary to prevent slippage of the specimen during the test, but not to the point where the specimen would be crushed.

10.3 Set the speed of testing at the proper rate as required in Section 9, and start the machine.

10.4 Record the load-extension curve of the specimen.

10.5 Record the load and extension at the yield point (if one exists) and the load and extension at the moment of rupture (break point).

11. Calculation

11.1 *Tensile Yield Strength*—Calculate the load corresponding to the yield point in Newtons (or pounds-force). Divide that load by the original minimum width of the specimen in meters (or inches). Express the result in newtons per millimeter (or pounds-force per inch) and report it to three significant figures as tensile yield strength.

11.2 *Tensile Break Strength*—Calculate the load corresponding to the point of rupture (break) in Newtons (or pounds-force). Divide that load by the original minimum width of the specimen in meters (or inches). Express the result in newtons per millimeter (or pounds-force per inch) and report it to three significant figures as tensile break strength.

11.3 *Percent Yield Elongation*—Calculate percent elongation at the yield point by reading the extension (change in gage length) at the moment the applicable load is reached. Divide that extension by the gage length for yield listed in Fig. 1 (GL_Y) and multiply by 100. Report percent yield elongation to ~~two significant figures.~~ the nearest 1%.

11.4 *Percent Break Elongation*—Calculate percent elongation at the break point by reading the extension (change in gage length) at the moment the applicable load is reached. Divide that extension by the gage length for break listed in Fig. 1 (GL_B) and multiply by 100. Report percent break elongation to ~~two significant figures.~~ the nearest 10%.

NOTE 8—It is possible for the specimens to not fail before reaching the maximum extension of the cross-head. If this occurs, the ultimate elongation shall be calculated in place of the break elongation. The ultimate elongation value will be calculated by reading the final extension (change in gage length) then dividing that by the gage length for break listed in Fig. 1 (GL_B) and multiply by 100. Report as percent ultimate elongation to two significant figures and include a ~~plus (+)~~ greater than (>) sign in front of the number along with a note stating that the limit of the cross-head was reached prior to the specimen breaking. The limit of the machine cross-head travel should be provided along with the information provided in Section 12 of this document.

11.5 Calculate the average~~,~~ and standard deviation ~~and coefficient of variation~~ of the five specimens in each direction (where applicable) for the four results listed in 11.1-11.4.

NOTE 9—Some of the low density polyethylene and very flexible materials may not exhibit a defined yield point. Therefore, 11.1 and 11.3 will not apply to these materials and should not be included in the report.

11.6 Calculate the standard deviation (estimated) as follows and report it to two significant figures:

$$S = \sqrt{\frac{(\Sigma X^2 - n\overline{X}^2)}{(n-1)}}$$

where:
S = estimated standard deviation,
X = value of single observation,
n = number of observations, and
$\overline{X}$ = arithmetic mean of the set of observations.

12. Report

12.1 Report the following information:

12.1.1 Complete identification of the material tested, including type, source, manufacturer's code numbers, form, principal dimensions, previous history, etc.,

12.1.2 Method of preparing test specimens,

12.1.3 Conditioning procedure used,

12.1.4 Ambient temperatures in test room,

12.1.5 Number of specimens tested,

12.1.6 Speed of testing,

12.1.7 Tensile yield strength (where applicable) and break strength, average value, and standard deviation of the five specimens in each direction,

12.1.8 Percent yield elongation (where applicable) and percent break elongation, average value, and standard deviation of the five specimens in each direction,

12.1.9 Date of test.

13. Precision and Bias

13.1 No precision and bias has been established yet for this test standard.

14. Keywords

14.1 nonreinforced; percent break elongation; percent yield elongation; polyethylene; polypropylene; tensile break strength; tensile yield strength