Designation: D6693/D6693M − 20

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

This standard is issued under the fixed designation D6693/D6693M; 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 [0.010 in.] and 6.3 mm [0.25 in.].

NOTE 1—This test method is not intended to precisely measure physical properties of a geomembrane for design purposes. This is an "index test" intended to be used for quality control and specification conformance purposes. The constant rate of crosshead movement of this test lacks accuracy from a theoretical standpoint, since crosshead movement as opposed to actual strain is used. A wide difference may exist between the rate of crosshead movement and the rate of strain in particular areas of the specimen since the specimen does not have a uniform width or cross-sectional area. This may disguise important effects or characteristics of these materials in the plastic state. Use of an extensometer, not included in this test, would more accurately measure strain and strain rate but would still have limitations for some geomembranes. Further, it is realized that variations in the thicknesses of test specimens, as permitted by this test method, 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. Test Method D4885 is a suitable performance test for many applications.

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]

D374/D374M Test Methods for Thickness of Solid Electrical Insulation

D412 Test Methods for Vulcanized Rubber and Thermoplastic Elastomers—Tension

D638 Test Method for Tensile Properties of Plastics

D4000 Classification System for Specifying Plastic Materials

D4439 Terminology for Geosynthetics

D4885 Test Method for Determining Performance Strength of Geomembranes by the Wide Strip Tensile Method

D5199 Test Method for Measuring the Nominal Thickness of Geosynthetics

D5994/D5994M Test Method for Measuring Core Thickness of Textured Geomembranes

E4 Practices for Force Verification of Testing Machines

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

E2586 Practice for Calculating and Using Basic Statistics

3. Terminology

3.1 *Definitions*—Definitions of terms applying to this test method appear in Terminology D4439.

[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.

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 D4000 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, 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.

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 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 inertial 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 E4.

NOTE 2—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 E4. 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.

5.1.6 *Crosshead Extension Indicator*—A suitable extension-indicating mechanism capable of showing the amount of change in the separation of the grips, that is, crosshead movement, for the calculation of a strain value for yield and break using the specified gauge length for each. This mechanism shall be essentially free of inertial lag at the specified rate of testing and shall indicate the crosshead movement with an accuracy of ±10 % of the indicated value.

6. Samples and Test Specimens

6.1 A sample can come from sheet, plate, or molded plastics and can be isotropic or anisotropic.

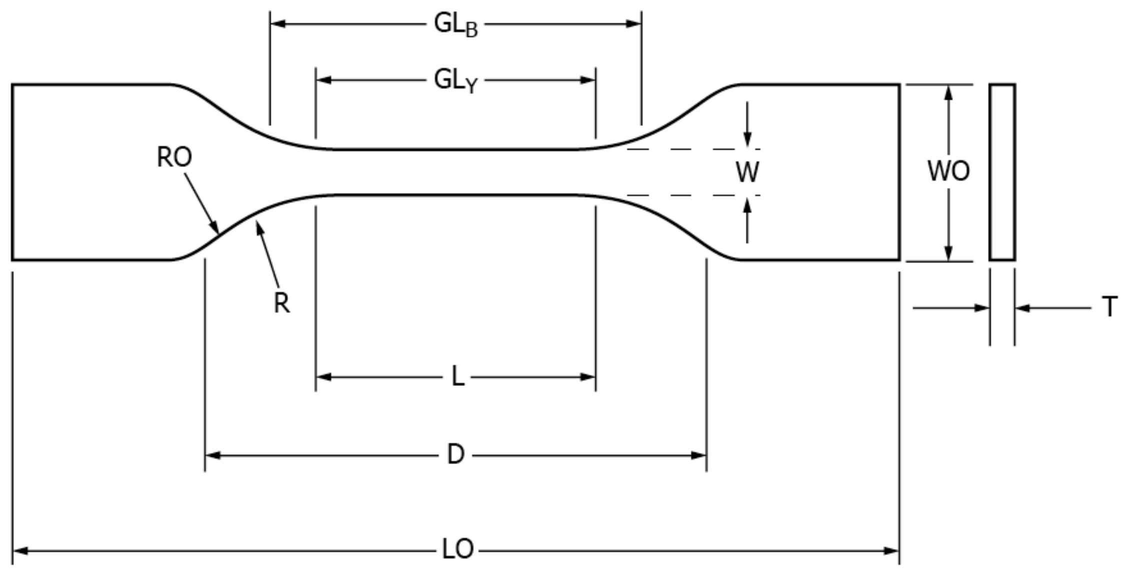
6.2 Record any necessary identification for each sample and maintain that identification with the prepared specimens.

6.3 *Test Specimen Dimensions:*

6.3.1 The test specimens shall conform to the dimensions shown in Fig. 1. This specimen geometry was adopted from Test Method D638 and is therefore equivalent to Type IV of said standard.

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

6.4 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



Description	Dimension, mm [in.]	Tolerances, mm [in.]
W—width of narrow section[A]	6 [0.25]	±0.5 [±0.02]
L—length of narrow section	33 [1.30]	±0.5 [±0.02]
GL_Y—gauge length for yield	33 [1.30]	. . .
GL_B—gauge length for break	50 [2.0]	. . .
WO—width overall	19 [0.75]	±6.4 [±0.25]
LO—length overall	115 [4.5]	No max, No min
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]

Specimen Dimensions for Type IV Dog Bone of Thickness, T, mm [in.]

[A] For the Type IV specimen, the internal width of the narrow section of the die shall be 6.00 ± 0.05 mm [0.250 ± 0.002 in.]. The dimensions are essentially those of Die C in Test Methods D412.

FIG. 1 Type IV Dog Bone Specimen

flaws or imperfections are present in the new specimen, the die should be inspected for flaws.

NOTE 3—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 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 4—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 5—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.

10. Procedure

10.1 Measure the width in accordance with Test Method D374/D374M and thickness of rigid flat specimens (Fig. 1) in accordance with Test Method D5199 for smooth geomembranes and Test Method D5994/D5994M for textured (nonsmooth) 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 in accordance with 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 metres [or inches]. Express the result in newtons per millimetre [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 metres [or inches]. Express the result in newtons per millimetre [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 using the amount of crosshead movement (extension) at the moment the applicable load is reached. Divide that extension by the gauge length for yield listed in Fig. 1 (GL_Y) and multiply by 100. This calculation considers all calculated elongations to be the result of deformation occurring only in the gauge length section of the specimen. See Appendix X1 for more background information. Report percent yield elongation to the nearest 1 %.

11.4 *Percent Break Elongation*—Calculate percent elongation at the break point by reading the change in crosshead movement (extension) at the moment the applicable load is reached. Divide that extension by the gauge length for break listed in Fig. 1 (GL_B) and multiply by 100. This calculation considers all calculated elongations to be the result of deformation occurring only in the nominal gauge length section of the specimen. See Appendix X1 for more background information. Report percent break elongation to the nearest 10 %.

NOTE 6—It is possible for the specimens to not fail before reaching the maximum extension of the crosshead. 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 (crosshead movement) then dividing that by the gauge length for break listed in Fig. 1 (GL_B) and multiplying by 100. Report as percent ultimate elongation to two significant figures and include a greater-than (>) sign in front of the number along with a note stating that the limit of the crosshead was reached prior to the specimen breaking. The limit of the machine crosshead travel should be provided along with the information provided in Section 12 of this document.

11.5 For each sample, calculate the average and standard deviation according to Practice E2586 for the five specimens in each direction (where applicable) for the four results listed in 11.1 – 11.4. Report the values to two significant figures.

NOTE 7—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.

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, and so forth,

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, and

12.1.9 Date of test.

13. Precision and Bias

13.1 *Precision:*

13.1.1 *Interlaboratory Testing Programs*—An interlaboratory testing program (ILS) was performed in 2003. The material descriptions and testing parameters are presented in Table 1. See Practice E691.

TABLE 1 Materials and Test Parameters

Material Description	No. of Laboratories	Speed of Testing
1.5 mm [60 mil] Smooth HDPE	8	50 mm/min [2 in./min]
1.5 mm [60 mil] Textured HDPE	8	50 mm/min [2 in./min]
1.0 mm [40 mil] Smooth fPP	5	500 mm/min [20 in./min]

13.1.2 *Test Results*—The precision information is presented in Table 2 for the three materials. The average values listed for the strength test results are in units of N/mm [lb/in.] and the elongation values in %.

13.2 *Bias*—The procedure in this test method for measuring the tensile properties of nonreinforced polyethylene and nonreinforced flexible polypropylene has no bias because the values of yield strength, yield elongation, break strength, and break elongation can only be defined in terms of a test method.

TABLE 2 Precision

Property	Test Dir.	Average	95 % Confidence Repeatability Limit	95 % Confidence Reproducibility Limit
1.5 mm [60 mil] Smooth HDPE				
Yield Strength	MD	30.5 (174)	4.3	8.7
	CD	31.5 (180)	3.7	10.4
Yield Elongation	MD	16	8.6	19.9
	CD	15	10.6	16.3
Break Strength	MD	51.2 (292)	9.0	9.8
	CD	51.5 (294)	11.1	15.0
Break Elongation	MD	770	7.3	11.0
	CD	820	8.2	12.7
1.5 mm [60 mil] Textured HDPE				
Yield Strength	MD	27.3 (156)	6.6	10.4
	CD	27.3 (156)	6.8	13.1
Yield Elongation	MD	15	10.9	17.7
	CD	14	11.3	17.5
Break Strength	MD	33.1 (189)	20.4	20.4
	CD	28.7 (164)	19.5	24.2
Break Elongation	MD	560	15.9	16.4
	CD	490	28.0	41.1
1.0 mm [40 mil] Smooth fPP				
Break Strength	MD	19.4 (111)	8.6	9.8
	CD	19.1 (109)	9.4	9.4
Break Elongation	MD	820	12.7	13.6
	CD	850	8.8	10.1

14. Keywords

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

APPENDIX

(Nonmandatory Information)

X1. STRAIN CALCULATION

X1.1 The calculation for strain used in this standard test method was developed prior to the use of what is considered to be modern universal test equipment for physical properties. HDPE was one of the primary geomembranes being tested (relevant because both elongation at yield and break were important). At the time, extensometers were not available in most geomembrane test laboratories. There were also other issues, explained below, that inspired the generation of the calculation used in this standard and, eventually, the rewriting of Test Method D638 using geomembrane-specific terms and "nominal" gauge lengths for calculation of elongation at yield and break.

X1.2 Absent in the past were computerized data acquisition hardware and software. Much of the equipment's output was crosshead movement versus load. More sophisticated equipment was capable of generating stress-strain curves on an X-Y plotter using an extensometer. Low-strain extensometers for yield properties could not be used for elongation at break, and the response time of the plotter required the use of very slow strain rates for yield properties. While some electronic high-strain extensometers were becoming available for measuring strain at break, they were not readily available in the majority of the laboratories and were not accurate enough for yield elongation measurements. Other high-strain extensometers utilized tapes with metal strips spaced 0.1 in. apart with an initial 1 in. extensometer grip separation. As the specimen was elongating, a blip was generated on the load/extension curve (every 10 % elongation) and the blips manually counted to be strain at break to the nearest 10 % (obviously of no use for strain at yield).

X1.3 Data calculations at the time were highly varied, as there was no common method being used. Modifications to Test Method D638 were frequently cited. Since the industry was not willing to embrace testing with extensometers, let alone two sets of specimens, one for yield and one for break, the calculation using nominal gauge lengths was developed by a small number of labs that had extensometers. They tested several HDPE geomembrane products using extensometers and calculated the nominal gauge length for yield and break that would give approximately the same values when using grip separation for calculating strain values. This calculation became included in standard material specifications for polyethylene and flexible polypropylene geomembranes and became included in Test Method D6693/D6693M when it was written.

X1.4 It is also important to point out that since this current standard generates strain values using nominal gauge lengths, the use of extensometers instead of crosshead movement will generate different values. Product specifications have been written and adopted using the standard as written. Changes to incorporate the use of an extensometer, if used for compliance with current specifications, may cause nonconformities that could result in the rejection of product.