INTERNATIONAL

**Designation: D5323 – 19a (Reapproved 2023)**

# Standard Practice for Determination of 2 % Secant Modulus for Polyethylene Geomembranes[1]

This standard is issued under the fixed designation D5323; 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 practice presents a technique for calculating the 2 % secant modulus for polyethylene geomembranes between 0.5 mm and 5 mm (20 mil and 200 mil) using Test Method D6693/D6693M.

1.2 This practice will facilitate modulus comparisons of similar materials by standardizing the method for deriving the points on the stress-strain curve from which the calculations are performed.

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

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]

D883 Terminology Relating to Plastics
D4439 Terminology for Geosynthetics
D6693/D6693M Test Method for Determining Tensile Properties of Nonreinforced Polyethylene and Nonreinforced Flexible Polypropylene Geomembranes

## 3. Terminology

3.1 *Definitions*—See Terminologies D883 and D4439 for general definitions.

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *modulus of elasticity, MPa* ($FL^{-2}$), *n*—the ratio of stress (nominal) to corresponding strain below the proportional limit of a material, expressed in force per unit area, such as megapascals (pounds-force per square inch).

3.2.1.1 *Discussion*—The stress-strain relations of many plastics do not conform to Hooke's law throughout the elastic range, but rather deviate therefrom even at strains well below the elastic limit. For such materials, the slope of the tangent to the stress-strain curve at a low strain is usually taken as the modulus of elasticity (or elastic modulus). Since the existence of a true proportional limit in polyethylene is questionable, and with the impracticality of measuring it reliably, the use of secant modulus for comparative evaluations is preferred.

3.2.2 *secant modulus, n*—the ratio of stress (nominal) to corresponding strain at any specified point on the stress-strain curve.

3.2.2.1 *Discussion*—The measurement units for secant modulus may change, depending on the standard used. For the purposes of this practice, the measurement units shall be force per unit area ($FL^{-2}$), such as megapascals (pounds-force per square inch).

## 4. Significance and Use

4.1 Where to draw the tangent to determine the modulus of elasticity is often unclear when performing tensile tests with polyethylene geomembranes. This problem results in a wide variation in test results and, therefore, makes this property unreliable for comparisons.

4.2 A secant modulus based on 2 % strain can be useful when making comparisons between materials, in quality control, and in comparing the same sample after being subjected to a nonstandard environment.

4.3 Secant modulus is an approximation of modulus of elasticity and generally results in a lower value than that for the modulus of elasticity.



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[1] This practice 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.

4.4 Although the technique for measuring 2 % secant modulus is described here, other percent secant moduli can be measured by this practice.

## 5. Procedure

5.1 Follow the test procedure described in Test Method D6693/D6693M.

5.1.1 A crosshead speed of 50 mm/min (2 in./min) is recommended for determining secant modulus, regardless of the type of geomembrane being evaluated. Faster crosshead speeds reduce resolution of the points on the curve.

5.1.2 High resolution of load and crosshead movement is important for obtaining accurate and reproducible values. Where possible, use settings on the testing equipment that will magnify this region.

5.2 Determine the load at 2 % strain.

5.2.1 Industry standard practice uses Test Method D6693/D6693M Type IV specimens. Hence, strain up to the yield point will be based on a gage length of 33 mm (1.3 in.). This represents the reduced area of the specimen. A gage length of 33 mm (1.3 in.) requires a crosshead movement of 0.66 mm (0.026 in.) for 2 % strain.

## 6. Calculations

6.1 *Normal Curve:*

6.1.1 Calculate the 2 % secant modulus as follows and as shown in Annex A2:

$$2\ \%\ \text{secant modulus} = \frac{\text{stress}}{\text{strain}} \tag{1}$$

where:

stress = force/area (at 2 % strain),
area = initial cross section area, and
strain = 0.02 (for 2 % secant modulus).

6.2 *Toe Compensation Curve:*

6.2.1 Calculate the 2 % secant modulus for toe compensation as shown in Annex A2.

6.3 *Pre-Stress Curves*—See Annex A3.

6.3.1 This test is invalid unless A3.2 is valid. Otherwise, do not use or perform any calculations.

## 7. Report

7.1 In addition to the reporting requirements given in Section 12 of Test Method D6693/D6693M, report the average 2 % secant modulus value and standard deviation based on the results from individual specimens tested from the sample.

## 8. Keywords

8.1 geomembranes; polyethylene; secant modulus



# ANNEXES

**(Mandatory Information)**

## A1. NORMAL STRESS-STRAIN (FORCE-ELONGATION) CURVE

A1.1 Fig. A1.1 represents the initial portion of the elastic region on what would be considered the normal (true) stress-strain curve for polyethylene. The 2 % secant modulus is the slope of the line *AC*. Point *B* represents 2 % strain and is equal to a distance that is 0.02 times the original gage length.

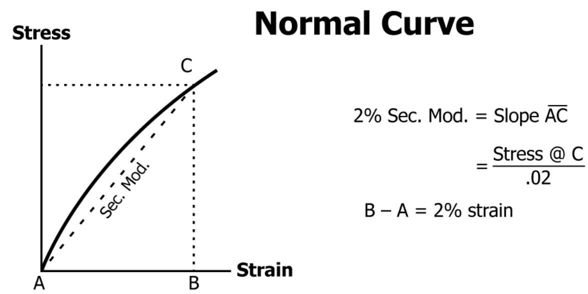


FIG. A1.1 Normal Curve

## A2. TOE COMPENSATION

A2.1 In some stress-strain curves (Fig. A2.1), a toe region, *AD*, exists that does not represent a property of the material. It is an artifact caused by alignment, a take-up of slack, or seating of the specimen. In order to obtain the correct value of such a parameter as modulus, this artifact must be compensated for to yield the corrected zero point on the strain axis.

A2.2 To correct for this artifact so that the actual zero-strain point can be found, construct a tangent to the maximum slope at the inflection point (*D*). This is extended to intersect the strain axis at Point *A*'. Using Point *A*' as zero strain, determine the new 2 % Strain Point *B*'. Locate Point *C*' on the curve that corresponds to *B*'. Using these corrected points, calculate the 2 % secant modulus by obtaining the slope of Line *A′C′*.



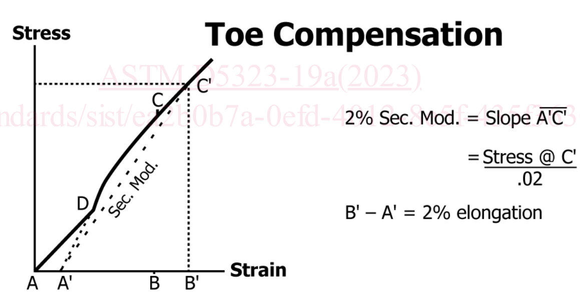


FIG. A2.1 Toe Compensation

## A3. PRE-STRESS CURVE

A3.1 Opposite of toe compensation is the indication of a load at 0 % strain (Fig. A3.1). This may be caused by the start of the chart not being synchronized precisely with the start of the crosshead, or by stressing the specimen when mounting it in the grips. If this problem exists, secant modulus cannot be calculated. To correct these problems, it is recommended that the chart be started prior to starting the crosshead, or the specimen be remounted, as the case may be.

A3.2 If the chart is started before the crosshead, 0 % strain is the point at which the load deviates distinctly from the base line. Note that the procedure for toe compensation may have to be used to determine 0 % strain if the chart looks similar to Fig. A2.1.