Designation: D4533/D4533M – 15

Standard Test Method for Trapezoid Tearing Strength of Geotextiles[1]

This standard is issued under the fixed designation D4533/D4533M; 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.

This standard has been approved for use by agencies of the U.S. Department of Defense.

1. Scope

1.1 This test method is an index test used to measure the force required to continue or propagate a tear in woven or non-woven geotextiles by the trapezoid method. While useful for quality control and acceptance testing, the trapezoid tear test does not provide all the information needed for all design applications and other test methods should be used.

1.2 This test method is applicable to most geotextiles that include woven fabrics, nonwoven fabrics, layered fabrics, knit fabrics, and felts that are used for geotextile 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 may not be exact equivalents; therefore, each system shall be used independently of the other. Combining values from the two systems may result in non-conformance with the standard.

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

2. Referenced Documents

2.1 *ASTM Standards:*[2]

D76/D76M Specification for Tensile Testing Machines for Textiles

D123 Terminology Relating to Textiles

D1776 Practice for Conditioning and Testing Textiles

D2905 Practice for Statements on Number of Specimens for Textiles (Withdrawn 2008)[3]

D4354 Practice for Sampling of Geosynthetics and Rolled Erosion Control Products(RECPs) for Testing

D4439 Terminology for Geosynthetics

E177 Practice for Use of the Terms Precision and Bias in ASTM Test Methods

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

3. Terminology

3.1 *Definitions:*

3.1.1 *atmosphere for testing geotextiles, n*—air maintained at a relative humidity of 65 ± 5 % and a temperature of 21 ± 2°C [70 ± 4°F].

3.1.2 *geotextile, n*—any permeable textile material used with foundation, soil, rock, earth, or any other geotechnical engineering related material as an integral part of a man-made product, structure, or system.

3.1.3 *tearing strength, n*—the force required to either (*1*) start, or (*2*) continue or propagate a tear in a fabric under specified conditions.

3.1.3.1 *Discussion*—This test method uses the maximum value of the tearing force as the tearing strength.

3.1.4 For definitions of other terms used in this test method, refer to Terminology D123 or Terminology D4439.

4. Summary of Test Method

4.1 An outline of an isosceles trapezoid is marked on a rectangular specimen cut for the determination of tearing strength (see Fig. 1), and the nonparallel sides of the trapezoid marked on the specimen are clamped in parallel jaws of a tensile testing machine. The separation of the jaws is continuously increased so the tear propagates across the specimen. At the same time, the force developed is recorded. The tearing strength, which is the maximum value of the tearing force, is obtained from the autographic force – extension curve (see Fig. 2).

5. Significance and Use

5.1 The trapezoid tear method is a test that produces tension along a reasonably defined course such that the tear propagates across the width of the specimen. The trapezoid tearing strength for woven fabrics is determined primarily by the

[1] This test method is under the jurisdiction of ASTM Committee D35 on Geosynthetics and is the direct responsibility of Subcommittee D35.01 on Mechanical Properties.

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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] The last approved version of this historical standard is referenced on www.astm.org.

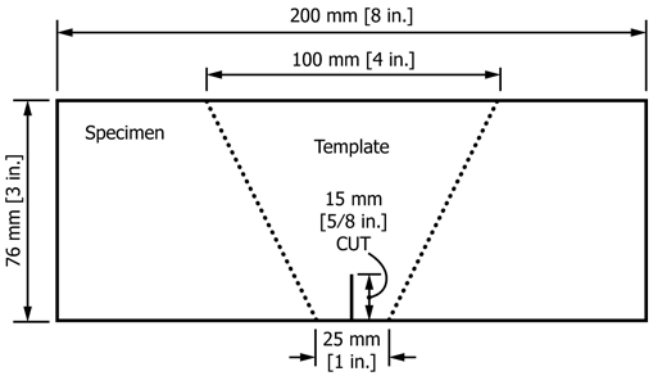

FIG. 1 Trapezoidal Template for Trapezoid Tearing Strength Test

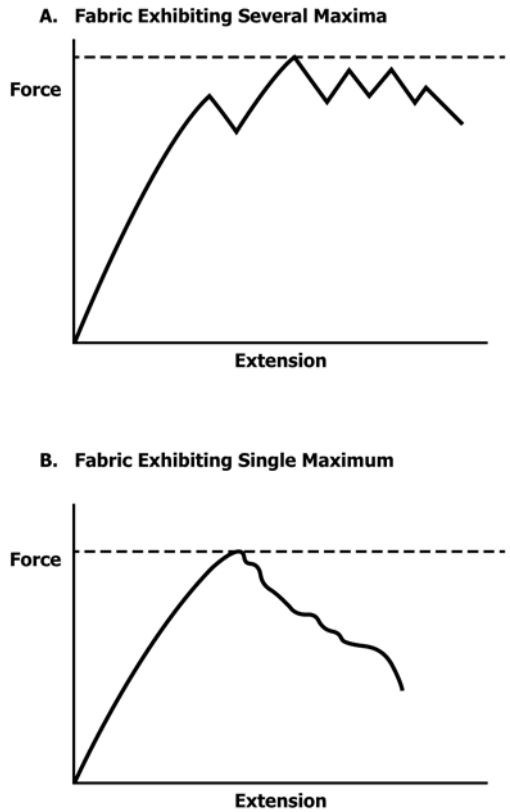

FIG. 2 Typical Tearing Force – Extension Curves for Individual Test Specimens

properties of the yarns that are gripped in the clamps. In nonwoven fabrics, because the individual fibers are more or less randomly oriented and capable of some reorientation in the direction of the applied load, the maximum trapezoid tearing strength is reached when the resistance to further reorientation is greater than the force required to rupture one or more fibers simultaneously.

5.2 The trapezoid tearing strength method is useful for estimating the relative tear resistance of different fabrics or different directions in the same fabric.

5.3 This test method may be used for acceptance testing of commercial shipments; however, caution is advised since information about between-laboratory precision is incomplete. Comparative tests as directed in 5.3.1 may be advisable.

5.3.1 In case of a dispute arising from differences in reported test results when using this test method for acceptance testing of commercial shipments, the purchaser and the supplier should conduct comparative tests to determine if there is a statistical bias between their laboratories. Competent statistical assistance is recommended for the investigation of bias. As a minimum, the two parties should take a group of test specimens that are as homogeneous as possible and that are from a lot of material of the type in question. Test specimens should then be randomly assigned in equal numbers to each laboratory for testing. The average results from the two laboratories should be compared using the appropriate Student's *t*-test and an acceptable probability level chosen by the two parties before testing is begun. If a bias is found, either its cause must be found and corrected or the purchaser and the supplier must agree to interpret future test results in the light of the known bias.

5.4 Most geotextile fabrics can be tested by this test method. Some modification of clamping techniques may be necessary for a given fabric, depending upon its structure. Special adaptation may be necessary with strong fabrics, or fabrics made from glass fibers, to prevent them from slipping in the clamps or being damaged as a result of being gripped in the clamps.

5.5 This test method may be used with constant-rate-of-traverse (CRT) or constant-rate-of-extension (CRE) type tension machines. However, there may be no overall correlation between the results obtained with the CRT machine and the CRE machine. Consequently, these two tension testers cannot be used interchangeably. In case of controversy, the CRE machine shall prevail.

6. Apparatus

6.1 *Tensile Testing Machine,* of the constant-rate-of-extension (CRE) or constant-rate-of-traverse (CRT) type with autographic recorder conforming to the requirements of Specification D76/D76M.

6.2 *Clamps,* having all gripping surfaces parallel, flat, and capable of preventing slipping of the specimen during a test, and measuring 50.8 by no less than 76.2 mm [2 by no less than 3 in.], with the longer dimension perpendicular to the direction of application of the load.

6.3 *Trapezoidal Template,* optional, having the dimensions shown in Fig. 1.

7. Sampling and Selection

7.1 *Lot Sample*—As a lot sample for acceptance testing, take at random the number of rolls of fabric directed in an applicable material specification or other agreement between the purchaser and the supplier, such as agreement to sample as directed in Practice D4354. Consider rolls of fabric to be the primary sampling units.

NOTE 1—An adequate specification or other agreement between the purchaser and the supplier requires taking into account the variability between rolls of fabric and between specimens from a swatch from a roll

of fabric so as to provide a sampling plan with a meaningful producer's risk, consumer's risk, acceptable quality level, and limiting quality level.

7.2 *Laboratory Sample*—Take for the laboratory sample a sample extending the width of the fabric and approximately 1 m [39.37 in.] along the selvage from each roll in the lot sample. The sample may be taken from the end portion of a roll, provided there is no evidence that it is distorted or different from other portions of the roll. In cases of dispute, take a sample that will exclude fabric from the outer wrap of the roll or the inner wrap around the core.

7.3 *Test Specimens*—Take test specimens as follows:

7.3.1 *Woven Fabrics*—Take the specimens to be used for the measurement of the tearing strength of machine direction yarns from different sets of machine direction yarns. Take the specimens to be used for the measurement of the tearing strength of cross-machine direction yarns from different sets of cross-machine direction yarns and, when possible, from fabric woven from different bobbins.

7.3.2 *Nonwoven Fabrics*—Take the specimens for the measurement of the machine direction tearing strength from different positions across the fabric. Take the specimens for the measurement of the cross-machine direction tearing strength from different positions along the length of the fabric.

7.3.3 *Cutting Test Specimens*—Take no specimens nearer the selvage or edge of the fabric than 1/20th of the fabric width or, 150 mm [6 in.] whichever is smaller. Cut rectangular specimens 76.2 by 201.6 mm [3 by 8 in.]. Cut the specimens to be used for the measurement of the tearing strength in the machine direction (or warp yarns), with the longer dimension parallel to the machine direction (or warp yarns). Cut the specimens to be used for the measurement of the tearing strength in the cross-machine direction (or filling yarns) with the longer dimension parallel to the cross-machine direction (or filling yarns). Mark each specimen with an isosceles trapezoid template (see Fig. 1). Make a preliminary cut 15.9 mm [0.625 in.] long at the center of the 25.4 mm [1 in.] edge, as shown Fig. 1.

NOTE 2—Cutting Test Specimen option: An option to cutting rectangular specimens is to use a six sided die shown in Fig. 3 and Fig. 4. Such specimen facilitates placement alignment and alleviates the need to use a template and mark the specimen prior to testing.

7.3.4 *Number of Specimens*—Unless otherwise agreed upon, as when provided in an applicable material specification, take a number of test specimens per swatch in the laboratory sample such that the user may expect at the 95 % probability level that the test result is not more than 5.0 % of the average above the true average of the swatch when testing in the machine and cross-machine directions, respectively. Determine the number of specimens per swatch as follows:

7.3.4.1 *Reliable Estimate of v*—When there is a reliable estimate of *v* based upon extensive past records for similar materials tested in the user's laboratory as directed in the method, calculate the required number of specimens for the machine and cross-machine directions as follows:

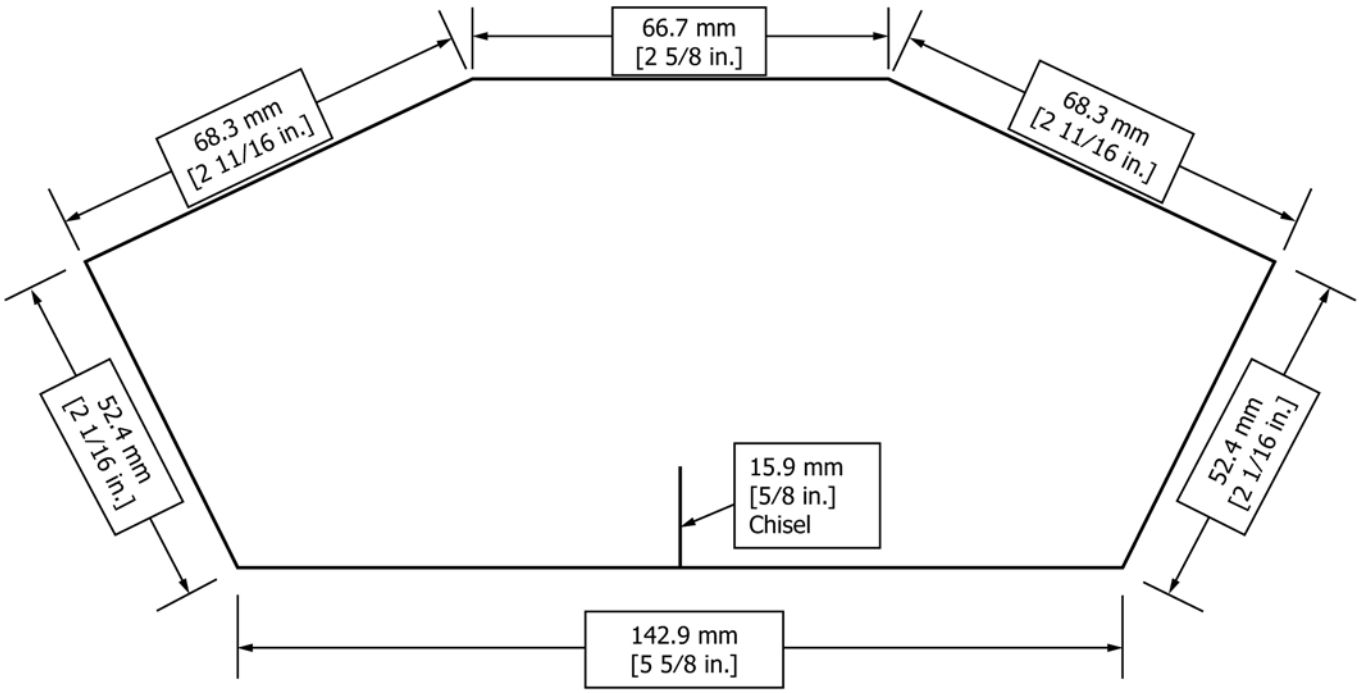

FIG. 3 Optional Trapezoidal Template for Trapezoid Tearing Strength Test

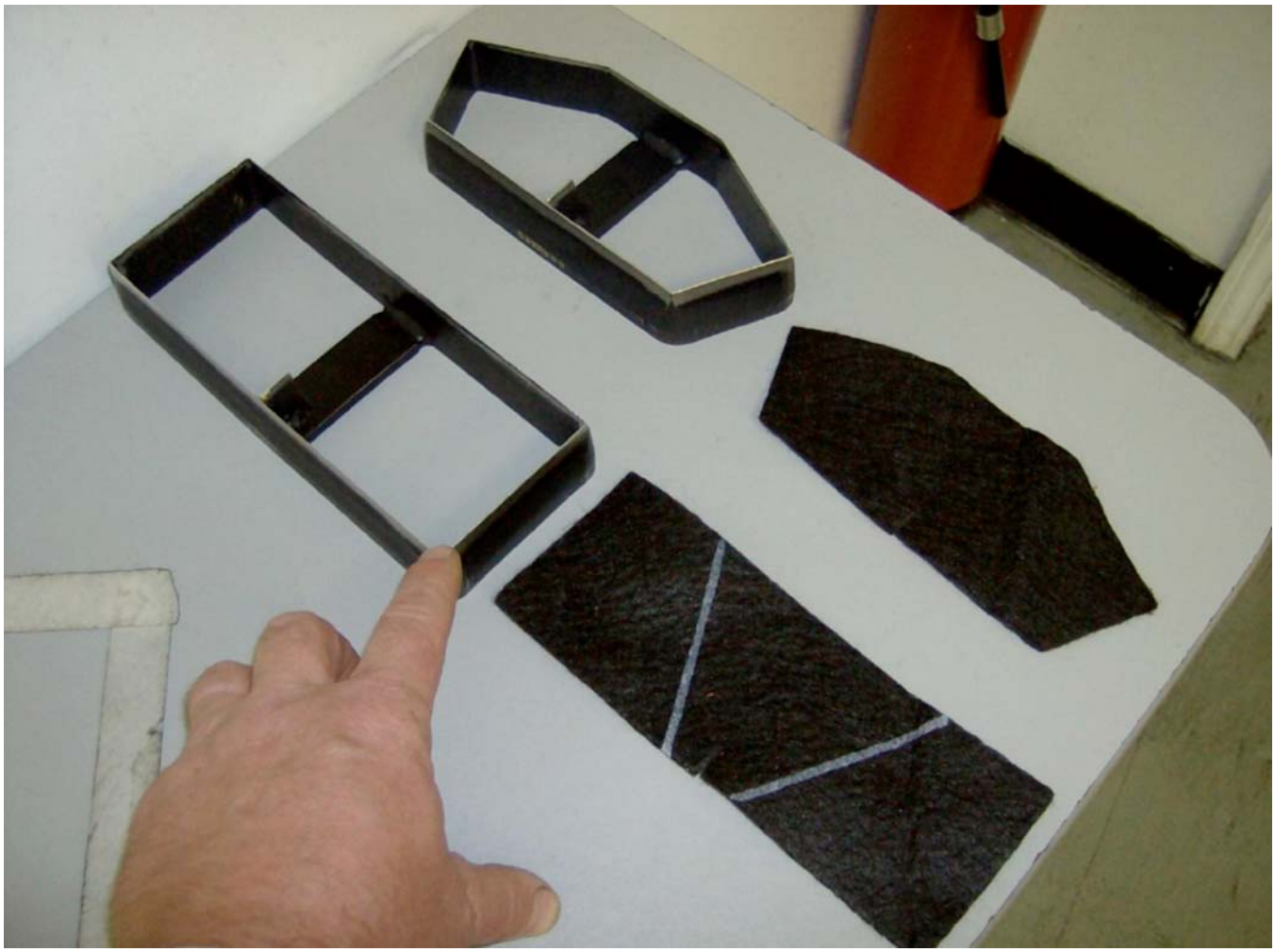

FIG. 4 Typical and Optional Tearing Force Dies and Individual Test Specimens

$$n = (tv/A)^2 \quad (1)$$

where:

n = number of test specimens (rounded upward to a whole number),

v = reliable estimate of the coefficient of variation of individual observations on similar materials in the user's laboratory under conditions of single-operator precision, %,

t = the value of Student's t for one-sided limits (see Table 1), a 95 % probability level, and the degrees of freedom associated with the estimate of v, and

A = 5.0 % of the average, the value of the allowable variation.

7.3.4.2 *No Reliable Estimate of v*—When there is no reliable estimate of v for the user's laboratory, Eq 1 should not be used directly. Instead, specify the fixed number (10) of specimens for the machine direction tests, and 10 specimens for the cross-machine direction tests. The number of specimens is calculated using v = 9.5 % of the average for both machine direction and cross-machine direction tests. These values for v are somewhat larger than usually found in practice. When a reliable estimate of v for the user's laboratory becomes available, Eq 1 will usually require fewer than the fixed number of specimens.

TABLE 1 Values of Student's *t* for One-Sided Limits and the 95 % Probability[A]

df	One-Sided	df	One-Sided	df	One-Sided
1	6.314	11	1.796	22	1.717
2	2.920	12	1.782	24	1.711
3	2.353	13	1.771	26	1.706
4	2.132	14	1.761	28	1.701
5	2.015	15	1.753	30	1.697
6	1.943	16	1.746	40	1.684
7	1.895	17	1.740	50	1.676
8	1.860	18	1.734	60	1.671
9	1.833	19	1.729	120	1.658
10	1.812	20	1.725		1.645

[A] Values in this table were calculated using Hewlett Packard HP 67/97 Users' Library Programs 03848D, "One-Sided and Two-Sided Critical Values of Student's *t*' and 00350D," Improved Normal and Inverse Distribution". For values at other than the 95 % probability level, see published tables of critical values of Student's *t* in any standard statistical text. Further use of this table is defined in Practice D2905.

8. Conditioning

8.1 Bring the specimens to moisture equilibrium in the atmosphere for testing geotextiles (3.1). Equilibrium is considered to have been reached when the increase 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. In general practice, the industry approaches equilibrium from the "as received" side.

NOTE 3—It is recognized that in practice, geotextile materials are frequently not weighed to determine when moisture equilibrium has been reached. While such a method cannot be accepted in cases of dispute, it may be sufficient in routine testing to expose the material to the standard atmosphere for testing for a reasonable period of time before the specimens are tested. A time of at least 24 h has been found acceptable in most cases. However, certain fibers may exhibit slow moisture equilization rates from the "as received" wet side. When this is known, a preconditioning cycle, as described in Practice D1776, may be agreed upon by the contractural parties for routine testing.

8.2 Specimens to be tested in the wet condition shall be immersed in water maintained at a temperature of 21 ± 2°C [70 ± 4°F]. The time of immersion must be sufficient to wet-out the specimens thoroughly; this is indicated by no significant change in strength or elongation following a longer period of immersion, and at least 2 min. To obtain thorough wetting, it may be necessary, and advisable, to add not more than 0.05 % of a nonionic neutral wetting agent to the water.

9. Procedure

9.1 Test the conditioned specimens in the standard atmosphere for testing as defined in 3.1.

9.2 Test the thoroughly wet specimen in the normal machine set-up within 2 min. after removal from the water.

9.3 Set the distance between the clamps at the start of the test at 25 ± 1 mm [1 ± 0.05 in.]. The upper 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 load range of the testing machine such that the maximum load occurs between 15 and 85 % of full-scale load. Set the machine to operate at a speed of 300 ± 10 mm/min [12 ± 0.5 in./min].

9.4 Secure the test specimen in the machine, clamping along the nonparallel sides of the trapezoid so that the end edges of the clamps are in line with the 25-mm [1-in.] long side of the trapezoid, and the cut is halfway between the clamps. Hold the short edge taut and let the remaining fabric lie in folds.

9.5 Start the machine and record the tearing force on the autographic recorder. The tearing force may not increase to a simple maximum value, but may show several maxima and minima, as shown in Fig. 2 (A). Record the maximum force obtained in newtons [lbf], as illustrated in Fig. 2 (A and B).

9.6 If a fabric slips in the jaws or if 25 % or more of the specimens break at a point within 5 mm [0.25 in.] of the edge of the jaw, then (*1*) the jaws may be padded; (*2*) the fabric may be coated under the jaw face area; or (*3*) the jaw face may be modified. If any of the modifications listed above are used, state the method of modification in the report.

9.7 If an individual test result deviates 25 % or more from the average test result of a swatch, it must be discarded and an additional specimen tested. Calculate the average excluding outlier values.

10. Calculation

10.1 For each swatch in the laboratory sample, calculate separately the average of the maximum tearing strengths of the machine direction (or warp) specimens and the average of the maximum tearing strengths of the cross-machine direction (or filling) specimens.

11. Report

11.1 Report the following:

11.1.1 State that the tests were performed as directed in this test method. Describe the material(s) or product(s) sampled and the method of sampling used.

11.1.2 Report the following information for each swatch in the laboratory sample:

11.1.2.1 Average of the maximum tearing strengths in newtons [lbf] for each direction.

11.1.2.2 Number of specimens tested for each direction.

11.1.2.3 Coefficient of variation of the observed tearing strength of individual specimens, if required.

11.1.2.4 Condition of the specimens (dry or wet).

12. Precision and Bias[4]

12.1 *Precision*—The precision of this test method is based on an interlaboratory study of D4533, Standard Test Method for Trapezoid Tearing Strength of Geotextiles, conducted in 2013. Ten laboratories tested a total of four different geotextile samples for tear strength. Every "test result" represents an individual determination. All labs were asked to report triplicate test results for each material tested. Practice E691 was followed for the design and analysis of the data; the details are given in ASTM Research Report No. RR:D35-1022.

12.1.1 *Repeatability Limit (r)*—Two test results obtained within one laboratory shall be judged not equivalent if they differ by more than the "r" value for that material; "r" is the interval representing the critical difference between two test results for the same material, obtained by the same operator using the same equipment on the same day in the same laboratory.

12.1.1.1 Repeatability limits are listed in Table 2.

12.1.2 *Reproducibility Limit (R)*—Two test results shall be judged not equivalent if they differ by more than the "R" value for that material; "R" is the interval representing the critical difference between two test results for the same material, obtained by different operators using different equipment in different laboratories.

12.1.2.1 Reproducibility limits are listed in Table 2.

12.1.3 The above terms (repeatability limit and reproducibility limit) are used as specified in Practice E177.

[4] Supporting data have been filed at ASTM International Headquarters and may be obtained by requesting Research Report RR:D35-1022. Contact ASTM Customer Service at service@astm.org.

TABLE 2 Maximum Tensile at Rupture (*lbf*)

Material	Average[A]	Repeatability Standard Deviation	Reproducibility Standard Deviation	Repeatability Limit	Reproducibility Limit
	$\bar{x}$	S_r	S_R	r	R
Woven Slit Tape Stabilization Geotextile	70.70	3.92	8.12	10.97	22.73
Light Weight Nonwoven Geotextile	56.63	4.21	4.93	11.78	13.80
Heavy Weight Nonwoven Geotextile	145.41	8.56	14.70	23.98	41.17
Woven Mono/Slit Tape Reinforcement Geotextile	190.32	12.35	29.96	34.58	83.90

[A] The average of the laboratories' calculated averages.

12.1.4 Any judgment in accordance with statements 12.1.1 and 12.1.2 would have an approximate 95 % probability of being correct.

12.2 *Bias*—At the time of the study, there was no accepted reference material suitable for determining the bias for this test method, therefore no statement on bias is being made.

12.3 The precision statement was determined through statistical examination of 108 reported results, from nine laboratories, on four materials. These four materials were identified as the following:

Woven Slit Tape Stabilization Geotextile
Light Weight Nonwoven Geotextile
Heavy Weight Nonwoven Geotextile
Woven Mono/Slit Tape Reinforcement Geotextile

12.4 To judge the equivalency of two test results, it is recommended to choose the material closest in characteristics to the test material.