Designation: D6637/D6637M − 15

Standard Test Method for Determining Tensile Properties of Geogrids by the Single or Multi-Rib Tensile Method[1]

This standard is issued under the fixed designation D6637/D6637M; 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 strength properties of geogrids by subjecting strips of varying width to tensile loading.

1.2 Three alternative procedures are provided to determine the tensile strength, as follows:

1.2.1 *Method A*—Testing a single geogrid rib in tension (N or lbf).

1.2.2 *Method B*—Testing multiple geogrid ribs in tension (kN/m or lbf/ft).

1.2.3 *Method C*—Testing multiple layers of multiple geogrid ribs in tension (kN/m or lbf/ft).

1.3 This test method is intended for quality control and conformance testing of geogrids.

1.4 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.

1.5 *This standard may involve hazardous materials, operations, and equipment. 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
D4354 Practice for Sampling of Geosynthetics and Rolled Erosion Control Products(RECPs) for Testing
D4439 Terminology for Geosynthetics
D5262 Test Method for Evaluating the Unconfined Tension Creep and Creep Rupture Behavior of Geosynthetics

3. Terminology

3.1 *Definitions:*

3.1.1 *atmosphere for testing geosynthetics, n*—air maintained at a relative humidity of 50 to 70 % and a temperature of 21 ± 2°C [70 ± 4°F].

3.1.2 *breaking force, (F), n*—the force at failure.

3.1.3 *corresponding force, n*—synonym for force at specified elongation.

3.1.4 *force at specified elongation, FASE, n*—a force associated with a specific elongation on the force-elongation curve (synonym for corresponding force.)

3.1.5 *force-elongation curve, n*—in a tensile test, a graphical representation of the relationship between the magnitude of an externally applied force and the change in length of the specimen in the direction of the applied force (synonym for stress-strain curve.)

3.1.6 *geogrid, n*—a geosynthetic formed by a regular network of integrally connected elements with apertures greater than 6.35 mm [¼ in.] to allow interlocking with surrounding soil, rock, earth, and other surrounding materials to primarily function as reinforcement. **D5262**

3.1.7 *geosynthetic, n*—a 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.

3.1.8 *index test, n*—a test procedure which may contain known bias, but which may be used to establish an order for a set of specimens with respect to the property of interest.

3.1.9 *integral, adj*—in geosynthetics, forming a necessary part of the whole; a constituent.

3.1.10 *junction, n*—the point where geogrid ribs are interconnected to provide structure and dimensional stability.

[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.

3.1.11 *rib, n*—for geogrids, the continuous elements of a geogrid which are interconnected to a node or junction.

3.1.12 *rupture, n*—for geogrids, the breaking or tearing apart of ribs.

3.1.13 *tensile, adj*—capable of tensions, or relating to tension of a material.

3.1.14 *tensile strength,* (α_f)*, n*—for geogrids the maximum resistance to deformation developed for a specific material when subjected to tension by an external force. Tensile strength of geogrids is the characteristic of a sample as distinct from a specimen and is expressed in force per unit width.

3.1.15 *tensile test, n*—for geosynthetics, a test in which a material is stretched uniaxially to determine the force-elongation characteristics, the breaking force, or the breaking elongation.

3.1.16 *tension, n*—the force that produces a specified elongation.

3.2 For definitions of other terms used in this test method, refer to Terminologies D123 and D4439.

4. Summary of Test Method

4.1 *Method A*—In this method, a single, representative rib specimen of a geogrid is clamped and placed under a tensile force using a constant rate of extension testing machine. The tensile force required to fail (rupture) the specimen is recorded. The ultimate single rib tensile strength (N or lbf) is then determined based on the average of six single rib tensile tests.

4.2 *Method B*—A relatively wide specimen is gripped across its entire width in the clamps of a constant rate of extension type tensile testing machine operated at a prescribed rate of extension, applying a uniaxial load to the specimen until the specimen ruptures. Tensile strength (kN/m or lbf/ft), elongation, and secant modulus of the test specimen can be calculated from machine scales, dials, recording charts, or an interfaced computer.

4.3 *Method C*—A relatively wide, multiple layered specimen is gripped across its entire width in the clamps of a constant rate of extension type tensile testing machine operated at a prescribed rate of extension, applying a uniaxial load to the specimen until the specimen ruptures. Tensile strength (kN/m or lbf/ft), elongation and secant modulus of the test specimen can be calculated from machine scales, dials recording charts, or an interfaced computer.

5. Significance and Use

5.1 The determination of the tensile force-elongation values of geogrids provides index property values. This test method shall be used for quality control and acceptance testing of commercial shipments of geogrids.

5.2 In cases of dispute arising from differences in reported test results when using this test method for acceptance testing of commercial shipments, the purchaser and 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 which are as homogeneous as possible and which are from a lot of material of the type in question. The 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 Student's t-test for unpaired data and an acceptable probability level chosen by the two parties before the testing began. If a bias is found, either its cause must be found and corrected or the purchaser and supplier must agree to interpret future test results in light of the known bias.

5.3 All geogrids can be tested by any of these methods. Some modification of techniques may be necessary for a given geogrid depending upon its physical make-up. Special adaptations may be necessary with strong geogrids, multiple layered geogrids, or geogrids that tend to slip in the clamps or those which tend to be damaged by the clamps.

6. Apparatus

6.1 *Testing Clamps*—The clamps shall be sufficiently wide to grip the entire width of the specimen (as determined by the test method) and with appropriate clamping power to prevent slipping or crushing (damage). For a given product, the same clamps shall be used in testing methods A, B, and C prior to making any comparison between results.

6.1.1 *Size of Jaw Faces*—Each clamp shall have jaw faces measuring wider than the width of the specimen.

6.2 *Tensile Testing Machine*—A testing machine of the constant rate of extension type as described in Specification D76/D76M shall be used. The machine shall be equipped with a device for recording the tensile force and the amount of separation of the grips. Both of these measuring systems shall be accurate to ±1.0 % and, preferably, shall be external to the testing machine. The rate of separation shall be uniform and capable of adjustment within the range of the test.

6.3 *Distilled Water and Nonionic Wetting Agent,* shall be used for wet specimens only.

6.4 *Extensometer*—When required by the method, a device capable of measuring the distance between two reference points on the specimen without any damage to the specimen or slippage, care being taken to ensure that the measurement represents the true movement of the reference points. Examples of extensometers include mechanical, optical, infrared or electrical devices.

7. Sampling

7.1 *Lot Sample*—Divide the product into lots and take the lot sample as directed in Practice D4354.

7.2 *Laboratory Sample*—For the laboratory sample, take a full roll width swatch long enough in the machine direction from each roll in the lot sample to ensure that the requirements in 8.1 can be met. The sample may be taken from the end portion of a roll provided there is no evidence it is distorted or different from other portions of the roll.

8. Test Specimen

8.1 The specimens shall consist of at least three (3) junctions or 300 mm [12 in.] in length, in order to establish a minimum specimen length in the direction of the test. The direction of the test shall be defined as either the machine direction (MD), cross-machine direction (CMD), or a nominal skewed angle referenced from the machine direction, according to Fig. 1, where MD and CMD are defined as 0° and 90°, respectively. All specimens should be free of surface defects, etc., not typical of the laboratory sample. Take no specimens nearer the selvage edge along the geogrid than 1⁄10 the width of the sample.

NOTE 1—If a comparison of one geogrid to another is to be made the length of each specimen shall be the same (as similar as possibly) and agreed upon by all parties.

8.2 *Preparation:*

8.2.1 *Method A*—Prepare each finished specimen, as shown in Fig. 2, to contain at least one intersecting rib (or set of ribs) crossing the test direction with at least three junctions (two apertures) in the direction of the testing, with the length dimension being designated and accurately cut parallel to the direction for which the tensile strength is being measured. See Note 2.

NOTE 2—In some applications, it may be necessary to perform tensile tests in more than one direction (for example, both the machine and the cross-machine direction). When testing a geogrid with ribs oriented in more than one direction, in all cases, the nominal rib direction of the tensile test specimen(s) should be clearly noted per Fig. 1.

8.2.2 *Method B*—Prepare each finished specimen, as shown in Fig. 3, to be a minimum of 200 mm wide and contain five ribs in the cross-test direction wide by at least three junctions (two apertures) or 300 mm [12 in.] long in the direction of the testing, with the length dimension being designated and accurately cut parallel to the direction for which the tensile strength is being measured.

8.2.3 *Method C*—Prepare each finished specimen, as shown in Fig. 3, to be a minimum of 200 mm wide and contain five ribs in the cross-test direction wide by at least three junctions (two apertures) or 300 mm [12 in.] long in the direction of the testing, with the length dimension being designated and accurately cut parallel to the direction for which the tensile strength is being measured. This must be repeated for each layer of geogrid included in the test.

8.2.4 Within Test Methods A, B, and C, the outermost ribs are commonly cut prior to testing to permit extra width of material in the clamps to minimize slippage within the clamps. If this procedure causes nonuniform distribution of load to the gauge length area of the specimen, the same width of material shall be included in the clamps as will be tested in the gauge length area. In either case, the test results shall be based on the unit of width associated with the number of intact ribs.

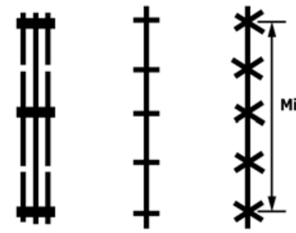

FIG. 2 Specimen Dimensions for Method A

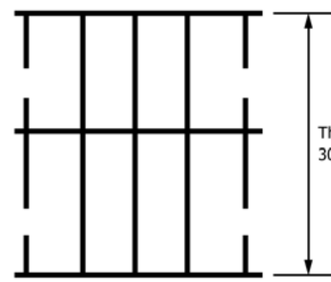

FIG. 3 Specimen Dimensions for Methods B and C

8.3 *Number of Test Specimens:*

8.3.1 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 no more than 5 % above the true average for each swatch in the laboratory sample for each required direction, see Note 2.

8.3.2 *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 using Eq 1, as follows:

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

where:

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

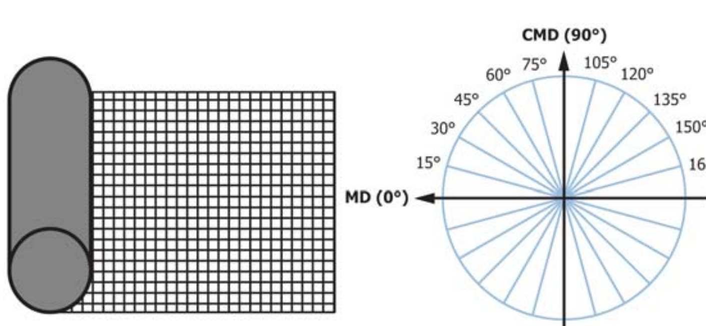

FIG. 1 Specimen Orientation and Test Direction

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, 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 allowable variation.

8.3.3 *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 of 5 specimens for the required direction. The number of specimens is calculated using v = 9.5 % of the average for the required direction. This value for v is 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.

9. Conditioning

9.1 Expose the specimens to the atmosphere for testing geosynthetics for a period long enough to allow the geogrid to reach equilibrium within this standard atmosphere. Consider the specimen to be at moisture equilibrium when the change 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. Consider the specimen to be at temperature equilibrium after 1 h of exposure to the atmosphere for testing geosynthetics.

9.2 Specimens to be tested in the wet condition shall be immersed in water for a minimum of one hour, maintained at a temperature of 21 ± 2°C [70 ± 4°F]. The time of immersion must be sufficient to wet-out the specimens thoroughly, as 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 or advisable to use distilled water.

9.3 Geogrids may be received in the laboratory rolled, thus it is important to flatten the specimens to avoid misleading elongation measurements. Geogrids which exhibit curl memory should be laid flat and weighted, until the geogrid remains flat without weight.

10. Procedure

10.1 Zero the testing system.

10.2 *Machine Set-Up Conditions*—At the start of the test, adjust the distance between the clamps or the distance from centerline to centerline of rollers to the greater distance of three junctions or 200 ± 3 mm [8.0 ± 0.1 in.], such that at least one transverse rib is contained centrally within the gauge length. At least one clamp should be supported by a free swivel or universal joint which will allow the clamp to rotate in the plane of the geogrid. Select the force range of the testing machine so the break occurs between 10 and 90 % of full-scale force. The test shall be conducted at a strain rate of 10 ± 3 % per minute of the gauge length based on the gauge length as depicted in Fig. 4.

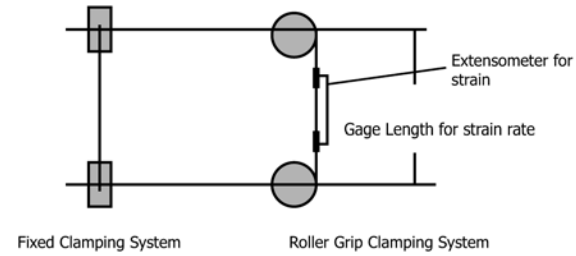

FIG. 4 Gauge Length for Fixed and Roller Grip Clamping Systems

10.3 Mount the specimen centrally in the clamps and tighten sufficiently to prevent damage to the specimen, see Notes 3 and 4. Measure the distance between clamp faces or centerline to centerline of the roller grips to determine test specimen gauge length External extensometers or other external means of measurement (for example, photo methods) are encouraged for all tests where modulus is to be measured, and must be used to determine displacement when roller clamps are used in testing. Documentation should be provided if a discrepancy arises when extensometers are not used during testing.

NOTE 3—Some modifications of clamping techniques may be necessary for a given geogrid depending upon its construction. Special clamping configurations may be necessary for geogrids constructed of coated fibers or yarns to prevent them from slipping in the clamps or being damaged as a result of being gripped too tightly in the clamps. When roller clamps are used an external extensometer, per Fig. 4, is often used to determine displacement. In this case, the distance between the moving feet of the extensometer will determine the gauge length for use in elongation calculations and not test speed.

NOTE 4—Care shall be taken while testing multiple geogrid layers to assure even tensioning of the layers and uniform clamping pressure. The test result shall be discarded if the result is a load at a small displacement or peak strength is reached without having all of the layers evenly tensioned.

10.4 Initiate the test by starting the testing machine and continue running the test until rupture occurs. Report the maximum force obtained to cause failure, the time to failure and the elongation at the measured maximum force.

10.4.1 If a specimen of one or more layers slips in the jaws, breaks at the edge of or in the jaws, or if for any reason attributed to faulty operation the result falls markedly below the average for the set of specimens, see 10.4.2.

10.4.2 The decision to discard the results as discussed in 10.4.1 shall be based on observation of the specimen during the test of the geogrid. In the absence of other criteria for such tests, any test which results in a value below 20 % of the average of all the other breaks shall be discarded. No other break shall be discarded unless the test is known to be faulty.

10.4.3 It is difficult to determine the precise reason why certain specimens break near the edge of the jaws. If a jaw break is caused by damage to the specimen by the jaws, then the results should be discarded. If, however, it is merely due to randomly distributed weak places, it is a perfectly legitimate result. In some cases, it may also be caused by a concentration of stress in the area adjacent to the jaws because they prevent the specimen from contracting in width as the force is applied. In these cases, a break near the edge of the jaws is inevitable and shall be accepted as a characteristic of the particular method of test.

10.5 If a geogrid manifests any slippage in the jaws or if more than 24 % 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 geogrid may be coated under the jaw face area, or (*3*) the surface of the jaw face may be modified. If any of the modifications listed above are used, state the method of modification in the report.

10.6 *Measurement of Elongation*—Measure the elongation of the geogrid at any stated force by means of a suitable recording device at the same time as the tensile strength is determined, unless otherwise agreed upon, as provided for in an applicable material specification. Measure the elongation to three significant figures.

10.6.1 The strain within the specimen is calculated from the measurement of elongation as discussed in 10.6 and shown in Fig. 4. It can also be obtained independently of the cross head movement. These measurements can be made with extensometers or area measuring devices which are set to read the center portion of the specimen and containing at least one transverse rib. When used, the minimum extensometer gauge length shall be 60 mm.

11. Calculation

11.1 *For Method A (Single Rib Specimen)*—From the test data, the average ultimate rib strength in N [lbf] is calculated by averaging the value of maximum force at rupture for all accepted specimen results. The average elongation at failure shall be determined separately for specimens in each test direction and expressed as the percentage increase in length, based upon the initial gauge length of the specimen. Report this as the elongation at failure.

11.2 *For Methods B and C (Wide Width Specimen):*

11.2.1 *Slack Displacement (d_o) and Slack Tension (T_o)*—Slack in the geosynthetic reinforcement may have developed during test set-up or due to the testing equipment. For each test, the tensile load-displacement curve (Fig. 5) may be examined to establish a point where the testing equipment fully engages the specimen, that is, pick up load. The displacement where this occurs will be designated as the slack displacement, d_o. The applied tension at the slack displacement will be designated as the slack tension, T_o. Both values must be recorded in the report.

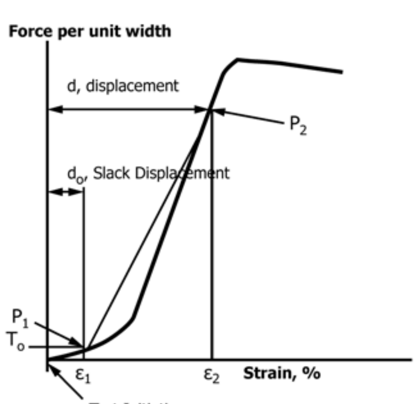

FIG. 5 Stress-Strain Curve with Complete Test Results

11.2.1.1 The slack tension, T_o , shall be limited to 1.25 % of the peak tensile strength or 225N [50 lbf]. The slack tension may only be applied once. The time between application of slack tension and test initiation must be less than two minutes. A slack displacement, d_o, should be selected in which the slack tension, T_o, does not violate these criteria.

NOTE 5—The slack tension, T_o, and slack displacement, d_o, may both be designated as equal to zero even if there is some slack behavior.

11.2.2 Calculate the tensile strength for individual wide width specimens (see Note 6); that is, calculate the equivalent force per unit width expressed in N/m [lbf/in.] of width, using Eq 2:

$$\alpha_f = [(F_p - T_o)/Nr] \times Nt \tag{2}$$

where:

α_f = equivalent force per unit width, N/m [lbf/in.];
F_p = observed maximum force, N [lbf];
T_o = Slack tensile load, N [lbf];
Nr = number of tensile elements being tested; and
Nt = number of tensile elements per unit width, equal to N_c/b (see Note 7).

NOTE 6—This equation is only for use in the determination of the wide-width tensile strength of the specimen based on Methods B and C above. This test method does not address the possible correlation between single-rib and wide-width tensile strength.

NOTE 7—Nt is determined by taking the average of three measurements from samples that are 95 % of the manufactured product roll width. Each measurement is performed by measuring the distance from the central point of the starting aperture (center line to center line aperture dimension divided by 2) to the center point of the aperture a distance equal to 95 % of the manufactured product roll width away from the starting aperture (this establishes the *b* value). As such, this measurement will result in a fractional value. The number of tensile elements, N_c, within this distance, *b*, are counted and *Nt* is determined by dividing the N_c value by the *b* value. For multiple layer geogrids, "*b*" should be measured using the single layer. The number of tensile elements, N_c, within this distance, "*b*", are counted and multiplied by the number of layers found in the test specimen.

11.2.3 *Strain*—Calculate the percent strain for individual specimens; see Fig. 5. That is, calculate the elongation of specimens, expressed as the percentage increase in length of the specimen using Eq 2 for XY type recorders, or Eq 3 for manual readings.

$$\varepsilon\rho = (\Delta L \times R \times 100)/C_c \times L \tag{3}$$

$$\varepsilon\rho = (\Delta L \times 100)/L$$

where:

$\varepsilon\rho$ = elongation, %;
d_o = distance from zero force to the point where the curve leaves the zero load axis, mm [in.];
d = distance along the zero load axis from the point the curve leaves the zero load axis to a point of corresponding force, mm [in.];
R = testing speed rate, m/min [in./min];
C_c = recording chart speed, m/min [in./min];
L = $L_o + d_o$ = slack displacement plus the initial nominal gauge length, mm [in.]; and
ΔL = $(d - d_o)$ = the unit change in length from the slack displacement point to the corresponding measured force, mm [in.].

11.2.4 Gauge marks or extensometers are preferred to define a specific test section of the specimen, per Fig. 4; when these devices are used, only the length defined by the gauge marks or extensometers shall be used in the calculation. Gauge marks must not damage the geogrid.

11.2.5 *Secant Modulus*—Per Fig. 5, select a force per unit width for a specified elongation ε_2, and label the corresponding point on the force-elongation curve as P_2. Likewise, label a second point, P_1, at a specified elongation, ε_1, taken at d_o. Draw a straight line (secant) through both points P_1 and P_2 intersecting the zero load axis. Calculate secant tensile modulus using Eq 4.

$$J_{sec} = (\alpha_f \times 100)/\varepsilon_p \quad (4)$$

where:

J_{sec} = secant tensile modulus, N/m [lbf/ft.], at corresponding elongation;

α_f = peak force minus slack tension times the number of tensile elements in a unit width (m or ft) divided by the number of elements tested. This is the equivalent force per unit width, N/m [lbf/ft] at a designated percent strain; and

ε_p = per Eq 4, corresponding percent strain with respect to the force per unit width.

12. Report

12.1 *For Test Method A*—The report for geogrid rib tensile strength should include the following:

12.1.1 The maximum individual rib tensile strength, N [lbf], and elongation at failure for each specimen and the average ultimate rib tensile strength, N [lbf], average elongation at failure, and standard deviation for each set of specimens;

12.1.2 Make and model of the testing machine;

12.1.3 Type, size, and facing of grips, and description of any changes made to the grips;

12.1.4 The number of specimen tested;

12.1.5 Test conditions;

12.1.6 Any departures from standard procedure;

12.1.7 Identification and description of geogrid sample(s);

12.1.8 Description of type and location of failure for each test;

12.1.9 Direction of testing; and

12.1.10 Full set of load versus strain charts.

12.2 *For Test Methods B and C*—Report that the specimens were tested as directed in this test method, or any deviations from this test method. Describe all materials or products sampled and the method of sampling for each material.

12.2.1 Report all of the following applicable items for the machine direction and where appropriate, the cross machine direction of all materials tested:

12.2.2 Ultimate tensile strength, αf, in kN/m [lbf/ft];

12.2.3 Elongation at the ultimate tensile strength in percent, and the method of measuring elongation;

12.2.4 Secant modulus in kN [lbf] of width, see Fig. 5, and 11.2.5. If the secant modulus is reported, state that portion of the force-elongation curve used to determine the modulus, that is, ε_1 to ε_2 at zero tension, elongation reported as ε_2 secant modulus. If it is agreed between parties that the secant modulus be reported then the entire load-strain curve should be recorded and reported as depicted in Fig. 5;

12.2.5 The standard deviation or the coefficient of variation of the test results;

12.2.6 Number of tensile elements, ribs, within the width of specimens;

12.2.7 Number of specimens tested;

12.2.8 Make and model of the testing machine;

12.2.9 Grip separation (initial);

12.2.10 Type, size, and facing of grips, and description of any changes made to the grips;

12.2.11 Conditioning of specimens, including details of temperature, relative humidity, and conditioning time; and

12.2.12 Anomalous behavior, such as tear failure or failure at the grip.

13. Precision and Bias

13.1 *Precision*—The precision of this test method is being established.

13.2 *Bias*—This test method has no bias since the values of those properties can be defined only in terms of a test method.

14. Keywords

14.1 geogrid; geogrid rib; geosynthetic; geotextile; index test; tensile test