Designation: D 5083 – 96

Standard Test Method for Tensile Properties of Reinforced Thermosetting Plastics Using Straight-Sided Specimens[1]

1. Scope

1.1 This test method covers the determination of the tensile properties of thermosetting reinforced plastics using test specimens of uniform nominal width when tested under defined conditions of pretreatment, temperature, humidity, and testing-machine speed.

NOTE 1—Experience with this test method to date has been limited to glass-reinforced thermosets. Applicability to other materials remains to be determined.

1.2 This test method can be used for testing materials of any thickness up to 14 mm (0.55 in.).

NOTE 2—This test method is not intended to cover precise physical procedures. It is recognized that the constant-rate-of-crosshead-movement type of test leaves much to be desired from a theoretical standpoint, that wide differences may exist between rate-of-crosshead movement and rate of strain between gage marks on the specimen, and that the testing speeds specified disguise important effects characteristic of materials in the plastic state. Further, it is realized that variations in the thicknesses of test specimens that are permitted by these procedures, 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.

NOTE 3—Use of this test method for testing materials of thicknesses greater than 14 mm (0.55 in.) is not recommended. Reducing the thickness by machining may be acceptable for materials of uniform reinforcement amount and direction, but is generally not recommended.

1.3 Test data obtained by this test method is relevant and appropriate for use in engineering design.

1.4 The values stated in SI units are to be regarded as standard. The inch-pound units 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.*

NOTE 4—This test method is technically equivalent to ISO 527-4 when the Type 2 ISO specimen is used, except for the difference in the lengths of the specimens.

2. Referenced Documents

2.1 *ASTM Standards:*

D 374 Test Methods for Thickness of Solid Electrical Insulation[2]
D 618 Practice for Conditioning Plastics and Electrical Insulating Materials for Testing[3]
D 638 Test Method for Tensile Properties of Plastics[3]
D 883 Terminology Relating to Plastics[3]
D 3039 Test Method for Tensile Properties of Polymer Matrix Composite Materials[4]
D 4000 Classification System for Specifying Plastic Materials[5]
E 4 Practices for Force Verification of Testing Machines[6]
E 83 Practice for Verification and Classification of Extensometers[6]
E 691 Practice for Conducting an Interlaboratory Study to Determine the Precision of a Test Method[7]

2.2 *ISO Standard:*

ISO 527 Part 4 Plastics—Determination of Tensile Properties—Test Conditions for Isotropic and Orthotropic Fibre-Reinforced Plastic Composites[8]

3. Terminology

3.1 *Definitions*—Definitions of terms applying to this test method appear in Terminology D 883.

4. Significance and Use

4.1 This test method is intended primarily as a quality-control test and as a screening test for fiber-reinforced laminates. It is particularly useful when the length of the reinforcement exceeds 12.7 mm (0.5 in.). Results obtained by this procedure may differ from those obtained by Test Methods D 638 and D 3039. In the case of disagreement, values

---

[1] This test method is under the jurisdiction of ASTM Committee D-20 on Plastics and is the direct responsibility of Subcommittee D20.10 on Mechanical Properties.

Current edition approved July 10, 1996. Published September 1996. Originally published as D 5083 – 90. Last previous edition D 5083 – 95.

Note 4 was modified in this edition.

[2] *Annual Book of ASTM Standards*, Vol 10.01.

[3] *Annual Book of ASTM Standards*, Vol 08.01.

[4] *Annual Book of ASTM Standards*, Vol 15.03.

[5] *Annual Book of ASTM Standards*, Vol 08.02.

[6] *Annual Book of ASTM Standards*, Vol 03.01.

[7] *Annual Book of ASTM Standards*, Vol 14.02.

[8] Available from American National Standards Institute, 11 W. 42nd St., 13th Floor, New York, NY 10036.

obtained from Test Methods D 638 and D 3039 shall govern.

4.2 This test method is designed to produce tensile property data for quality control and research and development. Factors that influence the tensile properties, and should therefore be reported, are: material, methods of material and specimen preparation, specimen conditioning, test environment, speed of testing, void content, and volume percent reinforcement.

4.3 It is realized that a material cannot be tested without also specifying the method of preparation of that material. Hence, when comparative tests of materials per se are desired, the greatest 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 specimen, care must be taken to secure the maximum degree of uniformity in details of preparation, treatment, and handling.

4.4 Tensile properties may provide useful data for engineering design purposes. However, because of the high degree of sensitivity exhibited by many reinforced 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 (including impact and creep) and range of environmental conditions.

NOTE 5—Since the existence of a true elastic limit in plastics (as in many other organic materials and in many metals) is debatable, the propriety of applying the term "elastic modulus" in its quoted generally accepted definition to describe the "stiffness" or stress-strain characteristics of plastic materials is highly dependent on such factors as rate of application of stress, temperature, previous history of specimen, etc. However, stress-strain curves for plastics, determined as described in this test method, almost always show a linear region at low stresses. A straight line drawn tangent to this portion of the curve permits calculation of an elastic modulus of the usually defined type. Such a constant is useful if its arbitrary nature and dependence on time, temperature, and similar factors are realized.

4.5 For many materials, there may be a specification that requires the use of this test method, but with some procedural modifications that take precedence when adhering to the specification. Therefore, it is advisable to refer to that material specification before using this test method. Table 1 of Classification D 4000 lists the ASTM materials standards that currently exist.

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 *Grip*:

5.1.3.1 Grips for holding the test specimen between the fixed member and the movable member. The grips shall be self-aligning, that is, they shall be attached to the fixed and movable member, respectively, in such a manner that they will move freely into alignment as soon as any load is applied, so that the long axis of the test specimen will coincide with the direction of the applied load through the center line of the grip assembly. Align the specimen as perfectly as possible with the direction of pull so that no rotary motion that may induce slippage will occur in the grips; there is a limit to the amount of misalignment self-aligning grips will accommodate.

TABLE 1 Tensile Strength at Break, psi, for Six Laboratories, Six Materials

NOTE 1—SMC = Sheet Molding Compound.
BMC = Bulk Molding Compound.
POLY = Polyester Resin/Glass Fiber Mat Reinforced.
PUL = Pultruded Ladder Rail.
CSM = Vinylester/Glass Fiber Mat Reinforced.
URE = Urethane Resin/Glass Fiber Mat Reinforced.

Straight-Sided					
Material	Average	S_r[A]	S_R[B]	r[C]	R[D]
BMC	6125	580	784	1624	2197
SMC	9650	669	708	1875	1983
CSM	12 882	1431	1475	4009	4131
URE	16 491	844	844	2365	2365
POLY	17 784	1599	1599	4477	4477
PUL	81 868	1902	3188	5326	8927

[A] S_r is the within-laboratory standard deviation of the average ((median/other function)).

[B] S_R is the between laboratories standard deviation of the average ((median/other function)).

[C] r is the within-laboratory repeatability limit = 2.8 S_r .

[D] R is the between-laboratories reproducibility limit = 2.8 S_R .

5.1.3.2 Mount the test specimen in such a way that slippage relative to the grips is prevented insofar as possible. Grip surfaces that are deeply scored or serrated with a pattern similar to those of a coarse single-cut file, serrations about 0.09 in. (2.4 mm) apart and about 0.06 in. (1.6 mm) deep or finer, have been found satisfactory for most 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, or plastic or rubber-coated fabric, commonly called hospital sheeting, between the specimen and the grip surface. Number 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. 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 controlled velocity with respect to the stationary member, this velocity to be regulated as specified in Section 8.

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 6—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 E 4. Hence, it is recommended that each machine be studied individually and verified as often as may be found necessary. It may be necessary to perform this function daily.

5.1.6 The fixed member, movable member, drive mechanism, and grips shall be constructed of such materials and in such proportions that the total elastic longitudinal strain of the system constituted by these parts does not exceed 1 % of the total longitudinal strain between the two gage marks on the test specimen at any time during the test and at any load up to the rated capacity of the machine.

5.2 *Strain*—Strain may be determined by means of an extension indicator or strain indicator. If Poisson's ratio is to be determined, the specimen must be instrumented to measure strain in both longitudinal and lateral directions.

5.2.1 *Extension Indicator (Extensometer)*—A suitable instrument for determining the distance between two designated fixed points within the gage length of the test specimen as the specimen is stretched. It is desirable, but not essential, that this instrument automatically record the distance, or any change in it, or of the elapsed time from the start of the test, or both. If only the latter is obtained, load-time data must also be taken. This instrument shall be essentially free of inertia at the specified speed of testing. Extensometers shall be classified and calibration periodically verified in accordance with Practice E 83.

5.2.2 *Modulus Measurements*—For modulus measurement, an extensometer with a maximum strain error of 0.0002 mm/mm or 0.0002 in./in. that automatically and continuously records strain shall be used. A Class B-2 extensometer (see Practice E 83) meets this requirement.

5.2.3 *Low-Extension Measurements*—For low-extension measurements beyond the modulus range but below 20 % extension, the extensometer system must meet, at least, Practice E 83 Class C requirements. This requires a fixed strain error of .0025 mm (.001 in.) or less, or the capability of reading to ±1 % of the indicated strain, whichever is greater.

5.2.4 *High-Extension Measurements*—For measurements greater than 20 %, and beyond the yield point of the material, strain-measuring techniques with error no greater than ±10 % of the measured value are acceptable.

5.2.5 When desired, the specimen may be instrumented with strain gages. Proper preparation of the specimen surface and gage as well as mounting of the gage to the specimen surface, is mandatory to ensure reliable and accurate strain measurements.

NOTE 7—Bonded strain gages can accurately measure strain directly below the gage. Reinforced or discontinuous laminates may produce localized strain fields directly under the gage that are not identified by standard averaging extensometers. For strain gages whose lengths are too short, localized strain fields under the gage may cause misleading results.

5.3 *Micrometers*:

5.3.1 Suitable micrometers for measuring the width and thickness of the test specimen to an incremental discrimination of at least 0.025 mm (0.001 in.) should be used. All width and thickness measurements of rigid and semirigid plastics may be measured with a hand micrometer with ratchet. A suitable instrument for measuring the thickness of non-rigid test specimens shall have: a contact measuring pressure of 25 ± 2.5 kPa (3.6 ± 0.36 psi); a movable circular contact foot 6.35 ± 0.025 mm (0.250 ± 0.001 in.) in diameter; and a lower fixed anvil large enough to extend beyond the contact foot in all directions and parallel to the contact foot within 0.005 mm (0.0002 in.) over the entire foot area. Flatness of foot and anvil shall conform to Test Methods D 374.

5.3.2 An optional instrument equipped with a circular contact foot 15.88 ± 0.08 mm (0.625 ± 0.003 in.) in diameter is recommended for thickness measuring of process samples or larger specimens at least 15.88 mm (0.625 in.) in minimum width.

6. Test Specimen

6.1 *Geometry*:

6.1.1 The test specimen shall be of uniform nominal width. These specimens may be prepared by cutting materials from sheets or plates or may be prepared by compression or injection molding of the material to be tested. Take care in machining the sides of the specimen so that smooth flat parallel surfaces and sharp clear edges to within 0.025 mm (0.001 in.) result.

6.1.2 The standard test specimen shall be in the form of a rectangular prism. The preferred specimen size is 25.4 by 3.175 by 215.9 mm (1 by 0.125 by 8.5 in.), with a dimension tolerance of ±0.0025 mm (0.001 in.).

NOTE 8—Machining the thickness of laminates with certain constructions (such as woven roving) can change the material properties. In such cases, the specimen should be testing in the as-produced thickness up to a maximum of 14 mm (0.55 in.).

6.2 *Preparation*—Prepare the test specimens by machining from materials in sheet, plates, slab, or similar form. Specimens may also be prepared by molding the material to be tested.

NOTE 9—Specimens prepared by injection molding may have different tensile properties than specimens prepared by machining because of the orientation induced. This effect may be more pronounced in specimens with narrow sections.

6.2.1 All surfaces of the specimen shall be free of visible flaws, scratches, or imperfections. Specimens may be cut with a saw utilizing a water-cooled diamond abrasive blade without the need for further sanding. If another type of cutting device is used, carefully remove the marks left by coarse machining operations with a fine file or abrasive. The filed surfaces shall then be smoothed with abrasive paper (No. 00 or finer). Make sure that finishing sanding strokes are in a direction parallel to the long axis of the test specimen. Remove all flash from a molded specimen, taking care not to disturb the molded surfaces. In machining a specimen, avoid undercuts that would exceed the dimensional tolerances. Take care to avoid other common machining errors.

6.2.2 If it is necessary to place gage marks on the specimen, make these with a wax crayon or India ink that will not affect the material being tested. Do not scratch, punch, or impress the specimen when making gage marks.

6.2.3 When testing materials that may be anisotropic, prepare duplicate sets of test specimens with their long axes respectively parallel with, and normal to, the suspected direction of anisotropy.

7. Number of Test Specimens

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

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

7.3 Discard specimens that break at some obvious fortuitous flaw, or that do not break between grips. Make retests, unless such flaws constitute a variable to be studied.

8. Speed of Testing

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

8.2 The standard speed of testing shall be 5 mm/min (0.2 in./min) unless otherwise specified.

8.3 Modulus determinations may be made at the speed selected for the other tensile properties when the recorder response and resolution are adequate.

9. Conditioning

9.1 *Conditioning*—Condition the test specimens at 23 ± 2°C (73.4 ± 3.6°F) and 50 ± 5 % relative humidity in accordance with Procedure A of Practice D 618 for those tests where conditioning is required. In cases of disagreement, the tolerances shall be ±1°C (1.8°F) and ±2 % relative humidity.

9.2 *Test Conditions*—Conduct tests in the standard laboratory atmosphere of 23 ± 2°C (73.4 ± 3.6°F) and 50 ± 5 % relative humidity, unless otherwise specified in the test methods. In cases of disagreements, the tolerances shall be ±1°C (1.8°F) and ±2 % relative humidity.

10. Procedure

10.1 Measure the width and thickness of the rigid flat specimen with a suitable micrometer to the nearest 0.025-mm (0.001-in.) at several points along its length. Calculate and record the minimum value of the cross-sectional area. The average cross-sectional area should also be calculated and recorded for modulus calculations (see 11.2).

10.2 Place the specimen in the grips of the testing machine, 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 115 mm (4.5 in.). 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 Attach the extension indicator. When the modulus is being determined, the extension indicator must continuously record the distance the specimen is stretched (elongated) within the gage length as a function of the load through the initial (linear) portion of the load-elongation curve.

10.4 . Set the speed of testing at the proper rate as required in Section 8, and start the machine.

10.5 Record the load-extension curve of the specimen.

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

NOTE 10—If it is desired to measure both the modulus and failure properties (yield or break, or both), it may be necessary, in the case of highly extensible materials, to run two independent tests. The high magnification extensometer normally used to determine properties up to the yield point may not be suitable for tests involving high extensibility. If allowed to remain attached to the specimen, the extensometer could be permanently damaged. A broad-range incremental extensometer may be needed when such materials are taken to rupture.

10.7 Use a suitable statistical technique to identify any possible outliers in the data. However, do not discard any outliers unless some physical reason may be identified to explain the presence of the outlier, such as an aberrant specimen, a temporary change in testing condition, etc.

11. Calculation

11.1 *Tensile Strength*—Calculate the tensile strength by dividing the maximum load in newtons (or pounds-force) by the original minimum cross-sectional area of the specimen in square metres (or square inches). Express the result in pascals (or pounds-force per square inch) and report it to three significant figures as "tensile strength at yield" or "tensile strength at break," whichever term is applicable.

11.2 *Modulus of Elasticity*—Calculate the modulus of elasticity by extending the initial linear portion of the load-extension curve and dividing the difference in stress corresponding to any segment of section on this straight line by the corresponding difference in strain. Compute all elastic modulus values using the average initial cross-sectional area of the test specimens. Express the result in pounds-force per square inch (pascals) reported to three significant figures.

11.3 For each series of tests, calculate the arithmetic mean of all values obtained and report it as the "average value" for the particular property in question.

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

$$s = \sqrt{(\Sigma \bar{X}^2 - nX^2)/(n - 1)} \qquad (1)$$

where:

s = estimated standard deviation,
X = value of single observation,
n = number of observations, and
$\bar{X}$ = 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, and previous history,

12.1.2 Method of preparing test specimens,

12.1.3 Type of test specimen and dimensions,

12.1.4 Conditioning procedure used,

12.1.5 Atmospheric conditions in test room,

12.1.6 Type and description of the extension or strain-measurement device and the recording equipment used,

12.1.7 Number of specimens tested,

12.1.8 Speed of testing,

12.1.9 Tensile strength at yield or break, average value and standard deviation,

12.1.10 Tensile stress at yield or break, if applicable, average value and standard deviation, 12.1.11 Modulus of elasticity, average value and standard deviation, and

12.1.12 Date of test.

13. Precision and Bias

13.1 Table 1 is based on a round robin conducted in 1991 and analyzed by the procedures of Practice E 691. It involved six materials tested by six laboratories. Each laboratory prepared and tested five specimens per average. Three averages per laboratory were generated for each material evaluated.

NOTE 11—The values shown in Table 1 and Table 2 were obtained from a round robin which was not done strictly by the procedures established in Practice E 691. However, the data will serve as a guide to the reproducibility and repeatability of the test until a more thorough round robin can be completed.

NOTE 12—**Caution:** The following explanation of *r* and *R* (13.2.1-13.2.3) are only intended to present a meaningful way of considering the approximate precision of this test method. The data in Table 1 and Table 2 should not be rigorously applied to acceptance or rejection of material, as those data are specified to the round robin and may not be representative of other lots, conditions, materials, or laboratories. Users of this test method should apply the principles outlined in the 1977 edition of Practice E 691 to generate data specific to their laboratory and materials, or between specific laboratories. The principles outlined in 13.2.1 through 13.2.3 would then be valid for such data.

13.2 *Concept of r and R*—If S_r and S_R have been calculated from a large enough body of data, and for test results that were averages (medians/other functions) from testing X^A specimens are as follows:

13.2.1 *Repeatability Limit*, *r*—(Comparing two test results for the same material, obtained by the same operator using the same equipment on the same day.) The two test results should be judged not equivalent if they differ by more than the "*r*" value for that material.

TABLE 2 Modulus of Elasticity, psi, for Six Laboratories, Six Materials

NOTE 1—SMC = Sheet Molding Compound.
BMC = Bulk Molding Compound.
POLY = Polyester Resin/Glass Fiber Mat Reinforced.
PUL = Pultruded Ladder Rail.
CSM = Vinylester/Glass Fiber Mat Reinforced.
URE = Urethane Resin/Glass Fiber Mat Reinforced.

Straight-Sided					
Material	Average	S_r[A]	S_R[B]	r[C]	R[D]
BMC	2 036 997	114 331	160 376	320 126	449 051
SMC	1 739 808	78 248	145 115	219 096	406 321
CSM	1 303 284	93 862	115 137	262 813	322 382
URE	1 133 010	64 164	64 164	179 659	179 659
POLY	1 629 407	107 570	131 608	301 197	368 503
PUL	4 358 796	174 997	180 470	489 991	505 315

[A] S_r is the within-laboratory standard deviation of the average ((median/other function)).

[B] S_R is the between laboratories standard deviation of the average ((median/other function)).

[C] r is the within-laboratory repeatability limit = 2.8 S_r .

[D] R is the between-laboratories reproducibility limit = 2.8 S_R .

13.2.2 *Reproducibility Limit*, *R*—(Comparing two test results for the same material, obtained by different operators using different equipment in different laboratories on different days.) The two test results should be judged not equivalent if they differ by more than the" *R*" value for that material.

13.2.3 Any judgment in accordance with 13.2.1 or 13.2.2 would have an approximate 95 % (0.95) probability of being correct.

13.3 There are no recognized standards by which to estimate bias of this test method.