Designation: D6272 – 10

Standard Test Method for Flexural Properties of Unreinforced and Reinforced Plastics and Electrical Insulating Materials by Four-Point Bending[1]

This standard is issued under the fixed designation D6272; 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 flexural properties of unreinforced and reinforced plastics, including high-modulus composites and electrical insulating materials in the form of rectangular bars molded directly or cut from sheets, plates, or molded shapes. These test methods are generally applicable to rigid and semirigid materials. However, flexural strength cannot be determined for those materials that do not break or that do not fail in the outer fibers. This test method utilizes a four point loading system applied to a simply supported beam.

1.2 This test method may be used with two procedures:

1.2.1 *Procedure A,* designed principally for materials that break at comparatively small deflections.

1.2.2 *Procedure B,* designed particularly for those materials that undergo large deflections during testing.

1.2.3 Procedure A shall be used for measurement of flexural properties, particularly flexural modulus, unless the material specification states otherwise. Procedure B may be used for measurement of flexural strength.

1.3 Comparative tests may be run according to either procedure, provided that the procedure is found satisfactory for the material being tested.

1.4 The values stated in SI units are to be regarded as the standard. The values provided 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 1—This test method is equivalent to ISO 14125 (Method B).

2. Referenced Documents

2.1 *ASTM Standards:*[2]

D618 Practice for Conditioning Plastics for Testing
D638 Test Method for Tensile Properties of Plastics
D790 Test Methods for Flexural Properties of Unreinforced and Reinforced Plastics and Electrical Insulating Materials
D883 Terminology Relating to Plastics
D4000 Classification System for Specifying Plastic Materials
D5947 Test Methods for Physical Dimensions of Solid Plastics Specimens
E4 Practices for Force Verification of Testing Machines
E83 Practice for Verification and Classification of Extensometer Systems
E691 Practice for Conducting an Interlaboratory Study to Determine the Precision of a Test Method

2.2 *ISO Standard:*[3]

ISO 14125 (Method B) Fibre-Reinforced Plastic Composites—Determination of Flexural Properties

3. Terminology

3.1 *Definitions:*

3.1.1 Definitions of terms applying to these test methods appear in Terminology D883 and Annex A2 of Test Method D638.

4. Summary of Test Method

4.1 A bar of rectangular cross section rests on two supports and is loaded at two points (by means of two loading noses), each an equal distance from the adjacent support point. The distance between the loading noses (the load span) is either one third or one half of the support span (see Fig. 1). A support span-to-depth ratio of 16:1 shall be used unless there is reason to suspect that a larger span-to-depth ratio may be required, as

[1] This test method is under the jurisdiction of ASTM Committee D20 on Plastics and is the direct responsibility of Subcommittee D20.10 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] Available from American National Standards Institute (ANSI), 25 W. 43rd St., 4th Floor, New York, NY 10036, http://www.ansi.org.

***A Summary of Changes section appears at the end of this standard**

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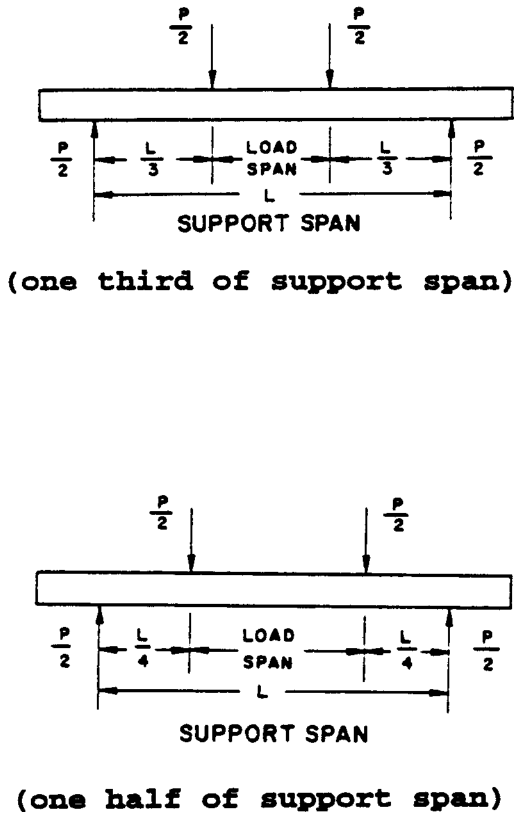


FIG. 1 Loading Diagram

may be the case for certain laminated materials (see Section 7 and Note 8 for guidance).

4.2 The specimen is deflected until rupture occurs in the outer fibers or until the maximum fiber strain (see 12.7) of 5 % is reached, whichever occurs first.

5. Significance and Use

5.1 Flexural properties determined by this test method are especially useful for quality control and specification purposes.

5.2 This test method may be more suited for those materials that do not fail within the strain limits imposed by Test Method D790. The major difference between four point and three point bending modes is the location of the maximum bending moment and maximum axial fiber stress. In four point bending the maximum axial fiber stress is uniformly distributed between the loading noses. In three point bending the maximum axial fiber stress is located immediately under the loading nose.

5.3 Flexural properties may vary with specimen depth, temperature, atmospheric conditions, and the difference in rate of straining specified in Procedures A and B.

5.4 Before proceeding with this test method, reference should be made to the specification of the material being tested. Any test specimen preparation, conditioning, dimensions, or testing parameters covered in the material specification, or both, shall take precedence over those mentioned in this test method. If there are no material specifications, then these default conditions apply. Table 1 in Classification D4000 lists the ASTM materials standards that currently exist.

6. Apparatus

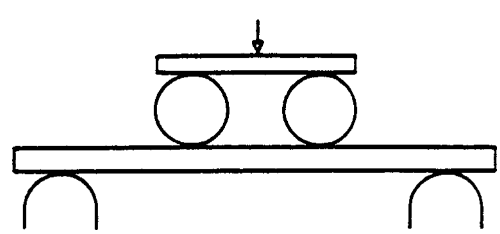
6.1 *Testing Machine*—A properly calibrated testing machine that can be operated at constant rates of crosshead motion over the range indicated, and in which the error in the load measuring system shall not exceed ± 1 % of maximum load expected to be measured. It shall be equipped with a deflection measuring device. The stiffness of the testing machine shall be such that the total elastic deformation of the system does not exceed 1 % of the total deflection of the test specimen during testing, or appropriate corrections shall be made. The load indicating mechanism shall be essentially free from inertial lag at the crosshead rate used. The accuracy of the testing machine shall be verified in accordance with Practices E4.

6.2 *Loading Noses and Supports*—The loading noses and supports shall have cylindrical surfaces. In order to avoid excessive indentation, or failure due to stress concentration directly under the loading noses, the radii of the loading noses and supports shall be 5.0 ± 0.1 mm (0.197 ± 0.004 in.) unless otherwise specified or agreed upon between the interested parties. When other loading noses and supports are used they must comply with the following requirements: they shall be at least 3.2 mm (1⁄8 in.) for all specimens, and for specimens 3.2 mm (1⁄8 in.) or greater in depth, the radius of the supports may be up to 1.6 times the specimen depth. They shall be this large if significant indentation or compressive failure occurs. The arc of the loading noses in contact with the specimen shall be sufficiently large to prevent contact of the specimen with the sides of the noses (see Fig. 2).

NOTE 2—Test data have shown that the loading noses and support dimensions can influence the flexural modulus and flexural strength values. The loading noses dimension has the greater influence. Dimensions of loading noses and supports must be specified for material specifications.

6.3 *Deflection Measuring Device*—A properly calibrated device to measure the deflection of the beam at the common center of the loading span, that meets or exceeds Practice E83, Class C, shall be used. The device shall automatically and continuously record the deflection during the test.

6.4 *Micrometers*—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 semi-rigid 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 ± 0.036 psi), a movable circular contact foot



NOTE 1—Default radii 5.0 mm; see 6.2.

FIG. 2 Loading Noses and Supports (Example of One Third Support Span)

6.35 ± 0,025 mm (0.250 ± 0.001 in.) in diameter and a fixed anvil 6.35 ± 0,025 mm (0.250 ± 0.001 in.) in diameter and being 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 the portion of the calibration section of Test Method D5947.

7. Test Specimen

7.1 The specimens may be cut from sheets, plates, or molded shapes, or may be molded to the desired finished dimensions. The actual dimensions used in Section 12 (Calculation) shall be measured in accordance with Test Method D5947.

NOTE 3—Any necessary polishing of specimens shall be done only in the lengthwise direction of the specimen.

7.2 *Sheet Materials (Except Laminated Thermosetting Materials and Certain Materials Used for Electrical Insulation, Including Vulcanized Fiber and Glass Bonded Mica):*

7.2.1 *Materials 1.6 mm (1⁄16 in.) or Greater in Thickness*—For flatwise tests, the depth of the specimen shall be the thickness of the material. For edgewise tests, the width of the specimen shall be the thickness of the sheet, and the depth shall not exceed the width (see Notes 5 and 6). For all tests, the support span shall be 16 (tolerance ± 1) times the depth of the beam. Specimen width shall not exceed one fourth of the support span for specimens greater than 3.2 mm (1⁄8 in.) in depth. Specimens 3.2 mm or less in depth shall be 12.7 mm (1⁄2 in.) in width. The specimen shall be long enough to allow for overhanging on each end of at least 10 % of the support span, but in no case less than 6.4 mm (1⁄4 in.) on each end. Overhang shall be sufficient to prevent the specimen from slipping through the supports.

NOTE 4—Whenever possible, the original surface of the sheet shall be unaltered. However, where testing machine limitations make it impossible to follow the above criterion on the unaltered sheet, one or both surfaces shall be machined to provide the desired dimensions, and the location of the specimens with reference to the total depth shall be noted. The value obtained on specimens with machined surfaces may differ from those obtained on specimens with original surfaces. Consequently, any specifications for flexural properties on the thicker sheets must state whether the original surfaces are to be retained or not. When only one surface was machined, it must be stated whether the machined surface was on the tension or compression side of the beam.

NOTE 5—Edgewise tests are not applicable for sheets that are so thin that specimens meeting these requirements cannot be cut. If specimen depth exceeds the width, buckling may occur.

7.2.2 *Materials Less than 1.6 m (1⁄16 in.) in Thickness*—The specimen shall be 50.8 mm (2 in.) long by 12.7 mm (1⁄2 in.) wide, tested flatwise on a 25.4-mm (1-in.) support span.

NOTE 6—Use of the formulas for simple beams cited in these test methods for calculating results presumes that beam width is small in comparison with the support span. Therefore, the formulas do not apply rigorously to these dimensions.

NOTE 7—Where machine sensitivity is such that specimens of these dimensions cannot be measured, wider specimens or shorter support spans, or both, may be used, provided the support span-to-depth ratio is at least 14 to 1. All dimensions must be stated in the report (see also Note 6).

7.3 *Laminated Thermosetting Materials and Sheet and Plate Materials Used for Electrical Insulation, Including Vulcanized Fiber and Glass-Bonded Mica*—For paper-base and fabric-base grades over 25.4 mm (1 in.) in nominal thickness, the specimens shall be machined on both surfaces to a depth of 25.4 mm. For glass-base and nylon-base grades, specimens over 12.7 mm (1⁄2 in.) in nominal depth shall be machined on both surfaces to a depth of 12.7 mm. The support span-to-depth ratio shall be chosen such that failures occur in the outer fibers of the specimens, due only to the bending moment (see Note 8). Three recommended support span-to-depth ratios are 16, 32, and 40 to 1. When laminated materials exhibit low compressive strength perpendicular to the laminations, they shall be loaded with a large radius loading noses (up to 1.5 times the specimen depth) to prevent premature damage to the outer fibers.

7.4 *Molding Materials (Thermoplastics and Thermosets)*—The recommended specimen for molding materials is 127 by 12.7 by 3.2 mm (5 by 1⁄2 by 1⁄8 in.) tested flatwise on a support span, resulting in a support span-to-depth ratio of 16 (tolerance + 4 or – 2). Thicker specimens should be avoided if they exhibit significant shrink marks or bubbles when molded.

7.5 *High-Strength Reinforced Composites, Including Highly Orthotropic Laminates*—The support span-to-depth ratio shall be chosen such that failures occur in the outer fibers of the specimens, due only to the bending moment (Note 8). Three recommended support span-to-depth ratios are 16:1, 32:1, and 40:1. However, for some highly anisotropic composites, shear deformation can significantly influence modulus measurements, even at span-to-depth ratios as high as 40:1. Hence, for these materials, an increase in span-to-depth ratio to 60:1 is recommended to eliminate shear effects when modulus data are required. It should also be noted that the flexural modulus of highly anisotropic laminates is a strong function of ply-stacking sequence and will not necessarily correlate with tensile modulus, that is not stacking-sequence dependent.

NOTE 8—As a general rule, support span-to-depth ratios of 16 to 1 are satisfactory when the ratio of the tensile strength to shear strength is less than 8 to 1, but the support span-to-depth ratio must be increased for composite laminates having relatively low shear strength in the plane of the laminate and relatively high tensile strength parallel to the support span.

8. Number of Test Specimens

8.1 At least five specimens shall be tested for each sample in the case of isotropic materials or molded specimens.

8.2 For each sample of anisotropic material in sheet form, at least five specimens shall be tested for each of the following conditions. Recommended conditions are flatwise and edgewise tests on specimens cut in lengthwise and crosswise directions of the sheet. For the purposes of this test, "lengthwise" shall designate the principal axis of anisotropy and shall be interpreted to mean the direction of the sheet known to be stronger in flexure. "Crosswise" shall be the sheet direction known to be the weaker in flexure and shall be at 90° to the lengthwise direction.

9. Conditioning

9.1 *Conditioning*—Condition the test specimens in accordance with Procedure A of Practice D618, unless otherwise

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specified by contract or the relevant ASTM material specification. Temperature and humidity tolerances shall be in accordance with Section 7 of Practice D618 unless specified differently by contract or material specification.

9.2 *Test Conditions*—Conduct the tests the same temperature and humidity used for conditioning with tolerances in accordance with Section 7 of Practice D618 unless otherwise specified by contract or the relevant ASTM material specification.

10. Procedure

10.1 *Procedure A:*

10.1.1 Use an untested specimen for each measurement. Measure the width and depth of the specimen to the nearest 0.03 mm (0.001 in.) at the center of the support span. For specimens less than 2.54 mm (0.100 in.) in depth, measure the depth to the nearest 0.003 mm (0.0005 in.). These measurements shall be made in accordance with Test Method D5947.

10.1.2 Determine the support span to be used as described in Section 7 and set the support span to within 1 % of the determined value.

10.1.3 Measure the span accurately to the nearest 0.1 mm (0.004 in.) for spans less than 63 mm (2.5 in.) and to the nearest 0.3 mm (0.012 in.) for spans greater than or equal to 63 mm (2.5 in.). Use the measured span for all calculations. See Annex A2 for information on the determination of and setting of the span.

10.1.4 Calculate the rate of crosshead motion as follows, and set the machine as near as possible to that calculated rate for a load span of one third of the support span:

$$R = 0.185ZL^2/d \tag{1}$$

For a load span of one half of the support span:

$$R = 0.167ZL^2/d \tag{2}$$

where:

R = rate of crosshead motion, mm (in.)/min,
L = support span, mm (in.),
d = depth of beam, mm (in.), and
Z = rate of straining of the outer fibers, mm/mm (in./in.) min. Z shall equal 0.01.

In no case shall the actual crosshead rate differ from Eq 1 or Eq 2, by more than ± 10 %.

10.1.5 Align the loading noses and supports so that the axes of the cylindrical surfaces are parallel and the load span is either one third or one half of the support span. This parallelism may be checked by means of a plate containing parallel grooves into which the loading noses and supports will fit when properly aligned. Center the specimen on the supports, with the long axis of the specimen perpendicular to the loading noses and supports. The loading nose assembly shall be of the type which will not rotate.

10.1.6 Apply the load to the specimen at the specified crosshead rate, and take simultaneous load-deflection data. Measure deflection by a device under the specimen in contact with it at the common center of the spans, the device being mounted stationary relative to the specimen supports. Do not use the movement of the loading noses relative to the supports. Make appropriate corrections for indentation in the specimens and deflections in the weighing system of the machine. Load-deflection curves may be plotted to determine the flexural yield strength, secant or tangent modulus of elasticity, and the total work measured by the area under the load-deflection curve.

10.1.7 If no break has occurred in a specimen by the time the maximum strain in the outer fibers has reached 0.05 mm/mm (in./in.), discontinue the test (Notes 9 and 10). The deflection at which this strain occurs may be calculated by letting r equal 0.05 mm/mm (in./in.) as follows for a load span of one third of the support span:

$$D = 0.21rL^2/d \tag{3}$$

For a load span of one half of the support span:

$$D = 0.23rL^2/d \tag{4}$$

where:

D = midspan deflection, mm (in.),
r = strain, mm/mm (in./in.),
L = support span, mm (in.), and
d = depth of beam, mm (in.).

NOTE 9—For some materials the increase in strain rate provided under Procedure B may induce the specimen to yield or rupture, or both, within the required 5 % strain limit.

NOTE 10—Beyond 5 % strain, these test methods are not applicable, and some other property might be measured (for example, Test Method D638 may be considered).

10.2 *Procedure B:*

10.2.1 Use an untested specimen for each measurement.

10.2.2 Test conditions shall be identical to those described in 10.1, except that the rate of straining of the outer fibers shall be 0.10 mm/mm (in./in.)/min.

10.2.3 If no break has occurred in the specimen by the time the maximum strain in the outer fibers has reached 0.05 mm/mm (in./in.), discontinue the test (Note 10).

11. Retests

11.1 Values for properties at rupture shall not be calculated for any specimen that breaks at some obvious, fortuitous flaw, unless such flaws constitute a variable being studied. Retests shall be made for any specimen on which values are not calculated.

12. Calculation

NOTE 11—In determination of the calculated value of some of the properties listed in this section it is necessary to determine if the toe compensation (see Annex A1) adjustment must be made. This toe compensation correction shall be made only when it has been shown that the toe region of the curve is due to the takeup of slack, alignment, or seating of the specimen and not an authentic material response.

12.1 *Maximum Fiber Stress*—When a beam is loaded in flexure at two central points and supported at two outer points, the maximum stress in the outer fibers occurs between the two central loading points that define the load span (see Fig. 2). This stress may be calculated for any point on the load-deflection curve for relatively small deflections by the following equation for a load span of one third of the support span (see Notes 12 and 13):

$$S = PL/bd^2 \tag{5}$$

For a load span of one half of the support span:

$$S = 3PL/4bd^2 \quad (6)$$

where:

S = stress in the outer fiber throughout the load span, MPa (psi),
P = load at a given point on the load-deflection curve, N (lbf),
L = support span, mm (in.),
b = width of beam, mm (in.), and
d = depth of beam, mm (in.).

NOTE 12—Eq 5 and 6 apply strictly to materials for which the stress is linearly proportional to strain up to the point of rupture and for which the strains are small. Since this is not always the case, a slight error will be introduced in the use of this equation. The equation will, however, be valid for comparison data and specification values up to the maximum fiber strain of 5 % for specimens tested by the procedure herein described. It should be noted that the maximum stress may not occur in the outer fibers for a highly orthotropic laminate. Laminated beam theory must be applied to determine the maximum tensile stress at failure. Thus, Eq 5 and 6 yield an apparent strength based on homogeneous beam theory. This apparent strength is highly dependent on the ply-stacking sequence for highly orthotropic laminates.

NOTE 13—The above calculation is not valid if the specimen is slipping excessively between the supports.

12.2 *Maximum Fiber Stress, for Beams Tested at Large Support Spans*—If support span-to-depth ratios greater than 16 to 1 are used with resultant deflections in excess of 10 % of the support span occurring, the maximum stress may be reasonably approximated with the following formula for a load span of one third of the support span:

$$S = (PL/bd^2)\cdot[1 + (4.70D^2/L^2) - (7.04Dd/L^2)] \quad (7)$$

For a load span of one half of the support span:

$$S = (3PL/4bd^2)\cdot[1 - (10.91Dd/L^2)] \quad (8)$$

where:
S, P, L, b, and d are the same as for Eq 5, and
D = maximum deflection of the center of the beam, mm (in.).

NOTE 14—When large support span-to-depth ratios are used, significant end forces are developed at the supports which affect the moment in a simply supported beam. An approximate correction factor is given in Eq 7 and 8 to correct for these end forces in large support span-to-depth ratio beams where relatively large deflections exist.

NOTE 15—The limitations defined for Eq 5 and 6 in Notes 13 and 14 apply also to Eq 7 and 8.

12.3 *Flexural Strength*—The flexural strength is equal to the maximum stress in the outer fibers at the moment of break (for highly orthotropic laminates, see Note 12). It is calculated in accordance with Eq 5, Eq 6, Eq 7, and Eq 8 by letting P equal the load at the moment of break. If the material does not break, this part of the test is not applicable. In this case, it is suggested that yield strength, if applicable, be calculated and that the corresponding strain be reported also (see 12.4, 12.6, and 12.7).

12.4 *Flexural Yield Strength*—Some materials that do not break at outer fiber strains up to 5 % may give load-deflection curves that show a point, Y, at which the load does not increase with an increase in deflection. In such cases, the flexural yield strength may be calculated in accordance with Eq 5, or Eq 6 by letting P equal the load at Point Y.

12.5 *Flexural Offset Yield Strength*—Offset yield strength is the stress at which the stress-strain curve deviates by a given strain (offset) from the tangent to the initial straight line portion of the stress-strain curve. The value of the offset must be given whenever this property is calculated.

NOTE 16—This value may differ from flexural yield strength defined in 12.4. Both methods of calculation are described in the annex to Test Method D638.

12.6 *Stress at a Given Strain*—The maximum fiber stress at any given strain may be calculated in accordance with Eq 5, Eq 6, Eq 7, and Eq 8 by letting P equal the load read from the load-deflection curve at the deflection corresponding to the desired strain (for highly orthotropic laminates, see Note 12).

12.7 *Maximum Strain*—The maximum strain in the outer fibers also occurs at midspan, and it may be calculated as follows for a load span of one third of the support span:

$$r = 4.70Dd/L^2 \quad (9)$$

For load span of one half of the support span:

$$r = 4.36Dd/L^2 \quad (10)$$

where:

r = maximum strain in the outer fibers, mm/mm (in./in.),
D = maximum deflection of the center of the beam, mm
L = support span, mm (in.), and
d = depth, mm (in.).

12.8 *Tangent Modulus of Elasticity*—The tangent modulus of elasticity is the ratio, within the elastic limit, of stress to corresponding strain and shall be expressed in megapascals (pounds per square inch). It is calculated by drawing a tangent to the steepest initial straight-line portion of the load-deflection curve and using Eq 11 for a load span of one third the support span and Eq 12 for a load span of one half of the support span, as follows:

$$E_B = 0.21L^3m/bd^3 \quad (11)$$

$$E_B = 0.17L^3m/bd^3 \quad (12)$$

where:

E_B = modulus of elasticity in bending, MPa (psi),
L = support span, mm (in.),
b = width of beam tested, mm (in.),
d = depth of beam tested, mm (in.), and
m = slope of the tangent to the initial straight-line.

NOTE 17—Shear deflections can seriously reduce the apparent modulus of highly anisotropic composites when they are tested at low span-to-depth ratios.[4] For this reason, a span-to-depth ratio of 60 to 1 is recommended for flexural modulus determinations. Flexural strength should be determined on a separate set of replicate specimens at a lower span-to-depth ratio that induces tensile failures in the outer fibers of the beam along its lower face. Since the flexural modulus of highly anisotropic laminates is a critical function of ply-stacking sequence, it will not necessarily correlate with tensile modulus, which is not stacking-sequence dependent.

12.9 *Secant Modulus of Elasticity*—The secant modulus of elasticity is the ratio of stress to corresponding strain at any

[4] See Whitney, J. M., et al, "Analysis of the Flexure Test for Laminated Composite Materials," *ASTM STP 546*, 1974, pp. 30–45.

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given point on the stress-strain curve, or the slope of the straight line that joins the origin and a selected point on the actual stress-strain curve. It shall be expressed in megapascals (pounds per square inch). The selected point is generally chosen at a specified stress or strain. It is calculated in accordance with Eq 11 or Eq 12 by letting *m* equal the slope of the secant to the load-deflection curve.

12.10 *Arithmetic Mean*—For each series of tests, the arithmetic mean of all values obtained shall be calculated to three significant figures and reported as the "average value" for the particular property in question.

12.11 *Standard Deviation*—The standard deviation (estimated) shall be calculated as follows and reported in two significant figures:

$$s = \sqrt{\left(\sum X^2 - n\bar{X}^2\right)/(n-1)} \tag{13}$$

where:

s = estimated standard deviation,
X = value of single observation,
n = number of observations, and
$\bar{X}$ = arithmetic mean of the set of observations.

12.12 See Annex A1 for information on toe compensation.

13. Report

13.1 Report the following information:

13.1.1 Complete identification of the material tested, including type, source, manufacturer's code number, form, principal dimensions, and previous history (for laminated materials, ply-stacking sequence shall be reported),

13.1.2 Direction of cutting and loading specimens, including machining or other alterations that result in asymmetrical specimen preparation.

13.1.3 Conditioning procedure,

13.1.4 Depth and width of specimen,

13.1.5 Procedure used,

13.1.6 Load span length,

13.1.7 Support span length,

13.1.8 Support span-to-depth ratio,

13.1.9 Radius of supports and loading noses,

13.1.10 Rate of crosshead motion,

13.1.11 Maximum strain in the outer fibers of the specimen,

13.1.12 Flexural strength (if applicable), average value, and standard deviation,

13.1.13 Tangent or secant modulus of elasticity in bending, average value, standard deviation, and the strain level used if secant modulus,

13.1.14 Flexural yield strength (if desired), average value, and standard deviation,

13.1.15 Flexural offset yield strength (if desired), with offset or strain used, average value, and standard deviation,

13.1.16 Stress at any given strain up to and including 5 % (if desired), with strain used, average value, and standard deviation,

13.1.17 Type of behavior, whether yielding or rupture, or both, or other observation, occurring within the 5 % strain limit, and

13.1.18 Date of test.

14. Precision and Bias

14.1 The precision of this test method is under investigation by a task group of Section 20.10.01. Anyone wishing to participate in this work may contact the Chairman of Section D20.10.01, at ASTM Headquarters.

14.2 *Repeatability*—The repeatability standard deviation has been determined to be:

	Mean, 10^3 mPa	V_r	I_r
Flexural stress at break	143	1.5	4.2
Flexural modulus	3143	4.3	12.2

General purpose polystyrene was tested under repeatability conditions.

14.3 *Bias*—No statement may be made about the bias of this test method, as there is no standard reference material or reference test method available.

15. Keywords

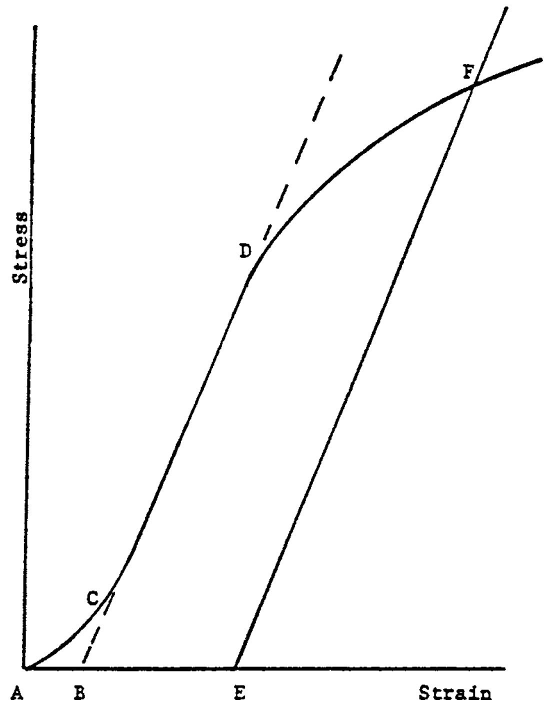
15.1 flexural properties; four point bending; plastics; stiffness; strength

ANNEXES

(Mandatory Information)

A1. TOE COMPENSATION

A1.1 In a typical stress-strain curve (see Fig. A1.1) there is a toe region, *AC*, that does not represent a property of the material. It is an artifact caused by a takeup of slack and alignment or seating of the specimen. In order to obtain correct values of such parameters as modulus, strain, and offset yield point, this artifact must be compensated for to give the corrected zero point on the strain or extension axis.

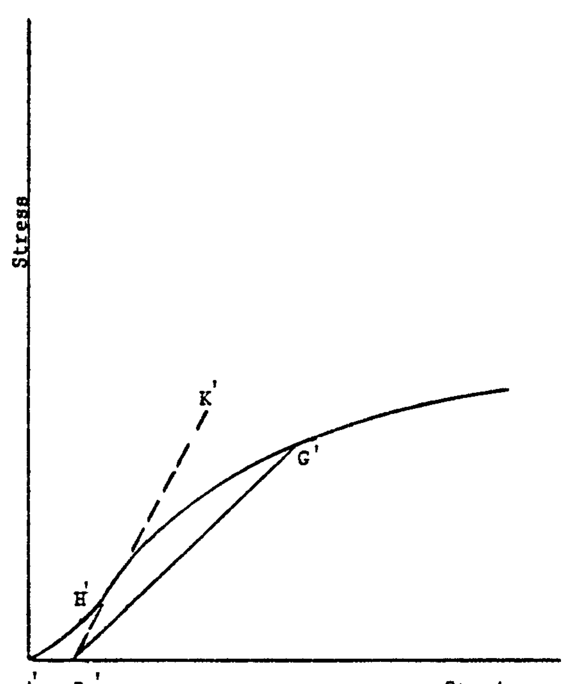


NOTE 1—Some chart recorders plot the mirror image of this graph.

FIG. A1.1 Material with Hookean Region

A1.2 In the case of a material exhibiting a region of Hookean (linear) behavior (see Fig. A1.1), a continuation of the linear (*CD*) region of the curve is constructed through the zero-stress axis. This intersection (*B*) is the corrected zero-strain point from which all extensions or strains must be measured, including the yield offset (*BE*), if applicable. The elastic modulus can be determined by dividing the stress at any point along the Line *CD* (or its extension) by the strain at the same point (measured from Point *B*, defined as zero-strain).

A1.3 In the case of a material that does not exhibit any linear region (see Fig. A1.2), the same kind of toe correction of



NOTE 1—Some chart recorders plot the mirror image of this graph.

FIG. A1.2 Material with No Hookean Region

the zero-strain point can be made by constructing a tangent to the maximum slope at the inflection Point H'. This is extended to intersect the strain axis at Point B', the corrected zero-strain point. Using Point B' as zero strain, the stress at any point (G') on the curve can be divided by the strain at that point to obtain a secant modulus (slope of Line $B'G'$). For those materials with no linear region, any attempt to use the tangent through the inflection point as a basis for determination of an offset yield point may result in unacceptable error.

A2. MEASURING AND SETTING SPAN

A2.1 For flexural fixtures that have adjustable spans, it is important that the span between the supports is maintained constant or the actual measured span is used in the calculation of stress, modulus and strain, and the loading noses are positioned and aligned properly with respect to the supports. Some simple steps as follows can improve the repeatability of your results when using these adjustable span fixtures.

A2.2 *Measurement of Span*:

A2.2.1 This technique is needed to ensure that the correct span, not an estimated span, is used in the calculation of results.

A2.2.2 Scribe a permanent line or mark at the exact center of the support where the specimen makes complete contact. The type of mark depends on whether the supports are fixed or rotatable (see Figs. A2.1 and A2.2).

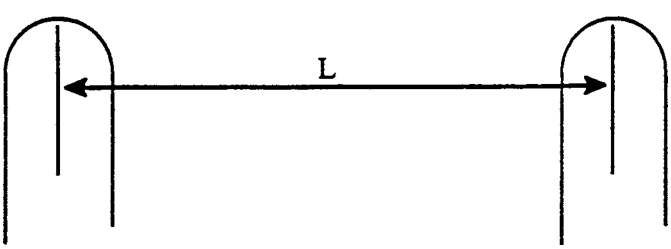
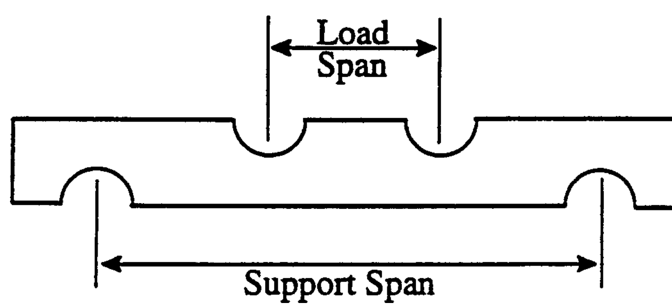


FIG. A2.1 Markings on Fixed Specimen Supports

FIG. A2.2 Markings on Rotatable Specimen Supports

A2.2.3 Using a vernier caliper with pointed tips that is readable to at least 0.1 mm (0.004 in.), measure the distance between the supports, and use this measurement of span in the calculations.

A2.3 *Setting the Span and Alignment of Loading Nose(s)*—To ensure a consistent day-to-day setup of the span and ensure the alignment and proper positioning of the loading nose, simple jigs should be manufactured for each of the standard setups used. An example of a jig found to be useful is shown in Fig. A2.3.



NOTE 1—Radii of cutouts match radii of noses and supports.

FIG. A2.3 Fixture Used to Align Loading Noses and Supports

SUMMARY OF CHANGES

Committee D20 has identified the location of selected changes to this standard since the last issue (D6272 - 02(2008)$^{\varepsilon 1}$) that may impact the use of this standard. (April 1, 2010)

(1) Revised Section 9.