INTERNATIONAL

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Standard Test Method for Compressive Properties of Unidirectional Polymer Matrix Composite Materials Using a Sandwich Beam[1]

This standard is issued under the fixed designation D5467/D5467M; 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 in-plane compressive properties of polymer matrix composite materials reinforced by high-modulus fibers in a sandwich beam configuration. The composite material forms are limited to continuous-fiber composites of unidirectional orientation. This test procedure introduces compressive load into a thin skin bonded to a thick honeycomb core with the compressive load transmitted into the sample by subjecting the beam to four-point bending.

1.2 This procedure is applicable primarily to laminates made from prepreg or similar product forms. Other product forms may require deviations from the test method.

1.3 The values stated in either SI units or inch-pound units are to be regarded separately as standard. The values stated in each system may not be exact equivalents; therefore, each system shall be used independently of the other. Combining values from the two systems may result in non-conformance with the standard.

1.3.1 Within the text the inch-pound units are shown in brackets.

NOTE 1—Additional procedures for determining compressive properties of polymer matrix composites may be found in Test Methods D3410/D3410M and D695.

1.4 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

2. Referenced Documents

2.1 *ASTM Standards:*[2]

D695 Test Method for Compressive Properties of Rigid Plastics
D792 Test Methods for Density and Specific Gravity (Relative Density) of Plastics by Displacement
D883 Terminology Relating to Plastics
D2584 Test Method for Ignition Loss of Cured Reinforced Resins
D2734 Test Methods for Void Content of Reinforced Plastics
D3171 Test Methods for Constituent Content of Composite Materials
D3410/D3410M Test Method for Compressive Properties of Polymer Matrix Composite Materials with Unsupported Gage Section by Shear Loading
D3878 Terminology for Composite Materials
D5229/D5229M Test Method for Moisture Absorption Properties and Equilibrium Conditioning of Polymer Matrix Composite Materials
E4 Practices for Force Verification of Testing Machines
E6 Terminology Relating to Methods of Mechanical Testing
E111 Test Method for Young's Modulus, Tangent Modulus, and Chord Modulus
E122 Practice for Calculating Sample Size to Estimate, With Specified Precision, the Average for a Characteristic of a Lot or Process
E177 Practice for Use of the Terms Precision and Bias in ASTM Test Methods
E251 Test Methods for Performance Characteristics of Metallic Bonded Resistance Strain Gages
E456 Terminology Relating to Quality and Statistics
E1237 Guide for Installing Bonded Resistance Strain Gages
E1309 Guide for Identification of Fiber-Reinforced Polymer-Matrix Composite Materials in Databases (Withdrawn 2015)[3]
E1434 Guide for Recording Mechanical Test Data of Fiber-Reinforced Composite Materials in Databases (Withdrawn 2015)[3]
E1471 Guide for Identification of Fibers, Fillers, and Core Materials in Computerized Material Property Databases (Withdrawn 2015)[3]

[1] This test method is under the jurisdiction of ASTM Committee D30 on Composite Materials and is the direct responsibility of Subcommittee D30.04 on Lamina and Laminate Test Methods.

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[2] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

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

3. Terminology

3.1 *Definitions*—Terminology D3878 defines terms relating to high-modulus fibers and their composites. Terminology D883 defines terms relating to plastics. Terminology E6 defines terms relating to mechanical testing. Terminology E456 and Practice E177 define terms relating to statistics. In the event of a conflict between terms, Terminology D3878 shall have precedence over the other terminology standards.

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *nominal value, n*—a value, existing in name only, assigned to a measurable property for the purpose of convenient designation. Tolerances may be applied to a nominal value to define an acceptable range for the property.

3.2.2 *orthotropic material, n*—a material with a property of interest that, at a given point, possesses three mutually perpendicular planes of symmetry defining the principal material coordinate system for that property.

3.2.3 *principal material coordinate system, n*—a coordinate system with axes that are normal to the planes of symmetry that exist within the material.

3.2.4 *reference coordinate system, n*—a coordinate system for laminated composites used to define ply orientations. One of the reference coordinate system axes (normally the Cartesian *x*-axis) is designated the reference axis, assigned a position, and the ply principal axis of each ply in the laminate is referenced relative to the reference axis to define the ply orientation for that ply.

3.2.5 *specially orthotropic, adj*—a description of an orthotropic material as viewed in its principal material coordinate system. In laminated composites, a specially orthotropic laminate is a balanced and symmetric laminate of the $(0_i/90_j)_{ns}$ family as viewed from the reference coordinate system, such that the membrane-bending coupling terms of the stress-strain relation are zero.

3.2.6 *transition strain,* $\varepsilon^{transition}$ *, n*—the strain value at the mid-range of the transition region between the two essentially linear portions of a bilinear stress-strain or strain-strain curve (a transverse strain-longitudinal strain curve as used for determining Poisson's ratio).

3.3 *Symbols:*

3.3.1 a—distance between neutral axes of test and opposite facesheets.

3.3.2 A—cross-sectional area of test facesheet.

3.3.3 CV—sample coefficient of variation, in percent.

3.3.4 E_o—modulus of elasticity of the opposite facesheet in the test direction.

3.3.5 E_f—modulus of elasticity of the test facesheet in the test direction.

3.3.6 F^{cu}—ultimate compressive strength.

3.3.7 G_{xz}—through-thickness shear modulus of elasticity.

3.3.8 h_c—thickness of core.

3.3.9 σ^c—compressive normal stress.

4. Summary of Test Method

4.1 A sandwich beam composed of two facesheets separated by a relatively deep honeycomb core, as shown in Fig. 1, is loaded in four-point bending. The main component of the compression test specimen is the face sheet that is loaded in

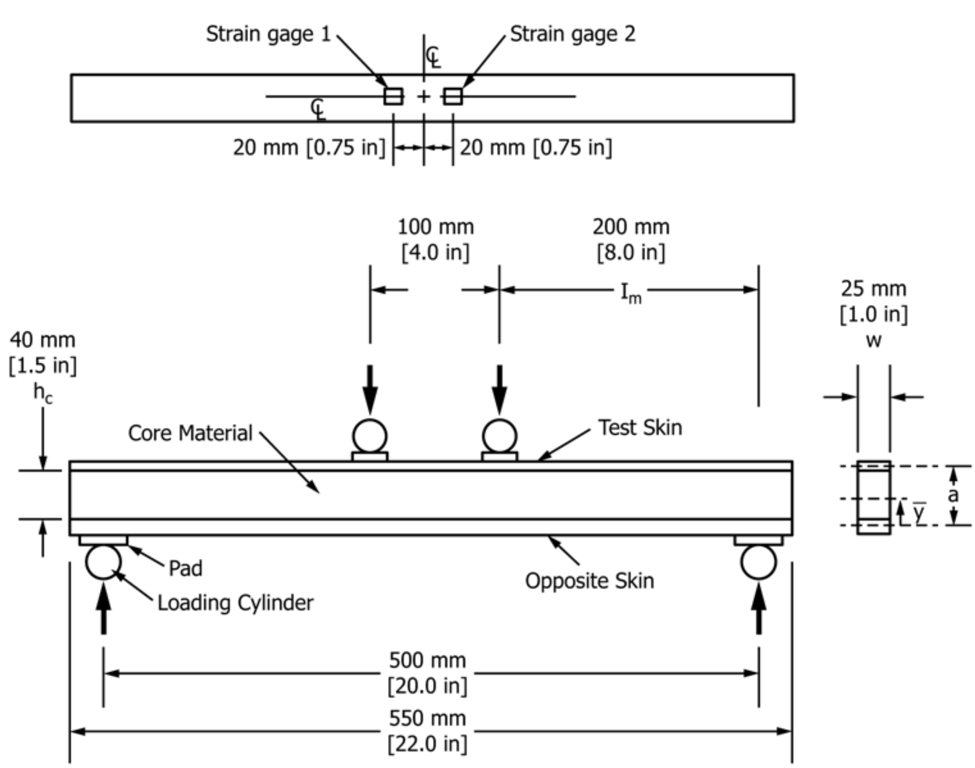

FIG. 1 Longitudinal Compression Sandwich Beam Test Specimen

compression during flexure, with the material direction of interest oriented along the length of the beam. The other facesheet is of a material and size carefully selected to preclude its influence on the test results. The ultimate compressive strength of the material is determined from the load at which the test facesheet of the sandwich beam fails in an acceptable compression failure mode. If the specimen strain is monitored with strain or deflection transducers then the stress-strain response of the material can be determined, from which can be derived the compressive modulus of elasticity for this configuration.

5. Significance and Use

5.1 This test method is designed to produce membrane compressive property data for material specifications, research and development, quality assurance, and structural design and analysis. Factors that influence the compressive response and should therefore be reported include the following: material, methods of material and specimen preparation, specimen conditioning, environment of testing, specimen alignment, speed of testing, time at reinforcement. Properties, in the test direction, that may be obtained from this test method include:

5.1.1 Ultimate compressive strength,

5.1.2 Ultimate compressive strain,

5.1.3 Compressive (linear or chord) modulus of elasticity, and

5.1.4 Transition strain.

6. Interferences

6.1 *Test Method Sensitivities*—Compressive strength for a single material system has been shown to differ when determined by different test methods. Such differences can be attributed to specimen alignment effects, specimen geometry effects, and fixture effects even though efforts have been made to minimize these effects.

6.2 *Material and Specimen Preparation*—Compressive modulus, and especially compressive strength, are sensitive to poor material fabrication practices, damage induced by improper coupon machining, and lack of control of fiber alignment. Fiber alignment relative to the specimen coordinate axis should be maintained as carefully as possible, although no standard procedure to insure this alignment exists. Procedures found satisfactory include the following: fracturing a cured unidirectional laminate near one edge parallel to the fiber direction to establish the [0] direction or laying in small filament count tows of contrasting color fiber (aramid in carbon laminates and carbon in aramid or glass laminates) parallel to the [0] direction either as part of the prepreg production or as part of panel fabrication.

6.3 *Calculation*—Stress equations are based on beam theory.

7. Apparatus

7.1 *Micrometers*—The micrometer(s) shall use a suitable size diameter ball-interface on irregular surfaces such as the bag-side of a laminate, and a flat anvil interface on machined edges or very smooth tooled surfaces. The accuracy of the instruments shall be suitable for reading to within 1 % of the sample width and thickness. For typical specimen geometries, an instrument with an accuracy of ±2.5 μm [±0.0001 in.] is desirable for thickness measurement, while an instrument with an accuracy of ±25 μm [±0.001 in.] is desirable for width measurement.

7.2 *Compressive Fixture*—A fixture of four loading cylinders or cylindrical supports capable of loading the sandwich beam as shown in Fig. 1. The fixture shall be installed between the steel platens of the testing machine. To avoid local crushing or failure as a result of stress concentrations under the loading cylinders, the diameter of loading cylinders may be up to 1.5 times the sandwich thickness, and loading pads may be needed under the loading cylinders (see 11.6).

7.3 *Testing Machine*—The testing machine shall be in conformance with Practices E4 and shall satisfy the following requirements:

7.3.1 *Testing Machine Heads*—The testing machine shall have two loading heads, with at least one movable along the testing axis.

7.3.2 *Drive Mechanism*—The testing machine drive mechanism shall be capable of imparting to the movable head a controlled displacement rate with respect to the stationary head. The displacement rate of the movable head shall be capable of being regulated as specified in 11.3.

7.3.3 *Load Indicator*—The testing machine load-sensing device shall be capable of indicating the total load being carried by the test specimen. This device shall be essentially free from inertia lag at the specified rate of testing and shall indicate the load with an accuracy over the load range(s) of interest of within ±1 % of the indicated value, as specified by Practices E4. The load range(s) of interest may be fairly low for modulus evaluation, much higher for strength evaluation, or both, as required.

NOTE 2—Obtaining precision load data over a large range of interest in the same test, such as when both elastic modulus and ultimate load are being determined, place extreme requirements on the load cell and its calibration. For some equipment, a special calibration may be required. For some combinations of material and load cell, simultaneous precision measurement of both elastic modulus and ultimate strength may not be possible, and measurement of modulus and strength may have to be performed in separate tests using a different load cell range for each test.

7.4 *Strain-Indicating Device*—Strain data, if required, shall be determined by means of strain gages.

7.4.1 *Bonded Resistance Strain Gages*—Strain gage selection is a compromise based on the procedure and the type of material to be tested. Strain gages should have an active grid length of 3 mm [0.125 in.] or less; (1.5 mm [0.06 in.] is preferable). Gage calibration certification shall comply with Test Methods E251. Some guidelines on the use of strain gages on composites are presented below, with a general discussion on the subject in Footnote 8.[4]

7.4.1.1 Surface preparation of fiber-reinforced composites in accordance with Practice E1237 can penetrate the matrix material and cause damage to the reinforcing fibers, resulting

[4] Pendleton, R. P. and Tuttle, M. E., *Manual on Experimental Methods for Mechanical Testing of Composites*, Society for Experimental Mechanics, Bethel, CT, 1989.