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Standard Guide for Testing Polymer Matrix Composite Materials[1]

This standard is issued under the fixed designation D4762; 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 guide summarizes the application of ASTM standard test methods (and other supporting standards) to continuous-fiber reinforced polymer matrix composite materials. The most commonly used or most applicable ASTM standards are included, emphasizing use of standards of Committee D30 on Composite Materials.

1.2 This guide does not cover all possible standards that could apply to polymer matrix composites and restricts discussion to the documented scope. Commonly used but non-standard industry extensions of test method scopes, such as application of static test methods to fatigue testing, are not discussed. A more complete summary of general composite testing standards, including non-ASTM test methods, is included in the Composite Materials Handbook (MIL-HDBK-17).[2] Additional specific recommendations for testing textile (fabric, braided) composites are contained in Guide D6856.

1.3 This guide does not specify a system of measurement; the systems specified within each of the referenced standards shall apply as appropriate. Note that the referenced standards of ASTM Committee D30 are either SI-only or combined-unit standards with SI units listed first.

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:*[3]

2.1.1 *Standards of Committee D30 on Composite Materials*

C271/C271M Test Method for Density of Sandwich Core Materials
C272 Test Method for Water Absorption of Core Materials for Structural Sandwich Constructions
C273/C273M Test Method for Shear Properties of Sandwich Core Materials
C297/C297M Test Method for Flatwise Tensile Strength of Sandwich Constructions
C363/C363M Test Method for Node Tensile Strength of Honeycomb Core Materials
C364/C364M Test Method for Edgewise Compressive Strength of Sandwich Constructions
C365/C365M Test Method for Flatwise Compressive Properties of Sandwich Cores
C366/C366M Test Methods for Measurement of Thickness of Sandwich Cores
C393/C393M Test Method for Core Shear Properties of Sandwich Constructions by Beam Flexure
C394 Test Method for Shear Fatigue of Sandwich Core Materials
C480/C480M Test Method for Flexure Creep of Sandwich Constructions
C481 Test Method for Laboratory Aging of Sandwich Constructions
C613/C613M Test Method for Constituent Content of Composite Prepreg by Soxhlet Extraction
D2344/D2344M Test Method for Short-Beam Strength of Polymer Matrix Composite Materials and Their Laminates
D3039/D3039M Test Method for Tensile Properties of Polymer Matrix Composite Materials
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
D3479/D3479M Test Method for Tension-Tension Fatigue of Polymer Matrix Composite Materials

[1] This guide is under the jurisdiction of ASTM Committee D30 on Composite Materials and is the direct responsibility of Subcommittee D30.01 on Editorial and Resource Standards.

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[2] Available from Standardization Documents Order Desk, DODSSP, Bldg. 4, Section D, 700 Robbins Ave., Philadelphia, PA 19111-5098, http://dodssp.daps.dla.mil.

[3] 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.

D3518/D3518M Test Method for In-Plane Shear Response of Polymer Matrix Composite Materials by Tensile Test of a 45 Laminate
D3529/D3529M Test Method for Matrix Solids Content and Matrix Content of Composite Prepreg
D3530/D3530M Test Method for Volatiles Content of Composite Material Prepreg
D3531 Test Method for Resin Flow of Carbon Fiber-Epoxy Prepreg
D3532 Test Method for Gel Time of Carbon Fiber-Epoxy Prepreg
D3800 Test Method for Density of High-Modulus Fibers
D3878 Terminology for Composite Materials
D4018 Test Methods for Properties of Continuous Filament Carbon and Graphite Fiber Tows
D4102 Test Method for Thermal Oxidative Resistance of Carbon Fibers
D4255/D4255M Test Method for In-Plane Shear Properties of Polymer Matrix Composite Materials by the Rail Shear Method
D5229/D5229M Test Method for Moisture Absorption Properties and Equilibrium Conditioning of Polymer Matrix Composite Materials
D5379/D5379M Test Method for Shear Properties of Composite Materials by the V-Notched Beam Method
D5448/D5448M Test Method for Inplane Shear Properties of Hoop Wound Polymer Matrix Composite Cylinders
D5449/D5449M Test Method for Transverse Compressive Properties of Hoop Wound Polymer Matrix Composite Cylinders
D5450/D5450M Test Method for Transverse Tensile Properties of Hoop Wound Polymer Matrix Composite Cylinders
D5467/D5467M Test Method for Compressive Properties of Unidirectional Polymer Matrix Composite Materials Using a Sandwich Beam
D5528 Test Method for Mode I Interlaminar Fracture Toughness of Unidirectional Fiber-Reinforced Polymer Matrix Composites
D5687/D5687M Guide for Preparation of Flat Composite Panels with Processing Guidelines for Specimen Preparation
D5766/D5766M Test Method for Open-Hole Tensile Strength of Polymer Matrix Composite Laminates
D5961/D5961M Test Method for Bearing Response of Polymer Matrix Composite Laminates
D6115 Test Method for Mode I Fatigue Delamination Growth Onset of Unidirectional Fiber-Reinforced Polymer Matrix Composites
D6264/D6264M Test Method for Measuring the Damage Resistance of a Fiber-Reinforced Polymer-Matrix Composite to a Concentrated Quasi-Static Indentation Force
D6415/D6415M Test Method for Measuring the Curved Beam Strength of a Fiber-Reinforced Polymer-Matrix Composite
D6416/D6416M Test Method for Two-Dimensional Flexural Properties of Simply Supported Sandwich Composite Plates Subjected to a Distributed Load
D6484/D6484M Test Method for Open-Hole Compressive Strength of Polymer Matrix Composite Laminates
D6507 Practice for Fiber Reinforcement Orientation Codes for Composite Materials
D6641/D6641M Test Method for Compressive Properties of Polymer Matrix Composite Materials Using a Combined Loading Compression (CLC) Test Fixture
D6671/D6671M Test Method for Mixed Mode I-Mode II Interlaminar Fracture Toughness of Unidirectional Fiber Reinforced Polymer Matrix Composites
D6742/D6742M Practice for Filled-Hole Tension and Compression Testing of Polymer Matrix Composite Laminates
D6772 Test Method for Dimensional Stability of Sandwich Core Materials
D6790 Test Method for Determining Poisson's Ratio of Honeycomb Cores
D6856 Guide for Testing Fabric-Reinforced Textile Composite Materials
D6873/D6873M Practice for Bearing Fatigue Response of Polymer Matrix Composite Laminates
D7028 Test Method for Glass Transition Temperature (DMA Tg) of Polymer Matrix Composites by Dynamic Mechanical Analysis (DMA)
D7078/D7078M Test Method for Shear Properties of Composite Materials by V-Notched Rail Shear Method
D7136/D7136M Test Method for Measuring the Damage Resistance of a Fiber-Reinforced Polymer Matrix Composite to a Drop-Weight Impact Event
D7137/D7137M Test Method for Compressive Residual Strength Properties of Damaged Polymer Matrix Composite Plates
D7205/D7205M Test Method for Tensile Properties of Fiber Reinforced Polymer Matrix Composite Bars
D7248/D7248M Test Method for Bearing/Bypass Interaction Response of Polymer Matrix Composite Laminates Using 2-Fastener Specimens
D7249/D7249M Test Method for Facing Properties of Sandwich Constructions by Long Beam Flexure
D7250/D7250M Practice for Determining Sandwich Beam Flexural and Shear Stiffness
D7264/D7264M Test Method for Flexural Properties of Polymer Matrix Composite Materials
D7291/D7291M Test Method for Through-Thickness Flatwise Tensile Strength and Elastic Modulus of a Fiber-Reinforced Polymer Matrix Composite Material
D7332/D7332M Test Method for Measuring the Fastener Pull-Through Resistance of a Fiber-Reinforced Polymer Matrix Composite

D7336/D7336M Test Method for Static Energy Absorption Properties of Honeycomb Sandwich Core Materials
D7337/D7337M Test Method for Tensile Creep Rupture of Fiber Reinforced Polymer Matrix Composite Bars
D7522/D7522M Test Method for Pull-Off Strength for FRP Bonded to Concrete Substrate
D7565/D7565M Test Method for Determining Tensile Properties of Fiber Reinforced Polymer Matrix Composites Used for Strengthening of Civil Structures
D7615/D7615M Practice for Open-Hole Fatigue Response of Polymer Matrix Composite Laminates
D7616/D7616M Test Method for Determining Apparent Overlap Splice Shear Strength Properties of Wet Lay-Up Fiber-Reinforced Polymer Matrix Composites Used for Strengthening Civil Structures
D7617/D7617M Test Method for Transverse Shear Strength of Fiber-reinforced Polymer Matrix Composite Bars
E1309 Guide for Identification of Fiber-Reinforced Polymer-Matrix Composite Materials in Databases
E1434 Guide for Recording Mechanical Test Data of Fiber-Reinforced Composite Materials in Databases
E1471 Guide for Identification of Fibers, Fillers, and Core Materials in Computerized Material Property Databases
F1645/F1645M Test Method for Water Migration in Honeycomb Core Materials

2.1.2 *Standards of Committee D20 on Plastics*

C581 Practice for Determining Chemical Resistance of Thermosetting Resins Used in Glass-Fiber-Reinforced Structures Intended for Liquid Service
D256 Test Methods for Determining the Izod Pendulum Impact Resistance of Plastics
D543 Practices for Evaluating the Resistance of Plastics to Chemical Reagents
D570 Test Method for Water Absorption of Plastics
D618 Practice for Conditioning Plastics for Testing
D638 Test Method for Tensile Properties of Plastics
D648 Test Method for Deflection Temperature of Plastics Under Flexural Load in the Edgewise Position
D671 Test Method for Flexural Fatigue of Plastics by Constant-Amplitude-of-Force
D695 Test Method for Compressive Properties of Rigid Plastics
D696 Test Method for Coefficient of Linear Thermal Expansion of Plastics Between 30C and 30C with a Vitreous Silica Dilatometer
D790 Test Methods for Flexural Properties of Unreinforced and Reinforced Plastics and Electrical Insulating Materials
D792 Test Methods for Density and Specific Gravity (Relative Density) of Plastics by Displacement
D953 Test Method for Bearing Strength of Plastics
D1505 Test Method for Density of Plastics by the Density-Gradient Technique
D1822 Test Method for Tensile-Impact Energy to Break Plastics and Electrical Insulating Materials
D2471 Practice for Gel Time and Peak Exothermic Temperature of Reacting Thermosetting Resins
D2583 Test Method for Indentation Hardness of Rigid Plastics by Means of a Barcol Impressor
D2584 Test Method for Ignition Loss of Cured Reinforced Resins
D2734 Test Methods for Void Content of Reinforced Plastics
D2990 Test Methods for Tensile, Compressive, and Flexural Creep and Creep-Rupture of Plastics
D3418 Test Method for Transition Temperatures and Enthalpies of Fusion and Crystallization of Polymers by Differential Scanning Calorimetry
D3846 Test Method for In-Plane Shear Strength of Reinforced Plastics
D4065 Practice for Plastics: Dynamic Mechanical Properties: Determination and Report of Procedures
D4473 Test Method for Plastics: Dynamic Mechanical Properties: Cure Behavior
D5083 Test Method for Tensile Properties of Reinforced Thermosetting Plastics Using Straight-Sided Specimens
D6272 Test Method for Flexural Properties of Unreinforced and Reinforced Plastics and Electrical Insulating Materials by Four-Point Bending

2.1.3 *Standards of Other ASTM Committees*

E228 Test Method for Linear Thermal Expansion of Solid Materials With a Push-Rod Dilatometer
E289 Test Method for Linear Thermal Expansion of Rigid Solids with Interferometry
E1269 Test Method for Determining Specific Heat Capacity by Differential Scanning Calorimetry
E1461 Test Method for Thermal Diffusivity by the Flash Method
E1922 Test Method for Translaminar Fracture Toughness of Laminated and Pultruded Polymer Matrix Composite Materials

3. Terminology

3.1 Definitions related to composite materials are defined in Terminology D3878.

3.2 Symbology for specifying the orientation and stacking sequence of a composite laminate is defined in Practice D6507.

3.3 For purposes of this document, "low modulus" composites are defined as being reinforced with fibers having a modulus ≤20 GPa (≤3.0×10^6 psi), while "high-modulus" composites are reinforced with fiber having a modulus >20 GPa (>3.0×10^6 psi).

4. Significance and Use

4.1 This guide is intended to aid in the selection of standards for polymer matrix composite materials. It specifically summarizes the application of standards from ASTM Committee D30 on Composite Materials that apply to continuous-fiber reinforced polymer matrix composite materials. For reference and comparison, many commonly used or applicable ASTM standards from other ASTM Committees are also included.

5. Standard Specimen Preparation

5.1 Preparation of polymer matrix composite test specimens is described in Guide D5687/D5687M.

6. Standard Test Methods

6.1 ASTM test methods for the evaluation of polymer matrix composites are summarized in the tables. Advantages, disadvantages, and other comments for each test method are included where appropriate. Where possible, a single preferred test method is identified.

TEST METHOD CATEGORY	TABLE
Lamina/Laminate Static Properties	Table 1
Lamina/Laminate Dynamic Properties	Table 2
Laminate/Structural Response	Table 3
Sandwich Constructions	Table 4
Constituent/Precursor/Thermophysical Properties	Table 5
Environmental Conditioning/Resistance	Table 6

7. Standard Data Reporting

7.1 *Constituent Material Description*—Data reporting of the description of composite material constituents is documented in Guide E1471.

7.2 *Composite Material Description*—Data reporting of the description of composite materials is documented in Guide E1309.

7.3 *Composite Material Test Data*—Data reporting of mechanical test data results for composite materials is documented in Guide E1434.

8. Keywords

8.1 bearing strength; bearing-bypass interaction; coefficient of thermal expansion; composite materials; composites; compression; compressive strength; constituent content; crack-growth testing; creep; creep strength; CTE; curved-beam strength; damage; damage resistance; damage tolerance; data recording; data records; delamination; density; drop-weight impact; elastic modulus; fastener pull-through; fatigue; fiber; fiber volume; filament; filled-hole compression strength; filled-hole tensile strength; flatwise tensile strength; flexural modulus; flexure; fracture; fracture toughness; gel time; glass transition temperature; hoop-wound; impact; impact strength; lamina; laminate; matrix content; mixed mode; mode I; mode II; mode III; modulus of elasticity; moisture content; moisture diffusivity; OHC; OHT; open-hole compressive strength; open-hole tensile strength; out-of-plane compressive strength; out-of-plane shear strength; out-of-plane tensile strength; panel; plate; Poisson's ratio; polymer matrix composites; prepreg; reinforcement; reinforcement content; reinforcement volume; resin; resin content; sandwich construction; shear; shear modulus; shear strength; short-beam strength; specific heat; strain energy release rate; strength; structure; tensile strength; tension; thermal conductivity; thermal diffusivity; thermal expansion coefficient; tow; V-notched beam strength; void content; winding; yarn

TABLE 1 Lamina/Laminate Static Test Methods

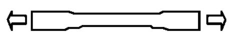
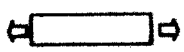
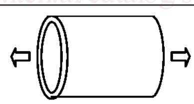
Test Method	Specimen	Measured Property	Description and Advantages	Disadvantages	Comments
		In-Plane Tensile Test Methods			
D3039/D3039M		Tensile Strength	Straight sided specimen. Suitable for both random, discontinuous and continuous-fiber composites. Tabbed and untabbed configurations available.	Tabbed configurations require careful adhesive selection and special specimen preparation. Certain laminate layups prone to edge delamination which can affect tensile strength results.	Preferred for most uses. Provides additional configurations, requirements, and guidance that are not found in D5083. Limited to laminates that are balanced and symmetric with respect to the test direction.
		Tensile Modulus, Poisson's Ratio, Stress-Strain Response	Requires use of strain or displacement transducers. Modulus measurements do not require use of tabs.		Modulus measurements typically robust.
D638		Tensile Strength, Tensile Modulus	"Dumbbell" shaped specimen. Ease of test specimen preparation.	Stress concentration at the radii. Unsuitable for highly oriented fiber composites.	Not recommended for high-modulus composites. Technically equivalent to ISO 527-1.
D5083		Tensile Strength, Tensile Modulus	Straight-sided, untabbed specimen only.	Suitable for plastics and low-modulus composites.	A straight-sided alternative to D638. Technically equivalent to ISO 527-4 except as noted below: (*a*) This test method does not include testing of the Type I dog-bone shaped specimen described in ISO 527-4. Testing of this type of specimen, primarily used for reinforced and unreinforced thermoplastic materials, is described in D638. (*b*) The thickness of test specimens in this test method includes the 2 mm to 10 mm thickness range of ISO 527-4, but expands the allowable test thickness to 14 mm.
D5450/D5450M		Transverse (90°) Tensile Strength	Hoop wound cylinder with all 90° (hoop) plies loaded in axial tension. Develops data for specialized process/ form.	Limited to hoop-wound cylinders. Limited to transverse tensile properties. Must bond specimen to fixture.	Must ensure adequate bonding to fixture.
		In-Plane Compression Test Methods			
D6641/D6641M		Compressive Strength	Untabbed, or tabbed straight-sided specimen loaded via a combination of shear and end-loading. Smaller lighter, less expensive fixture than that of D3410/ D3410M. Better also at non-ambient environments. Suitable for continuous fiber composites.	Tabbed specimens are required for determining compressive strength of laminates containing more than 50% 0° plies.	Preferred method. Thickness must be sufficient to prevent column buckling. Limited to laminates that are balanced and symmetric and contain at least one 0° ply. For strength determination, untabbed specimens are limited to a maximum of 50 % 0° plies, or equivalent.
		Compressive Modulus, Poisson's Ratio, Stress-Strain Response	Requires use of strain or displacement transducers.		Unidirectional tape or tow composites can be tested using untabbed specimens to determine unidirectional modulus and Poisson's ratio.

TABLE 1 *Continued*

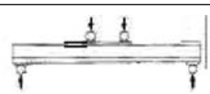
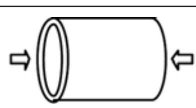
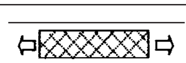
Test Method	Specimen	Measured Property	Description and Advantages	Disadvantages	Comments
D695		Compressive Strength, Compressive Modulus	"Dogbone" shaped specimen with loading applied at the ends via a platen. Tabs are optional.	Failure mode is often end-crushing. Stress concentrations at radii. Specimen must be dog boned and ends must be accurately machined. No assessment of alignment.	Not recommended for highly oriented or continuous fiber composites. Modified version of D695 released as SACMA SRM 1 test method is widely used in aerospace industry, but ASTM D30 and MIL-HDBK-17 prefer use of D6641/D6641M method.
D3410/D3410M		Compressive Strength	Straight sided specimen with load applied by shear via fixture grips. Suitable for random, discontinuous and continuous fiber composites. Tabbed and untabbed configurations available.	Strain gages required to verify alignment. Poor for non-ambient testing due to massive fixture.	Expensive and heavy/bulky fixturing. Thickness must be sufficient to prevent column buckling.
		Compressive Modulus, Poisson's Ratio, Stress-Strain Response	Requires use of strain or displacement transducers.		
D5467/D5467M		Compressive Strength, Compressive Modulus, Stress-Strain Response	Sandwich beam specimen loaded in 4-point bending. Intended result is a compression failure mode of the facesheet. Data is especially applicable to sandwich structures. Fixturing is simple compared to other compression tests.	An expensive specimen that is not recommended unless the structure warrants its use. Strain gages required to obtain modulus and strain-to-failure data. Narrow (1 in. wide) specimen may not be suitable for materials with coarse features, such as fabrics with large filament count tows (12K or more) or certain braided materials.	Must take care to avoid core failure modes. Limited to high-modulus composites. Due to the nature of the specimen construction and applied flexural loading these results may not be equivalent to a similar laminate tested by other compression methods such as D3410/D3410M or D6641/D6641M.
D5449/D5449M		Transverse (90°) Compressive Strength	Hoop-wound cylinder with all 90° (hoop) plies loaded in compression. Develops data for specialized process/form.	Limited to hoop-wound cylinders. Limited to transverse compressive properties. Must bond specimen to fixture.	Must ensure adequate bonding to fixture.
		In-Plane Shear Test Methods			
~~D3518/D3518M~~	 -	~~Shear Strength, Shear Modulus, Stress- Strain Response~~	~~Tensile test of [+45/-45]ns layup.~~ ~~Simple test specimen and test method.~~	~~Poor specimen for measuring ultimate shear strength due to large non-linear response.~~ ~~Limited to material forms/processes that can be made in flat ±45° form.~~ ~~Biaxial transducers required to obtain modulus and strain-to-failure data.~~	~~Widely used due to its low cost and relationsh ip to act ual structural lamina tes.~~

TABLE 1 *Continued*

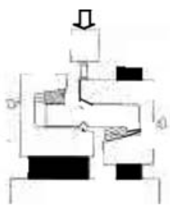
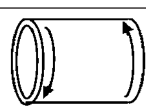
Test Method	Specimen	Measured Property	Description and Advantages	Disadvantages	Comments
D3518/D3518M		Shear Modulus, Stress-Strain Response, Maximum Shear Stress	Tensile test of [+45/-45]ns layup. Simple test specimen and test method.	Poor specimen for measuring ultimate shear strength due to large non-linear response. Limited to material forms/processes that can be made in flat ±45° form. Biaxial transducers required to obtain modulus and strain-to-failure data. Maximum shear stress determination is dependent upon instrumentation-based strain measurements at high shear strain magnitudes.	Widely used due to its low cost and simplicity. Specimen gage section is not under pure shear stress, and stress fields local to free edges are complex.
D5379/D5379M		Shear Strength, Shear Modulus, Stress-Strain Response	V-notched specimen loaded in special bending fixture. Along with D7078/D7078M, provides the best shear response of the standardized methods. Provides shear modulus and strength. Can be used to test most composite types. Produces a relatively pure and uniform shear stress state.	May be necessary to tab the specimen. Specimen can be difficult to machine. Biaxial strain gages required to obtain modulus and strain-to-failure data. Requires good strain-gage installation technique. In-plane tests not suitable for materials with coarse features, such as fabrics with large filament count tows (12K or more) or certain braided materials. Unacceptable failure modes, especially with high-strength laminates, can occur due to localized failure of the specimen at the loading points.	Recommended for quantitative data, or where shear modulus or stress/strain data are required. Enables correlation with out-of-plane properties. Must monitor strain data for specimen buckling. Limited to the following forms: (*a*) unidirectional tape or tow laminates with fibers parallel or perpendicular to loading axis. (*b*) woven fabric laminates with the warp direction parallel or perpendicular to loading axis. (*c*) laminates with equal numbers of 0° and 90° plies with the 0° plies parallel or perpendicular to loading axis. (*d*) short-fiber composites with majority of the fibers randomly distributed. The most accurate modulus measurements obtained from laminates of the [0/90] family.
D4255/D4255M		Shear Strength, Shear Modulus, Stress-Strain Response	Rail shear methods. Suitable for both random and continuous fiber composites.	Difficult test to run. Historically has had poor reproducibility. Stress concentrations at gripping areas. Strain gages required to obtain modulus and strain-to-failure data.	Expensive specimen. Best reserved for testing of laminates.
D5448/D5448M		Shear Strength, Shear Modulus, Stress-Strain Response	Hoop-wound cylinder with all 90° (hoop) plies loaded in torsion. Develops data for specialized process/form.	Limited to hoop-wound cylinders. Limited to in-plane shear properties. Must bond specimen to fixture.	Must ensure adequate bonding to fixture.

TABLE 1 *Continued*

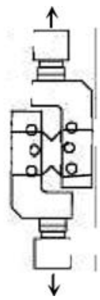
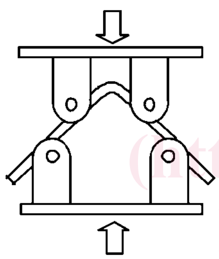
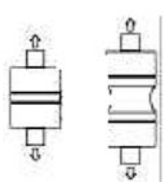
Test Method	Specimen	Measured Property	Description and Advantages	Disadvantages	Comments
D7078/D7078M		Shear Strength, Shear Modulus, Stress-Strain Response	V-notched specimen loaded in rail shear fixture. Along with D5379/D5379M, provides the best shear response of the standardized methods. Provides shear modulus and strength. Can be used to test most composite types. Produces a relatively pure and uniform shear stress state. Generally does not require tabs. Permits testing of fabric and textile composites with large unit cells. Less susceptible to loading point failures than D5379/D5379M.	Specimen can be difficult to machine. Biaxial strain gages required to obtain modulus and strain-to-failure data. Requires good strain-gage installation technique.	Recommended for quantitative data, or where shear modulus or stress/strain data are required. Enables correlation with out-of-plane properties. Must monitor strain data for specimen buckling. Material form limitations are equivalent to those for D5379/D5379M. The most accurate modulus measurements obtained from laminates of the [0/90} family.
			Out-of-Plane Tensile Test Methods		
D6415/D6415M		Curved Laminate Strength	Right-angle curved laminate specimen loaded in 4-point bending. Suitable for continuous fiber composites.	A complex stress state is generated in the specimen that may cause an unintended complex failure mode. There is typically a large amount of scatter in the curved beam strength data. While the failure mode is largely out-of-plane, the result is generally considered a structural test of a curved beam rather than a material property.	Limited to composites with defined layers (no through-the-thickness reinforcement). For structural comparison, the same manufacturing process should be used for both the test specimen and the structure. Non-standard versions of the curved-beam test yield a different stress state that may affect the strength and failure mode.
		Interlaminar Tensile Strength	See above.	See above.	Tests for interlaminar tensile strength limited to unidirectional materials with fibers oriented continuously along the legs and around the bend.
D7291/D7291M		Flatwise Tensile Strength, Flatwise Modulus	Cylindrical or reduced gage section "spool" specimen loaded in tension. Uses adhesively bonded thick metal end-tabs for load introduction. Suitable for continuous or discontinuous fiber composites. Subjects a relatively large volume of material to an almost uniform stress field.	Results are sensitive to system alignment and load eccentricity. Surface finish and parallelism affect strength results. Results are sensitive to thermal residual stresses, adhesive, and surface preparation at end-tab bondlines.	Requires bonding and machining of laminate and end-tabs. End-tabs may be reused within geometric limits. Low crosshead displacement rate (0.1 mm/mim [0.005 in./min]. Valid tests require failures away from the end-tab bondline.
			Out-of-Plane Shear Test Methods		

TABLE 1 *Continued*

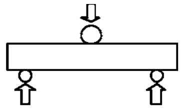
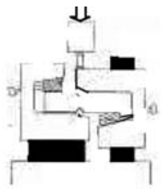
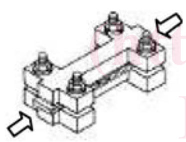
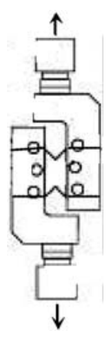
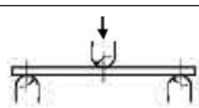
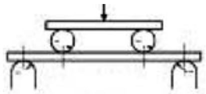
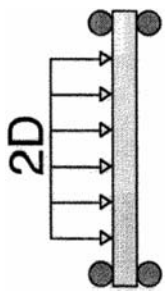
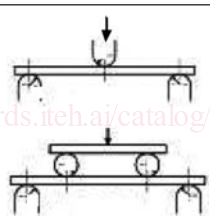
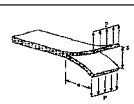
Test Method	Specimen	Measured Property	Description and Advantages	Disadvantages	Comments
D2344/D2344M		Short Beam Strength	Short rectangular beam specimen loaded in 3-point bending. Short Beam Strength is a good indicator of resin-dominated properties. Simple, inexpensive specimen and test configuration.	Short Beam Strength may be related to interlaminar shear strength, but the stress state is quite mixed, and so results are not recommended as an assessment of shear strength due to stress concentrations and high secondary stresses at loading points. Shear modulus cannot be measured.	Intended primarily for quality control, comparative data, and assessment of environmental effects.
D5379/D5379M		Interlaminar Shear Strength, Interlaminar Shear Modulus	V-notched specimen loaded in special bending fixture. Along with D7078/D7078M, provides the best shear response of the standardized methods. Provides shear modulus and strength. Can be used to test most composites. Produces a relatively pure and uniform shear stress state.	May be necessary to tab the specimen. Specimen can be difficult to machine. Strain gages required to obtain modulus and strain-to-failure data. Requires good strain-gage installation technique. Requires a very thick laminate, 20 mm (0.75 in.) for out-of-plane properties.	Recommended for quantitative data, or where shear modulus or stress/strain data are required. Enables correlation with in-plane properties. Must monitor strain data for specimen buckling.
D3846		Shear Strength	Specimen with two machined notches loaded in compression. Suitable for randomly dispersed and continuous fiber reinforced materials. May be preferable to D2344/D2344M for materials with randomly dispersed fiber orientations.	Failures may be sensitive to accuracy of notch machining. Stress concentrations at notches. Failure may be influenced by the applied compression stress. Requires post-failure measurement of shear area. Shear modulus cannot be measured.	Specimen loaded in compression utilizing the D695 loading/stabilizing jig. Shear loading occurs in a plane between two machined notches. Often a problematic test. Note that this is an out-of-plane shear test (using recognized terminology), despite the title that indicates in-plane shear loading.
D7078/D7078M		Interlaminar Shear Strength, Interlaminar Shear Modulus	V-notched specimen loaded in rail shear fixture. Along with D5379/D5379M, provides the best shear response of the standardized methods. Provides shear modulus and strength. Can be used to test most composites. Produces a relatively pure and uniform shear stress state. Less susceptible to loading point failures than D5379/D5379M.	Specimen can be difficult to machine. Strain gages required to obtain modulus and strain-to-failure data. Requires good strain-gage installation technique. Requires an extremely thick laminate, typically consisting of multiple co-bonded sub-laminates, for out-of-plane properties.	Recommended for quantitative data, or where shear modulus or stress/strain data are required. Enables correlation with in-plane properties. Must monitor strain data for specimen buckling.
Laminate Flexural Test Methods					
D790		Flexural Strength, Flexural Modulus, Flexural Stress-Strain Response	Flat rectangular specimen loaded in 3-point bending. Suitable for randomly dispersed and continuous fiber reinforced materials. Ease of test specimen preparation and testing.	Stress concentrations and secondary stresses at loading points. Results sensitive to specimen and loading geometry, strain rate.	Failure mode may be tension, compression, shear, or combination.

TABLE 1 *Continued*

Test Method	Specimen	Measured Property	Description and Advantages	Disadvantages	Comments
D6272		Flexural Strength, Flexural Modulus, Flexural Stress-Strain Response	Flat rectangular specimen loaded in 4-point bending. Suitable for randomly dispersed and continuous fiber reinforced materials. Ease of test specim en preparation and testing. Choice of two procedures enable adjustable tension/ compression/ shear load distribution.	Center-point deflection requires secondary instrumentation. Results sensitive to specimen and loading geometry, strain rate. Span-to-depth ratio must increase for laminates with high tensile strength with respect to in-plane shear strength.	The quarter-span version is recommended for highmodulus composites. Failure mode may be tension, compression, shear, or combination.
D6416/D6416M		Pressure-Deflection Response, Pressure-Strain Response, Plate Bending and Shear Stiffness	Two-dimensional plate flexure induced by a well-defined distributed load. Apparatus, instrumentation ensure applied pressure distribution is known. Failures typically initiate away from edges. Specimens are relatively large, facilitating study of manufacturing defects and process variables.	For studies of failure mechanics and other quantitative sandwich analyses, only small panel deflections are allowed. The test fixture is necessarily more elaborate, and some calibration is required to verify simply-supported boundary conditions. Results highly dependent upon panel edge boundary conditions and pressure distribution. Relatively large specimen and support fixture geometry.	The same caveats applying to D7249/D7249M could apply to D6416/D6416M. However, this method is not limited to sandwich composites; D6416/D6416M can be used to evaluate the 2-dimensional flexural properties of any square plate. Distributed load is provided using a water-filled bladder. Ratio of support span to average specimen thickness should be between 10 to 30.
D7264/D7264M		Flexural Strength, Flexural Modulus, Flexural Stress-Strain Response	Recommended for high-modulus composites. Flat rectangular specimen loaded in 3 or 4-point bending. Suitable for randomly dispersed and continuous fiber reinforced materials. Ease of test specimen preparation and testing. Standardized load and support spans to simplify calculations and to standardize geometry.	Center-point deflection measurement requires secondary instrumentation. Results sensitive to specimen and loading geometry, strain rate. Span-to-depth ratio may need to increase for laminates with high tensile strength with respect to in-plane shear strength.	Standard support span-to-thickness ratio is 32:1. For 4-point load, load points are set at one-half of the support span. Failure mode may be tension, compression, shear, or combination.
		Fracture Toughness Test Methods			
D5528		Mode I Interlaminar Fracture Toughness, G_{Ic}	Flat rectangular specimen with delamination insert loaded in tension. Suitable for unidirectional tape or tow laminates. Relatively stable delamination growth.	Specimens must be hinged at the loading points. Crack growth not always well behaved.	Calculations assume linear elastic behavior. Crack growth should be observed from both sides of the specimen.