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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
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

[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.

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
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[4]

D695 Test Method for Compressive Properties of Rigid Plastics

D696 Test Method for Coefficient of Linear Thermal Expansion of Plastics Between -30°C and 30°C 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[4]

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.

[4] Withdrawn.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

TABLE 1 Lamina/Laminate Static Test Methods

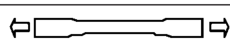
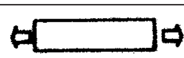
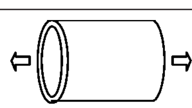
Test Method	Specimen	Measured Property	Description and Advantages	Disadvantages	Comments
		In-Plane Tensile Test Methods			
D3039/D3039M		Tensile Strength	Straight sided specimen. Suitable for both random, discontinuous and continuous-fiber composites. Tabbed and untabbed configurations available.	Tabbed 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*

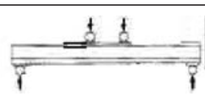
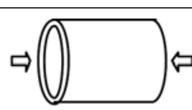
Test Method	Specimen	Measured Property	Description and Advantages	Disadvantages	Comments
D695		Compressive Strength, Compressive Modulus	"Dogbone" shaped specimen with loading applied at the ends via a platen. Tabs are optional.	Failure mode is often end-crushing. Stress concentrations at radii. Specimen 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 relationship to actual structural laminates.

TABLE 1 *Continued*

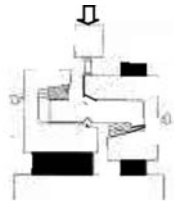
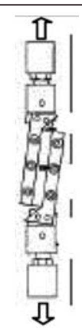
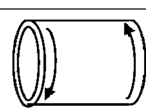
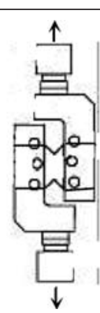
Test Method	Specimen	Measured Property	Description and Advantages	Disadvantages	Comments
D5379/D5379M		Shear Strength, Shear Modulus, Stress-Strain Response	V-notched specimen loaded in special bending fixture. Along with D7078/D7078M, provides the best shear response of the standardized methods. Provides 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.
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.

TABLE 1 *Continued*

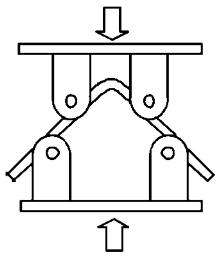
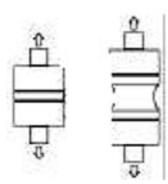
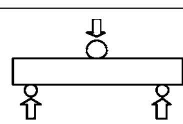
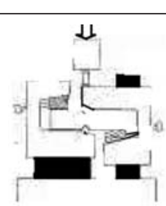
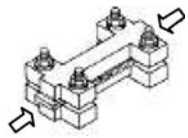
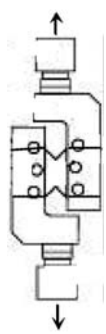
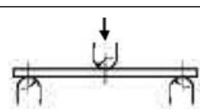
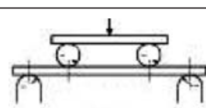
Test Method	Specimen	Measured Property	Description and Advantages	Disadvantages	Comments
		Out-of-Plane Tensile Test Methods			
D6415/D6415M		Curved Laminate Strength	Right-angle curved laminate specimen loaded in 4-point bending. Suitable for continuous fiber composites.	A complex stress state is generated 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			
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.

TABLE 1 *Continued*

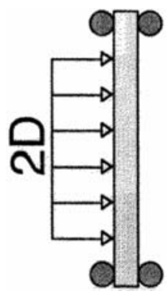
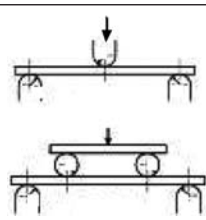
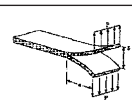
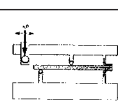
Test Method	Specimen	Measured Property	Description and Advantages	Disadvantages	Comments
D3846		Shear Strength	Specimen with two machined notches loaded in compression. Suitable for randomly dispersed and continuous fiber reinforced materials. May be preferable to D2344/D2344M for materials with randomly 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.
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.

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

TABLE 1 *Continued*

Test Method	Specimen	Measured Property	Description and Advantages	Disadvantages	Comments
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.
D6671/D6671M		Mixed Mode I/II Interlaminar Fracture Toughness, G_c	Flat rectangular specimen with delamination insert loaded in bending. Suitable for unidirectional tape or tow laminates. Tests at most mode mixtures. Constant mode mixtures with crack growth. Can obtain initiation and propagation toughness values.	Specimens must be hinged at the loading points. Crack growth not always well behaved. Complicated loading apparatus.	Good alignment is critical. Calculations assume linear elastic behavior.

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;

TABLE 1 *Continued*

Test Method	Specimen	Measured Property	Description and Advantages	Disadvantages	Comments
E1922		Translaminar Fracture Toughness, K_{TL}	Flat rectangular specimen containing an edge notch loaded in tension. Simple test to perform.	Results are only valid for the particular laminate tested. Laminates producing large damage zones do not give valid values.	

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 2 Lamina/Laminate Dynamic Test Methods

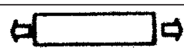
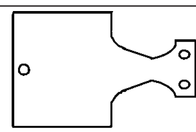
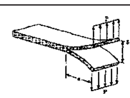
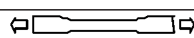
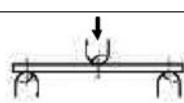
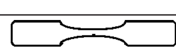
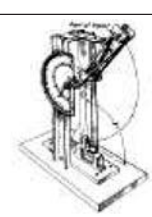
Test Method	Specimen	Measured Property	Description and Advantages	Disadvantages	Comments
In-Plane Tension/Tension Fatigue Test Methods					
D3479/D3479M		Tension-Tension Stress-Cycles (S-N) Data	Uses D3039/D3039M tensile test specimen, with axial tension-tension cyclic loading. Suitable for both random and continuous-fiber composites.	Stress concentrations at the end tabs. End tab machining and bonding required.	Careful specimen preparation is critical. Appropriate specimen geometry may vary from material to material. User should be prepared to do preliminary fatigue tests to optimize tab configurations and materials.
In-Plane Flexural Fatigue Test Methods					
D671		Flexural Stress-Cycles (S-N) Data	Constant-force cantilever specimen. Inexpensive high cycle fatigue (HCF) method.	Stress concentrations at notches. Results sensitive to specimen thickness. Not suitable for continuous-fiber composites.	This test method should not be used for continuous-fiber composites. Flexural tests are typically considered structural tests, not material property tests.
Fatigue Crack-Growth/Toughness Test Methods					
D6115		Mode I Fatigue Delamination Initiation; Toughness-Cycles (G-N) Data	Uses D5528 DCB specimen, with cyclic loading. Produces threshold fatigue data (G_{Imax} versus N).	Does not produce da/dN data. The limitations and comments for D5528 also apply.	
Tensile Creep Test Methods					
D2990		Tensile Strain versus Time	Uses D638 tensile specimen, with long-duration loading. Ease of test specimen preparation.	Stress concentrations at specimen radii.	Not suitable for continuous fiber composites; instead use D3039/D3039M type specimen.
Flexural Creep Test Methods					
D2990		Flexural Deflection versus Time	Uses D790 flexure specimen, with long-duration loading. Includes both 3 and 4-point bending test setups. Simple to set up and run.	Continuous-fiber flexural material response is complex, making results hard to interpret or generalize. Results sensitive to specimen and loading geometry. Failure mode may vary.	Not widely used in advanced composites industry.
Tensile Impact Test Methods					
D1822		Tensile Impact Energy of Rupture	Relatively inexpensive test machine.	Stress concentrations at the radii. Very small test specimens. Not instrumented.	Not suitable for continuous fiber composites.
Flexural Impact Test Methods					
D256		Impact Energy of Rupture	Notched specimen. Flexibility in testing methods.	Not instrumented. Varying failure modes. Sensitive to test specimen geometry variations.	This test provides a structural impact property, not a material impact property.

TABLE 3 Laminate/Structural Test Methods

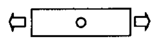
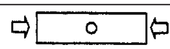
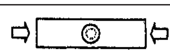
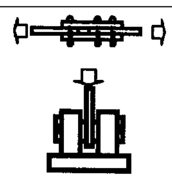
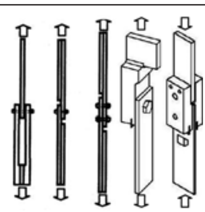
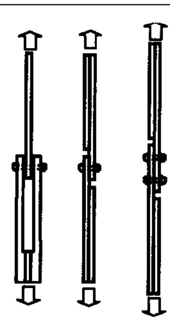
Test Method	Specimen	Measured Property	Description and Advantages	Disadvantages	Comments
		Notched Laminate Tension Test Methods			
D5766/D5766M		Open Hole Tensile Strength	Straight-sided, untabbed, open hole configuration. Procedure nearly equivalent to D3039/D3039M.	Limited to multi-directional laminates with balanced and symmetric stacking sequences.	Provides requirements and guidance on specimen configuration and failure modes.
D6742/D6742M		Filled Hole Tensile Strength	Straight-sided, untabbed, filled hole configuration. Procedure and specimen nearly equivalent to D3039/D3039M, D5766/D5766M.	Same as D5766/D5766M.	Same as D5766/D5766M. Also provides guidance on hole tolerances, fastener torque/preload.
		Notched Laminate Compression Test Methods			
D6484/D6484M		Open Hole Compressive Strength	Straight-sided, untabbed, open hole configuration. Fixture can be loaded using either hydraulic grips or end platens.	Limited to multi-directional laminates with balanced and symmetric stacking sequences.	Provides requirements and guidance on specimen configuration and failure modes.
D6742/D6742M		Filled Hole Compressive Strength	Straight-sided, untabbed, filled hole configuration. Procedure, specimen and apparatus nearly equivalent to D6484/D6484M.	Same as D6484/D6484M.	Same as D6484/D6484M. Also provides guidance on hole tolerances, fastener torque/preload.
		Bolted Joint Test Methods			
D953		Static Pin Bearing Strength	One fastener, double shear pin bearing specimen. Two methods available: tensile and compressive pin bearing. Monitors global load versus deformation behavior.	Focus is plastics. Does not account for various fastener geometries, torque/preload levels. Deformation local to hole is not measured.	Some specimen geometric properties (for example, width/diameter ratio) vary from D5961/D5961M guidelines. Not recommended for continuous fiber composites.
D5961/D5961M		Static Bearing Strength	One and two fastener double and single shear bearing specimens loaded in tension or compression. Multiple specimen configurations provided to assess a variety of structural joint configurations. Procedures provided to monitor inelastic deformation behavior at hole.	Limited to multi-directional laminates with balanced and symmetric stacking sequences. Response highly dependent upon specimen configuration and fastener torque/preload. Limited to bearing failure modes only. Some details of specimen configurations are not suitable for determining bypass failure strengths.	Provides requirements and guidance on specimen configuration, type of loading, hole tolerances, fastener torque/preload and failure modes.
D6873/D6873M		Bearing Stress-Cycles (S-N) Data	Specimen and apparatus equivalent to D5961/D5961M, with cyclic loading procedures provided to monitor hole elongation for a variety of joint configurations and fatigue loading conditions.	Same as D5961/D5961M. Certain tests may require fastener removal or a variant quasi-static loading ratio to monitor hole elongation.	Same as D5961/D5961M. Also provides guidance on fatigue loading ratio effects. Currently limited to D5961/D5961M Procedure A and B specimen configurations.

TABLE 3 *Continued*

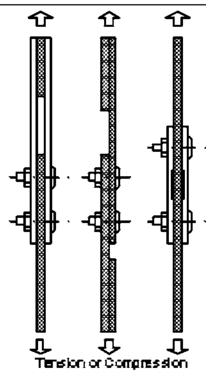
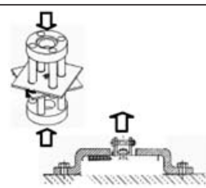
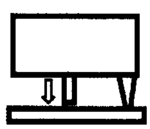
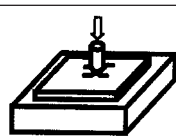
Test Method	Specimen	Measured Property	Description and Advantages	Disadvantages	Comments
D7248/D7248M		Bearing-Bypass Interaction	One and two fastener double and single shear specimens loaded in tension or compression. Multiple specimen configurations provided to assess a variety of joint configurations and fastener force proportions, optimized to promote bypass-dominated failure modes.	Limited to multidirectional laminates with balanced and symmetric stacking sequences. Response highly dependent upon specimen configuration and fastener torque/ preload. Limited to bypass failure modes only. Procedure C requires doubler plate calibration to extract fastener force proportion values.	Provides requirements and guidance on specimen configuration, type of loading, hole tolerances, fastener torque/preload, failure modes, and fastener force proportion measurement.
D7332/D7332M		Fastener Pull-Through Resistance	Two specimen configurations, Procedure A (compression-loaded fixture) for fastener screening, Procedure B (tension-loaded fixture) for composite joint configuration assessments.	Limited to multidirectional laminates with balanced and symmetric stacking sequences. Response highly dependent upon specimen configuration and fastener characteristics.	Provides requirements and guidance on specimen configuration, hole tolerances, fastener characteristics, failure modes, and force-displacement response characterization.
Static Indentation and Impact Damage Resistance Test Methods					
D2583		Indentation Hardness	Provides a relative measure of hardness based upon load versus indentation depth response. Barcol impressor is portable, and load is applied by hand.	Focus is plastics and low-modulus composites. Does not record force versus indentation depth response. Does not evaluate resulting damage state.	Uses flat-tipped indenter.
D6264/D6264M		Static Indentation Damage Resistance (Force-Indenter Displacement Response, Dent Depth, Damage Characteristics)	Flat rectangular laminated plate subject to a static point loading. Permits damage resistance testing of simply-supported and rigidly backed plate specimens. Uses a conventional testing machine. Contact force and indenter displacement data are obtained.	Limited to continuous fiber composites without through-the-thickness reinforcement. Test method does not address dynamic indentation effects. Narrow range of permissible specimen thicknesses.	Uses 12.7 mm (0.50 in.) diameter hemispherical indenter. Often used to approximate the damage state caused by a dynamic impact. Multi-directional fiber laminates with balanced and symmetric stacking sequences are usually used. The damage response is a function of the indentor geometry, support conditions and specimen configuration.

TABLE 3 *Continued*

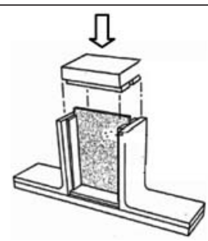
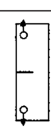
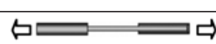
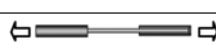
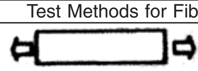
Test Method	Specimen	Measured Property	Description and Advantages	Disadvantages	Comments
D7136/D7136M		Drop-Weight Impact Damage Resistance (Indenter Contact Force and Velocity versus Time, Dent Depth, Damage Characteristics)	Flat rectangular laminated plate subject to a dynamic dropweight point loading. Permits damage resistance testing of simply-supported plate specimens. Uses a dedicated dropweight device, preferably with velocity detection equipment.	Limited to continuous fiber composites without through-the-thickness reinforcement. Results are very sensitive to impactor mass, diameter, drop height, and other parameters. Narrow range of permissible specimen thicknesses.	Uses 16 mm (0.625 in.) diameter hemispherical indenter. Multi-directional fiber laminates with balanced and symmetric stacking sequences are usually used. The damage response is a function of the impactor mass and geometry, drop height, support conditions and specimen configuration.
Static Indentation and Impact Damage Tolerance Test Methods					
D7137/D7137M		Compression Residual Strength and Deformation	Flat rectangular laminated plate, previously damaged through static indentation or dropweight impact, subjected to static compressive loading with a picture-frame test fixture.	Limited to continuous fiber composites without through-the-thickness reinforcement. Results are very sensitive to pre-existent damage state, edge-restraint conditions, and other parameters. Narrow range of permissible specimen thicknesses.	Multi-directional fiber laminates with balanced and symmetric stacking sequences are usually used. Initial damage diameter is limited to half the specimen width. Results are specific to the test configuration and damage state evaluated.
Trans-laminar Fracture Test Methods					
E1922		Translaminar Fracture Toughness, K_{TL}	Flat rectangular specimen containing an edge notch loaded in tension. Simple test to perform	Results only valid for the particular laminate tested; laminates producing large damage zones do not give valid values	
Reinforcement Bar Test Methods					
D7205/D7205M		Composite Bar Tensile Strength	Bar typically bonded with anchors to avoid grip end failures.	Nominal cross-sectional area is determined volumetrically, is an average value.	Specific to tensile elements used in reinforced, prestressed, or post-tensioned concrete.
D7337/D7337M		Composite Bar Tensile Creep Rupture	Same specimen as D7205/D7205M, subjected to a constant sustained tensile force.	Same as D7205/D7205M. Spare specimens must be tested to attain minimum specimen counts in case invalid failures occur.	A minimum of four force ratios are required to calculate the one-million hour creep rupture capacity.
Test Methods for Fiber Reinforced Polymer (FRP) Matrix Composites Used to Strengthen Civil Structures					
D7565/D7565M		Tensile Properties (Force/Width, Stiffness)	Provides procedures for preparing and testing FRP composites. References D3039/D3039M for specimen testing.	Calculations are based upon force per unit width due to high potential variation in FRP laminate thickness.	Covers testing of both wet-layup and preimpregnated FRP composites.

TABLE 3 *Continued*

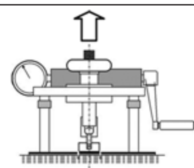
Test Method	Specimen	Measured Property	Description and Advantages	Disadvantages	Comments
D7522/D7522M		Pull-Off Bond Strength	Adhesion test device is attached to a circular sample of FRP bonded to a concrete substrate. Tensile force is applied normal to the plane of the FRP-concrete bond. Used in both laboratory and field applications to control quality of FRP and adhesives.	Results are sensitive to system alignment, load eccentricity, and specimen uniformity.	Multiple failure modes may be observed at multiple locations (FRP, adhesive or concrete substrate, or combinations thereof). FRP and concrete must be scored to define test section.

TABLE 4 Sandwich Construction Test Methods

Test Method	Specimen	Measured Property	Description and Advantages	Disadvantages	Comments
			In-Plane Compression Test Methods		
C364/C364M		Sandwich Compressive Strength	Untabbed, straight-sided sandwich specimen which is end-loaded. Uses simple lateral end supports for load introduction.	Test is sensitive to unintended loading eccentricities. Requires that specimens be bonded into lateral end supports. Testing of specimens with thin facings may require potting or tabs to resist end-crushing.	Multiple failure modes may be observed. Acceptable failure modes include facesheet buckling, facesheet compression, facesheet dimpling, core compression and core shear.
			Out-of-Plane Tensile Test Methods		
C297/C297M		Sandwich or Core Flatwise Tensile Strength	Square or cylindrical gage section sandwich or core specimen loaded in through-thickness tension. Uses adhesively bonded thick metal blocks for load introduction.	Results are sensitive to system alignment and load eccentricity. Results are sensitive to adhesive and surface preparation at loading block bondlines.	Valid tests require failures away from the loading block bondline. Used to assess and compare core and core-to-facing through-thickness tensile strengths.
			Out-of-Plane Compressive Test Methods		
C365/C365M		Core Flatwise Compressive Strength, Core Flatwise Compressive Modulus	Square or cylindrical gage section sandwich core specimen loaded in through-thickness compression. No test-specific fixtures are required.	Results are sensitive to system alignment, load eccentricity, and thickness variation which can cause local crushing. Core edges may need to be stabilized using resin or facings to avoid local crushing.	Strength results must be reported as stabilized or non-stabilized. Standard aerospace practice uses stabilized specimens for modulus determination.
D7336/D7336M		Core Compressive Crush Stress, Core Crush Stroke	Square or cylindrical gage section sandwich core specimen loaded in through-thickness compression beyond intitial core failure.	Limited to honeycomb cores. Results are sensitive to system alignment, load eccentricity, and core thickness variation.	Specimen is often precrushed to aid crush stroke determination and promote uniformity of crush properties.
			Out-of-Plane Shear Test Methods		
C273/C273M		Core Shear Strength, Core Shear Modulus	Rectangular gage section sandwich or core specimen bonded to steel loading plates. Tensile or compressive loading of assembly imparts a through-thickness shear force to the core.	Requires that specimens be bonded to load plates. Results are sensitive to adhesive and surface preparation at load plate bondlines. Results are sensitive to system alignment, load eccentricity, and core thickness variation.	Does not produce pure shear, but secondary stress effects are minimal.

TABLE 4 *Continued*

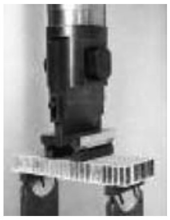
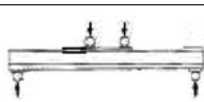
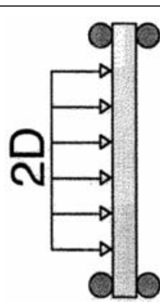
Test Method	Specimen	Measured Property	Description and Advantages	Disadvantages	Comments
C393/C393M		Core Shear Strength, Core Shear Modulus	Rectangular sandwich beam specimen. Ease of specimen construction and testing. Includes both 3-point and 4-point techniques. Core shear stiffness may be determined using Practice D7250/D7250M.	Method limited to 1D bending. Failures often dominated by stress concentrations and secondary stresses at loading points, especially for low-density cores and thin facings. Specified beam geometry required to ensure simple sandwich beam theory is valid. Specimen must be carefully designed to obtain the desired failure mode.	Specimen is designed to induce core shear failure, but failure may initiate in a non-core element (facings, adhesive) of the sandwich structure. Span-to-depth ratio >20:1 is recommended when testing for shear modulus. The ratio of face sheet thickness to core thickness (t/c) should be <0.10.
C394		Core Shear Stress Cycles (S-N) Data	Specimen and apparatus equivalent to C273/C273M, except that core is bonded directly to loading plates.	Same as C273/C273M. Limited to non-reversed fatigue loading conditions.	Same as C273/C273M.
			Flexural Test Methods		
D7249/D7249M		Sandwich Flexural Stiffness, Facesheet Compressive Strength, Facesheet Tensile Strength	Rectangular sandwich beam specimen. Ease of specimen construction and testing. Standard geometry uses 4-point loading technique. Flexural stiffness may be determined using Practice D7250/D7250M.	Method limited to 1D bending. Failures often dominated by stress concentrations and secondary stresses at loading points, especially with specimens having low-density cores and thin facings. Specified beam geometry required to ensure simple sandwich beam theory is valid. Specimen must be carefully designed to obtain the desired failure mode.	Specimen is designed to induce facing tensile or compressive failure, but failure may initiate in a non-facing element (core, adhesive) of the sandwich structure. The ratio of face sheet thickness to core thickness (t/c) should be <0.10.
D5467/D5467M		Facesheet 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.	Limited to high-modulus composites. An expensive specimen that is not recommended unless the structure warrants its use. Strain gages required to obtain modulus and strain-to-failure data.	Must take care to avoid core failure modes. 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.
D6416/D6416M		Pressure-Deflection Response, Pressure-Strain Response, Sandwich 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 (above) 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 sandwich specimen thickness should be between 10 to 30.

TABLE 4 *Continued*

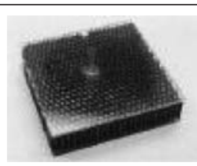
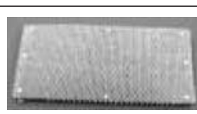
Test Method	Specimen	Measured Property	Description and Advantages	Disadvantages	Comments
C480/C480M		Flexural Deflection versus Time	Flat rectangular sandwich beam specimen loaded in 3-point bending.	Failures often dominated by stress concentrations and secondary stresses at loading points. Specimen must be carefully designed to obtain the desired failure mode.	Loading is imparted to the sandwich beam using a weight attached to a lever arm.
		Core Constituent Property Test Methods			
C271/C271M		Core Density	Flat rectangular sandwich core specimen.	Results are sensitive to length, width and thickness variation.	
C366/C366M		Core Thickness	Flat rectangular sandwich core specimen. Two methods provided (roller, disk).	Results are sensitive to applied pressure during measurement.	
C272		Core Water Absorption	Flat rectangular sandwich core specimen. Two methods provided (immersion, humidity conditioning).	Results are sensitive to water collected on surfaces.	For specimens that collect water on surfaces, specimens may be dipped in alcohol which is allowed to evaporate.
F1645/F1645M		Honeycomb Core Water Migration	Flat rectangular sandwich core specimen bonded to transparent facings. Water is introduced into one cell and permeates through the sample.	Results are sensitive to the permeability of the facings and adhesive. A constant head of water must be maintained to ensure consistent pressure.	Water migration may be monitored either by mass or volumetric measurement. Colored dye may be added to water to aid in visualizing migration.
C363/C363M		Honeycomb Core Node Tensile Strength	Flat rectangular sandwich core specimen. Specimen ends are pinned into loading fixture which is loaded in tension.	Strength is sensitive to specimen alignment and load eccentricity. Failure can be dominated by stress concentration at load introduction locations.	Property formerly entitled core delamination strength.
D6772		Honeycomb Core Dimensional Stability	Flat rectangular sandwich core specimen, measures in-plane core dimensional stability after thermal exposure.	Requires accurate geometric measurement of core deformation after thermal exposure.	Recommended to pot selected cells with resin or adhesive to aid deformation measurement.
D6790		Honeycomb Core Poisson's Ratio	Flat square sandwich core specimen. Specimen is bent around a cylinder. Dimensional measurements are used to determine Poisson's ratio.	Requires accurate geometric measurement of core deflection.	

TABLE 5 Constituent/Precursor/Thermophysical Test Methods

Test Method	Specimen	Measured Property	Description and Advantages	Disadvantages	Comments
Reinforcement Property Test Methods					
D3800		Fiber Density	Test method for density of high-modulus continuous and discontinuous fibers.		
D4018		Carbon Fiber Tow Properties: -Tensile Modulus -Tensile Strength -Density -Mass per Unit Length -Sizing Content -Moisture Absorption	Provides test methods for continuous filament carbon and graphite yarns, rovings and tows. Tensile properties are determined using resin-impregnated fiber.	Tensile testing requires careful specimen preparation. The resin used to impregnate the fibers can affect the tensile test results.	
D4102		Fiber Weight Loss	Test method for determining weight loss of carbon fibers exposed to hot ambient air. Exposure conditions are: -24 h at 375°C (707°F). -500 h at 315°C (600°F).		Determines oxidative resistance of carbon fibers for use in high-temperature applications.
Matrix (Resin) Physical Property Test Methods					
D792		Density	Test method for density of plastics using immersion methods. Ease of test specimen preparation and testing.	Some specimens may be affected by water; alternate immersion liquids are optional.	
D1505		Density	Test method for density of plastics using density gradient method.		Typically used for film and sheeting materials
D2471		Gel Time	Test method for determining gel time and peak exothermic temperature of reacting thermosetting resins		Used for testing neat resins. For composite prepregs, see D3532 below.
D4473		Cure Behavior	Test method for cure behavior of plastics by measuring dynamic mechanical properties.		
Extent of Cure Test Methods					
D3531		Resin Flow	Test method for resin flow of prepreg tape or sheet using square 2-ply specimen heated in a platen press.	Limited to carbon fiber-epoxy prepreg materials.	
D3532		Gel Time	Test method for gel time of prepreg tape or sheet	Limited to carbon fiber-epoxy prepreg materials.	
Constituent Content Test Methods					
C613/C613M		Constituent Content	Test method for Soxhlet extraction procedure to determine the matrix content, reinforcement content, and filler content of composite material prepreg.	Limited to prepreg materials.	Not suitable for cured composites.
D3171		Fiber, Resin, Void Content	Test method for fiber, resin, and void content of resin-matrix composites by either digestion of the matrix or by thickness of a material of known fiber areal weight (void content not determined). Includes methods for metal matrix composites as well.		The resin digestion methods are primarily intended for cured thermoset matrices but may also be suitable for some thermoplastics as well as prepreg resin content for materials that do not respond well to other methods.

TABLE 5 *Continued*

Test Method	Specimen	Measured Property	Description and Advantages	Disadvantages	Comments
		Constituent Content Test Methods (cont'd)			
D3529/D3529M		Resin Content	Test method for matrix solids content and matrix content using extraction by organic solvent.	Limited to prepreg materials. Resins that have started to cross-link (for example, B-staged resins) may be difficult to extract; D3171 methods are recommended for these materials. Does not determine or require reporting of reinforcement content.	Not suitable for cured composites.
D3530/D3530M		Volatiles Content	Test method for volatiles content of epoxy-matrix prepreg tape and sheet	Limited to prepreg materials. Limited to reinforcement material types which are substantially unaffected by the temperature selected for use in removing volatiles from the matrix material.	Not suitable for cured composites.
D2734		Void Content	Test methods for void content of reinforced plastics. Ease of test specimen preparation and testing.	Limited to composites for which the effects of ignition on the materials are known. May not be suitable for reinforcements consisting of metals, organic materials, or inorganic materials that may gain or lose weight. The presence of filler in some composites is not accounted for.	D3171 is preferred for advanced composites. Void content of less than 1 % is difficult to measure accurately.
D2584		Resin Content	Test method for ignition loss of cured reinforced resins. Ease of test specimen preparation and testing.	The presence of filler in some composites is not accounted for.	D3171 is preferred for advanced composites. Result may be used as resin content under specified limitations.
		Thermo-Physical Test Methods			
D696		Thermal Expansion versus Temperature Curves, Coefficients of Thermal Expansion	Test method for linear thermal expansion of plastic materials having coefficients of expansion greater than 1×10^{-6}/°C by use of a vitreous silica dilatometer. Ease of test specimen preparation and testing. Suitable for random and continuous fiber composites.	Limited to temperature range of -30°C to 30°C. Use E228 for other temperatures.	This test method cannot be used for very low thermal expansion coefficient materials, such as unidirectional graphite fiber composites.
E228		Thermal Expansion versus Temperature Curves, Coefficients of Thermal Expansion	Test method for linear thermal expansion over the temperature range of -180 to 900°C using vitreous silica push rod or tube dilatometers. Suitable for discontinuous or continuous fiber composites of defined orientation state.		Good for low values of thermal expansion. Precision greater than for D696. Precision significantly lower than for E289.

TABLE 5 *Continued*

Test Method	Specimen	Measured Property	Description and Advantages	Disadvantages	Comments
			Thermo-Physical Test Methods (cont'd)		
E289		Thermal Expansion versus Temperature Curves, Coefficients of Thermal Expansion	Test method for linear thermal expansion of rigid solids using either a Michelson or Fizeau interferometer. Suitable for composites with very low values of thermal expansion.		Precision is listed as better than +40 nm/m/K.
E1461		Thermal Diffusivity	Uses laser flash technique.		With specific heat measurement, can be used to calculate thermal conductivity indirectly.
E1269		Specific Heat	Uses Differential Scanning Calorimetry.		
			Transition Temperature Test Methods		
D648		Heat Deflection Temperature	Test method for determining temperature at which an arbitrary deformation occurs when specimen is subjected to an arbitrary set of testing conditions. Ease of test specimen preparation and testing.	Deflection temperature is dependent on specimen thickness and fiber reinforcement variables.	Test data used for material screening. Test data is not intended for design purposes.
D3418		Glass Transition Temperature (Tg)	Test method for determination of transition temperatures of polymers by differential thermal analysis or differential scanning calorimetry (DSC). Ease of test specimen preparation and testing.	Not suitable for composites with low resin content.	The correlation between thermally measured transition temperatures and mechanical property transitions has not been suitably established.
D4065		Transition Temperatures, Elastic Moduli, Loss Moduli	Practice for determining the transition temperatures, elastic, and loss moduli of plastics over a range of temperatures, frequencies, or time, by free vibration and resonant or nonresonant forced vibration techniques. Can use variety of test specimen geometries and loading methods.	Requires specialized equipment.	For best results, tests should be run on unreinforced resin.
D7028		Glass Transition Temperature (DMA Tg)	Test method for determining the glass transition temperature (Tg) of composites using Dynamic Mechanical Analysis (DMA) in flexural loading mode. Tests can be performed using both dry and wet specimens (moisture conditioned) to allow for comparison.	Requires specialized equipment. Results are sensitive to the oscillation frequency, heating rate and specimen/test geometries.	Intended for polymer matrix composites reinforced by continuous, oriented, high modulus fibers. One of the major fiber directions must be parallel to the length of the specimen.

TABLE 6 Environmental Conditioning/Resistance Test Methods

Test Method	Specimen	Measured Property	Description and Advantages	Disadvantages	Comments
Equilibrium Moisture Content/Conditioning Test Methods					
D5229/D5229M		Through-Thickness Moisture Diffusivity, Equilibrium Moisture Content, Equilibrium Conditioning	Rigorous determination of moisture equilibrium for various exposure levels (including dry) as well as moisture absorption constants. Used for conditioning test coupons prior to use in other test methods	Requires long-conditioning times for many materials. Assumes 1-D Fickian behavior for material absorption constant determination.	A faster two-specimen approach documented in MIL-HDBK-17 has not yet been included in this standard.
D570		Equilibrium Percentage Increase in Weight	Determination of equilibrium weight increase due to long-term immersion in water.	Weighing schedule is independent of material diffusion characteristics.	D5229/D5229M is preferred for general moisture conditioning of composites.
Non-Equilibrium Conditioning Test Methods					
D618		None.	Test method for conditioning plastics prior to test.	No standard mechanical tests are specified. Weight gain is not monitored.	Not recommended for conditioning composites.
D570		Percentage Increase in Weight	Determination of weight increase due to immersion in water for a defined period.	Multiple conditioning options are provided, with limited guidance provided on selection of parameters.	D5229/D5229M is preferred for general moisture conditioning of composites.
Environmental Aging Test Methods					
C481		Property Retention After Aging	Sandwich construction specimens subjected to environmental aging cycles.	Standard environmental cycles may not be representative of all sandwich construction applications.	Two standard aging cycles are defined.
Chemical Resistance Test Methods					
C581		Changes to: Hardness, Weight, Thickness, Specimen Appearance Appearance of Immersion Media, Flexural Strength, Flexural Modulus.	Test method for chemical resistance of thermosetting resins. Ease of test specimen preparation and testing. Flexible exposure conditions.	The only mechanical tests specified are flexural. Weight gain is not monitored. No standard exposure times or temperatures are specified.	Exposure chemicals, times, temperatures are left to the user's discretion.
D543		Changes to: Weight, Thickness, Specimen Appearance Tensile Strength, Tensile Modulus.	Practices for evaluating the resistance of plastics to chemical reagents. Standard exposure time and temperature set as a starting point.	The only mechanical loading type specified is tensile; others are optional	Longer exposure times may be desirable. Other mechanical loading types may be specified.