This international standard was developed in accordance with internationally recognized principles on standardization established in the Decision on Principles for the Development of International Standards, Guides and Recommendations issued by the World Trade Organization Technical Barriers to Trade (TBT) Committee.

Designation: D8066/D8066M − 23

Standard Practice
Unnotched Compression Testing of Polymer Matrix Composite Laminates[1]

This standard is issued under the fixed designation D8066/D8066M; 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 practice provides instructions for using the Test Method D6484/D6484M open hole compression test fixture to determine unnotched compressive strength of multi-directional laminates. The composite material forms are limited to continuous-fiber reinforced polymer matrix composites in which the laminate is both symmetric and balanced with respect to the test direction. The range of acceptable test laminates and thicknesses are described in 8.2.1.

1.2 *Units*—The values stated in either SI units or inch-pound units are to be regarded separately as standard. The values stated in each system are not necessarily exact equivalents; therefore, to ensure conformance with the standard, each system shall be used independently of the other, and values from the two systems shall not be combined.

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

1.3 *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, health and environmental practices and determine the applicability of regulatory limitations prior to use.*

1.4 *This international standard was developed in accordance with internationally recognized principles on standardization established in the Decision on Principles for the Development of International Standards, Guides and Recommendations issued by the World Trade Organization Technical Barriers to Trade (TBT) Committee.*

2. Referenced Documents

2.1 *ASTM Standards:*

D695 Test Method for Compressive Properties of Rigid Plastics
D792 Test Methods for Density and Specific Gravity (Relative Density) of Plastics by Displacement
D883 Terminology Relating to Plastics
D3410/D3410M Test Method for Compressive Properties of Polymer Matrix Composite Materials with Unsupported Gage Section by Shear Loading
D3171 Test Methods for Constituent Content of Composite Materials
D3878 Terminology for Composite Materials
D5229/D5229M Test Method for Moisture Absorption Properties and Equilibrium Conditioning of Polymer Matrix Composite Materials
D5467/D5467M Test Method for Compressive Properties of Unidirectional Polymer Matrix Composite Materials Using a Sandwich Beam
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
D7249/D7249M Test Method for Facesheet Properties of Sandwich Constructions by Long Beam Flexure
E6 Terminology Relating to Methods of Mechanical Testing
E132 Test Method for Poisson's Ratio at Room Temperature
E177 Practice for Use of the Terms Precision and Bias in ASTM Test Methods
E456 Terminology Relating to Quality and Statistics

3. Terminology

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

3.2 *Definitions of Terms Specific to This Standard—*

NOTE 1—If the term represents a physical quantity, its analytical dimensions are stated immediately following the term (or letter symbol) in fundamental dimension form, using the following ASTM International standard symbology for fundamental dimensions, shown within square

[1] This test method is under the jurisdiction of ASTM Committee D30 on Composite Materials and is the direct responsibility of Subcommittee D30.05 on Structural Test Methods.

Current edition approved May 1, 2023. Published June 2023. Originally approved in 2017. Last previous edition approved in 2017 as D8066/D8066M – 17. DOI: 10.1520/D8066_D8066M-23.

brackets: [M] for mass, [L] for length, [T] for time, [θ] for thermodynamic temperature, and [nd] for non-dimensional quantities. Use of these symbols is restricted to analytical dimensions when used with square brackets, as the symbols may have other definitions when used without the brackets.

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

3.3 *Symbols:*

A—cross-sectional area of a specimen

B_y—face-to-face percent bending in specimen

CV—sample coefficient of variation, in percent

E^c—laminate compressive modulus

F^{unc}_x—ultimate unnotched compressive strength in the test direction

h—specimen thickness

P^{max}—maximum force carried by test specimen prior to failure

P_1—load at ε_{x1}

P_2—load at ε_{x2}

w—specimen width

ε_{x1}—actual measured axial strain value nearest lower end of strain range used

ε_{x2}—actual measured axial strain value nearest upper end of strain range used

ε_{y1}—actual measured transverse strain value nearest lower end of strain range used

ε_{y2}—actual measured transverse strain value nearest upper end of strain range used

ε_{xg1}—indicated axial strain from Gage 1 (used in % bending equation)

ε_{xg2}—indicated axial strain from Gage 2 (used in % bending equation)

$v_{xy}{}^c$—Compressive Poisson's ratio

4. Summary of Practice

4.1 In accordance with Test Method D6484/D6484M, perform a uniaxial compression test of a balanced, symmetric laminate without a hole.

5. Significance and Use

5.1 This practice provides supplemental instructions for the use of Test Method D6484/D6484M to determine unnotched compressive strength data for material specifications, research and development, material design allowables, and quality assurance. Factors that influence compressive strengths and shall therefore be reported include the following: material, methods of material fabrication, accuracy of lay-up, laminate stacking sequence and overall thickness, specimen preparation, specimen conditioning, environment of testing, specimen alignment and gripping, speed of testing, time at temperature, void content, and volume percent reinforcement. Composite properties in the test direction that may be obtained from this test method include:

5.1.1 Unnotched compressive (UNC) strength, F_x^{unc},

5.1.2 Ultimate compressive strain,

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

5.1.4 Poisson's ratio in compression.

5.2 This practice provides a compression test method for laminates containing fibers in multiple fiber directions, particularly those combining axial (0 degree) fibers and off-axis (± θ degree) fibers. Other compression strength test methods include SACMA SRM-1 (also known as the modified D695), D3410/D3410M, D5467/D5467M, D6641/D6641M, and D7249/D7249M. The SRM-1 test uses 12.6 mm [0.50 in.] wide specimens, which is only appropriate for unidirectional tape, cross-ply [0/90]ns tape, or small unit-cell-size fabrics (e.g. 3K-70-P). Larger cell-size fabrics (for example, spread-tow 12K fabrics) should be tested with wider specimens. The standard D3410/D3410M and D6641/D6641M test fixtures do permit the use of wider specimens, for example, 25.4 mm [1.0 in.] wide, and thus can be used to test laminates containing both axial and off-axis fibers; however their gage lengths are relatively short. Test Method D5467/D5467M is intended to obtain the compressive strength of unidirectional laminates, but is expensive due to the sandwich beam configuration. Test Method D7249/D7249M is intended to obtain the compressive strength of sandwich facesheets.

5.2.1 Advantages of this practice include:

5.2.1.1 Avoiding the use of tabs, which are typically required with the end-loaded SRM-1 specimen, which are often required with the shear loaded Test Method D3410/D3410M specimen, and sometimes required with the Test Method D6641/D6641M test specimen, in order to obtain valid failure modes, and

5.2.1.2 Longer and wider gage section imposing less constraint on in-plane transverse displacement.

5.2.2 Disadvantages of this practice include:

5.2.2.1 Longer and wider specimen, thus consuming more material than other standards noted above

6. Interferences

6.1 *Environment*—Results are affected by the environmental conditions under which the tests are conducted. Laminates tested in various environments can exhibit significant differences in both failure force and failure mode. Experience has demonstrated that elevated temperature, humid environments are generally critical for compressive strength. However, critical environments must be assessed independently for each material system and stacking sequence tested.

6.2 *Material Orthotropy*—The degree of laminate orthotropy strongly affects the failure mode and measured strengths. Valid strength results should only be reported when appropriate failure modes are observed, according to Section 12.

6.3 *Thickness Scaling*—Thick composite structures do not necessarily fail at the same strengths as thin structures with the same laminate orientation (that is, strength does not always scale linearly with thickness). Thus, data gathered using the test method described in this practice may not translate directly into equivalent thick-structure properties.

6.4 *Support Fixture*—Results are affected by the amount of lateral pressure applied to the test specimen by the support fixture. Sources of variation in this lateral pressure include fixture grip surface, fixture bolt torque, hydraulic gripping pressure, and fixture shimming choices, and should be controlled and reported as required in Section 11, Procedure, and Section 14, Report. Testing unnotched specimens in the Test Method D6484/D6484M support fixture is very sensitive to fixture gaps, tolerances, and alignment; the fixture can become bent due to high unnotched compressive failure forces, therefore the fixture dimensions should be periodically checked. The support fixture can inhibit the growth of delamination damage by inhibiting out-of-plane deformation, and by relieving force from the specimen via friction effects.

NOTE 2—It has been found for at least one carbon tape material that the thermal-spray gripping surface on the Test Method D6484/D6484M test fixture (see Flagnote 2 in Test Method D6484/D6484M Figures 5 to 8) can lead to premature failures at the ends of the gripped areas, and that smooth grip surfaces (no thermal spray) yield superior strength results (**1**).[2]

6.5 *Type of Loading*—Differences in force versus crosshead displacement and force versus extensometer strain response may be observed when comparing hydraulic grip-loaded specimens with end-loaded specimens. Hydraulic grip-loaded data typically exhibit linear behavior at the onset of loading. At high force levels, some nonlinear behavior may be observed due to grip slippage. End-loaded data typically display some initial nonlinear behavior at low force levels, due to seating of the specimen/fixture assembly underneath the load platens, but then exhibit linear behavior to failure. The use of specimen end loading is not allowed by this standard for unnotched specimen testing, as it often leads to end brooming/crushing failures in unnotched compression specimens.

7. Apparatus

7.1 *General Apparatus*—General apparatus shall be in accordance with Test Method D6484/D6484M.

7.2 *Strain-Indicating Device*—When required by the test requestor, longitudinal strain shall be either *a)* simultaneously measured using strain gages on opposite faces in the center of the specimen (so as to be within the support fixture opening) to allow for a correction as a result of any bending of the specimen, *b)* measured by use of edge mounted extensometers, or *c)* suitable non-contact strain measurement devices. When Poisson's ratio is to be determined, the specimen shall be strain gaged instrumented to measure strain in the lateral direction using the same type of transducer. The same type of strain transducer shall be used for all strain measurements on any single coupon. Attachment of the strain-indicating device to the coupon shall not cause damage to the specimen surface. Refer to Test Method D3410/D3410M for additional requirements for strain measurement on compression specimens.

7.3 *Data Acquisition Equipment*—Equipment capable of recording force and strain data is required.

8. Sampling and Test Specimens

8.1 *Sampling*—shall be in accordance with Test Method D6484/D6484M.

8.2 *Geometry:*

8.2.1 *Stacking Sequence*—The standard laminates shall have multidirectional fiber orientations (fibers shall be oriented in a minimum of two directions) and balanced and symmetric stacking sequences. Nominal thickness shall be 4 mm [0.160 in.], with a permissible range of 3 mm to 5 mm [0.125 in. to 0.200 in.], inclusive. Fabric laminates containing satin-type weaves shall have symmetric warp surfaces, unless otherwise specified and noted in the report.

NOTE 3—Typically, a $[45_i/–45_i/0_j/90_k]ns$ tape or $[45_i/0_j]ns$ fabric laminate should be selected such that a minimum of 5 % of the fibers lay in each of the four principal orientations. This laminate design has been found to yield the highest likelihood of acceptable failure modes. Note that testing $[0_i/90_j]ns$ tape or fabric laminates can result in acceptable failure modes (see also Section 5). Consult Practice D6507 for information on fiber orientation codes.

8.2.2 *Specimen Configuration*—The test specimen configuration shall be in accordance with Test Method D6484/D6484M. No hole, notch or damage shall be introduced into the specimen.

8.3 *Specimen Preparation*—Specimens shall be prepared in general accordance with Test Method D6484/D6484M, with the omission of the hole.

9. Calibration

9.1 The accuracy of all measuring equipment shall have certified calibrations that are current at the time of use of the equipment.

10. Conditioning

10.1 The recommended pre-test condition is effective moisture equilibrium at a specific relative humidity as established by Test Method D5229/D5229M; however, if the test requestor does not explicitly specify a pre-test conditioning environment, no conditioning is required and the test specimens may be tested as prepared.

10.2 The pre-test specimen conditioning process, to include specified environmental exposure levels and resulting moisture content, shall be reported with the test data.

NOTE 4—The term moisture, as used in Test Method D5229/D5229M, includes not only the vapor of a liquid and its condensate, but the liquid itself in large quantities, as for immersion.

10.3 If no explicit conditioning process is performed the specimen conditioning process shall be reported as "unconditioned" and the moisture content as "unknown."

11. Procedure

11.1 *Parameters to Be Specified Before Test:*

11.1.1 The specimen sampling method, specimen type and geometry, and conditioning travelers (if required).

11.1.2 All other parameters documented in Test Method D6484/D6484M.

11.2 *General Instruction:*

11.2.1 Any deviations from these procedures, whether intentional or inadvertent, shall be reported.

11.2.2 If specific gravity, density, reinforcement volume, or void volume are to be reported, then obtain these samples from the same panels being tested. Specific gravity and density may

[2] The boldface numbers in parentheses refer to a list of references at the end of this standard.

be evaluated by means of Test Method D792. Volume percent of the constituents may be evaluated by one of the matrix digestion procedures of Test Method D3171, or, for certain reinforcement materials such as glass and ceramics, by the matrix burn-off technique of Test Method D3171.

11.2.3 Condition the specimens as required. Specimens shall be stored in the conditioned environment until test time, if the test environment is different than the conditioning environment.

11.2.4 Following final specimen machining but before conditioning and testing, measure the specimen width, *w*, and the specimen thickness, *h*, recording the average of three measurements. The width and thickness measurements shall be made in the gage section of the specimen, taking care not to measure directly over a strain gage or gage adhesive. The precision of all measurements shall be within 1 % of the dimension, unless otherwise specified in this practice. Dimensions shall be recorded to three significant figures in units of millimeters [inches].

NOTE 5—The test requester may request that additional measurements be performed after the machined specimens have gone through any conditioning or environmental exposure.

11.3 *Test Procedure*—The compression test of the laminate specimen shall be performed in accordance with Test Method D6484/D6484M. Specimen grip loading shall be used. End loading is not allowed as it often leads to end brooming/crushing failures.

NOTE 6—When testing a conditioned specimen at elevated temperature with no fluid exposure control, the percentage moisture loss of the specimen prior to test completion may be estimated by placing a conditioned traveler coupon of known weight within the test chamber at the same time the specimen is placed in the chamber. Upon completion of the test, the traveler coupon is removed from the chamber, weighed, and the percentage weight loss calculated and reported.

11.4 *Data Recording*—Record force versus crosshead displacement (and force versus strain, if extensometers or gages are used) continuously, or at frequent regular intervals; for this test method, a sampling rate of 2 to 3 data recordings per second, and a target minimum of 100 data points per test are recommended. If any initial failures are noted, record the force, displacement, and mode of damage at such points. Record the method used to determine the initial failure (visual, acoustic emission, etc.). Record the maximum force and the crosshead displacement at, or as near as possible to, the moment of rupture.

12. Validation

12.1 Values for ultimate properties shall not be calculated for any specimen that breaks at some obvious flaw, unless such flaw constitutes a variable being studied. Retests may be performed for any specimen on which values are not calculated.

12.2 Inspect the tested specimen and note the type and location of the failure. For valid tests, final failure of the specimen occurs within the gage section (the gage section being the center 100 mm (4.0 in.) section of the test specimen which is not contacted by the D6484/D6484M fixture grip plate surfaces). The failure mode may be brooming in the gage section, transverse or through-thickness shear, longitudinal splitting, delamination, or combinations thereof, among possibly other forms. Which failure modes are deemed acceptable will be governed by the particular material, laminate configuration, and application. In general, failures that initiate within the gripped length do not arrest and hence invalidate the test.

12.3 A significant fraction of failures in a sample population occurring away from the gage area shall be cause to reexamine the means of force introduction into the material. Factors considered should include the fixture gripping surface texture, fixture alignment, grip pressure, grip alignment, separation of fixture halves, specimen thickness taper, and uneven machining of specimen ends.

NOTE 7—Other valuable data that can be useful in understanding testing anomalies and gripping or specimens slipping problems include force versus time data.

12.4 The occurrence of specimen buckling invalidates the test. Buckling failures cannot be detected by visual inspection of the specimen during or after the test. Only the use of back-to-back strain gages or similar instrumentation provides a reasonable indication.

12.5 Even if the specimen does not buckle, the induced bending may be excessive. This can be due to imperfections in the test specimen, the test fixture, or the testing procedure. When face mounted strain gage measurements are made, Eq 1 shall be used to calculate percent bending. Additional details are given in Test Method D3410/D3410M.

$$B_y = \text{percent bending} = \frac{(\varepsilon_{xg1} - \varepsilon_{xg2})}{(\varepsilon_{xg1} + \varepsilon_{xg2})} \times 100 \quad (1)$$

where:

ε_{xg1} = indicated axial strain from Gage 1 and

ε_{xg2} = indicated axial strain from Gage 2.

The sign of the calculated Percent Bending indicates the direction in which the bending is occurring. This information is useful in determining if the bending is being induced by a systematic error in the test specimen, testing apparatus, or test procedure, rather than by random effects from test to test.

12.6 When face mounted strain gage measurement is required by the test requestor, for the test results to be considered valid, percent bending in the specimen shall be less than 10 % as determined by Eq 1. Determine percent bending at the midpoint of the strain range used for chord modulus calculations (see 13.2). The same requirement shall be met up to (but not necessarily at) the failure strain for the strength and strain-to-failure data to be considered valid. If possible, a plot of percent bending versus average strain should be recorded to aid in the determination of failure mode.

12.6.1 Although amounts of bending greater than 10 % may not decrease the measured compressive strength, the presence of large amounts of bending does suggest some irregularity in specimen preparation, testing procedure or test fixture. Thus, achievement of less than 10 % bending at failure is required for the test to be considered valid (see also Test Method D3410/D3410M). The use of back-to-back strain gages on the first few specimens of a group provides a good indication of the general