



Designation: **D6641/D6641M – 16**<sup>ε2</sup> **D6641/D6641M – 23**

## Standard Test Method for Compressive Properties of Polymer Matrix Composite Materials Using a Combined Loading Compression (CLC) Test Fixture<sup>1</sup>

This standard is issued under the fixed designation D6641/D6641M; 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 ( $\epsilon$ ) indicates an editorial change since the last revision or reapproval.

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<sup>ε1</sup> NOTE—A label in Figure 3 was corrected editorially in March 2017.

<sup>ε2</sup> NOTE—Editorial corrections were made to the adjunct information in March 2021.

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### 1. Scope

1.1 This test method determines the compressive strength and stiffness properties of polymer matrix composite materials using a combined loading compression (CLC) (**1**)<sup>2</sup> test fixture. This test method is applicable to general composites that are balanced and symmetric. The specimen may be untabbed (Procedure A) or tabbed (Procedure B), as required. One requirement for a successful test is that the specimen ends do not crush during the test. Untabbed specimens are usually suitable for use with materials of low orthotropy, for example, fabrics, chopped fiber composites, and laminates with a maximum of 50 % 0° plies, or equivalent (see 6.4). Materials of higher orthotropy, including unidirectional composites, typically require tabs.

1.2 The compressive force is introduced into the specimen by combined end- and shear-loading. In comparison, Test Method **D3410/D3410M** is a pure shear-loading compression test method and Test Method **D695** is a pure end-loading test method.

1.3 Unidirectional (0° ply orientation) composites as well as multi-directional composite laminates, fabric composites, chopped fiber composites, and similar materials can be tested.

1.4 The values stated in either SI units or inch-pound units are to be regarded separately as standard. Within the test the inch-pound units are shown in brackets. The values stated in each system are not exact equivalents; therefore, each system must be used independently of the other. Combining values from the two systems may result in nonconformance with the standard.

NOTE 1—Additional procedures for determining the compressive properties of polymer matrix composites may be found in Test Methods **D3410/D3410M**, **D5467/D5467M**, and **D695**.

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

1.6 *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.*

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<sup>1</sup> This test method is under the jurisdiction of ASTM Committee **D30** on Composite Materials and is the direct responsibility of Subcommittee **D30.04** on Lamina and Laminate Test Methods.

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<sup>2</sup> Boldface numbers in parentheses refer to the list of references at the end of this test method.

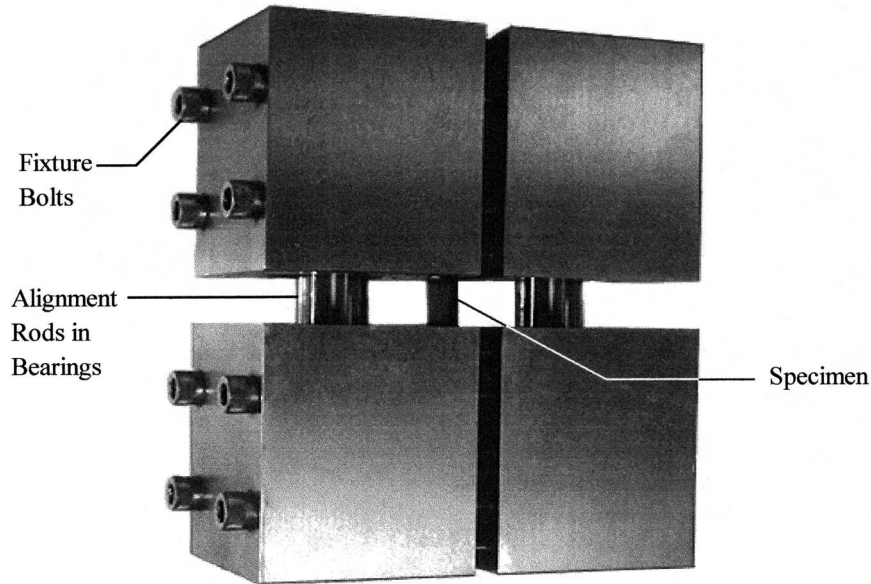


FIG. 1 Photograph of a Typical Combined Loading Compression (CLC) Test Fixture

## 2. Referenced Documents

### 2.1 ASTM Standards:<sup>3</sup>

D695 Test Method for Compressive Properties of Rigid Plastics

D883 Terminology Relating to Plastics

D3410/D3410M Test Method for Compressive Properties of Polymer Matrix Composite Materials with Unsupported Gage Section by Shear Loading

D3878 Terminology for Composite Materials

D5229/D5229M Test Method for Moisture Absorption Properties and Equilibrium Conditioning of Polymer Matrix Composite Materials

D5379/D5379M Test Method for Shear Properties of Composite Materials by the V-Notched Beam Method

D5467/D5467M Test Method for Compressive Properties of Unidirectional Polymer Matrix Composite Materials Using a Sandwich Beam

D5687/D5687M Guide for Preparation of Flat Composite Panels with Processing Guidelines for Specimen Preparation

E4 Practices for Force Calibration and Verification of Testing Machines

E6 Terminology Relating to Methods of Mechanical Testing

E122 Practice for Calculating Sample Size to Estimate, With Specified Precision, the Average for a Characteristic of a Lot or Process

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

E691 Practice for Conducting an Interlaboratory Study to Determine the Precision of a Test Method

~~E1309 Guide for Identification of Fiber-Reinforced Polymer Matrix Composite Materials in Databases (Withdrawn 2015)<sup>4</sup>~~

~~E1434 Guide for Recording Mechanical Test Data of Fiber-Reinforced Composite Materials in Databases (Withdrawn 2015)<sup>4</sup>~~

~~E1471 Guide for Identification of Fibers, Fillers, and Core Materials in Computerized Material Property Databases (Withdrawn 2015)<sup>4</sup>~~

### 2.2 ASTM Adjunct:

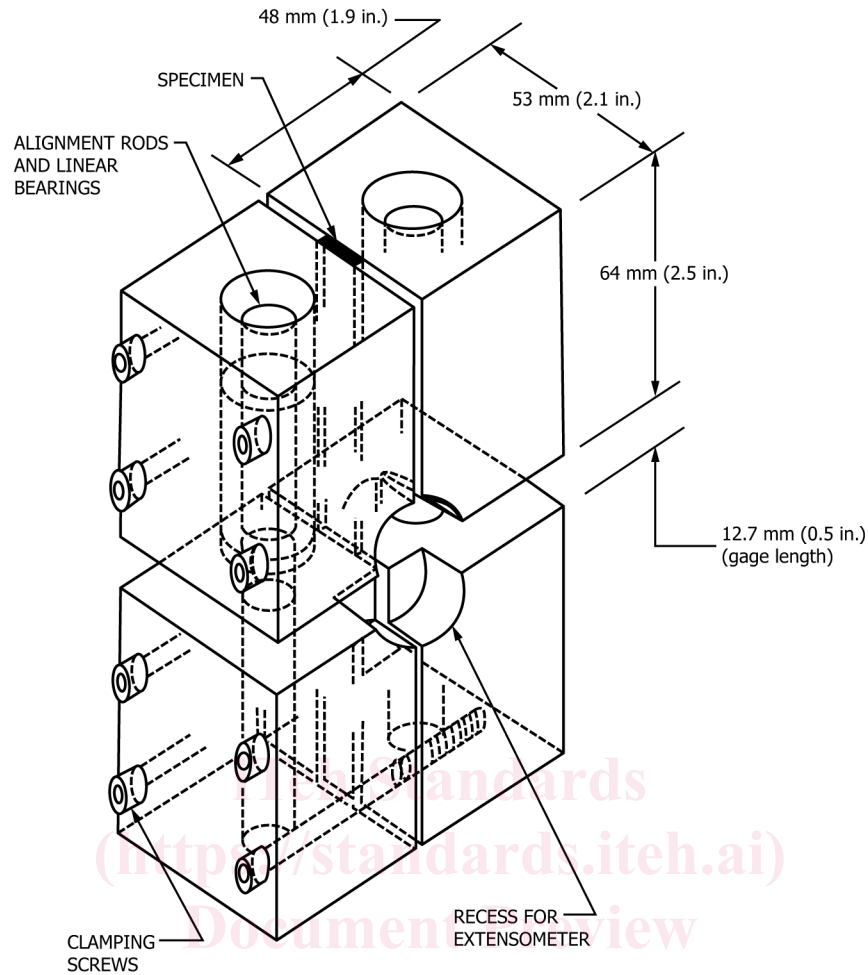
Combined Loading Compression (CLC) Test Fixture, D 6641/D6641M<sup>4</sup>

## 3. Terminology

3.1 *Definitions*—Terminology D3878 defines terms relating to high-modulus fibers and their composites. Terminology D883

<sup>3</sup> For referenced ASTM standards, visit the ASTM website, [www.astm.org](http://www.astm.org), or contact ASTM Customer Service at [service@astm.org](mailto:service@astm.org). For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

<sup>4</sup> A detailed drawing for the fabrication of the test fixture shown in Figs. 1 and 2 is available from ASTM Headquarters, [www.astm.org](http://www.astm.org). Order Adjunct No. ADJD6641-E-PDF.



Note: Using standard M6x1 (1/4-28 UNF) screws, the bolt torque required to test most composite material specimens successfully is typically between 2.5 and 3.0 N-m [20 and 25 in.-lb.].

FIG. 2 Dimensioned Sketch of a Typical Combined Loading Compression (CLC) Test Fixture

defines terms relating to plastics. Terminology E6 defines terms relating to mechanical testing. Terminology E456 and Practice E177 define terms relating to statistics. In the event of a conflict between terms, Terminology D3878 shall have precedence over the other Terminology standards.

3.2 Symbols:  $A$ —cross-sectional area of specimen in gage section

$B_y$ —face-to-face percent bending in specimen

$CV$ —sample coefficient of variation, in percent

$E^c$ —laminare compressive modulus

$F^{cu}$ —laminare ultimate compressive strength

$F^{cr}$ —Euler buckling stress

$G_{xz}$ —through-thickness shear modulus of laminare

$h$ —specimen thickness

$I$ —moment of inertia of specimen cross section

$l_g$ —specimen gage length

$n$ —number of specimens

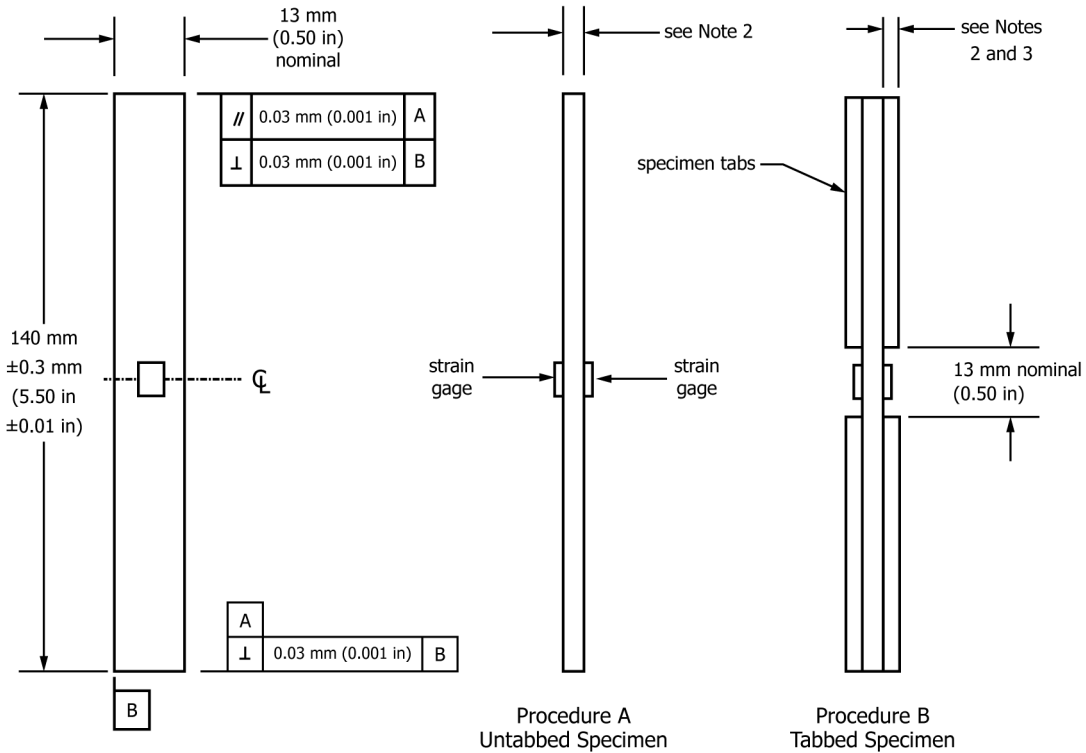
$P$ —load carried by test specimen

$P^f$ —load carried by test specimen at failure

$s$ —as used in a lay-up code, denotes that the preceding ply description for the laminare is repeated symmetrically about its midplane

$s_{n-1}$ —sample standard deviation

$w$ —specimen gage width



(1) The specimen ends must be parallel to each other within 0.03 mm [0.001 in.] and also perpendicular to the longitudinal axis of the specimen within 0.03 [0.001 in.], for both Procedures A and B.

(2) Nominal specimen and tabbing thickness can be varied, but must be uniform. Thickness irregularities (for example, thickness taper or surface imperfections) shall not exceed 0.03 mm [0.001 in.] across the specimen or tab width or 0.06 mm [0.002 in.] along the specimen grip length or tab length.

(3) Tabs are typically square-ended and on the order of 1.6 mm [0.06 in.] thick, but thickness can be varied as required, as discussed in 8.2.

(4) The faces of the specimen may be lapped slightly to remove any local surface imperfections and irregularities, thus providing flatter surfaces for more uniform gripping by the fixture.

FIG. 3 Typical Test Specimen Configuration

$\bar{x}$ —sample mean (average)

$x_i$ —measured or derived property

$\varepsilon$ —indicated normal strain from strain transducer

$\varepsilon_x$ —laminar axial strain

$\varepsilon_y$ —laminar in-plane transverse strain

$\varepsilon_1, \varepsilon_2$ —strain gage readings

$\nu_{xy}^c$ —compressive Poisson's ratio

#### 4. Summary of Test Method

4.1 A test fixture such as that shown in Figs. 1 and 2, or any comparable fixture, can be used to test the untapped (Procedure A) or tabbed (Procedure B) straight-sided composite specimen of rectangular cross section shown schematically in Fig. 3. A typical specimen is 140 mm [5.5 in.] long and 13 mm [0.5 in.] wide, having an unsupported (gage) length of 13 mm [0.5 in.] when installed in the fixture. A gage length greater or less than 13 mm is acceptable, subject to specimen buckling considerations (see 8.2). The 13-mm [0.5 in.] gage length provides sufficient space to install bonded strain gages when they are required. The fixture, which subjects the specimen to combined end- and shear-loading, is itself loaded in compression between flat platens in a universal testing machine. Load-strain data are collected until failure occurs (or until a specified strain level is achieved if only compressive modulus or Poisson's ratio, or both, are to be determined, and not the complete stress-strain curve to failure).

#### 5. Significance and Use

5.1 This test method is designed to produce compressive property data for material specifications, research and development,



quality assurance, and structural design and analysis. When tabbed (Procedure B) specimens, typically unidirectional composites, are tested, the CLC test method (combined shear end loading) has similarities to Test Methods **D3410/D3410M** (shear loading) and **D695** (end loading). When testing lower strength materials such that untabbed CLC specimens can be used (Procedure A), the benefits of combined loading become particularly prominent. It may not be possible to successfully test untabbed specimens of these same materials using either of the other two methods. When specific laminates are tested (primarily of the  $[90/0]_{ns}$  family, although other laminates containing at least one  $0^\circ$  ply can be used), the CLC data are frequently used to “back out”  $0^\circ$  ply strength, using lamination theory to calculate a  $0^\circ$  unidirectional lamina strength (**1, 2**). Factors that influence the compressive response include: type of material, methods of material preparation and lay-up, specimen stacking sequence, specimen preparation, specimen conditioning, environment of testing, 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 Ultimate compressive strength,

5.1.2 Ultimate compressive strain,

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

5.1.4 Poisson’s ratio in compression.

## 6. Interferences

6.1 Because of partial end loading of the specimen in this test method, it is important that the ends of the specimen be machined flat, parallel to each other, and perpendicular to the long axis of the coupon (see **Fig. 3**), just as for Test Method **D695**. Improper preparation may result in premature end crushing of the specimen during loading, excessive induced bending, or buckling, potentially invalidating the test.

6.2 Erroneously low laminate compressive strengths will be produced as a result of Euler column buckling if the specimen is too thin in relation to the gage length (see **8.2**). In such cases, the specimen thickness must be increased or the gage length reduced. A practical limit on reducing gage length is maintaining adequate space in which to attach strain gages, if required. A gage length of at least about 9 mm [0.35 in.] is typically required for this purpose. Bending or buckling, or both, can usually only be detected by the use of back-to-back strain gages mounted on the faces of the specimen (**3**). Bending and buckling are not visually obvious during the test, or from an examination of the specimen failure mode.

6.3 For a valid test, final failure of the specimen must occur within the gage section. Which failure modes are deemed acceptable will be governed by the particular material, configuration, and application (see **12.1.2.2**).

6.4 Untabbed (Procedure A) specimens of continuous-fiber-reinforced laminates having more than 50 % axially oriented ( $0^\circ$ ) plies may require higher than acceptable fixture clamping forces to prevent end crushing. Excessive clamping forces induce at the ends of the gage section local stress concentrations that may produce erroneously low strength results (see **11.2.7**). In such cases, the specimen must be tabbed (Procedure B).

6.5 If the outermost plies of a laminate are oriented at  $0^\circ$ , the local stress concentrations at the ends of the specimen gage section may lead to premature failure of these primary load-bearing plies, producing erroneously low laminate strength results. This is particularly true for specimens with low numbers of plies, since then the outer plies represent a significant fraction of the total number of plies (**1**).

6.6 The compressive strength and stiffness properties of unidirectional composites as well as all laminate configurations may be determined using this test method, subject to some limitations (**1**). One limitation is that the fixture clamping forces induced by the applied bolt torques required to successfully fail the composite before specimen end crushing must not induce significant stress concentrations at the ends of the gage section (**4**). Such stress concentrations will degrade the measured compressive strength. For example, testing an untabbed high-strength unidirectional composite is likely to be unsuccessful because of the excessive clamping forces required to prevent specimen end crushing, whereas a lower strength unidirectional composite may be successfully tested using acceptable clamping forces. The use of a tabbed specimen to increase the bearing area at the specimen ends is then necessary (**1, 5**). An untabbed thickness-tapered specimen, although nonstandard, has also been used to successfully test high-strength unidirectional composites (**5**).





6.7 In multidirectional laminates, edge effects can affect the measured strength and modulus of the laminate.

6.8 Strain anomalies may occur as the specimen approaches ultimate force. These anomalies are likely to cause the apparent bending measurement of the specimen to deviate from the actual bending the specimen is experiencing. Examples of strain anomalies are, but not limited to, strain gauge disbond, strain gauge lead separation and surface ply separation.

## 7. Apparatus and Supplies

7.1 *Micrometers and Calipers*—A micrometer having a suitable-size diameter ball interface on irregular surfaces such as the bag-side of a laminate, and with a 4 mm to 8 mm [0.16 in. to 0.32 in.] nominal diameter ball interface or a flat anvil interface shall be used to measure the specimen thickness. A ball interface is recommended for thickness measurements when at least one surface is irregular (for example, a course peel ply surface which is neither smooth nor flat). A micrometer or caliper with a flat anvil interface on machined edges or very smooth tooling surfaces, shall be used. A caliper of suitable size can also be used on machined edges or very smooth tooling surfaces. shall be used for measuring length, width, and other machined surface dimensions. The use of alternative measurement devices is permitted if specified (or agreed to) by the test requestor and reported by the testing laboratory. The accuracy of these instruments the instrument(s) shall be suitable for reading to within 1 % of the sample length, width and thickness specimen dimensions. For typical specimen geometries, an instrument with an accuracy of  $\pm 2.5 \mu\text{m}$  [ $\pm 0.0001$  in.] is desirable  $\pm 0.005 \text{ mm}$  [ $\pm 0.0002$  in.] is adequate for thickness and width measurement, measurements, while an instrument with an accuracy of  $\pm 25 \mu\text{m}$  [ $\pm 0.001$  in.] is desirable for length measurements.  $\pm 0.025 \text{ mm}$  [ $\pm 0.001$  in.] is adequate for measurement of length and other machined surface dimensions.

7.2 *Torque Wrench*—Calibrated within the torque range required.

7.3 *Testing Machine*—A calibrated testing machine shall be used which can be operated at constant crosshead speed over the specified range. The test machine mechanism shall be essentially free from inertial lag at the crosshead speeds specified. The machine shall be equipped with an appropriate force-measuring device (for example, a load cell). The accuracy of the test machine shall be in accordance with Practices E4.

7.4 *Conditioning Chamber*—When conditioning materials in other than ambient laboratory environments, a temperature-/moisture-level at non-laboratory environments, a temperature-/vapor-level controlled environmental conditioning chamber is required that shall be capable of maintaining the required relative temperature to within  $\pm 3^\circ\text{C}$  [ $\pm 5^\circ\text{F}$ ]  $\pm 3^\circ\text{C}$  [ $\pm 5^\circ\text{F}$ ] and the required relative vapor humidity level to within  $\pm 5\%$   $\pm 3\%$ . Chamber conditions shall be monitored either on an automated continuous basis or on a manual basis at regular intervals.

7.5 *Environmental Chamber*—A chamber capable of enclosing the test fixture and specimen while they are mounted in the testing machine, and capable of achieving the specified heating/cooling rates, test temperatures, and environments, shall be used when nonambient conditions are required during testing. An environmental test chamber is required for test environments other than ambient testing laboratory conditions. This chamber shall be capable of maintaining the gage section of the test specimen within  $\pm 3^\circ\text{C}$  [ $\pm 5^\circ\text{F}$ ] of test specimen and fixture at the required test temperature environment during the mechanical test. In addition, the chamber may have to be capable of maintaining environmental conditions such as fluid exposure or relative humidity during the test. The test temperature shall be maintained within  $\pm 3^\circ\text{C}$  [ $\pm 5^\circ\text{F}$ ] of the required temperature. The relative humidity level controlled within the test chamber shall be defined by the test requestor.

7.6 *Compression Fixture*—A test fixture such as that shown in Figs. 1 and 2, or a comparable fixture, shall be used. The fixture shown introduces a controllable ratio of end loading to shear loading into the specimen, by controlling the torque applied to the clamping screws.

7.7 *Strain-Indicating Device*—Longitudinal strain shall be simultaneously measured on opposite faces of the specimen to allow for a correction as a result of any bending of the specimen, and to enable detection of Euler (column) buckling. Back-to-back strain measurement shall be made for all five specimens when the minimum number of specimens allowed by this test method are tested. If more than five specimens are to be tested, then a single strain-indicating device may be used for the number of specimens greater than the five, provided the total number of specimens are tested in a single test fixture and load frame throughout the tests, that no modifications to the specimens or test procedure are made throughout the duration of the tests, and provided the bending requirement (see 12.312.4 and 12.412.5) is met for the first five specimens. If these conditions are not met, then all specimens must be instrumented with back-to-back devices. When Poisson's ratio is to be determined, the specimen shall be instrumented to