Designation: D 6641/D 6641M – 01$^{\epsilon 1}$

Standard Test Method for Determining the Compressive Properties of Polymer Matrix Composite Laminates Using a Combined Loading Compression (CLC) Test Fixture[1]

This standard is issued under the fixed designation D 6641/D 6641M; 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.

ϵ^1 NOTE—The designation, D 6641/D 6641M, was editorially corrected to be a dual standard in December 2001.

1. Scope

1.1 This test method establishes a procedure for determining the compressive strength and stiffness properties of polymer matrix composite materials using a combined loading compression (CLC) (**1**)[2] or comparable test fixture. This test method is applicable to general flat laminates that are balanced and symmetric and contain at least one 0° ply. The standard specimen is untabbed, and, thus, for strength determination, the laminate is limited to a maximum of 50 % 0° plies, or equivalent (see 6.4).

1.2 The compressive force is introduced into the specimen by combined end- and shear-loading. In comparison, Test Method D 3410/D 3410M is a pure shear-loading compression test method and Test Method D 695 is a pure end-loading test method.

1.3 Unidirectional (0° ply orientation) composites can be tested to determine unidirectional composite modulus and Poisson's ratio, but not compressive strength.

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 D 3410/D 3410M, D 5467, and D 695.

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

2. Referenced Documents

2.1 *ASTM Standards:*

D 695 Test Method for Compressive Properties of Rigid Plastics[3]
D 883 Terminology Relating to Plastics[3]
D 3410/D 3410M Test Method for Compressive Properties of Polymer Matrix Composite Materials with Unsupported Gage Section by Shear Loading[4]
D 3878 Terminology for Composite Materials[4]
D 5467 Test Method for Compressive Properties of Unidirectional Polymer Matrix Composites Using a Sandwich Beam[4]
D 5687/D 5687M Guide for Preparation of Flat Composite Panels with Processing Guidelines for Specimen Preparation[4]
E 4 Practices for Force Verification of Testing Machines[5]
E 6 Terminology Relating to Methods of Mechanical Testing[5]
E 122 Practice for Calculating Sample Size to Estimate, with a Specified Tolerable Error, the Average for a Characteristic of a Lot or Process[6]
E 132 Test Method for Poisson's Ratio at Room Temperature[5]
E 177 Practice for Use of the Terms Precision and Bias in ASTM Test Methods[6]
E 456 Terminology Relating to Quality and Statistics[6]
E 1309 Guide for Identification of Fiber-Reinforced Polymer Matrix Composite Materials in Databases[4]
E 1434 Guide for Recording Mechanical Test Data of Fiber-Reinforced Composite Materials in Databases[4]

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

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[2] Boldface numbers in parentheses refer to the list of references at the end of this test method.

[3] *Annual Book of ASTM Standards*, Vol 08.01.
[4] *Annual Book of ASTM Standards*, Vol 15.03.
[5] *Annual Book of ASTM Standards*, Vol 03.01.
[6] *Annual Book of ASTM Standards*, Vol 14.02.

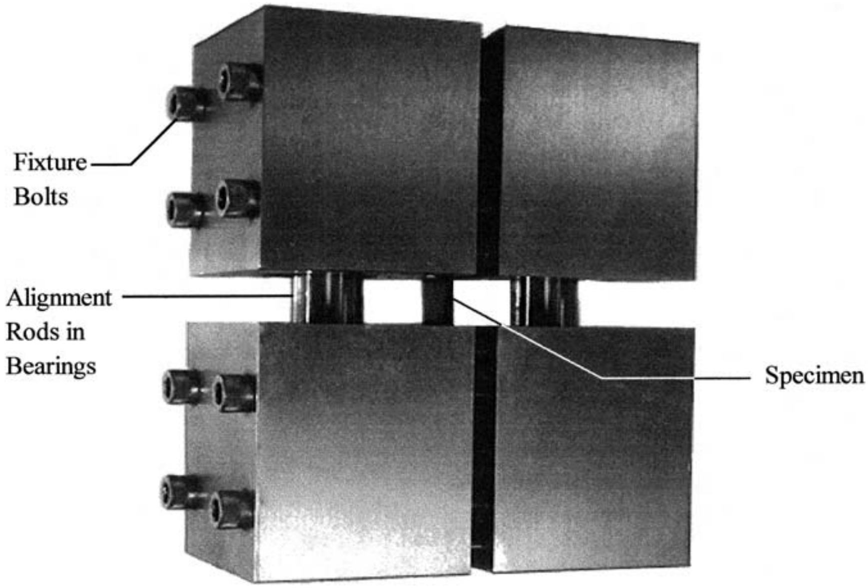


FIG. 1 Photograph of a Typical Combined Loading Compression (CLC) Test Fixture

E 1471 Guide for Identification of Fibers, Fillers, and Core Materials in Computerized Material Property Databases[4]

2.2 *ASTM Adjunct:*

Combined Loading Compression (CLC) Test Fixture, D 6641[7]

2.3 *Other Documents:*[8]

ANSI Y14.5-1999, "Dimensioning and Tolerancing—Includes Inch and Metric"

ANSI B46.1-1995, "Surface Texture (Surface Roughness, Waviness and Lay)"

3. Terminology

3.1 *Definitions*—Terminology D 3878 defines terms relating to high-modulus fibers and their composites. Terminology D 883 defines terms relating to plastics. Terminology E 6 defines terms relating to mechanical testing. Terminology E 456 and Practice E 177 define terms relating to statistics. In the event of a conflict between terms, Terminology D 3878 shall have precedence over the other Terminology standards.

3.2 *Symbols*:

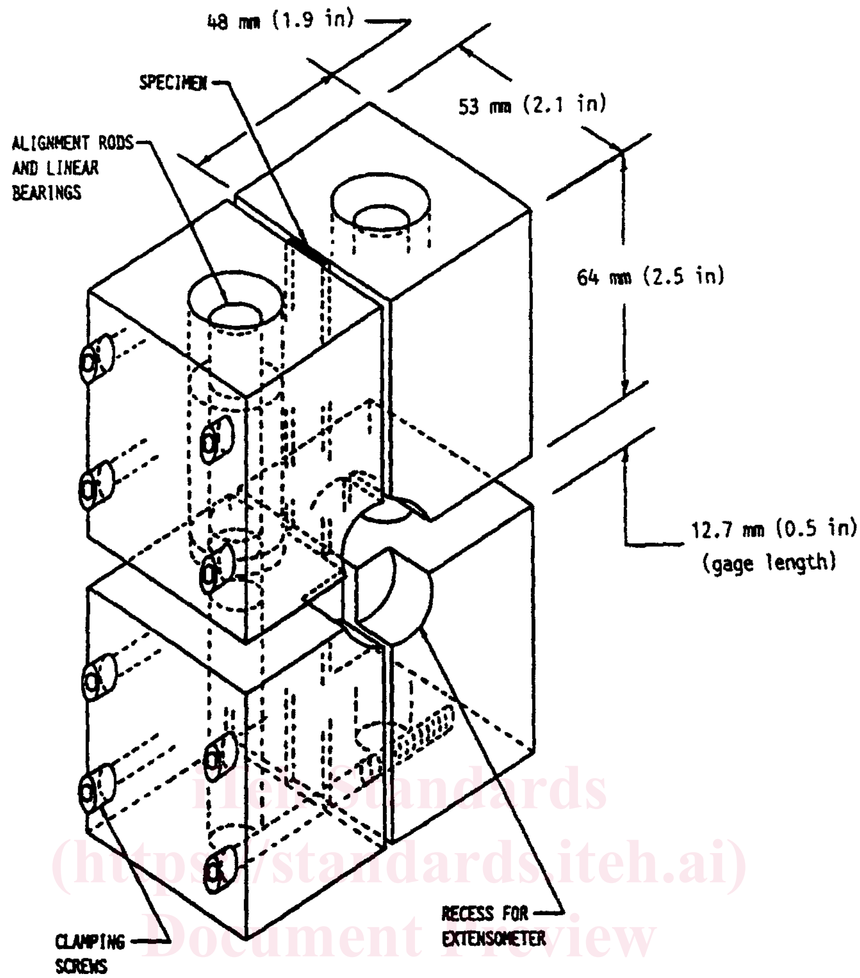
A—cross-sectional area of specimen in gage section
B_y—face-to-face percent bending in specimen
BF—back-out factor
CV—sample coefficient of variation, in percent
E^c—laminate compressive modulus
F^{cu}—laminate ultimate compressive strength
$F^{cu}_{0° plies}$—compressive stress in 0° plies at laminate failure
F^{cr}—Euler buckling stress
G_{xz}—through-thickness shear modulus of laminate
G_{12}—in-plane shear modulus of the 0° plies
G_{13}, G_{23}—through-thickness shear moduli of the 0° plies
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 laminate is repeated symmetrically about its midplane
s_{n-1}—sample standard deviation
V_0—volume fraction of 0° plies in laminate
V_{90}—volume fraction of 90° plies in laminate
w—specimen gage width
$\bar{x}$—sample mean (average)
x_i—measured or derived property
ϵ—indicated normal strain from strain transducer
ϵ_x—laminate axial strain
ϵ_y—laminate in-plane transverse strain
ϵ_1, ϵ_2—strain gage readings
ν_{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 untabbed, straight-sided composite specimen of rectangular cross section shown schematically in Fig. 3. A typical specimen is 140 mm [5.5 in.] long and 12 mm [0.5 in.] wide, having an unsupported (gage) length of 12 mm [0.5 in.] when installed in the fixture. A gage length between 12 mm and 25 mm [1.0 in.] is acceptable, subject to specimen buckling considerations (see 8.2). This 12-mm 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, is to be determined, and not the complete stress-strain curve to failure).

[7] A detailed drawing for the fabrication of the test fixture shown in Figs. 1 and 2 is available from ASTM Headquarters. Order Adjunct No. ADJD6641.

[8] Available from American National Standards Institute, 25 W. 43rd St., 4th Floor, New York, NY 10036.



Note: Using standard ¼-in. 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

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 specific laminates are tested (primarily of the $[90/0]_{ns}$ family, although other laminates containing a maximum of 50 % 0° plies can be used), the data are frequently used to "back out" 0° ply strength, using laminate theory to calculate a 0° 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. Laminate 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,

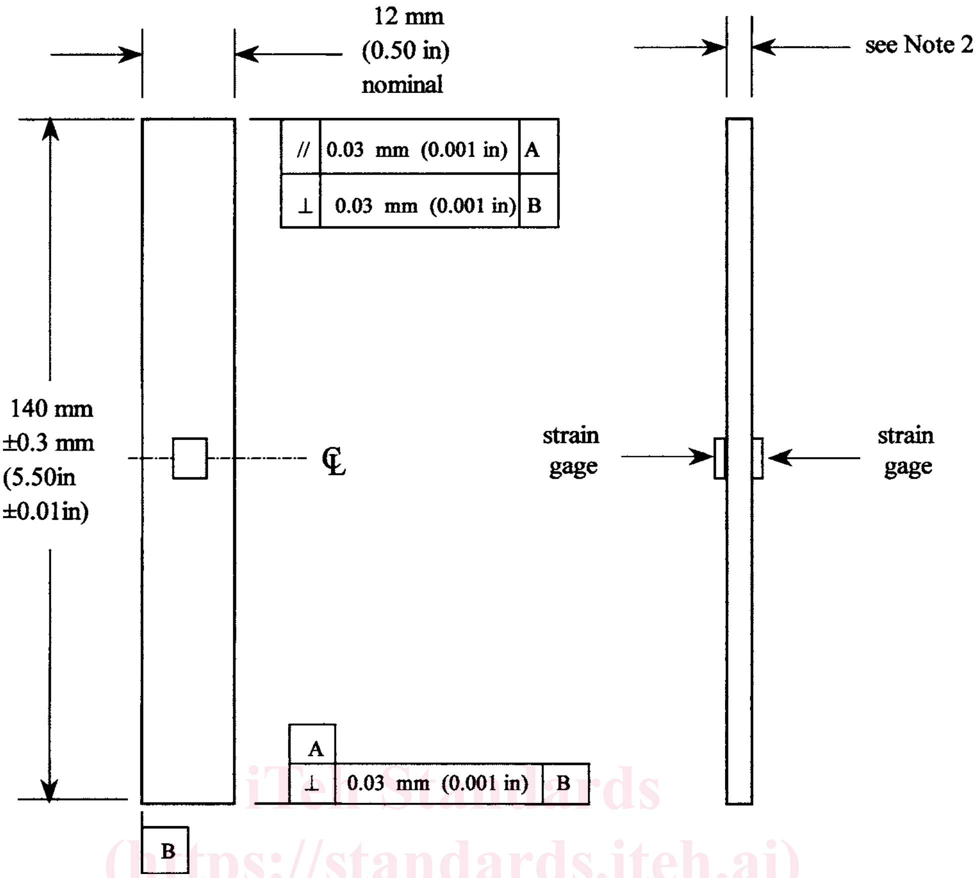
5.1.3 Compressive (linear or chord) modulus of elasticity, and

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 parallel to each other and perpendicular to the long axis of the coupon (see Fig. 3). 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 below the minimum gage length required. A practical limit on reducing gage length is maintaining adequate space in which to attach strain gages. 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 or by examining the specimen failure mode (**3**). Bending and buckling are not visually obvious during the test.



Notes:
(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.].
(2) Nominal specimen 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 width or 0.06 mm [0.002 in.] along the specimen length.
(3) 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

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, laminate configuration, and application (see 10.1).

6.4 Continuous-fiber-reinforced laminates having more than 50 % axially oriented (0°) plies may require higher than acceptable fixture clamping forces to prevent end crushing. Therefore, such specimens are considered nonstandard. Excessive clamping forces induce at the ends of the gage section local stress concentrations that may produce erroneously low strength results (see 9.2.7).

6.5 If the outermost plies of the laminate are oriented at 0°, 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 other laminate configurations may also be determined using this same untabbed specimen 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 possible, although nonstandard, and not desirable as tabs also induce stress concentrations at the ends of the gage section (**1**, **5**). An untabbed thickness-tapered specimen, although nonstandard, has also been used to test successfully high-strength unidirectional composites (**5**).

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

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 a flat anvil interface on machined edges or very smooth tooled surfaces, shall be used.