



Designation: ~~D3410/D3410M – 03 (Reapproved 2008)~~ D3410/D3410M – 16

Standard Test Method for Compressive Properties of Polymer Matrix Composite Materials with Unsupported Gage Section by Shear Loading¹

This standard is issued under the fixed designation D3410/D3410M; 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.

This standard has been approved for use by agencies of the U.S. Department of Defense.

1. Scope

1.1 This test method determines the in-plane compressive properties of polymer matrix composite materials reinforced by high-modulus fibers. The composite material forms are limited to continuous-fiber or discontinuous-fiber reinforced composites for which the elastic properties are specially orthotropic with respect to the test direction. This test procedure introduces the compressive force into the specimen through shear at wedge grip interfaces. This type of force transfer differs from the procedure in Test Method **D695** where compressive force is transmitted into the specimen by end-loading, Test Method **D6641/D6641M** where compressive force is transmitted by combined shear and end loading, and Test Method **D5467/D5467M** where compressive force is transmitted by subjecting a honeycomb core sandwich beam with thin skins to four-point bending.

1.2 This test method is applicable to composites made from unidirectional tape, wet-tow placement, textile (for example, fabric), short fibers, or similar product forms. Some product forms may require deviations from the test method.

1.3 The values stated in either SI units or inch-pound units are to be regarded separately as standard. Within the text the inch-pounds 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 compressive properties of resin-matrix composites may be found in Test Methods **D695**, **D5467/D5467M**, and **D6641/D6641M**.

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:²

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

D2584 Test Method for Ignition Loss of Cured Reinforced Resins

D2734 Test Methods for Void Content of Reinforced Plastics

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

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

¹ This specification 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 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.



- D6641/D6641M Test Method for Compressive Properties of Polymer Matrix Composite Materials Using a Combined Loading Compression (CLC) Test Fixture
- E4 Practices for Force Verification of Testing Machines
- E6 Terminology Relating to Methods of Mechanical Testing
- E83 Practice for Verification and Classification of Extensometer Systems
- E111 Test Method for Young's Modulus, Tangent Modulus, and Chord Modulus
- 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
- E251 Test Methods for Performance Characteristics of Metallic Bonded Resistance Strain Gages
- E456 Terminology Relating to Quality and Statistics
- E1237 Guide for Installing Bonded Resistance Strain Gages
- E1309 Guide for Identification of Fiber-Reinforced Polymer-Matrix Composite Materials in Databases (Withdrawn 2015)³
- E1434 Guide for Recording Mechanical Test Data of Fiber-Reinforced Composite Materials in Databases (Withdrawn 2015)³
- E1471 Guide for Identification of Fibers, Fillers, and Core Materials in Computerized Material Property Databases (Withdrawn 2015)³
- 2.2 *ASTM Adjunct:*
- Compression Fixture, Fixture D3410 Method B⁴
- 2.3 *Other ANSI Documents:*⁵
- ANSI Y14.5M-1982
- ANSI/ASME B46.1-1985

3. Terminology

3.1 Terminology D3878 defines terms relating to high-modulus fibers and their composites. 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 Terminology standards.

3.2 Definitions of Terms Specific to This Standard:

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.

3.2.2 *orthotropic material, n*—a material with a property of interest that, at a given point, possesses three mutually perpendicular planes of symmetry defining the principal material coordinate system for that property.

3.2.3 *principal material coordinate system, n*—a coordinate system with axes that are normal to the planes of symmetry that exist within the material.

3.2.4 *reference coordinate system, n*—a coordinate system for laminated composites used to define ply orientations. One of the reference coordinate system axes (normally the Cartesian x -axis) is designated the reference axis, assigned a position, and the ply principal axis of each ply in the laminate is referenced relative to the reference axis to define the ply orientation for that ply.

3.2.5 *specially orthotropic, adj*—a description of an orthotropic material as viewed in its principal material coordinate system. In laminated composites, a specially orthotropic laminate is a balanced and symmetric laminate of the $[0_i/90_j]_{ns}$ family as viewed from the reference coordinate system, such that the membrane-bending coupling terms of the stress-strain relation are zero.

3.2.6 *transition strain, $e^{transition}$, n*—the strain value at the mid-range of the transition region between the two essentially linear portions of a bilinear stress-strain or strain-strain curve (a transverse strain-longitudinal strain curve as used for determining Poisson's ratio).

3.3 Symbols:

3.3.1 A —cross-sectional area of specimen.

3.3.2 B_y —percent bending in specimen.

3.3.3 CV —sample coefficient of variation, in percent.

3.3.4 E —modulus of elasticity in the test direction.

3.3.5 F^{cu} —ultimate compressive stress (compressive strength).

³ The last approved version of this historical standard is referenced on www.astm.org.

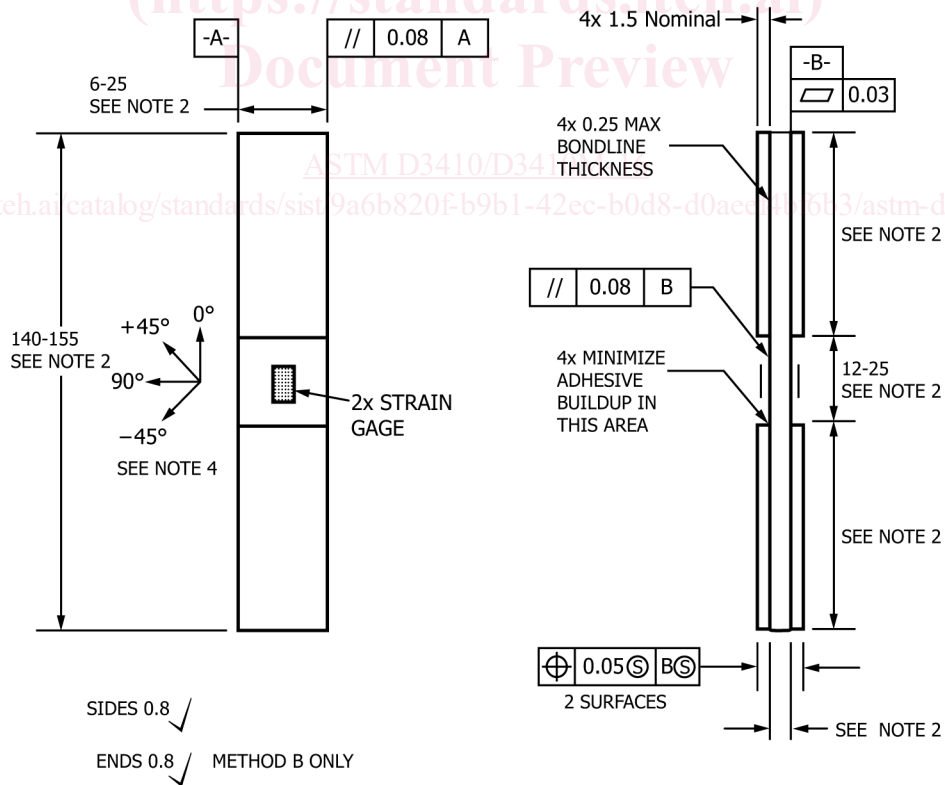
⁴ A blueprint of the detailed drawing for the construction of the fixture shown in Fig. 4 is available at a nominal cost from ASTM International Headquarters, 100 Barr Harbor Dr., PO Box C700, West Conshohocken, PA 19428-2959. Order Adjunct ADJD3410.

⁵ Available from American National Standards Institute (ANSI), 25 W. 43rd St., 4th Floor, New York, NY 10036-10036, <http://www.ansi.org>.

- 3.3.6 G_{xz} —through-thickness shear modulus of elasticity.
- 3.3.7 h —specimen thickness.
- 3.3.8 i, j, n —as used in a layup code, the number of repeats for a ply or group of plies of a material.
- 3.3.9 l_g —specimen gage length.
- 3.3.10 n —number of specimens.
- 3.3.11 P —force applied to test specimen.
- 3.3.12 P^f —force applied to test specimen at failure.
- 3.3.13 P^{max} —maximum force before failure.
- 3.3.14 s —as used in a layup code, denotes that the preceding ply description for the laminate is repeated symmetrically about its midplane.
- 3.3.15 s_{n-1} —sample standard deviation.
- 3.3.16 w —specimen width.
- 3.3.17 x_f —measured or derived property.
- 3.3.18 \bar{x} —sample mean (average).
- 3.3.19 $\bar{\epsilon}$ —indicated normal strain from strain transducer.
- 3.3.20 ν^c —compressive Poisson’s ratio.
- 3.3.21 σ_c —compressive normal stress.

4. Summary of Test Method

4.1 A flat strip of material having a constant rectangular cross section, as shown in the specimen drawings of Figs. 1-4, is loaded in compression by a shear force acting along the grips. The shear force is applied via wedge grips in a specially-designed fixture shown in Figs. 5-7. The influence of this wedge grip design on fixture characteristics is discussed in 6.1.



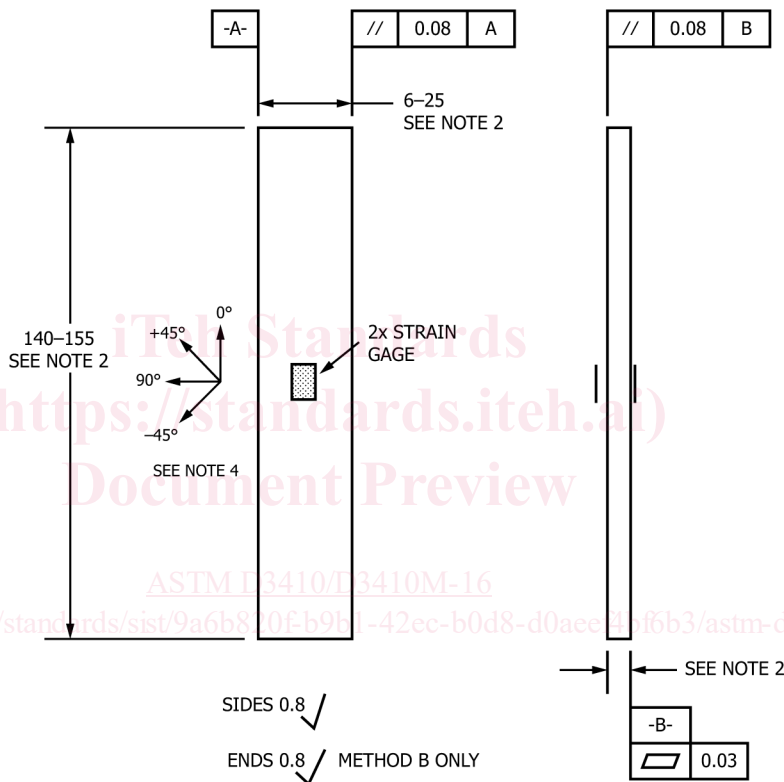
Notes:

- 1. Drawing interpretation per ANSI Y14.5M-1982 and ANSI/ASME B46.1-1985.
- 2. See Section 8 and Table 2 and Table 3 of the test standard for values of required or recommended width, thickness, gage length, tab length and overall length.
- 3. See test standard for values of material, ply orientation, use of tabs, tab material, tab angle, and tab adhesive.
- 4. Ply orientation tolerance relative to -A- ±0.5°.

FIG. 1 Compression Test Specimen Drawing, (SI with Tabs)

Notes:

1. Drawing interpretation per ANSI Y14.5M-1982 and ANSI/ASME B46.1-1985
2. See Section 8 and Tables 2 and 3 of the test standard for values of required or recommended width, thickness, gage length, tab length and overall length.
3. See test standard for values of material, ply orientation, use of tabs, tab material, tab angle and tab adhesive.
4. Ply orientation tolerance relative to -A- $\pm 0.5^\circ$



**COMPRESSION TEST SPECIMEN WITHOUT TABS
SI VERSION**

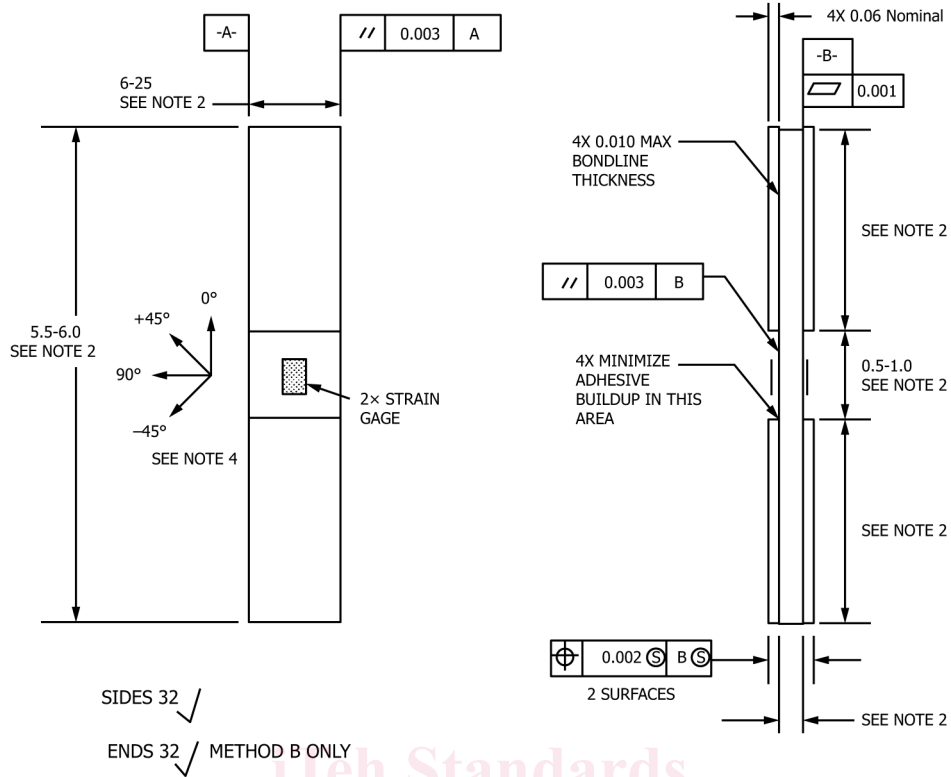
All Dimensions in mm

FIG. 2 Compression Test Specimen Drawing, (SI without Tabs)

4.2 To obtain compression test results, the specimen is inserted into the test fixture which is placed between the platens of the testing machine and loaded in compression. The ultimate compressive stress of the material, as obtained with this test fixture and specimen, can be obtained from the maximum force carried before failure. Strain is monitored with strain or displacement transducers so the stress-strain response of the material can be determined, from which the ultimate compressive strain, the compressive modulus of elasticity, Poisson's ratio in compression, and transition strain can be derived.

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. Factors that influence the compressive response and should therefore be



Notes:

1. Drawing interpretation per ANSI Y14.5M-1982 and ANSI/ASME B46.1-1985.
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3. See test standard for values of material, ply orientation, use of tabs, tab material, tab angle and tab adhesive.
4. Ply orientation tolerance relative to -A- $\pm 0.5^\circ$.

FIG. 3 Compression Test Specimen Drawing, (Inch-Pound with Tabs)

reported include the following: material, methods of material preparation and layup, specimen stacking sequence, specimen preparation, specimen conditioning, environment of testing, specimen alignment and gripping, speed of testing, time at temperature, void content, and volume percent reinforcement. 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,
- 5.1.4 Poisson's ratio in compression, and
- 5.1.5 Transition strain.

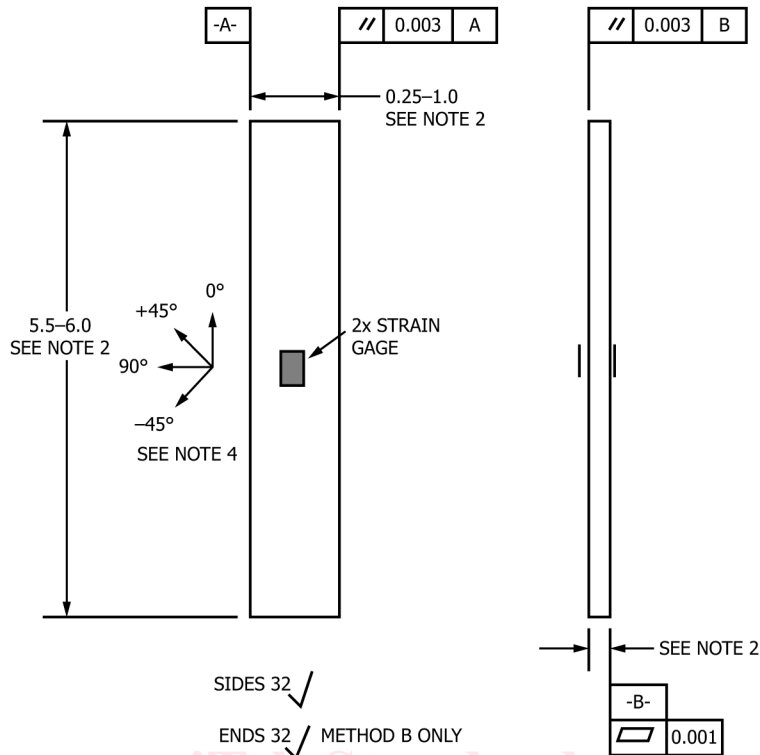
6. Interferences

6.1 *Test Fixture Characteristics*—This test method transmits force to the specimen via tapered rectangular wedge grips. The rectangular wedge grip design is used to eliminate the wedge seating problems induced by the conical wedges of the so-called Celanese compression test fixture previously utilized in this test method (1).⁶ Earlier versions of this test method containing full details of the Celanese test method, including Test Method D3410/D3410M-95, are available.⁵ Another fixture characteristic that can have a significant effect on test results is the surface finish of the mating surfaces of the wedge grip assembly. Since these surfaces undergo sliding contact they must be polished, lubricated, and nick-free (11.5.1).

NOTE 2—An acceptable level of polish for the surface finish of wedge grip mating surfaces has been found to be one that ranges from 2 to 12 micro in. rms with a mean finish of 7 micro in. rms.

6.1.1 The specimen gripping faces of the wedge grips are typically roughened in some manner, as required for the particular application. Examples include serrated (7 to 8 serrations/cm) or thermal-sprayed tungsten carbide particle (100 grit) grip faces (see also 8.3.3).

⁶ Boldface numbers in parentheses refer to the list of references at the end of this test method.



**COMPRESSION TEST SPECIMEN WITH TABS
INCH-POUND VERSION**

All Dimensions in inches

Notes:

1. Drawing interpretation per ANSI Y14.5M-1982 and ANSI/ASME B46.1-1985.
2. See Section 8 and Table 2 and Table 3 of the test standard for values of required or recommended width, thickness, gage length, tab length, and overall length.
3. See test standard for values of material, ply orientation, use of tabs, tab material, tab angle and tab adhesive.
4. Ply orientation tolerance relative to -A- $\pm 0.5^\circ$.

FIG. 4 Compression Test Specimen Drawing, (Inch-Pound without Tabs)

6.2 *Test Method Sensitivity*—Compression strength for a single material system has been shown to differ when determined by different test methods. Such differences can be attributed to specimen alignment effects, specimen geometry effects, and fixture effects even though efforts have been made to minimize these effects. Examples of differences in test results between various test methods can be found in Refs (1,2).

6.3 *Material and Specimen Preparation*—Compression modulus, and especially ultimate compressive stress, are sensitive to poor material fabrication practices, damage induced by improper specimen machining, and lack of control of fiber alignment. Fiber alignment relative to the specimen coordinate axis should be maintained as carefully as possible, although no standard procedure to ensure this alignment exists. Procedures found satisfactory include the following: fracturing a cured unidirectional laminate near one edge parallel to the fiber direction to establish the 0° direction, or laying in small filament count tows of contrasting color fiber (aramid in carbon laminates and carbon in aramid or glass laminates) parallel to the 0° direction either as part of the prepreg production or as part of panel fabrication.

6.4 *Tabbing and Tolerances*—The data resulting from this test method has been shown to be sensitive to the flatness and parallelism of the tabs, so care should be taken to ensure that the specimen tolerance requirements are met. This usually requires precision grinding of the tab surfaces after bonding them to the specimen.

6.5 *Thickness and Gage Length Selection*—The gage section for this test method is unsupported, resulting in a tradeoff in the selection of specimen gage length and the specimen thickness. The gage length must be short enough to be free from Euler (column) buckling, yet long enough to allow stress decay to uniaxial compression and to minimize Poisson restraint effects as a result of the grips. Minimum thickness requirements are provided in 8.2.3.

6.6 *Gripping*—A high percentage of grip-induced failures, especially when combined with high material data scatter, is an indicator of specimen gripping problems.