Standard Test Method for
Axial Compression Test of Reinforced Plastic and Polymer Matrix Composite Vertical Members[1]

1. Scope

1.1 This test method covers the evaluation of vertical members in axial compression for "full-sized" specimens with various end conditions with constant cross-sections throughout the length.

1.2 This test method is limited to reinforced plastic and polymer matrix composite materials and covers the determination of the compressive properties of structural members. The method is intended primarily for members of rectangular cross section, but is also applicable to irregularly shaped studs, round posts, or special sections.

1.3 This test method covers short-term axial load testing under standard indoor atmospheric conditions. It does not address: sampling, the ability of the material to carry a sustained long-term load, design load derivations, temperature effects, performance under freeze/thaw or salt spray exposure conditions, chemical/UV exposure effects, or engineering analysis/modeling needed to extrapolate the results to conditions other than those tested. Each of these factors, and potentially others, need to be considered by the design professional or product standard development committee before using the information generated by this test method to assess structural adequacy.

1.4 Short sections are not covered in this test method and should be tested using a material test standard such as Test Method D6108 or Test Methods D198.

1.5 The values stated in inch-pound units are to be regarded as standard. The values given in parentheses are mathematical conversions to SI units that are provided for information only and are not considered standard.

1.6 *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]
D198 Test Methods of Static Tests of Lumber in Structural Sizes
D883 Terminology Relating to Plastics
D2915 Practice for Sampling and Data-Analysis for Structural Wood and Wood-Based Products
D3878 Terminology for Composite Materials
D6108 Test Method for Compressive Properties of Plastic Lumber and Shapes
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
E575 Practice for Reporting Data from Structural Tests of Building Constructions, Elements, Connections, and Assemblies
E631 Terminology of Building Constructions

3. Terminology

3.1 *Definitions*—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. In the event of a conflict between terms, Terminology D3878 shall have precedence over the other standards.

3.1.1 For definitions of terms in this standard, see Terminology E631.

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *full-sized specimen*—full-sized specimens (meaning full cross-sectional area) tested with standard lengths with various end conditions and bracing conditions about the weak and strong member axes. The end conditions addressed include: eccentricity, fixed, pinned.

3.2.2 *short sections* (not considered in this test method)—compressive test sections having a maximum length, L, less than 17 times the least radius of gyration, r, where r = $\sqrt{(I/A)}$.

3.3 *Symbols:*

3.3.1 σ = compressive strength.

3.3.2 σ′ = compressive stress at proportional limit.

3.3.3 E = compressive modulus of elasticity.

3.3.4 E' = apparent modulus of elasticity.

3.3.5 A = cross-sectional area.

3.3.6 Δ_L = change in length from original gage length at proportional limit.

3.3.7 L_G = gage length of compression column.

3.3.8 P_{max} = maximum load borne by column loaded to failure.

3.3.9 P' = applied load at proportional limit, lbf (N).

4. Summary of Test Method

4.1 The structural member is subjected to a compressive force distributed on the contact surface of the specimen in a direction generally parallel to the longitudinal axis. The specimens are either loaded to failure or proof loaded. The test method is intended to determine the axial compressive strength of standard full-size specimens tested with various end conditions including: built-in eccentricity, pinned, fixed, or as required to accomplish the experimental objective. Lateral bracing may be installed as required to accomplish the experimental objective.

5. Significance and Use

5.1 The compressive properties obtained by axial compression will provide information such as: modulus of elasticity, stress at proportional limit and compressive strength for the end support, and lateral bracing condition tested.

5.2 This test method addresses only full-sized specimens for determination of compressive strength and compressive modulus of elasticity intended for application to actual length members with end conditions and lateral bracing as intended.
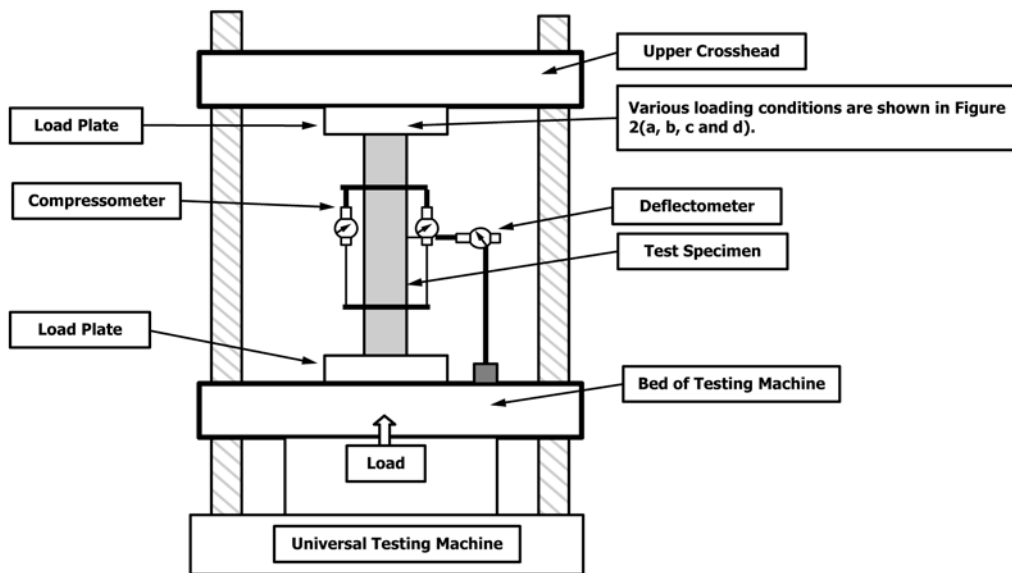
Note 1—The effective length of the column with respect to buckling is affected by the end conditions. A fixed end condition results in an effective length for buckling that is less than the actual length of the column, by as much as 50 %.

6. Apparatus

6.1 *Drive Mechanism*—A drive mechanism for imparting to a movable loading head a uniform controlled velocity with respect to the stationary base.

6.2 *Load Indicator*—A load-indicating mechanism capable of showing the total compressive force on the specimen. This force-measuring system shall be calibrated to ensure accuracy in accordance with Practices E4. A schematic representation of the typical test set up is shown in Fig. 1.

6.3 *End Conditions*—The end conditions used for the test shall be chosen to satisfy the experimental objectives. Options include:

6.3.1 *Fixed*—With a fixed end condition as conceptually depicted in Fig. 2(a), a spherical bearing block may be used at either end of the column to ensure uniform contact. When spherical bearing blocks are used, the radius of the sphere shall be as small as practicable, in order to facilitate adjustment of the bearing plate to the specimen, and yet large enough to provide adequate spherical bearing area. This radius is usually one to two times the greatest cross-section dimension. The center of the sphere shall be on the plane of the specimen contact surface. The size of the compression plate shall be larger than the contact surface. It has been found convenient to provide an adjustment for moving the specimen on its bearing plate with respect to the center of spherical rotation to ensure axial loading.

6.3.2 *Pinned*—As conceptually depicted in Fig. 2(b), a pinned end condition shall use a fixture capable of rotating about an axis perpendicular to the column length. The size of the compression plate shall be larger than the column contact surface. The pivot point of the fixture shall be aligned with the
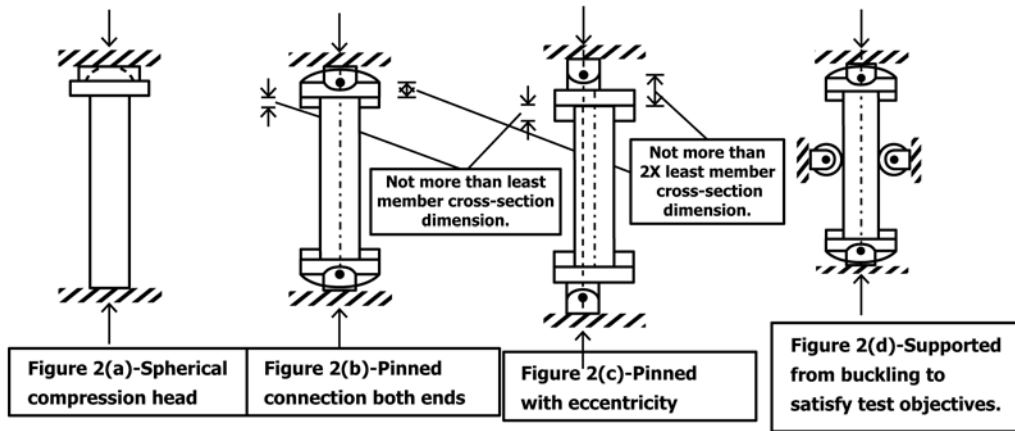

FIG. 1 Test Set-Up

FIG. 2 Various Loading Conditions

centerline of the test column. Depending upon the experimental objectives, the pivot(s) shall be positioned to permit rotation about the weak column axis, the strong column axis, or both. The pivot locations shall be positioned as close to the column bearing surface as practical, but at a distance of not more than two times the smallest column cross-sectional dimension. The pivot points of the fixtures shall consist of greased bolts, knife edges, ball-bearings, or other details that minimize the frictional rotation restraint of the fixture. Retainer blocks, angles, clamping fixtures, or other attachments may be used to ensure that the column does not slide off the bearing fixtures under load. However, these devices shall not protrude along the column length a distance greater than the minimum cross-sectional dimension of the column.

6.3.3 *Eccentric*—An eccentric load may be applied by using a pinned end condition that is not aligned with the member centerline as depicted in Fig. 2(c). The degree of eccentricity about each member axis shall be selected to satisfy the experimental objectives and recorded.

6.3.4 *Other*—An alternate end condition may be chosen to specifically replicate a field application condition or other experimental objective. The details of the non-standard end conditions shall be fully described and reported.

6.4 *Bracing*—As conceptually illustrated in Fig. 2(d), lateral bracing shall be installed as required to satisfy the experimental objectives. The bracing fixtures employed for the test shall use a roller or other detailing to minimize friction to provide lateral restraint without imparting axial resistance to the column. The number, position, and details of the braces about each axis shall be reported.

NOTE 2—Bracing may be installed about the weak axis, the strong axis, or both.

6.5 *Compressometer*—A compressometer as shown in Fig. 1 shall be used. The measuring instruments shall conform to class D (or better) of Practice E83.

6.5.1 *Gage Length*—For modulus of elasticity calculations, a device shall be provided by which the deformation of the specimen is measured with respect to specific paired gage points defining the gage length. To obtain test data representative of the test material as a whole, such paired gage points shall be located symmetrically on the lengthwise surface of the specimen as far apart as feasible, yet at least one times the larger cross-sectional dimension from each of the contact surfaces. At least two pairs of such gage points on diametrically opposite sides of the specimen shall be used to measure the average deformation.

6.6 *Deflectometer*—A suitable device to measure out-of-plane deflection of the member as shown in Fig. 1.

NOTE 3—A dial gage or electronic displacement transducer mounted to the frame of the machine reacting at mid-height of the specimen is a satisfactory method.

7. Test Specimen and Sampling

7.1 The test specimen shall consist of a structural member commercially used in structural applications, that is, in sizes greater than 2 by 2-in. (51 by 51-mm) cross section.

7.2 *Identification*—Material or materials of the test specimen shall be identified as fully as possible by including the origin or source of supply, composition, manufacturing process and conditioning, chemical treatment, fabrication, and other pertinent physical or mechanical details that may affect the strength. Details of this information shall depend on the material or materials in the member.

7.3 The material being tested shall be representative of production. Where prototypes (non-production) are tested, the specimens shall be specifically identified as such.

7.4 The number of replicates shall be chosen to satisfy the experimental objectives. As a guideline, Practice D2915 can be used to determine the number of samples.

7.5 *Specimen Dimensions*—The weight and dimensions, as well as moisture content (if applicable) of the specimen, shall be measured before test. Weights and dimensions (length and cross section) shall be measured to three significant figures. Sufficient measurements of the cross section shall be made along the length of the specimen to describe shape characteristics and to determine the smallest section. Document any initial curvature of full sized specimens about each axis.

7.6 *Specimen Length*—Effective buckling length shall be calculated as 0.5 times the actual specimen length for test conducted with fixed end conditions, and the distance between

pivot locations for pinned end conditions, with this length determined separately for each possible buckling direction when unidirectional pins are used.

Note 4—For example, when pins are used to enable buckling in the weak axis direction but not in the strong axis direction, the effective buckling length for the weak axis shall be the actual specimen length (distance to pivot points) and the effective buckling length for the strong axis shall be 0.5 times the actual specimen length.

8. Procedure

8.1 *Conditioning*—Unless otherwise indicated in the material specification, condition and perform testing on specimens exposed to standard laboratory temperature and humidity (72 ± 5°F and 65 ± 10 % R.H.).

8.2 *Test Procedure:*

8.2.1 *Test Set-up*—Cut the specimen to the proper length so that the contact surfaces are plane, parallel to each other, and normal to the long axis of the specimen. Position the specimen in the test machine using the end condition and bracing fixtures selected for the test.

Note 5—A sharp fine-toothed saw of either the crosscut or "novelty" crosscut type has been used satisfactorily for obtaining the proper end surfaces for some materials. Accurate and square cuts help to ensure uniform load distribution. Power equipment with accurate table guides are especially recommended for this work. Use of shims to achieve full bearing is acceptable.

8.2.2 *Centering*—Center the specimens within the frame and relative to the fixtures as required to either induce or eliminate any desired eccentricity.

8.2.3 *Initial Curvature*—The specimen shall typically be installed and tested with its natural initial curvature present about each member axis and with the braces and support conditions adjusted as necessary to accommodate it. If the end fixtures or braces are used to induce or limit the curvature about any axis, then it shall be documented in the report and the curvature of the specimen at the time of testing shall be reported.

8.3 *Speed of Testing*—Set the speed of testing to a nearly constant strain rate in the gage section. The strain rate shall be selected so as to produce failure within 1 to 10 min. The load may be paused as necessary to remove any deformation measurement equipment prior to failure.

8.4 *Dithering*—If lateral braces or rotational end restrains are employed, then the specimen shall be repeatedly "dithered" during the test using a hammer, pole, or other device sufficient to break any friction in the braces and end restraints. The frequency of the dithering shall be at least once every five seconds.

Note 6—Dithering is important to release and allow the test member to buckle naturally. The technician needs to be properly trained in this technique.

8.5 *Load-Deformation Curves*—If load-deformation data are to be obtained, note the load and deflection at first failure, at changes in slope of curve, and at maximum load. Measure the mid-height deflection in the direction of eccentricity to determine when bending initiates.

8.6 *Records*—Record the maximum load, as well as a description and sketch of the failure relating the failure to the location of any imperfections in the specimen. Reexamine the section of the specimen containing the failure during analysis of the data.

9. Calculation

9.1 Compute physical and mechanical properties in accordance with Terminology E6, and as follows (see compressive notations):

9.1.1 Stress at proportional limit = P'/A in psi (MPa).

9.1.2 Compressive strength = P_{max}/A in psi (MPa).

9.1.3 Apparent modulus of elasticity, $E' = P' L_G/(A\Delta_L)$ in psi (MPa).

9.1.3.1 A = Cross-sectional area, in.^{2} (mm^2).

9.1.3.2 E' = Apparent modulus of elasticity, psi (MPa).

9.1.3.3 Δ_L = Change in length from original gage length at proportional limit, in (mm).

9.1.3.4 L_G = Gage length of compression column, in. (mm).

9.1.3.5 P_{max} = Maximum load borne by column loaded to failure, lbf (N).

9.1.3.6 P' = Applied load at proportional limit, lbf (N).

10. Report

10.1 Report the results of the testing in accordance with Practice E575. At a minimum, the report shall include the following:

10.1.1 A complete description of the test materials, including: composition, grade, imperfections, dimensions and initial curvature about each member axis.

10.1.2 A description and photograph of the end support conditions used for the tests.

10.1.3 The temperature and relative humidity of the laboratory during the tests.

10.1.4 A description and photograph of the lateral bracing used about each member axis. The position and type of bracing shall be documented.

10.1.5 Any magnitude of any load eccentricity induced about each member axis.

10.1.6 The initial curvature of the specimen in the test frame about each member axis.

10.1.7 The time to failure.

10.1.8 Any deformation data recorded during the test.

10.1.9 The peak loads and failure modes.

10.1.10 Information on the test specimens complying with 7.5.

10.1.11 Information complying with Section 9.

11. Precision and Bias

11.1 Insufficient information is currently available to characterize the precision and bias of the test methods described here. As the test methods are more widely used, their precision and bias will be characterized. A task group is being assembled to implement an interlaboratory precision and bias study for this test method.

12. Keywords

12.1 axial compression; polymer matrix composite materials; reinforced plastic; vertical members