Designation: D 6108 – 03

Standard Test Method for Compressive Properties of Plastic Lumber and Shapes[1]

This standard is issued under the fixed designation D 6108; 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 test method covers the determination of the mechanical properties of plastic lumber and shapes, when the entire cross-section is loaded in compression at relatively low uniform rates of straining or loading. Test specimens in the "as-manufactured" form are employed. As such, this is a test method for evaluating the properties of plastic lumber or shapes as a product and not a material property test method.

1.2 Plastic lumber and plastic shapes are currently made predominantly with recycled plastics. However, this test method would also be applicable to similar manufactured plastic products made from virgin resins, or where the product is non-homogenous in the cross-section.

1.3 The values stated in inch–pound units are to be regarded as the standard. The values given in parentheses are for information only.

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.*

NOTE 1—There is no similar or equivalent ISO standard.

2. Referenced Documents

2.1 *ASTM Standards:*

D 618 Practice for Conditioning Plastics for Testing[2]
D 883 Terminology Relating to Plastics[2]
D 4000 Classification System for Specifying Plastic Materials[3]
D 5033 Guide for the Development of Standards Relating to the Proper Use of Recycled Plastics[4]
D 5947 Test Methods for Physical Dimensions of Solid Plastics Specimens[4]
D 6111 Test Method for Bulk Density and Specific Gravity of Plastic Lumber and Shapes by Displacement[4]
E 4 Practices for Load Verification of Testing Machines[5]
E 83 Practice for Verification and Classification of Extensometers[5]
E 691 Practice for Conducting an Interlaboratory Study to Determine the Precision of a Test Method[6]

3. Terminology

3.1 *Definitions:*

3.1.1 *compressive deformation*—the decrease in length produced in the gage length of the test specimen by a compressive load. It is expressed in units of length.

3.1.2 *compressive strain*—the ratio of compressive deformation to the gage length of the test specimen, that is, the change in length per unit of original gage length along the longitudinal axis. It is expressed as a dimensionless ratio.

3.1.3 *compressive strength*—the maximum compressive stress (nominal) carried by a test specimen during a compression test. It may or may not be the compressive stress (nominal) carried by the specimen at the moment of rupture.

3.1.4 *compressive stress (nominal)*—the compressive load per unit area of minimum (or effective as calculated in accordance with Test Method D 6111) original cross section within the gage boundaries, carried by the test specimen at any given moment. It is expressed in force per unit area.

3.1.4.1 *Discussion*—The expression of compressive stress in terms of the minimum original cross section is almost universally used. Under some circumstances the compressive stress has been expressed per unit of prevailing cross section. This stress is called the "true compressive stress".

3.1.5 *compressive stress-strain diagram*—a diagram in which values of compressive stress are plotted as ordinates against corresponding values of compressive strain as abscissas.

3.1.6 *compressive yield point*—the first point on the stress-strain diagram at which an increase in strain occurs without an increase in stress.

[1] This test method is under the jurisdiction of ASTM Committee D20 on Plastics and is the direct responsibility of Subcommittee D20.20 on Plastic Products (Section D20.20.01).

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[2] *Annual Book of ASTM Standards*, Vol 08.01.
[3] *Annual Book of ASTM Standards*, Vol 08.02
[4] *Annual Book of ASTM Standards*, Vol 08.03.
[5] *Annual Book of ASTM Standards*, Vol 03.01.
[6] *Annual Book of ASTM Standards*, Vol 14.02.

***A Summary of Changes section appears at the end of this standard.**

3.1.7 *modulus of elasticity*—the ratio of compressive stress (nominal) to corresponding compressive strain below the proportional limit of a material. It is expressed in force per unit area based on the effective/average initial cross-sectional area.

3.1.8 *percent compressive strain*—the compressive deformation of a test specimen expressed as a percent of the original gage length.

3.1.9 *plastic lumber*, *n*—a manufactured product composed of more than 50 weight percent resin, and in which the product generally is rectangular in cross-section and typically supplied in board and dimensional lumber sizes, may be filled or unfilled, and may be composed of single or multiple resin blends.

3.1.10 *plastic shape*, *n*—a manufactured product composed of more than 50 weight percent resin, and in which the product generally is not rectangular in cross-section, may be filled or unfilled, and may be composed of single or multiple resin blends.

3.1.11 *proportional limit*—the greatest compressive stress that a material is capable of sustaining without any deviation from proportionality of stress to strain (Hooke's law). It is expressed in force per unit area.

3.1.12 *resin, n*—a solid or pseudosolid organic material often of high molecular weight, which exhibits a tendency to flow when subjected to stress, usually has a softening or melting range, and usually fractures conchoidally. (See Terminology D 883.)

3.1.12.1 *Discussion*—In a broad sense, the term is used to designate any polymer that is a basic material for plastics.

3.1.13 *secant modulus*—the ratio of the compressive stress (nominal) to the corresponding value of compressive strain on the stress-strain diagram at a specified value of strain, typically one percent strain (0.01 mm/mm) for plastic lumber. It is expressed in force per unit area based on the effective initial cross-sectional area.

3.1.14 *stress at a given strain*—the stress on the stress-strain curve at a specified value of strain.

3.1.14.1 *Discussion*—The stress at a given strain should not be taken as the ultimate strength at failure. Typically a strain value of 3 % or 0.03 mm/mm is used for plastic lumber. The ultimate strength, or the maximum value of stress on the stress-strain diagram, can be higher for plastic lumber occurring at values of strain much greater than 3 %.

3.2 Additional definition of terms applying to this test method appear in Terminology D 883 and Guide D 5033.

4. Significance and Use

4.1 Compression tests provide information about the compressive properties of plastic lumber and shapes when these products are used under conditions approximating those under which the tests are made. For many materials, there may be a specification that requires the use of this test method, but with some procedural modifications that take precedence when adhering to the specification. Therefore, it is advisable to refer to that material specification before using this test method. Table 1 in Classification D 4000 lists the ASTM materials standards that currently exist.

4.2 Compressive properties include modulus of elasticity, secant modulus, compressive strength, and stress at a given strain. In the case of a material that fails in compression by a shattering fracture, the compressive strength has a very definite value. In the case of a material that does not fail in compression by a shattering fracture nor exhibits a compressive yield point, the compressive strength is an arbitrary one depending upon the degree of distortion that is regarded as indicating complete failure. Many plastic lumber materials will not exhibit a true yield point. Compressive strength can have no real meaning in such cases. For plastic lumber, the stress at a given strain of 3 % (0.03 in./in. [mm/mm]) is typically used.

4.3 Compression tests provide a standard method of obtaining data for research and development, quality control, acceptance or rejection under specifications, and special purposes. The tests cannot be considered significant for engineering design in applications differing widely from the load-time scale of the standard test. Such applications require additional tests such as impact, creep, and fatigue.

5. Apparatus

5.1 *Testing Machine*— Any suitable testing machine capable of control of constant-rate-of-crosshead movement and comprising essentially the following:

5.1.1 *Drive Mechanism*— A drive mechanism for imparting to the cross-head movable member, a uniform, controlled rate of movement with respect to the base (fixed member), with this cross-head rate to be regulated as specified in Section 9.

5.1.2 *Load Indicator*— A load-indicating mechanism capable of showing the total compressive load carried by the test specimen. The mechanism shall be essentially free from inertia-lag at the specified rate of testing and shall indicate the load with an accuracy of ±1 % of the maximum indicated value of the test (load). The accuracy of the testing machine shall be verified at least once a year in accordance with Practices E 4.

5.2 *Compressometer*— A suitable instrument for determining the distance between two fixed points on the test specimen at any time during the test. It is desirable that this instrument automatically record this distance (or any change in it) as a function of the load on the test specimen. The instrument shall be essentially free of inertia-lag at the specified rate of loading and shall conform to the requirements for a Class C extensometer as defined in Practice E 83.

5.2.1 The requirements for extensometers cited herein apply to compressometers as well.

5.2.2 Compression platen movement may be used to determine compressive displacements of test samples.

5.3 *Compression Platens*—A compression platen for applying the load to the test specimen. Parallel platens shall be used to apply the load to an unconfined type specimen. One of the compression platens shall be self aligning in order that the load may be applied evenly over the face of the specimen.

5.4 *Micrometers*— Suitable micrometers, reading to 0.01 in. for measuring the width, thickness, and length of the specimens.

6. Test Specimens

6.1 Test specimens for determining compressive properties of plastic lumber and shapes shall be cut from the "as manufactured" profile. Great care shall be taken in cutting and machining the ends so that smooth, flat parallel surfaces and sharp, clean edges result and are within 1/300 (0.0033) of the specimen length perpendicular to the long axis of the specimen. Plastic lumber is generally nonuniform through the cross-section; machining operations other than those required to provide flat, parallel ends shall not be carried out.

6.2 The standard test specimen, except as indicated in 6.3 to 6.4, shall be in the form of a right cylinder or prism whose height is twice its minimum width or diameter.

6.3 For rod material, the test specimen shall have a diameter equal to the diameter of the rod and whose height is twice its diameter.

6.4 When testing hollow profiles, the test specimen shall have a length equal to twice its minimum cross sectional dimension.

7. Number of Test Specimens

7.1 Five specimens shall be tested for each sample.

8. Conditioning

8.1 *Conditioning*— Condition the test specimens at 73.4 ± 3.6°F [23 ± 2°C] and 50 ± 5 % relative humidity for not less than 40 h prior to testing in accordance with Procedure A of Practice D 618, unless otherwise specified by the customer or product specification. In cases of disagreement, the tolerances shall be ±1°C and ±2 % relative humidity.

8.2 *Test Conditions*— Conduct tests in the Standard Laboratory Atmosphere of 73.4 ± 3.6°F [23 ± 2°C] and 50 ± 5 % relative humidity, unless otherwise specified by the customer or product specification. In cases of disagreement, the tolerances shall be ±1.8°F [±1°C] and ±2 % relative humidity.

9. Speed of Testing

9.1 Speed of testing shall be the relative rate of motion of the compression platens during the test. Rate of motion of the driven platen when the machine is running idle may be used if it can be shown that the resulting speed of testing is within the limits of variation allowed.

9.2 The standard speed of testing shall result in a strain rate of 0.03 ± 0.003 in./in./min [mm/mm/min]. At this speed a typical compression test on plastic lumber is expected to last 1 to 5 min.

10. Procedure

10.1 Measure the width and thickness or diameter of the specimen to a precision of 1 % of the measured dimension at several points along its length. Calculate and record the minimum value of the cross-sectional area. Measure the length of the specimen at several points and record the value (see Test Methods D 5947 for additional information).

10.1.1 For test specimens which have some characteristic that does not allow for accurate measurement of the cross-sectional area in accordance with 10.1, the effective cross-sectional area as determined from Test Method D 6111 may be used.

10.2 Place the test specimen between the surfaces of the compression platens, taking care to align the center line of its long axis with the center line of the platens to ensure that the ends of the specimen are parallel with the surface of the platens. Adjust the crosshead of the testing machine until it just contacts the top of the compression platen.

10.3 If only compressive strength or stress at a given strain are desired, proceed as follows:

10.3.1 Set the speed control so that it results in a strain rate of 0.03 ± 0.003 in./in./min [mm/mm/min] and start the test.

10.3.2 Record the maximum load carried by the specimen during the test (usually this will be the load at the moment of rupture). Or, record the value of load when the specified value of strain (3 % or 0.03 in./in. [mm/mm] for plastic lumber) is reached.

10.4 If stress-strain data are desired, proceed as follows:

10.4.1 Attach the compressometer if being used.

10.4.2 Set the speed control so that it results in a strain rate of 0.03 ± 0.003 in./in./min [mm/mm/min] and start the test.

10.4.3 Record loads and corresponding compressive strain at appropriate intervals of strain or, if the test machine is equipped with an automatic recording device, record the complete load-deformation curve.

10.4.4 Continue the test until the specimen fails or the specified value of strain (3 % or 0.03 in./in. [mm/mm] for plastic lumber) is reached.

11. Calculation

11.1 *Compressive Strength*—If the specimen exhibits a compressive yield point or otherwise fractures before a 3 percent strain, calculate the compressive strength by dividing the maximum compressive load carried by the specimen during the test by the original minimum or effective cross-sectional area of the specimen. Express the result in megapascals and report to three significant figures.

11.2 *Stress at a Given Strain*—Calculate the stress at a given strain by the method referred to in 3.1.10 at a strain value of 3 % or 0.03 in./in. [mm/mm]. Express the result in megapascals and report to three significant figures.

11.3 *Modulus of Elasticity*—When a Hookean region (proportional area) exists, calculate the modulus of elasticity by drawing a tangent to the initial linear portion of the stress-strain curve, selecting any point on this straight line portion, and dividing the compressive stress represented by this point by the corresponding strain, measure from the point where the extended tangent line intersects the strain-axis. Express the result in gigapascals and report to three significant figures (See Annex A1).

11.4 *Secant Modulus*— A secant modulus shall be calculated at a strain of 0.01 in./in. [mm/mm] as shown in Annex A1.

11.5 For each series of tests, calculate to three significant figures the arithmetic mean of all values obtained and report as the "average value" for the particular property in question.

11.6 Calculate the standard deviation (estimated) as follows and report to two significant figures:

$$s = \sqrt{[(\Sigma X^2 - n\bar{X}^2)/(n-1)]} \quad (1)$$

where:

s = estimated standard deviation,
X = value of single observation,
n = number of observations, and
$\bar{X}$ = arithmetic mean of the set of observations.

12. Report

12.1 Report the following information:

12.1.1 Complete identification of the material tested, including type, source, manufacturer's code number, form, principal dimensions, and previous history,

12.1.2 Laboratory name,

12.1.3 Date of test,

12.1.4 Method of preparing test specimens,

12.1.5 Type of test specimen and dimensions,

12.1.6 Conditioning procedure used, if nonstandard conditioning has been employed,

12.1.7 Atmospheric conditions in test room, if nonstandard conditioning has been employed,

12.1.8 Number of specimens tested and direction of loading with respect to axis of extrusion,

12.1.9 Speed of testing,

12.1.10 Compressive strength (if applicable) or stress at 3 % strain, average value, and standard deviation,

12.1.11 Modulus of elasticity or secant modulus at 1 % strain, average value, standard deviation, and

12.1.12 Specimen behavior or mode of failure during the test using the schematics provided in Fig. 1.

13. Precision and Bias

13.1 Tables 1 and 2 are based on a round-robin test conducted in 2001, in accordance with Practice E 691, involving two materials tested by five laboratories. For each material, all the specimens were prepared at one source. Each "test result" was the average of five individual determinations. Each laboratory obtained one test results for each material. (**Warning—**The following explanations of *r* and *R* (13.2-13.2.3) are intended only to present a meaningful way of considering the approximate precision of these test methods. The data given in Table 1 should not be applied rigorously to the acceptance or rejection of materials, as those data are specific to the round robin and may not be representative of other lots, conditions, materials, or laboratories. Users of these test methods should apply the principles outlined in Practice E 691 to generate data specific to their laboratory and materials, or between specific laboratories. The principles of 13.2-13.2.3 would then be valid for such data.)

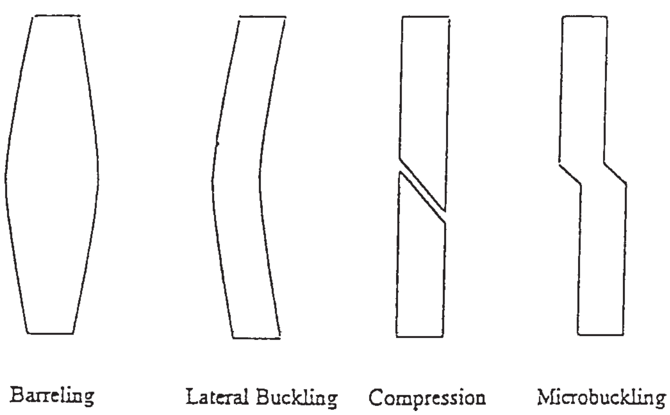

FIG. 1 Specimen Behavior or Mode of Failure

TABLE 1 Compressive Secant Modulus at 1 % Strain

Material	Mean	Values as a Percent of the Mean			
	ksi	V_r	V_R	I_r	I_R
Plastic Lumber 1	82.36	3.52 %	24.51 %	9.97 %	69.37 %
Plastic Lumber 2	100.76	7.21 %	32.38 %	20.42 %	91.62 %

V_r= Repeatability
I_r= 2.83 V_r
V_R= Reproducibility
I_R= 2.83 V_R

TABLE 2 Compressive Stress at 3 % Strain

Material	Mean	Values as a Percent of the Mean			
	psi	V_r	V_R	I_r	I_R
Material 1	1599.7	2.51 %	13.71 %	7.10 %	38.81 %
Material 2	1922.3	7.82 %	22.08 %	22.12 %	62.50 %

V_r= Repeatability
I_r= 2.83 V_r
V_R= Reproducibility
I_R= 2.83 V_R

NOTE 2—Practice E 691 for developing Precision and Bias Statement calls for using six materials and six laboratories. While only two materials and five laboratories were used in the round robin effort, the data have been analyzed and presented for use by future laboratories.

13.2 *Concept of "r" and "R" in Table 1*—If S_r and S_R have been calculated from a large enough body of data, and for test results that were averages from testing five specimens for each test result, then:

13.2.1 *Repeatability*—Two test results obtained within one laboratory shall be judged not equivalent if they differ by more than the *r* value for that material. *r* is the interval representing the critical difference between two test results for the same material, obtained by the same operator using the same equipment on the same day in the same laboratory.

13.2.2 *Reproducibility*—Two test results obtained by different laboratories shall be judged not equivalent if they differ by more than the *R* value for that material. *R* is the interval representing the critical difference between two test results for the same material, obtained by different operators using different equipment in different laboratories.

13.2.3 The judgments in 13.2.1 and 13.2.2 will have an approximately 95 % (0.95) probability of being correct.

13.3 *Bias*—No statement may be made about the bias of these test methods, as there is no standard reference material or reference test method that is applicable.

14. Keywords

14.1 compressive properties; compressive strength; modulus of elasticity; plastic lumber; plastic shapes; recycled plastic; secant modulus; stress at a given strain

ANNEX

(Mandatory Information)

A1. TOE COMPENSATION

A1.1 In a typical stress-strain curve (see Fig. A1.1) there is a toe region, *AC*, that does not represent a property of the material. It is an artifact caused by the slack, and alignment or seating of the specimen during the test. In order to obtain correct values of such parameters as modulus of elasticity, secant modulus, strain, and stress at a given strain this artifact must be compensated for to give the corrected zero point on the strain or extension axis.

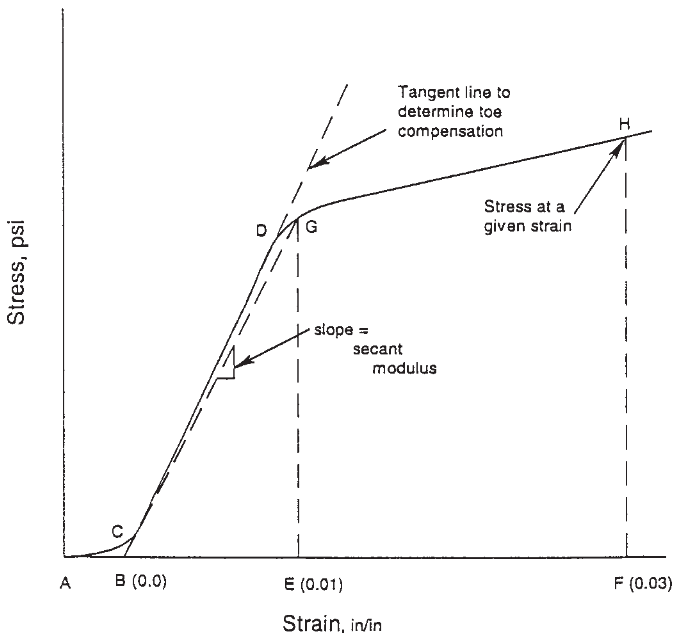

FIG. A1.1 Typical Stress-Strain for Plastic Lumber Under Compression with a Hookean Region

A1.2 In the case of a plastic lumber product (see Fig. A1.1), a continuation of the initial linear region (*CD*) of the curve is constructed through the zero-stress axis. This intersection (*B*) is the corrected zero-strain point from which all extensions or strains must be measured, including the value of strain (*BE*) at which the secant modulus is measured and the strain value (*BF*) at which the stress at 3 % strain is measured, if needed. The modulus of elasticity can be determined by dividing the stress at any point along the line *CD* (or its extension) by the strain at the same point (measured from point *B*, defined as zero-strain). The secant modulus is determined using the slope of the straight line connecting *B* and the point on the stress-strain curve corresponding to the specified strain value (1 % or 0.01 in./in. [mm/mm] for plastic lumber), that is, the slope of the line *BG*. The stress at a given strain is the value of the stress corresponding to the specified value of strain at point *F* (3 % or 0.03 in./in. [mm/mm] for plastic lumber), that is, the stress at point *H*.

SUMMARY OF CHANGES

This section identifies the location of selected changes to this test method. For the convenience of the user, Committee D20 has highlighted those changes that may impact the use of this test method. This section may also include descriptions of the changes, or reasons for the changes or both.

D 6108 - 03:

(*1*) Added Precision and Bias section.