Designation: D1621 – 16 (Reapproved 2023)

Standard Test Method for Compressive Properties of Rigid Cellular Plastics[1]

This standard is issued under the fixed designation D1621; 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 describes a procedure for determining the compressive properties of rigid cellular materials, particularly expanded plastics.

1.2 The values stated in SI units are to be regarded as the standard. The values in parentheses are for information only.

1.3 *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.*

NOTE 1—This test method and ISO 844 are technically equivalent.

1.4 *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.*

2. Referenced Documents

2.1 *ASTM Standards:*[2]

D618 Practice for Conditioning Plastics for Testing

E4 Practices for Force Calibration and Verification of Testing Machines

E83 Practice for Verification and Classification of Extensometer Systems

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

2.2 *ISO Standard:*

ISO 844 Cellular Plastics—Compression Test of Rigid Materials[3]

3. Terminology

3.1 *Definitions:*

3.1.1 *compliance*—the displacement difference between test machine drive system displacement values and actual specimen displacement.

3.1.2 *compliance correction*—an analytical method of modifying test instrument displacement values to eliminate the amount of that measurement attributed to test instrument compliance.

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

3.1.4 *compressive strain*—the dimensionless ratio of compressive deformation to the gage length of the test specimen or the change in length per unit of original length along the longitudinal axis.

3.1.5 *compressive strength*—the stress at the yield point if a yield point occurs before 10 % deformation (as in Fig. 1a) or, in the absence of such a yield point, the stress at 10 % deformation (as in Fig. 1b).

3.1.6 *compressive stress (nominal)*—the compressive load per unit area of minimum original cross section within the gage boundaries, carried by the test specimen at any given moment, expressed in force per unit area.

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

3.1.8 *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 D20.22 on Cellular Materials - Plastics and Elastomers.

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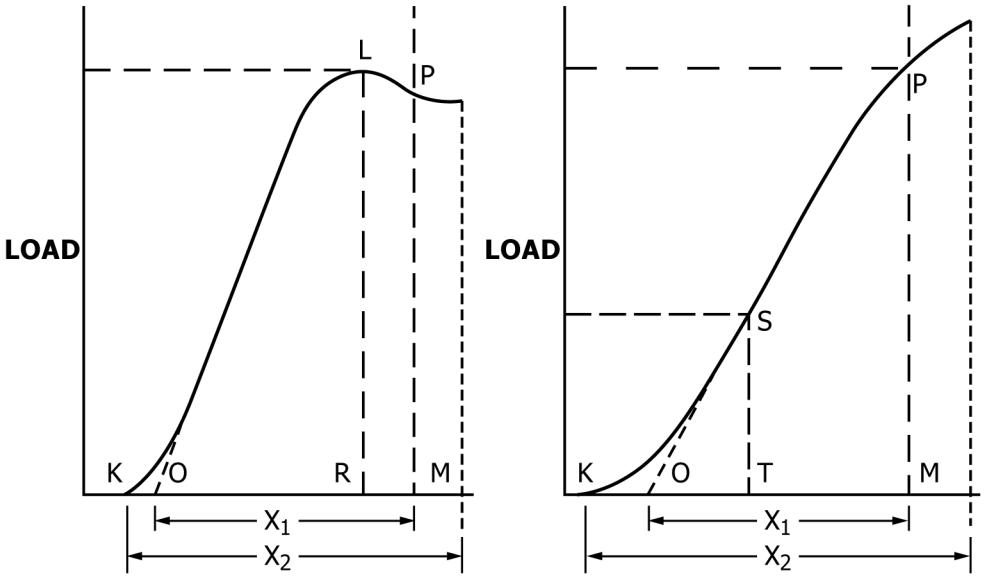
[2] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

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

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



X_1 = 10 % CORE DEFORMATION
X_2 = DEFLECTION (APPROXIMATELY 13 %)

FIG. 1 a Compressive Strength (See 3.1.5 and Section 9)

FIG. 1 b Compressive Strength (See 3.1.5 and Section 9)

3.1.9 *deflectometer*—a device used to sense the compressive deflection of the specimen by direct measurement of the distance between the compression platens.

3.1.10 *displacement*—compression platen movement after the platens contact the specimen, expressed in millimetres or inches.

3.1.11 *gage length*—the initial measured thickness of the test specimen expressed in units of length.

3.1.12 *modulus of elasticity*—the ratio of stress (nominal) to corresponding strain below the proportional limit of a material expressed in force per unit area based on the minimum initial cross-sectional area.

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

4. Significance and Use

4.1 This test method provides information regarding the behavior of cellular materials under compressive loads. Test data is obtained, and from a complete load-deformation curve it is possible to compute the compressive stress at any load (such as compressive stress at proportional-limit load or compressive strength at maximum load) and to compute the effective modulus of elasticity.

4.2 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.

4.3 Before proceeding with this test method, reference shall be made to the specification of the material being tested. Any test specimen preparation, conditioning, dimensions, or testing parameters, or a combination thereof, covered in the materials specification shall take precedence over those mentioned in this test method. If there are no material specifications, then the default conditions apply.

5. Apparatus

5.1 *Testing Machine*—A testing instrument that includes both a stationary and movable member and includes a drive system for imparting to the movable member (crosshead), a uniform, controlled velocity with respect to the stationary member (base). The testing machine shall also include the following:

5.1.1 *Load Measurement System*—A load measurement system capable of accurately recording the compressive load imparted to the test specimen. The system shall be indicate the load with an accuracy of ±1 % of the measured value or better. The accuracy of the load measurement system shall be verified in accordance with Practices E4.

5.2 *Compression Platens*—Two flat plates, one attached to the stationary base of the testing instrument and the other attached to the moving crosshead to deliver the load to the test specimen. These plates shall be larger than the specimen loading surface to ensure that the specimen loading is uniform. It is recommended that one platen incorporate a spherical seating mechanism to compensate for non-parallelism in the specimen's loading surfaces or non-parallelism in the base and crosshead of the testing instrument.

5.3 *Displacement Measurement System*—A displacement measurement system capable of accurately recording the compressive deformation of the test specimen during testing to an

accuracy of ±1 % of the measured value or better. This measurement is made through use of the test machine crosshead drive system or using a direct measurement of compression platen displacement.

5.3.1 *Direct Compression Platen Displacement*—This system shall employ a deflectometer that directly reads the distant between the upper and lower compression platens. The accuracy of the displacement measurement transducer shall be verified in accordance with Practices E83 and shall be classified as a Class C or better.

5.3.2 *Test Machine Crosshead Drive System*—This system shall employ the position output from the crosshead drive system as a indicator of compression platen displacement. This method is only appropriate when it is demonstrated that the effects of drive system compliance result in displacement errors of less than 1 % of the measurement or if appropriate compliance correction methods are employed to reduce the measurement error to less than 1 %.

5.3.2.1 *Determining Drive System Compliance*—Testing instrument drive systems always exhibit a certain level of compliance that is characterized by a variance between the reported crosshead displacement and the displacement actually imparted to the specimen. This variance is a function of load frame stiffness, drive system wind-up, load cell compliance and fixture compliance. This compliance can be measured then, if determined to be significant and empirically subtracted from test data to improve test accuracy. The procedure to determine compliance follows:

(1) Configure the test system to match the actual test configuration.

(2) Position the two compression platens very close to each other simulating a zero thickness specimen in place.

(3) Start the crosshead moving at 12.5 mm (0.5 in.)/min in the compression direction recording crosshead displacement and the corresponding load values.

(4) Increase load to a point exceeding the highest load expected during specimen testing. Stop the crosshead and return to the pre-test location.

(5) The recorded load-deflection curve, starting when the compression platens contact one another, is defined as test system compliance

5.3.2.2 *Performing Compliance Correction*—Using the load-deflection curve created in 5.3.2.1, measure the system compliance at each given load value. On each specimen test curve at each given load value, subtract the system compliance from each recorded displacement value. This will be the new load-deflection curve for use in calculations starting in Section 9.

5.4 *Micrometer Dial Gauge,* caliper, or steel rule, suitable for measuring dimensions of the specimens to ±1 % of the measured values.

6. Test Specimen

6.1 The test specimen shall be square or circular in cross section with a minimum of 25.8 cm^2 (4 $in.^2$) and maximum of 232 cm^2 (36 $in.^2$) in area. The minimum height shall be 25.4 mm (1 in.) and the maximum height shall be no greater than the width or diameter of the specimen. Care should be taken so that the loaded ends of the specimen are parallel to each other and perpendicular to the sides.

NOTE 2—Cellular plastics are not ideal materials, and the compressive modulus may appear significantly different, depending on the test conditions, particularly the test thickness. All data that are to be compared should be obtained using common test conditions.

6.2 All surfaces of the specimen shall be free from large visible flaws or imperfections.

6.3 If the material is suspected to be anisotropic, the direction of the compressive loading must be specified relative to the suspected direction of anisotropy.

6.4 A minimum of five specimens shall be tested for each sample. Specimens that fail at some obvious flaw should be discarded and retests made, unless such flaws constitute a variable the effect of which it is desired to study.

7. Conditioning

7.1 *Conditioning*—Condition the test specimens at 23 ± 2°C (73.4 ± 3.6°F) and 50 ± 10 % relative humidity for not less than 40 h prior to test in accordance with Procedure A of Practice D618, unless otherwise specified in the contract or relevant material specification. In cases of disagreement, the tolerances shall be ±1°C (±1.8°F) and ±5 % relative humidity.

7.2 *Test Conditions*—Conduct tests in the standard laboratory atmosphere of 23 ± 2°C (73.4 ± 3.6°F) and 50 ± 10 % relative humidity, unless otherwise specified. In cases of disagreement, the tolerances shall be ±1°C (±1.8°F) and ±5 % relative humidity.

8. Procedure

8.1 Measure the dimensions of the specimen to a precision of ±1 % of the measurement as follows:

8.1.1 Thicknesses up to and including 25.4 mm (1 in.) shall be measured using a dial-type gauge having a foot with minimum area of 6.45 cm^2 (1 $in.^2$). Hold the pressure of the dial foot to 0.17 ± 0.03 kPa (0.025 ± 0.005 psi).

8.1.2 Measure dimensions over 25.4 mm (1 in.) with a dial gauge, a sliding-caliper gauge, or a steel scale. When a sliding-caliper gauge is employed, the proper setting shall be that point at which the measuring faces of the gauge contact the surfaces of the specimen without compressing them.

8.1.3 Record each dimension as an average of three measurements.

8.2 Place the specimen between the compression platens ensuring that the specimen center-line is aligned with the center-line of the compression platens and the load will be distributed as uniformly as possible over the entire loading surface of the specimen. It will expedite the testing process if, when the specimen is in place, the upper platen is positioned close to, but not touching, the specimen.

8.2.1 If following 5.3.2.1, attach the deflectometer or compression extensometer to the compression platens.

8.3 Start the crosshead moving in the direction to compress the specimen with a rate of crosshead displacement equal to 10 % of the sample thickness per minute ±0.25 mm (±0.01 in.)/min.

8.4 Record compression platen displacement and the corresponding load data. This recorded curve will be used directly if following 5.3.2.1 or could be modified following 5.3.2.2.

8.5 Continue until a yield point is reached or until the specimen has been compressed approximately 13 % of its original thickness, whichever occurs first.

8.5.1 When specified, a deformation other than 10 % may be used as the point at which stress shall be calculated. In such a case, compress the specimen approximately 3 % more than the deformation specified. Substitute the specified deformation wherever "10 % deformation" is cited in Sections 9 and 10.

9. Calculation

9.1 Using a straightedge or through the use of computer software, carefully extend to the zero load line the steepest straight portion of the load-deflection curve examining only the lower portion of the load-deflection curve. This establishes the "zero deformation" or "zero strain" point (Point *O* in Fig. 1a and Fig. 1b). Measure all distances for deformation or strain calculations from this point.

9.2 Measure from Point *O* along the zero-load line a distance representing 10 % specimen deformation. At that point (Point *M* in Fig. 1a and Fig. 1b), draw a vertical line intersecting the load-deflection or load-strain curve at Point *P*.

9.2.1 If there is no yield point before Point *P* (as in Fig. 1b), read the load at Point *P*.

9.2.2 If there is a yield point before Point *P* (as Point *L* in Fig. 1), read the load and measure the percent core deformation or strain (Distance *O-R*) at the yield point.

9.2.3 Calculate the compressive strength by dividing the load (9.2.1 or 9.2.2) by the initial horizontal cross-sectional area of the specimen.

9.3 If compressive modulus is requested, choose any convenient point (such as Point *S* in Fig. 1b) along the steepest straight line portion of the load-deflection or load-strain curve. Read the load and measure the deformation or strain (Distance *O-T*) at that point.

9.3.1 Calculate the apparent modulus as follows:

$$E_c = WH/AD \quad (1)$$

where:

E_c = modulus of elasticity in compression, Pa (psi),
W = load, N (lbf),
H = initial specimen height, m (in.),
A = initial horizontal cross-sectional area, m^2 ($in.^2$), and
D = deformation, m (in.).

9.3.2 Calculate the estimated standard deviation as follows:

$$s = \sqrt{\left(\sum x^2 - n\bar{X}^2\right)/(n-1)} \quad (2)$$

where:

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

10. Report

10.1 Report the following information:

TABLE 1 Precision Data

Materials	Average, psi	S_r [A]	S_R [B]	r [C]	R [D]
A	13.6307	1.1491	1.6078	3.2174	4.5019
B	31.3183	1.0944	1.1213	3.0642	3.1398
C	10.3981	0.9796	1.0764	2.7430	3.0141

[A] S_r = within-laboratory standard deviation for the indicated material. It is obtained by pooling the within-laboratory standard deviations of the test results from all of the participating laboratories.
[B] S_R = between-laboratories reproducibility, expressed as standard deviation.
[C] r = within-laboratory critical interval between two test results = 2.8 × S_r.
[D] R = between-laboratories critical interval between two test results = 2.8 × S_R.

10.1.1 Complete identification of the material tested, including type, source, code numbers, form, principal dimensions, previous history, and so forth.

10.1.2 Number of specimens tested if different from that specified in 6.4.

10.1.3 Conditioning procedure used if different from that specified in Section 7.

10.1.4 Atmospheric conditions in test room if different from those specified in Section 7.

10.1.5 Values for each specimen, plus averages and standard deviations, of modulus (if requested) and compressive strength.

10.1.6 Deformation at maximum load to two significant figures.

10.1.7 Date of test.

11. Precision and Bias

11.1 Table 1 is based on a round robin[4] conducted in 1998 in accordance with Practice E691, involving three materials tested by seven laboratories. For each material, all of the samples were prepared at one source, but the individual specimens were prepared at the laboratories that tested them. Each test result was the average of seven individual determinations. Each laboratory obtained six test results for each material. Precision, characterized by repeatability (S_r and r) and reproducibility (S_R and R) has been determined as shown in Table 1. (**Warning—**The explanation of r and R are only intended to present a meaningful way of considering the approximate precision of this test method. The data in Table 1 should not be applied to acceptance or rejection of materials, as these data apply only to the materials tested in the round robin and are unlikely to be rigorously representative of other lots, formulations, conditions, materials, or laboratories. Users of this test method should apply the principles outlined in Practice E691 to generate data specific to their materials and laboratory.)

NOTE 3—The precision data presented in Table 1 was obtained using the test conditions defined in this test method. If a material specification defines other test conditions, this precision data shall not be assumed to apply.

12. Keywords

12.1 cellular plastics; compressive modulus; compressive strength

[4] Supporting data are available from ASTM Headquarters. Request RR:D20-1201.