Standard Test Method for Flexural Strength of Manufactured Carbon and Graphite Articles Using Four-Point Loading at Room Temperature[1]

This standard is issued under the fixed designation C 651; 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 Department of Defense.

1. Scope

1.1 This test method covers determination of the flexural strength of manufactured carbon and graphite articles using a simple beam in four-point loading at room temperature.

1.2 The values stated in inch-pound units are to be regarded as the standard. The values given 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 and health practices and determine the applicability of regulatory limitations prior to use.*

2. Referenced Documents

2.1 *ASTM Standards:*

C 78 Test Method for Flexural Strength of Concrete (Using Simple Beam with Third-Point Loading)[2]

C 709 Terminology Relating to Manufactured Carbon and Graphite[3]

E 4 Practices for Force Verification of Testing Machines[4]

E 177 Practice for Use of the Terms Precision and Bias in ASTM Test Methods[5]

E 691 Practice for Conducting an Interlaboratory Study to Determine the Precision of a Test Method[5]

3. Terminology

3.1 *Definitions of Terms Specific to This Standard:*

3.1.1 *flexural strength*—a measure of the ultimate load-carrying capacity of a specified beam in bending.

3.2 *Definitions*— For definitions of terms relating to manufactured carbon and graphite, see Terminology C 709.

4. Apparatus

4.1 The testing machine shall conform to the requirements of Practices E 4.

4.2 The four-point loading fixture shall consist of bearing blocks which ensure that forces applied to the beam are normal only and without eccentricity. (See Test Method C 78.)

4.2.1 The bearing block diameter shall be between 1/10 and 1/20 of the specimen support span. A hardened steel bearing block or its equivalent is necessary to prevent distortion of the loading member.

4.3 The directions of loads and reactions may be maintained parallel by judicious use of linkages, rocker bearings, and flexure plates. Eccentricity of loading can be avoided by the use of spherical bearings. Provision must be made in fixture design for relief of torsional loading to less than 5 % of the nominal specimen strength. Refer to the attached figure for a suggested four-point loading fixture.

5. Test Specimen

5.1 *Preparation*—The test specimen shall be prepared to yield a parallelepiped of rectangular cross section. The faces shall be parallel and flat within 0.001 in. (0.025 mm)/in. of length. In addition, the samples having a maximum particle size less than 0.006-in. (0.152-mm) diameter must be finished so that the surface roughness is less than 125 µin. AA. Sample edges should be free from visible flaws and chips.

5.2 *Size*—The size of the test specimen shall be selected such that the minimum dimension of the specimen is greater than 5 times the largest particle dimension. The test specimen shall have a length to thickness ratio of at least 8, and a width to thickness ratio not greater than 2.

5.3 *Measurements*—All dimensions shall be measured to the nearest 0.5 %.

5.4 *Orientation*—The specimen shall be marked on the end to denote its orientation with respect to the parent stock.

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[1] This test method is under the jurisdiction of ASTM Committee D02 on Petroleum Products and Lubricants and is the direct responsibility of Subcommittee D02.F on Manufactured Carbon and Graphite Products.

Current edition approved June 15, 1991. Published December 1991. Originally published as C 651 – 70. Last previous edition D 651 – 70 (1989).

[2] *Annual Book of ASTM Standards*, Vol 04.02.

[3] *Annual Book of ASTM Standards*, Vol 05.05.

[4] *Annual Book of ASTM Standards*, Vol 03.01.

[5] *Annual Book of ASTM Standards*, Vol 14.02.

5.5 *Drying*—Each specimen must be dried in a vented oven at 120 to 150°C for a period of 2 h. The sample must then be cooled to room temperature in a desiccator and held there prior to testing.

6. Procedure

6.1 Center the load applying bearing surfaces and the test specimen on the bearing blocks. The load span is at least two times the sample thickness, and the support span three times the load span, but not less than 1½ in. (38.1 mm). Overlap each end of the specimen by at least the specimen thickness. Refer to Fig. 1.

6.2 The load applying bearing surfaces shall make contact with the upper surface of the test specimen. Load and support bearing blocks must be parallel to each other and perpendicular to the test surfaces. Use a loading rate of 0.05 in. (1.27 mm)/min or less on screw-driven testing machines. On other test devices load the part at a uniform rate such that breakage occurs in 5 s or more.

7. Test Data Record

7.1 Measurements to 0.001 in. (0.025 mm) shall be made to determine the average width and thickness of the specimen at the section of failure.

7.2 The load at failure must be recorded to an accuracy of ±2 % of the full-scale value. A full-scale value of 1000 lb (454 kg) would require recording to an accuracy of ±20 lb (±9.08 kg).

8. Calculation

8.1 If the fracture occurs within the span length between the load bearing surfaces, calculate the flexural strength as follows:

$$S = PL / bd^2$$

where:

S = flexural strength, psi (MPa),
P = maximum applied load indicated by the testing machine, lb (kg),
L = support span length, in. (mm),
b = average width of specimen, in. (mm), and
d = average thickness of specimen, in. (mm).

8.2 If the fracture occurs outside of the span length between load bearing blocks, the results of the test shall be discarded but reported. If fracture occurs in less than 5 s, the results shall be discarded but reported.

8.3 A multiplying factor of 6.895 may be used to convert psi to MPa.

9. Report

9.1 The report of each test shall include the following:

9.1.1 Sample identification,

9.1.2 Average width to the nearest 0.001 in. (0.025 mm),

9.1.3 Average thickness to the nearest 0.001 in. (0.025 mm).

9.1.4 Span length, in. (mm),

9.1.5 Rate of loading, (in./min or ppm),

9.1.6 Maximum applied load, lb (kg),

9.1.7 Flexural strength calculated to the nearest 10 psi (5 MPa),

9.1.8 Defects in specimen,

9.1.9 Orientation and location of specimen, and

9.1.10 Failure mode and location.

10. Precision and Bias [6]

10.1 *Precision*—The precision statements given in this section are based on the comparison of the mean strength by the Student "t" test and carrying out the statistical analysis of the data obtained in a round robin as recommended by Practice E 691.

10.1.1 *Comparison of the Means*—The comparison of the means by the Student "t" test leads to the conclusion that the average strength values measured by each laboratory can be considered statistically equal to 95 percent confidence level.

10.1.2 *Repeatability (Single Instrument)*— The precision within laboratory of two single values of measured strength using Practice E 177 definition with the pooled standard deviation calculated using Practice E 691 is:

$$\text{Repeatability within laboratory} = 2\,(S_r)_j,$$

[6] Supporting data are available from ASTM International Headquarters. Request Research Report RR:C05-1011.

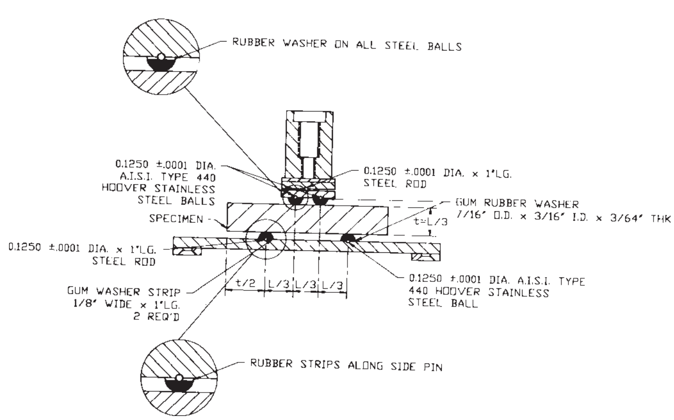

FIG. 1 Beam with Four-Point Loading

which yields a value for the material used in the round robin of 257 psi (1.8 MPa). This value converts into a strength percentage of ±5.5.

10.1.3 *Repeatability (Multi-Instrument)*— The precision between laboratories of two single values of measured strength using Practice E 177 definition with the component of variance between laboratories calculated using Practice E 691 is:

$$\text{Repeatability between laboratories} = 2\,(S_L)_j,$$

which yields a value for the material used in this round robin of 46 psi (0.5 MPa). This converts into a strength percentage of ±1.

10.2 *Bias*—No true statement on bias can be made because no reference carbon or graphite material exists.

11. Keywords

11.1 carbon; flexural strength; graphite; modulus of rupture