Designation: D7972 – 14

An American National Standard

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

This standard is issued under the fixed designation D7972; 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 determination of the flexural strength of manufactured carbon and graphite articles using a square, rectangular or cylindrical beam in three-point loading at room temperature.

1.2 The values stated in SI units are to be regarded as standard. No other units of measurement are included in this standard.

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:*[2]

C78 Test Method for Flexural Strength of Concrete (Using Simple Beam with Third-Point Loading)

C559 Test Method for Bulk Density by Physical Measurements of Manufactured Carbon and Graphite Articles

C1161 Test Method for Flexural Strength of Advanced Ceramics at Ambient Temperature

C1239 Practice for Reporting Uniaxial Strength Data and Estimating Weibull Distribution Parameters for Advanced Ceramics

C1322 Practice for Fractography and Characterization of Fracture Origins in Advanced Ceramics

D7775 Guide for Measurements on Small Graphite Specimens

E4 Practices for Force Verification of Testing Machines

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

3. Terminology

3.1 *Definitions:*

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

3.1.2 *grain—in manufactured (synthetic) carbon and graphite*, particle of filler material (usually coke or graphite) in the starting mix formulation. Also referred to as granular material, filler particle, or aggregate material.

4. Significance and Use

4.1 This test method provides a framework for material development, quality control, characterization, and design data generation purposes. The user needs to assess the applicability of the method on the specific material and for the intended use, as shown by the interlaboratory study.

4.2 This test method determines the maximum loading on a graphite specimen with simple beam geometry in three–point bending, and it provides a means for the calculation of flexural strength at ambient temperature and environmental conditions.

4.3 The flexure stress is computed based on simple beam theory with assumptions that the material is isotropic and homogeneous, the moduli of elasticity in tension and compression are identical, and the material is linearly elastic. For materials with large grains, the minimum specimen dimension should be significantly larger than the maximum grain size (see Guide D7775).

4.4 Flexural strength of a group of test specimens is influenced by several parameters associated with the test procedure. Such factors include the loading rate, test environment, specimen size, specimen preparation, and test fixtures. Specimen sizes and fixtures should be chosen to reduce errors due to material variability or testing parameters, such as friction and non-parallelism of specimen surfaces.

4.5 The flexural strength of a manufactured graphite or carbon material is dependent on both its inherent resistance to fracture and the size and severity of flaws. Variations in these cause a natural scatter in test results for a sample of test specimens. Fractographic analysis of fracture surfaces, although beyond the scope of this standard, is highly recommended for all purposes, especially if the data will be used for design as discussed in Practices C1239 and C1322.

[1] This test method is under the jurisdiction of ASTM Committee D02 on Petroleum Products, Liquid Fuels, and Lubricants and is the direct responsibility of Subcommittee D02.F0 on Manufactured Carbon and Graphite Products.

Current edition approved Dec. 1, 2014. Published February 2015. DOI: 10.1520/D7972-14.

[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.

4.6 The three-point test configuration exposes only a very small portion of the specimen to the maximum stress. Therefore, three-point flexural strengths are likely to be much greater than four-point flexural strengths. Three-point flexure has some advantages. It uses simpler test fixtures, allowing small specimen testing and fracture toughness measurements. However, four-point flexure is preferred and recommended for most characterization purposes.

5. Apparatus

5.1 *Loading*—Specimens may be loaded in any suitable testing machine provided that uniform rates of loading can be maintained. The testing machine shall be equipped with a means for retaining read-out of the maximum force applied to the specimen. The accuracy of the testing machine shall be in accordance with Practice E4.

5.2 *Fixture*—The three-point loading fixture shall consist of bearing blocks or cylindrical bearings spaced in a three-point loading configuration (see Test Method C1161). A hardened steel bearing block or its equivalent is necessary to prevent distortion of the loading member.

5.2.1 The fixture shall ensure that forces applied to the beam are normal only and without eccentricity through the use of spherical bearing blocks (see Test Method C78) or articulating roller bearing assemblies (see 5.3 and Test Method C1161).

5.2.2 The cylindrical bearing length shall be such that the test specimen width is fully supported, and the cylindrical bearing diameter shall be 0.75 to 1.5 times the specimen thickness/diameter.

5.2.3 The lower support bearings shall be free to rotate in order to relieve frictional constraints. The middle load bearing of the three-point fixture need not rotate. The three bearings shall be parallel over their length. The load application bearing (upper bearing) shall be centered with respect to the two lower support bearings within ±0.10 mm.

5.3 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 bearing blocks or articulating roller bearings.

5.3.1 *Semi-articulated Three-point Fixture*—Specimens prepared in accordance with the parallelism requirements of 6.1 may be tested in a semi-articulated fixture. The middle bearing shall be fixed and not free to roll. The two outer bearings shall be parallel to each other over their length. The two outer bearings shall articulate together as a pair to match the specimen surface, or the middle bearing shall articulate to match the specimen surface. All three bearings shall rest uniformly and evenly across the specimen surface. The fixture shall be designed to apply equal load to the two outer bearings.

5.3.2 *Fully-articulated Three-point Fixture*—Specimens that do not meet the parallelism requirements of 6.1 shall be tested in a fully-articulated fixture. Well-machined specimens may also be tested in a fully-articulating fixture. The two support (outer) bearings shall be free to roll outwards. The middle bearing shall not roll. Any two of the bearings shall be capable of articulating to match the specimen surface. All three bearings shall rest uniformly and evenly across the specimen surface. The fixture shall be designed to apply equal load to the two outer bearings.

TABLE 1 Specimen Sizes and Testing Configurations in the Interlaboratory Study

Configuration	Nominal Specimen Size (mm)	Specimen Thickness, d (mm)	Support Span, L (mm)	Crosshead Speed, mm/s (mm/m)
I	10 × 10 × 64	10	50.00	0.0042 (0.25)
II	9.5 × 4.8 × 64	4.8	50.00	0.0087 (0.52)
III	Ø10 × 64	10	50.00	0.0042 (0.25)
IV	25 × 25 × 150	25	100.00	0.0067 (0.40)
V	Ø25 × 150	25	100.00	0.0067 (0.40)

6. Test Specimen

6.1 *Specimen Size*—The size and geometry of the test specimens used in this interlaboratory study are shown in Table 1. It is recommended that the size of the test specimen is selected such that the minimum dimension of the specimen is greater than 5 times the largest particle dimension. It is recommended that the test specimen has a length to thickness/diameter ratio of at least 6, and a width to thickness ratio not greater than 2.

6.1.1 For test specimens that do not meet this ratio for strength testing, see Ref (**1**)[3] and Guide D7775.

6.2 *Preparation*—The test specimen shall be prepared to yield a parallelepiped of square or rectangular cross section or a cylinder. The faces of the parallelepiped specimens shall be parallel and flat within 0.025 mm/mm. In addition, the samples having a maximum particle size less than 0.15 mm in diameter must be finished so that the surface roughness is less than 3 µm Ra. Sample edges should be free from visible flaws and chips.

NOTE 1—For ease of machining to conventional standards, 3 µm Ra is equivalent to 125 µin. AA. For finishing of specimens with maximum particle sizes of greater than 0.150 mm, grain structure and porosity can limit the accurate measurement of roughness. In these cases, the surface roughness should be visually equivalent to 3 µm Ra as estimated based on the visible surface of the graphite.

NOTE 2—Surface preparation of test specimens can introduce machining microcracks which may have a pronounced effect on flexural strength. Machining damage imposed during specimen preparation can be either a random interfering factor, or an inherent part of the strength characteristic to be measured. With proper care and good machining practice, it is possible to obtain fractures during strength testing from the material's natural flaws. Surface preparation can also lead to residual stresses. Universal or standardized test methods of surface preparation do not exist. It should be understood that final machining steps may or may not negate machining damage introduced during the early course or intermediate machining.

6.3 *Measurements*—All dimensions shall be measured to an accuracy of 0.5 % (see Test Method C559).

6.4 *Orientation*—The specimen shall be marked or otherwise identified to denote its orientation with respect to the parent stock.

[3] The boldface numbers in parentheses refer to the list of references at the end of this standard.