



Designation: C1211 – 18 (Reapproved 2023)

Standard Test Method for Flexural Strength of Advanced Ceramics at Elevated Temperatures¹

This standard is issued under the fixed designation C1211; 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 advanced ceramics at elevated temperatures.² Four-point- $\frac{1}{4}$ -point and three-point loadings with prescribed spans are the standard as shown in Fig. 1. Rectangular specimens of prescribed cross-section are used with specified features in prescribed specimen-fixture combinations. Test specimens may be 3 by 4 by 45 to 50 mm in size that are tested on 40-mm outer span four-point or three-point fixtures. Alternatively, test specimens and fixture spans half or twice these sizes may be used. The test method permits testing of machined or as-fired test specimens. Several options for machining preparation are included: application matched machining, customary procedures, or a specified standard procedure. This test method describes the apparatus, specimen requirements, test procedure, calculations, and reporting requirements. The test method is applicable to monolithic or particulate- or whisker-reinforced ceramics. It may also be used for glasses. It is not applicable to continuous fiber-reinforced ceramic composites.

1.2 The values stated in SI 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, health, and environmental practices and determine the applicability of regulatory limitations prior to use.*

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.*

¹ This test method is under the jurisdiction of ASTM Committee C28 on Advanced Ceramics and is the direct responsibility of Subcommittee C28.01 on Mechanical Properties and Performance.

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² Elevated temperatures typically denote, but are not restricted to, 200 to 1600 °C.

2. Referenced Documents

2.1 ASTM Standards:³

- 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
- C1341 Test Method for Flexural Properties of Continuous Fiber-Reinforced Advanced Ceramic Composites
- C1368 Test Method for Determination of Slow Crack Growth Parameters of Advanced Ceramics by Constant Stress Rate Strength Testing at Ambient Temperature
- C1465 Test Method for Determination of Slow Crack Growth Parameters of Advanced Ceramics by Constant Stress-Rate Flexural Testing at Elevated Temperatures
- E4 Practices for Force Calibration and Verification of Testing Machines
- E220 Test Method for Calibration of Thermocouples By Comparison Techniques
- E230 Specification for Temperature-Electromotive Force (emf) Tables for Standardized Thermocouples

3. Terminology

3.1 Definitions:

3.1.1 *complete gage section, n*—the portion of the specimen between the two outer bearings in four-point flexure and three-point flexure fixtures.

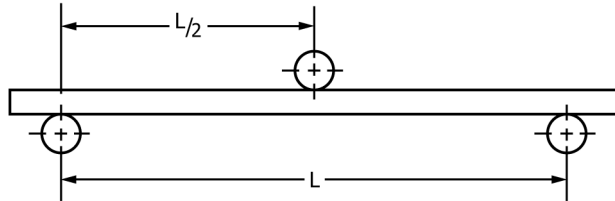
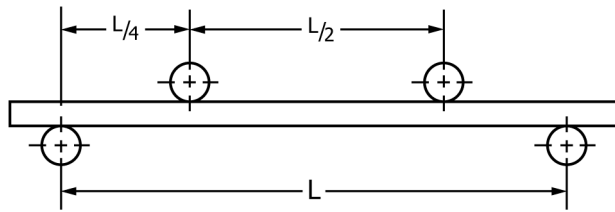
NOTE 1—In this standard, the complete four-point flexure gage section is twice the size of the inner gage section. Weibull statistical analyses, in this instance, only include portions of the specimen volume or surface which experience tensile stresses.

3.1.2 *flexural strength, $[FL^{-2}]$, n*—a measure of the ultimate strength of a specified beam in bending.

3.1.3 *four-point- $\frac{1}{4}$ -point flexure, n*—a configuration of flexural strength testing in which a specimen is symmetrically

³ 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.

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



NOTE 1—Configuration:

A: $L = 20$ mm

B: $L = 40$ mm

C: $L = 80$ mm

FIG. 1 Four-Point- $\frac{1}{4}$ -Point and Three-Point Fixture Configurations

loaded at two locations that are situated at one-quarter of the overall span, away from the outer two support bearings (see Fig. 1).

3.1.4 *fully articulating fixture, n* —a flexure fixture designed to be used either with flat and parallel specimens or with uneven or nonparallel specimens. The fixture allows full independent articulation, or pivoting, of all rollers about the specimen long axis to match the specimen surface. In addition, the upper or lower pairs are free to pivot to distribute force evenly to the bearing cylinders on either side.

NOTE 2—See Annex A1 for schematic illustrations of the required pivoting movements.

NOTE 3—A three-point fixture has the inner pair of bearing cylinders replaced by a single bearing cylinder.

3.1.5 *inert flexural strength, $[FL^{-2}]$, n* —a measure of the strength of a specified beam specimen in bending as determined in an appropriate inert condition whereby no slow crack growth occurs.

3.1.6 *inherent flexural strength, $[FL^{-2}]$, n* —the flexural strength of a material in the absence of any effect of surface grinding or other surface finishing process, or of extraneous damage that may be present. The measured inherent strength is in general a function of the flexure test method, test conditions, and test specimen size.

3.1.7 *inner gage section, n* —the portion of the specimen between the inner two bearings in a four-point flexure fixture.

3.1.8 *semi-articulating fixture, n* —a flexure fixture designed to be used with flat and parallel specimens. The fixture allows some articulation, or pivoting, to ensure the top pair (or bottom pair) of bearing cylinders pivot together about an axis parallel to the specimen long axis, in order to match the specimen

surfaces. In addition, the upper or lower pairs are free to pivot to distribute force evenly to the bearing cylinders on either side.

NOTE 4—See Annex A1 for schematic illustrations of the required pivoting movements.

NOTE 5—A three-point fixture has the inner pair of bearing cylinders replaced by a single bearing cylinder.

3.1.9 *slow crack growth (SCG), n* —subcritical crack growth (extension) which may result from, but is not restricted to, such mechanisms as environmentally assisted stress corrosion or diffusive crack growth.

3.1.10 *three-point flexure, n* —a configuration of flexural strength testing in which a specimen is loaded at a position midway between two support bearings (see Fig. 1).

4. Significance and Use

4.1 This test method may be used for material development, quality control, characterization, and design data generation purposes. This test method is intended to be used with ceramics whose flexural strength is ~ 50 MPa (~ 7 ksi) or greater.

4.2 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. The average grain size should be no greater than $\frac{1}{50}$ of the beam thickness. The homogeneity and isotropy assumptions in the test method rule out the use of it for continuous fiber-reinforced composites for which Test Method C1341 is more appropriate.

4.3 The flexural strength of a group of test specimens is influenced by several parameters associated with the test procedure. Such factors include the testing rate, test environment, specimen size, specimen preparation, and test fixtures. Specimen and fixture sizes were chosen to provide a balance between the practical configurations and resulting errors as discussed in Test Method C1161, and Refs (1-3).⁴ Specific fixture and specimen configurations were designated in order to permit the ready comparison of data without the need for Weibull size scaling.

4.4 The flexural strength of a ceramic 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 test method, is highly recommended for all purposes, especially if the data will be used for design as discussed in Ref (4) and Practices C1322 and C1239.

4.5 This method determines the flexural strength at elevated temperature and ambient environmental conditions at a nominal, moderately fast testing rate. The flexural strength under these conditions may or may not necessarily be the inert flexural strength. Flexure strength at elevated temperature may be strongly dependent on testing rate, a consequence of creep, stress corrosion, or slow crack growth. If the purpose of the test

⁴ The boldface numbers in parentheses refer to the list of references at the end of the text.