Designation: C 1358 – 96 (Reapproved 2000)

Standard Test Method for Monotonic Compressive Strength Testing of Continuous Fiber-Reinforced Advanced Ceramics with Solid Rectangular Cross-Section Specimens at Ambient Temperatures[1]

This standard is issued under the fixed designation C 1358; 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 compressive strength including stress-strain behavior under monotonic uniaxial loading of continuous fiber-reinforced advanced ceramics at ambient temperatures. This test method addresses, but is not restricted to, various suggested test specimen geometries as listed in the appendix. In addition, specimen fabrication methods, testing modes (load, displacement, or strain control), testing rates (load rate, stress rate, displacement rate, or strain rate), allowable bending, and data collection and reporting procedures are addressed. Compressive strength as used in this test method refers to the compressive strength obtained under monotonic uniaxial loading where monotonic refers to a continuous nonstop test rate with no reversals from test initiation to final fracture.

1.2 This test method applies primarily to advanced ceramic matrix composites with continuous fiber reinforcement: unidirectional (1–D), bi-directional (2–D), and tri-directional (3–D) or other multi-directional reinforcements. In addition, this test method may also be used with glass (amorphous) matrix composites with 1–D, 2–D, 3–D, and other multidirectional continuous fiber reinforcements. This test method does not directly address discontinuous fiber-reinforced, whisker-reinforced, or particulate-reinforced ceramics, although the test methods detailed here may be equally applicable to these composites.

1.3 The values stated in SI units are to be regarded as the standard and are in accordance with Practice E 380.

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.* Refer to Section 7 for specific precautions.

2. Referenced Documents

2.1 *ASTM Standards:*

C 1145 Terminology of Advanced Ceramics[2]

D 695M Test Method for Compressive Properties of Rigid Plastics [Metric][3]

D 3379 Test Method for Tensile Strength and Young's Modulus for High-Modulus Single-Filament Materials[4]

D 3410/D 3410M Test Method for Compressive Properties of Polymer Matrix Composite Materials With Unsupported Gage Section by Shear Loading[4]

D 3479 Test Methods for Tension-Tension Fatigue of Oriented Fiber, Resin Matrix Composites[4]

D 3878 Terminology of High Modulus Reinforcing Fibers and Their Composites[4]

E 4 Practices for Force Verification of Testing Machines[5]

E 6 Terminology Relating to Methods of Mechanical Testing[5]

E 83 Practice for Verification and Classification of Extensometers[5]

E 337 Test Method for Measuring Humidity with Psychometer (the Measurement of Wet-and Dry-Bulb Temperatures)[6]

E 380 Practice for Use of International System of Units (SI) (the Modernized Metric System)[6]

E 1012 Practice for Verification of Specimen Alignment Under Tensile Loading[4]

3. Terminology

3.1 *Definitions:*

3.1.1 The definitions of terms relating to compressive testing, advanced ceramics, and fiber-reinforced composites, appearing in Terminology E 6, Test Method D 695M, Practice E 1012, Terminology C 1145, Test Method D 3410, and Terminology D 3878 apply to the terms used in this test method.

[1] This test method is under the jurisdiction of ASTM Committee C–28 on Advanced Ceramics and is the direct responsibility of Subcommittee C28.07 on Ceramic Matrix Composites.

Current edition approved Dec. 10, 1996. Published December 1997.

[2] *Annual Book of ASTM Standards*, Vol 15.01.
[3] *Annual Book of ASTM Standards*, Vol 08.01.
[4] *Annual Book of ASTM Standards*, Vol 15.03.
[5] *Annual Book of ASTM Standards*, Vol 03.01.
[6] *Annual Book of ASTM Standards*, Vols 07.02, 11.03, and 15.09.

Pertinent definitions are shown as follows with the appropriate source given in parentheses. Additional terms used in conjunction with this test method are defined in 3.2.

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *advanced ceramic*, *n*—a highly engineered, high-performance predominantly non-metallic, inorganic, ceramic material having specific functional attributes. (See Terminology C 1145.)

3.2.2 *axial strain* [LL^{-1}], *n*—the average longitudinal strains measured at the surface on opposite sides of the longitudinal axis of symmetry of the specimen by two strain-sensing devices located at the mid length of the reduced section. (See Practice E 1012.)

3.2.3 *bending strain* [LL^{-1}], *n*—the difference between the strain at the surface and the axial strain. In general, the bending strain varies from point to point around and along the reduced section of the specimen. (See Practice E 1012.)

3.2.4 *breaking load [F]*, *n*—the load at which fracture occurs. (See Terminology E 6.)

3.2.5 *ceramic matrix composite*, *n*—a material consisting of two or more materials (insoluble in one another), in which the major, continuous component (matrix component) is a ceramic, while the secondary component(s) (reinforcing component) may be ceramic, glass-ceramic, glass, metal, or organic in nature. These components are combined on a macroscale to form a useful engineering material possessing certain properties or behavior not possessed by the individual constituents.

3.2.6 *compressive strength* [FL^{-2}], *n*—the maximum compressive stress which a material is capable of sustaining. Compressive strength is calculated from the maximum load during a compression test carried to rupture and the original cross-sectional area of the specimen. (See Terminology E 6.)

3.2.7 *continuous fiber-reinforced ceramic matrix composite (CFCC)*, *n*—a ceramic matrix composite in which the reinforcing phase consists of a continuous fiber, continuous yarn, or a woven fabric.

3.2.8 *gage length [L]*, *n*—the original length of that portion of the specimen over which strain or change of length is determined. (See Terminology E 6.)

3.2.9 *modulus of elasticity* [FL^{-2}], *n*—the ratio of stress to corresponding strain below the proportional limit. (See Terminology E 6.)

3.2.10 *proportional limit stress in compression* [FL^{-2}], *n*—the greatest stress that a material is capable of sustaining without any deviation from proportionality of stress to strain (Hooke's law).

3.2.10.1 *Discussion*—Many experiments have shown that values observed for the proportional limit vary greatly with the sensitivity and accuracy of the testing equipment, eccentricity of loading, the scale to which the stress-strain diagram is plotted, and other factors. When determination of proportional limit is required, specify the procedure and sensitivity of the test equipment. (See Terminology E 6)

3.2.11 *percent bending*, *n*—the bending strain times 100 divided by the axial strain. (See Practice E 1012).

3.2.12 *slow crack growth*, *n*—sub-critical crack growth (extension) that may result from, but is not restricted to, such mechanisms as environmentally-assisted stress corrosion or diffusive crack growth.

4. Significance and Use

4.1 This test method may be used for material development, material comparison, quality assurance, characterization, reliability assessment, and design data generation.

4.2 Continuous fiber-reinforced ceramic matrix composites (CFCCs) are generally characterized by fine-grain sized (<50 μm) matrices and ceramic fiber reinforcements. In addition, continuous fiber-reinforced glass (amorphous) matrix composites can also be classified as CFCCs. Uniaxial-loaded compressive strength tests provide information on mechanical behavior and strength for a uniformly stressed CFCC.

4.3 Generally, ceramic and ceramic matrix composites have greater resistance to compressive loads than tensile loads. Ideally, ceramics should be compressively stressed in use, although engineering applications may frequently introduce tensile stresses in the component. Nonetheless, compressive behavior is an important aspect of mechanical properties and performance. The compressive strength of ceramic and ceramic composites may not be deterministic Therefore, test a sufficient number of specimens to gain an insight into strength distributions.

4.4 Compression tests provide information on the strength and deformation of materials under uniaxial compressive stresses. Uniform stress states are required to effectively evaluate any nonlinear stress-strain behavior that may develop as the result of cumulative damage processes (for example, matrix cracking, matrix/fiber debonding, fiber fracture, delamination, etc.) that may be influenced by testing mode, testing rate, effects of processing or combination of constituent materials, or environmental influences. Some of these effects may be consequences of stress corrosion or sub-critical (slow) crack growth which can be minimized by testing at sufficiently rapid rates as outlined in this test method.

4.5 The results of compression tests of specimens fabricated to standardized dimensions from a particulate material or selected portions of a part, or both, may not totally represent the strength and deformation properties of the entire, full-size product or its in-service behavior in different environments.

4.6 For quality control purposes, results derived from standardized compressive test specimens may be considered indicative of the response of the material from which they were taken for given primary processing conditions and post-processing heat treatments.

4.7 The compressive behavior and strength of a CFCC are dependent on, and directly related to, the material. Analysis of fracture surfaces and fractography, though beyond the scope of this test method, are recommended.

5. Interferences

5.1 Test environment (vacuum, inert gas, ambient air, etc.) including moisture content (for example, relative humidity) may have an influence on the measured compressive strength. In particular, the behavior of materials susceptible to slow crack growth will be strongly influenced by test environment, testing rate, and test temperature. Conduct tests to evaluate the maximum strength potential of a material in inert environment