Designation: D8287/D8287M – 22

Standard Test Method for Compressive Residual Strength Properties of Damaged Sandwich Composite Panels[1]

1. Scope

1.1 This test method covers compression residual strength properties of sandwich constructions that have been subjected to quasi-static indentation or drop-weight impact per Practice D7766/D7766M.

NOTE 1—When used to determine the residual strength of drop-weight impacted plates, this test method is commonly referred to as the Sandwich Compression After Impact test method.

1.2 Several important test specimen parameters (for example, facesheet thickness, core thickness, and core density) are not mandated by this test method; however, repeatable results require that these parameters be specified and reported.

1.3 The method utilizes a flat, rectangular specimen, previously subjected to a damaging event, which is tested under edgewise compressive loading using a stabilization fixture.

1.4 The properties generated by this test method are highly dependent upon several factors, which include; specimen geometry, sandwich component materials and dimensions (facesheet, core, and adhesive), methods of fabrication, the type, size, and location of damage and boundary conditions. Thus, results are generally not scalable to other sandwich constructions, and are particular to the combination of geometric and physical conditions tested.

1.5 This test method can be used to test undamaged specimens, but care should be taken to prevent undesirable failure modes such as end crushing. Test Methods C364 and D7249/D7249M are the recommended test methods for undamaged sandwich panel compression strength by edgewise compression or long beam flexure, respectively.

1.6 *Units*—The values stated in either SI units or inch-pound units are to be regarded separately as standard. The values stated in each system are not necessarily exact equivalents; therefore, to ensure conformance with the standard, each system shall be used independently of the other, and values from the two systems shall not be combined.

1.6.1 Within the text, the inch-pound units are shown in brackets.

1.7 *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.*

1.8 *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]

C364 Test Method for Edgewise Compressive Strength of Sandwich Constructions

D792 Test Methods for Density and Specific Gravity (Relative Density) of Plastics by Displacement

D883 Terminology Relating to Plastics

D3171 Test Methods for Constituent Content of Composite Materials

D3878 Terminology for Composite Materials

D5229/D5229M Test Method for Moisture Absorption Properties and Equilibrium Conditioning of Polymer Matrix Composite Materials

D5687/D5687M Guide for Preparation of Flat Composite Panels with Processing Guidelines for Specimen Preparation

D7137 Test Method for Compressive Residual Strength Properties of Damaged Polymer Matrix Composite Plates

D7249/D7249M Test Method for Facesheet Properties of Sandwich Constructions by Long Beam Flexure

D7766/D7766M Practice for Damage Resistance Testing of Sandwich Constructions

D8388/D8388M Practice for Flexural Residual Strength

[1] This test method is under the jurisdiction of ASTM Committee D30 on Composite Materials and is the direct responsibility of Subcommittee D30.09 on Sandwich Construction.

Current edition approved Nov. 1, 2022. Published February 2023. DOI: 10.1520/D8287_D8287M-22.

[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.

Testing of Damaged Sandwich Constructions
E4 Practices for Force Calibration and Verification of Testing Machines
E6 Terminology Relating to Methods of Mechanical Testing
E122 Practice for Calculating Sample Size to Estimate, With Specified Precision, the Average for a Characteristic of a Lot or Process
E177 Practice for Use of the Terms Precision and Bias in ASTM Test Methods
E456 Terminology Relating to Quality and Statistics

3. Terminology

3.1 *Definitions*—Terminology D3878 defines terms relating to high-modulus fibers and their composites, as well as terms relating to sandwich constructions. Terminology D883 defines terms relating to plastics. Terminology E6 defines terms relating to mechanical testing. Terminology E456 and Practice E177 define terms relating to statistics. In the event of conflict between terms, Terminology D3878 shall have precedence over the other terminology standards.

NOTE 2—If the term represents a physical quantity, its analytical dimensions are stated immediately following the term (or letter symbol) in fundamental dimension form, using the following ASTM standard symbology for fundamental dimensions, shown within square brackets: [*M*] for mass, [*L*] for length, [*T*] for time, [θ] for thermodynamic temperature, and [*nd*] for non-dimensional quantities. Use of these symbols is restricted to analytical dimensions when used with square brackets, as the symbols may have other definitions when used without the brackets.

3.2 *Symbols:*

CV—coefficient of variation statistic of a sample population for a given property (in percent)

h—specimen thickness

l—specimen length

n—number of specimens per sample population

N^{CAI}—ultimate normalized compressive force in the test direction

P_{max}—maximum force carried by test specimen prior to failure

S_{n-1}—standard deviation statistic of a sample population for a given property

t—nominal facesheet thickness

w—specimen width

x_i—test result for an individual specimen from the sample population for a given property

$\bar{x}$—mean or average (estimate of mean) of a sample population for a given property

Δ—percent difference

ε—indicated strain from gage

4. Summary of Test Method

4.1 A uniaxial compression test is performed using a specimen which has been damaged and inspected prior to the application of compressive force. The damage state is imparted through out-of-plane loading caused by quasi-static indentation or drop-weight impact.

4.1.1 *Quasi-Static Indentation*—The rectangular specimen is damaged due to application of an out-of-plane static indentation force in accordance with Practice D7766/D7766M Procedure A or Procedure B.

4.1.2 *Drop-Weight Impact*—The rectangular specimen is damaged due to application of an out-of-plane drop-weight impact in accordance with Practice D7766/D7766M Procedure C.

4.2 The damaged specimen is installed in a multi-piece support fixture, that has been aligned to minimize loading eccentricities and induced specimen bending. The specimen/fixture assembly is placed between flat platens and end-loaded under compressive force until failure. Applied force, crosshead displacement, and strain data are recorded while loading.

4.3 Preferred failure modes pass through the damage in the specimen. However, acceptable failures may initiate away from the damage site, in instances when the damage produces a relatively low stress concentration or if the extent of damage is small, or both. Unacceptable failure modes are those related to load introduction by the support fixture, local edge support conditions, and specimen instability (unless the specimen is dimensionally representative of a particular structural application).

5. Significance and Use

5.1 Susceptibility to damage from concentrated out-of-plane forces is one of the major design concerns of many structures made of sandwich constructions. Knowledge of the damage resistance and residual strength properties of a sandwich construction is useful for product development and material selection.

5.2 The residual strength data obtained using this test method is most commonly used in material selection, research and development activities, and establishing design allowables.

5.3 The properties obtained using this test method can provide guidance in regard to the anticipated residual strength capability of sandwich constructions of similar facesheet and core material, adhesive, facesheet and core thickness, facesheet stacking sequence, and so forth. However, it must be understood that the residual strength of sandwich constructions is highly dependent upon several factors including geometry, thickness, stiffness, support conditions, and so forth. Significant differences in the relationships between the damage state and the residual compressive strength can result due to differences in these parameters.

5.4 The compression strength from this test may not be equivalent to the compression strength of sandwich structures subjected to flexural compression testing.

5.5 The reporting section requires items that tend to influence residual compressive strength to be reported; these include the following: facesheet and core materials, core density, cell size and wall thickness if applicable, film adhesive, methods of material fabrication, accuracy of lay-up orientation, facesheet stacking sequence and thickness, core thickness, overall specimen thickness, specimen geometry, specimen preparation, specimen conditioning, environment of testing, type, size and location of damage (including method of non-destructive inspection), specimen/fixture alignment and gripping, time at temperature, and speed of testing.

5.6 Results from the residual strength assessment include the following: normalized compressive residual strength N^{CAI}, compressive force as a function of crosshead displacement, and far-field surface strains as functions of crosshead displacement.

6. Interferences

6.1 The response of a damaged specimen is dependent upon many factors, such as facesheet material, facesheet thickness, facesheet ply thickness, facesheet stacking sequence, facesheet surface flatness (toolside or bagside surface), core material, core thickness, core density, cell size, cell wall thickness, adhesive, construction methods, environment, damage type, damage geometry, damage location, and loading/support conditions. Consequently, comparisons cannot be made between materials unless identical test configurations, test conditions, and sandwich constructions are used. Therefore, all deviations from the standard test configuration shall be reported in the results. Specific structural configurations and boundary conditions must be considered when applying the data generated using this test method to design applications.

6.2 *Material and Specimen Preparation*—Poor material fabrication practices, lack of control of fiber alignment, poor core bonding, and damage induced by improper specimen machining are known causes of high material data scatter in composites in general. Important aspects of sandwich construction preparation that contribute to data scatter include incomplete or nonuniform core bonding to facesheets, misalignment of core and facesheet elements, the existence of joints, voids or other core and facesheet discontinuities, out-of-plane curvature, facesheet thickness variation, surface roughness, and failure to meet the dimensional and squareness tolerances (parallelism and perpendicularity) specified in 8.2.

6.3 *Damage Mode*—Variations in the specimen damage modes produced during the damaging event can contribute to strength, stiffness, and strain data scatter.

6.4 *Damage Geometry and Location*—The size, shape, and location of damage (both within the plane of the specimen and through-the-thickness) can affect the deformation and strength behavior of the specimen significantly. Edge effects, boundary constraints, and the damaged stress/strain field can interact if the damage size becomes too large relative to the length and width dimensions of the specimen. The damage size, as measured in accordance with Practice D7766/D7766M, is limited to one-third of the unsupported specimen width (65 mm [2.6 in.]) to minimize interaction between damage and edge-related stress/strain fields.

NOTE 3—It is recommended that the damage be limited to one-fifth the specimen unsupported width (40 mm [1.6 in.]); however, this may not be practical in all cases. Also, it may not be possible to accurately predict the damage sizes prior to fabrication of the specimens; therefore, a pre-test impact survey program is recommended prior to specimen fabrication.

6.5 *Test Fixture Characteristics*—The configuration of the panel edge-constraint structure can have a significant effect on test results. In the standard test fixture, the top and bottom supports provide no clamp-up force, but provide some restraint to local out-of-plane rotation due to the fixture geometry. The knife-edge side supports provide resistance to out-of-plane movement at the edges, which increases the compressive force that would result in global buckling of the specimen. Edge supports must be co-planar. Results may be affected by the geometry of the various slide plates local to the specimen. Results may also be affected by the presence of gaps between the slide plates and the specimen, which can reduce the effective edge support and can result in concentrated load introduction conditions at the top and bottom specimen surfaces. Additionally, results may be affected by variations in torque applied to the slide plate fasteners; loose fasteners may also reduce the effective edge support.

6.6 *System Alignment*—Errors can result if the test fixture is not centered with respect to the loading axis of the test machine, and aligned or shimmed to apply an essentially uniaxial displacement to the loaded end of the specimen.

6.7 *Non-Destructive Inspection*—Non-destructive inspection (NDI) results are affected by the particular method utilized, the inherent variability of the NDI method, the experience of the operator, and so forth. Different NDI methods may be required for assessing the various damage modes that may arise during sandwich damage resistance testing. Damage location may also influence the selection of NDI methods.

6.8 *Specimen Instability*—Accurate detection of instability or incipient instability of the facesheets or the specimen may not be possible. The nature of the damage can have a significant effect upon local flexural rigidity, which may complicate the failure mode, limiting results to the unique configuration tested.

6.9 *Facesheet Load Distribution*—This test method effectively applies a uniform axial displacement to the test specimen. If the stiffness of the two facesheets is different, either due to the damage inflicted on one facesheet or due to one facesheet having more dimpling due to cocuring (bagside versus toolside effects), then accurate calculation of the facesheet stress in the damaged facesheet requires the use of strain gages on both facesheets to determine the load distribution. Where there is a significant difference in facesheet stiffnesses, use of Practice D8388/D8388M with damage applied to the compressive side facesheet may be more useful and appropriate.

6.10 *Out of Plane Deformation*—Depending on the damage state, facesheets, and core material, the stiffness differences between the damaged and undamaged facesheets may be significant. Visually monitor the test for excessive out-of-plane deformation.

NOTE 4—While Digital Image Correlation (DIC) currently is not formally used for strain measurement in ASTM standards (since there are no ASTM accepted calibration methods), it may be used to help quantify the amount of out-of-plane deformation and strain distributions as well as assess test validity.

6.11 *Potting*—Potting is commonly used to avoid facesheet separation and end brooming prior to specimen failure. Potting of the core may occur during or prior to bonding to the facesheets if the potting material is compatible with the facesheet cure cycle. Potting may also occur after the specimen is cured by removing the core at the ends and inserting potting material.