INTERNATIONAL

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Standard Practice for Flexural Residual Strength Testing of Damaged Sandwich Constructions[1]

This standard is issued under the fixed designation D8388/D8388M; 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 practice provides instructions for modifying the long beam flexure test method to determine the tensile or compressive residual strength properties of sandwich constructions that have been subjected to quasi-static indentation or drop-weight impact per Practice D7766/D7766M. The tensile or compressive strength result is determined by which facesheet contains the damage, either the loaded-span or support-span facesheet, based on how the specimen is positioned in the fixture.

1.2 This practice supplements Test Method D7249/D7249M with provisions for testing damaged sandwich specimens. Several important test specimen parameters (for example, facesheet thickness, core thickness and core density) are not mandated by this practice; however, repeatable results require that these parameters be specified and reported.

1.3 *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.

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

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, health, and environmental practices and determine the applicability of regulatory limitations prior to use.*

1.5 *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]

D883 Terminology Relating to Plastics

D3410/D3410M Test Method for Compressive Properties of Polymer Matrix Composite Materials with Unsupported Gage Section by Shear Loading

D3878 Terminology for Composite Materials

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

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

D7766/D7766M Practice for Damage Resistance Testing of Sandwich Constructions

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 a conflict between terms, Terminology D3878 shall have precedence over the other terminologies.

NOTE 1—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

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[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.

may have other definitions when used without the brackets.

3.2 *Symbols:*

b—specimen width

c—calculated core thickness

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

d—sandwich total thickness

F^{CAI}—facesheet ultimate residual strength (compressive)

F^{TAI}—facesheet ultimate residual strength (tensile)

k—core shear strength factor to ensure facesheet failure

L—length of loading span

l_{pad}—length of loading pad

n—number of specimens

P—applied force

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

S—length of support span

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

σ—facesheet stress

t —facesheet thickness

x_1—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

4. Summary of Practice

4.1 This test practice consists of subjecting a long beam of sandwich construction to a bending moment normal to the plane of the sandwich, using a 4-point loading fixture in accordance with Test Method D7249/D7249M. The sandwich beam has been damaged and inspected prior to testing. 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 beam 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 beam is damaged due to application of an out-of-plane drop-weight impact in accordance with Practice D7766/D7766M Procedure C.

4.2 Preferred failure modes pass through the damage in the sandwich beam. However, acceptable failures may initiate away from the damage site in instances when the damage produces a relatively low stress concentration, if the extent of damage is small, or both.

5. Significance and Use

5.1 This practice provides supplemental instructions that allow the use of Test Method D7249/D7249M to determine residual compressive or tensile strength properties of damaged sandwich constructions. Susceptibility to damage from concentrated out-of-plane forces is one of the major design concerns of many structures made using sandwich constructions. Knowledge of the residual strength properties of a sandwich panel is useful for product development, establishing design allowables, and material selection.

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

5.3 The properties obtained using this test practice can provide guidance in regard to the anticipated compressive or tensile 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 or tensile 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 pure edgewise (in-plane) compression.

5.5 The reporting section requires items that tend to influence residual 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, time at temperature, and speed of testing.

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 practice to design applications.

6.2 *Material and Specimen Preparation*—Poor material fabrication practices, lack of control of fiber alignment, and damage induced by improper specimen machining are known causes of high material data scatter in composites in general. Specific material factors that affect sandwich constructions include variability in core density and degree of cure of resin in both the facesheet matrix material and core bonding adhesive. Important aspects of sandwich panel specimen preparation that contribute to data scatter are 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, and surface roughness.

6.3 *Damage Geometry and Location*—The size, shape, and location of damage (both within the plane of the plate and through-the-thickness) can significantly affect the deformation and strength behavior of the specimen. 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.

6.4 *Core Material*—If the core material has insufficient shear or compressive strength, it is possible that the core may locally crush at or near the loading points thereby resulting in facesheet failure due to local stresses. In other cases, facesheet failure can cause local core crushing. When there is both facesheet and core failure in the vicinity of one of the loading points, it can be difficult to determine the failure sequence in a postmortem inspection of the specimen as the failed specimens look very similar for both sequences.

6.5 *Environment*—Results are affected by the environmental conditions under which specimens are conditioned, as well as the conditions under which the tests are conducted. Specimens tested in various environments can exhibit significant differences in both strength behavior and failure mode. Experience has demonstrated that cold temperature environments are generally critical for notched tensile strength, while elevated temperature, humid environments are generally critical for notched compressive strength. However, critical environments must be assessed independently for each specific combination of core material, facesheet material, facesheet stacking sequence, and core-to-facesheet interfacial adhesive (if used) that is tested.

6.6 *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.

6.7 *Method of Imparting Damage*—Refer to Practice D7766/D7766M for indentation or impact related interferences.

7. Apparatus

7.1 *Loading Fixtures*

7.1.1 *Standard Fixture Configuration*—The standard loading fixture shall consist of a 4-point loading configuration with two support bars that span the specimen width located below the specimen, and two loading bars that span the specimen width located on the top of the specimen (Fig. 1). The force shall be applied vertically through the loading bars, with the support bars fixed in place in the test machine. The standard loading fixture shall have the centerlines of the support bars separated by a distance of 610 mm [24.0 in.] and the centerlines of the loading bars separated by a distance of 150 mm [6.0 in.].

7.1.2 *Non-Standard Fixture Configurations*—All other loading fixture configurations (see Fig. 2) are considered non-standard and details of the fixture geometry shall be documented in the test report. Non-standard 4-point loading configurations have been retained within this practice because some sandwich panel designs require the use of non-standard loading configurations to achieve acceptable failure modes.

8. Sampling and Test Specimens

8.1 *Sampling*—Test at least five specimens per test condition unless valid results can be gained through the use of fewer specimens, as in the case of a designed experiment. For statistically significant data, consult the procedures outlined in Practice E122. Report the method of sampling.

8.2 *Geometry*—The standard specimen configuration should be used whenever the specimen design equations in Test Method D7249/D7249M indicate that the specimen will produce the desired facesheet failure mode. In cases where the standard specimen configuration will not produce a facesheet failure, a nonstandard specimen shall be designed to produce a facesheet failure mode.

NOTE 2—The recommended specimen width is five (5) times the damage width; however, this may not be practical in all cases. Additionally, 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. It may be beneficial to destructively inspect additional specimens containing damage, that will not undergo flexure testing, to thoroughly understand and document the damage associated with the tensile or compressive residual strength. As impact or indentation damage diameters are often on the order of 25 mm [1.0 in.], a typical specimen width is 125 mm [5.0 in.]. Specimen width should be minimized to avoid excessive anticlastic bending; a maximum width to support span ratio of 0.3 is recommended.

8.2.1 *Standard Specimen Configuration*—The standard test specimen shall be rectangular in cross section, with a width of 125 mm [5.0 in]. The depth of the specimen shall be equal to the thickness of the sandwich construction. The specimen length shall be equal to the support span length plus 50 mm [2 in.] or plus one-half the sandwich thickness, whichever is the greater.

8.2.2 *Non-Standard Specimen Configurations*—For non-standard specimen geometries, the width shall be not less than

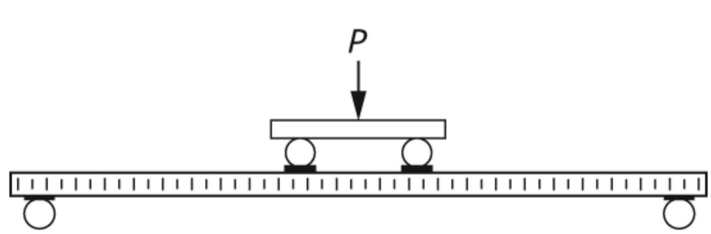

FIG. 1 Test Specimen and Fixture