Designation: D8453/D8453M – 22

Standard Practice for Open-Hole Flexural Strength of Sandwich Constructions[1]

This standard is issued under the fixed designation D8453/D8453M; 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 open-hole facesheet properties of flat sandwich constructions subjected to flexure in such a manner that the applied moments produce curvature of the sandwich facesheet planes and result in compressive and tensile forces in the facesheets. Permissible core material forms include those with continuous bonding surfaces (such as balsa wood and foams) as well as those with discontinuous bonding surfaces (such as honeycomb). This practice supplements Test Method D7249/D7249M with provisions for testing specimens that contain a centrally located through-hole.

1.2 *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 may not be exact equivalents; therefore, to enforce conformance with the standard, each system shall be used independently of the other, and values from the two systems shall not be combined.

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

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.*

2. Referenced Documents

2.1 *ASTM Standards:*[2]

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
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 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 standards.

3.2 *Definitions of Terms Specific to This Standard:*

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 nondimensional 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.

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

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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.

3.2.1 *diameter-to-facesheet thickness ratio, D/t [nd], n—in an open-hole specimen*, the ratio of the hole diameter to the facesheet thickness.

3.2.1.1 *Discussion*—The diameter-to-thickness ratio may be either a nominal value determined from nominal dimensions or an actual value determined from measured dimensions.

3.2.2 *width-to-diameter ratio, b/D [nd], n—in an open-hole specimen*, the ratio of the specimen width to the hole diameter.

3.2.2.1 *Discussion*—The width-to-diameter ratio may be either a nominal value determined from nominal dimensions or an actual value determined from measured dimensions.

3.3 *Symbols:*

b—width of specimen across hole

D—hole diameter

F^{ohu}—facesheet ultimate open-hole (notched) strength (tensile or compressive)

L—length of loading span

P—applied force

S—length of support span

t—facesheet thickness

4. Summary of Practice

4.1 This practice consists of subjecting a long beam of sandwich construction, with a centrally located through-hole, to a bending moment normal to the plane of the sandwich, using a 4-point loading fixture in accordance with Test Method D7249/D7249M. Ultimate strength is calculated based on the gross cross-sectional area, disregarding the presence of the hole. While the hole causes a stress concentration and reduced net section, it is common aerospace practice to develop notched design allowable strengths based on gross section stress to account for various stress concentrations (flaws, damage, and so forth) not explicitly modeled in the stress analysis.

4.2 The only acceptable failure modes for ultimate open-hole sandwich facesheet strength are those that occur at/through the hole in one or both of the facesheets.

4.3 The open-hole strength is determined in either tension or compression dependent upon the facesheet of the sandwich panel in which the failure occurs through the hole.

5. Significance and Use

5.1 This practice provides supplemental instructions that allow the use of Test Method D7249/D7249M to determine the open-hole (notched) strength of the sandwich panel facesheets for structural design allowables, material specifications, and research and development. Due to the curvature of the flexural test specimen when loaded, the open-hole sandwich facesheet strength from this test may not be equivalent to the open-hole sandwich facesheet strength of sandwich structures subjected to pure edgewise (in-plane) tension or compression.

5.2 Factors that influence the notched facesheet strength and shall therefore be reported include the following: facesheet material, core material, adhesive material, methods of material fabrication, facesheet stacking sequence and overall thickness, core geometry (cell size), core density, adhesive thickness, specimen geometry (including hole diameter, diameter-to-thickness ratio, and width-to-diameter ratio), specimen preparation (especially of the hole), specimen conditioning, environment of testing, specimen alignment, loading procedure, speed of testing, facesheet void content, adhesive void content, and facesheet volume percent reinforcement. Further, notched facesheet strength may be different between precured/bonded and co-cured facesheets of the same material.

6. Interferences

6.1 *Hole Preparation*—Because of the dominating presence of the notch, and the lack of need to measure the material response, results from this test method are relatively insensitive to parameters that would be of concern in an unnotched tensile or compressive property test, such as notches, undercuts, rough or uneven surfaces, and delaminations due to inappropriate machining methods. However, since the notch has a dominant effect on the strength, consistent preparation of the hole, without damage to the sandwich specimen, is important to meaningful results. Damage caused by hole preparation may affect strength results. Some types of facesheet damage, such as longitudinal splitting and delamination, can blunt the stress concentration caused by the hole, increasing the force-carrying capacity of the specimen and the calculated strength. Other types of damage can reduce the calculated strength.

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 core specimen preparation that contribute to data scatter include the existence of joints, voids or other core discontinuities, out-of-plane curvature, and surface roughness.

6.3 *Geometry*—Results are affected by the ratio of specimen width to hole diameter (*b/D*); a ratio of 6 is recommended if the notch sensitivity is unknown. Results may also be affected by the ratio of hole diameter to facesheet thickness (*D/t*). Results may also be affected by facesheet thickness, and facesheet surface flatness (toolside or bagside surface in compression).

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 *Material Orthotropy*—The degree of facesheet orthotropy strongly affects the failure mode and measured notched strength. Valid notched strength results should only be reported when appropriate failure modes are observed, in accordance with 11.5.

6.7 *Facesheet Thickness Scaling*—Thick facesheet sandwich structures do not necessarily produce the same facesheet notched strength as thin facesheet sandwich structures with the same facesheet orientation (that is, facesheet notched strength does not always scale linearly with facesheet thickness). Thus, data gathered using this test method may not translate directly into equivalent thick-facesheet properties.

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 560 mm [22.0 in.] and the centerlines of the loading bars separated by a distance of 100 mm [4.0 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 standard 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 non-standard specimen shall be designed to produce a facesheet failure mode.

8.2.1 *Standard Specimen Configuration*—The standard test specimen shall be rectangular in cross section, with a width of 72 mm [3.0 in.], length of 600 mm [24.0 in.], and a centrally located through hole with a diameter of 12 mm [0.50 in.]. The depth of the specimen shall be equal to the thickness of the sandwich construction.

8.2.2 *Non-Standard Specimen Configurations*—For non-standard specimen geometries (see Fig. 3), the width shall be not less than twice the total thickness nor more than six times the total thickness, not less than three times the dimension of a core cell, nor greater than one quarter the span length. 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. Limitations on the maximum specimen width are intended to allow for the use of simplified sandwich beam calculations; plate flexure effects must be considered for specimens that are wider than the restrictions specified above. The hole diameter should be large enough to produce a statistically significant reduction in strength but small enough to minimize finite width effects. A specimen width-to-diameter (*b/D*) of 6 is recommended.

8.2.3 *Specimen Design*—Proper design of the sandwich flexure test specimen for determining compressive or tensile strength of the facesheets is required to avoid core crushing, core shear, or core-to-facesheet failures. The facesheets must be sufficiently thin and the support span sufficiently long such that moments are produced at applied forces low enough so that the allowable core shear stress will not be exceeded. The core must be sufficiently thick to avoid excessive deflection. The equations in Test Method D7249/D7249M subsection 8.2.3 can be used to size the test specimen.

8.3 *Facesheets:*

8.3.1 *Compression Side Facesheet*—Unless otherwise specified by the test requestor, the bag-side facesheet of a co-cured composite sandwich panel shall be placed as the upper, compression loaded facesheet during test, as facesheet compression strength is more sensitive to imperfections typical of bag-side surfaces than is facesheet tension strength.

NOTE 2—Tensile failures rarely occur unless the tensile facesheet is

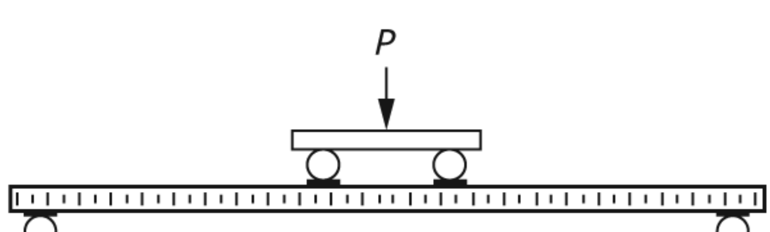

FIG. 1 Test Specimen and Fixture

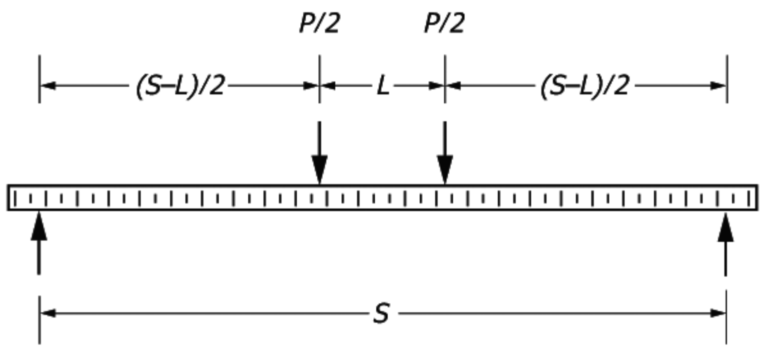

FIG. 2 Loading Configurations

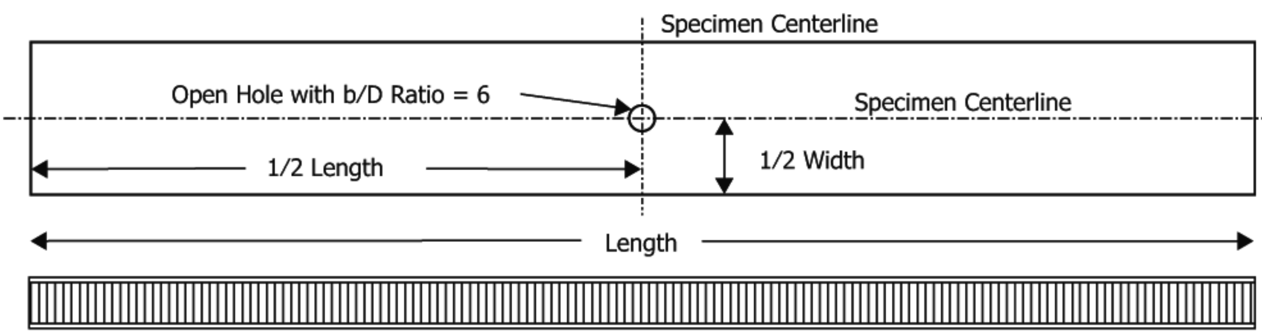

FIG. 3 Specimen Configurations

thinner or of different material than the compression facesheet, or when testing at cold environments.

8.3.2 *Layup*—The apparent notched facesheet strength obtained from this method may be dependent upon the facesheet stacking sequence. For the standard test configuration, facesheets consisting of a laminated composite material shall be balanced and symmetric about the sandwich beam midplane. The standard tape and fabric facesheets shall have multidirectional fiber orientations (fibers shall be oriented in a minimum of two directions).

8.3.3 *Stiffness*—For the standard specimen, the facesheets shall be the same material, thickness, and layup. The calculations assume constant and equal upper and lower facesheet stiffness properties. This assumption may not be applicable for certain facesheet materials (such as aramid fiber composites) which have significantly different tensile and compressive moduli or which exhibit significant non-linear stress-strain behavior.

8.3.4 *Facesheet Thickness*—Accurate measurement of facesheet thickness is difficult after bonding or co-curing of the facesheets and core. The test requestor is responsible for specifying the facesheet thicknesses to be used for the calculations in this test method. For metallic or precured composite facesheets which are secondarily bonded to the core, the facesheet thickness should be measured prior to bonding. In these cases, the test requestor may specify that either or both measured and nominal thicknesses be used in the calculations. For co-cured composite facesheets, the thicknesses are generally calculated using nominal per ply thickness values.

8.4 *Core*—For test specimens using a honeycomb core material, the core ribbon direction shall be oriented in the specimen lengthwise direction to aid in avoiding core shear failures. The core material shall be selected to provide sufficient local compression and shear strength under the loading points to avoid local core crushing or shear failures that precede and cause premature facesheet failure.

8.5 *Specimen Preparation and Machining*—Specimen preparation is extremely important for this test method. Guide D5687/D5687M provides recommended specimen preparation practices and should be followed where practical. Take precautions when cutting specimens from large panels to avoid notches, undercuts, rough or uneven surfaces, or delaminations due to inappropriate machining methods. Obtain final dimensions by water-lubricated precision sawing, milling, or grinding. The use of diamond coated machining tools has been found to be extremely effective for many material systems. Edges should be flat and parallel within the specified tolerances. Take special care to ensure that creation of the specimen through hole does not delaminate or otherwise damage the material surrounding the hole. Record and report the specimen cutting preparation method.

8.6 *Labeling*—Label the test specimens so that they will be distinct from each other and traceable back to the panel of origin, and will neither influence the test nor be affected by it.

9. Calibration

9.1 See Test Method D7249/D7249M.

10. Conditioning

10.1 See Test Method D7249/D7249M.

11. Procedure

11.1 *Parameters to Be Specified Before Test:*

11.1.1 See Test Method D7249/D7249M.