Designation: D8285/D8285M − 19

Standard Practice for Compressive Properties of Tapered and Stepped Joints of Polymer Matrix Composite Laminates by Sandwich Construction Long Beam Flexure[1]

This standard is issued under the fixed designation D8285/D8285M; 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 covers the procedure for determination of the compressive strength of a tapered or stepped bonded joint of polymer matrix composite materials. It is applicable to secondary bonded or co-bonded laminates with either unidirectional plies or woven fabric reinforcements. The materials to be bonded may be different systems. In the bondline, a separate adhesive material may or may not be used (example: adhesives may be used with a prepreg system or may not be used with a wet lay-up repair system). The range of acceptable test laminates and thicknesses are described in 8.2.7. The standard repair types are the same as for the tensile loading in Practice D8131/D8131M. While external patch repairs are not explicitly covered in this practice, these repairs could be tested as a non-standard specimen using this practice.

1.2 This practice supplements Test Method D7249/D7249M for compressive loading of facesheet sandwich constructions by long beam flexure. Several important test specimen parameters (for example, joint length, ply overlaps, step depth, and taper ratio) are not mandated by this practice; however, these parameters are required to be specified and reported to support repeatable results.

1.3 Unidirectional (0° ply orientation) composites as well as multi-directional composite laminates and fabric composites, can be tested.

1.4 *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.

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

1.5 *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.*

1.6 *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]

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
D7249/D7249M Test Method for Facesheet Properties of Sandwich Constructions by Long Beam Flexure
D8131/D8131M Practice for Tensile Properties of Tapered and Stepped Joints of Polymer Matrix Composite Laminates
E4 Practices for Force 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

[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.

E2533 Guide for Nondestructive Testing of Polymer Matrix Composites Used in Aerospace Applications

2.2 *SAE Document:*[3]

CMH-17 Composite Materials Handbook-17 - Volume I

3. Terminology

3.1 *Definitions*—Terminology D3878 defines terms relating to high-modulus fibers and their composites. 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 Terminology standards.

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 may have other definitions when used without the brackets.

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *co-bonded (repair) facesheet, n*—the co-bonded facesheet is the facesheet that is bonded to the parent pre-cured facesheet and cured in a second cure cycle.

3.2.2 *joint compressive strength, n*—ultimate compressive force experienced by the test specimen facesheet divided by the initial width of the joint area and the nominal thickness of the parent facesheet.

3.2.3 *nominal value, n*—a value, existing in name only, assigned to a measureable property for the purpose of convenient designation.

3.2.3.1 *Discussion*—Tolerances may be applied to a nominal value to define an acceptable range for the property.

3.2.4 *parent facesheet, n*—the parent facesheet is the facesheet that is cured during the first cure cycle.

3.2.5 *secondary bonded (repair) facesheet, n*—the secondary bonded facesheet is a pre-cured laminate that is bonded to the parent pre-cured facesheet using a separate adhesive material (sometimes referred to as a pre-cured patch repair).

3.3 *Symbols:*

c—core thickness

CV—sample coefficient of variation, in percent

d—sandwich total thickness

E_b^f—effective backskin (tension side) facesheet chord modulus

E_r^f—effective repair (compressive side) facesheet chord modulus

F_r^{cu}—ultimate compressive strength, based on repair laminate thickness

h_b—specimen nominal backskin side laminate facesheet thickness as specified by the test requestor (nominal ply thickness may be available from the relevant material specification)

h_p—specimen nominal compressive side parent laminate facesheet thickness as specified by the test requestor (nominal ply thickness may be available from the relevant material specification)

h_r—specimen nominal compressive side repair laminate facesheet thickness as specified by the test requestor (nominal ply thickness may be available from the relevant material specification)

L—length of loading span

S—length of support span

N_j—ultimate joint running force per ply

n—number of specimens

n_r—number of repair laminate plies

P_f—maximum force carried by test specimen at failure

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

w—specimen width

xi —test result for an individual coupon 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 *Tapered or Stepped Joint Compressive Strength*—In accordance with Test Method D7249/D7249M, but using a tapered or stepped joint facesheet configured specimen (Fig. 1 or Fig. 2), subjecting a long beam of sandwich construction to a bending moment normal to the plane of the sandwich, using a 4-point loading fixture. Deflection and strain versus force measurements are recorded.

4.2 The only acceptable failure modes for sandwich facesheet compressive strength are those which are internal to the compressive loaded facesheet. Failure of the sandwich core, the core-to-facesheet bond preceding failure of the facesheet, or the tension side facesheet are not acceptable failure modes. Careful post-test inspection of the specimen is required as facesheet failure occurring in proximity to the loading points can be caused by local through-thickness compression or shear failure of the core that precedes failure of the facesheet.

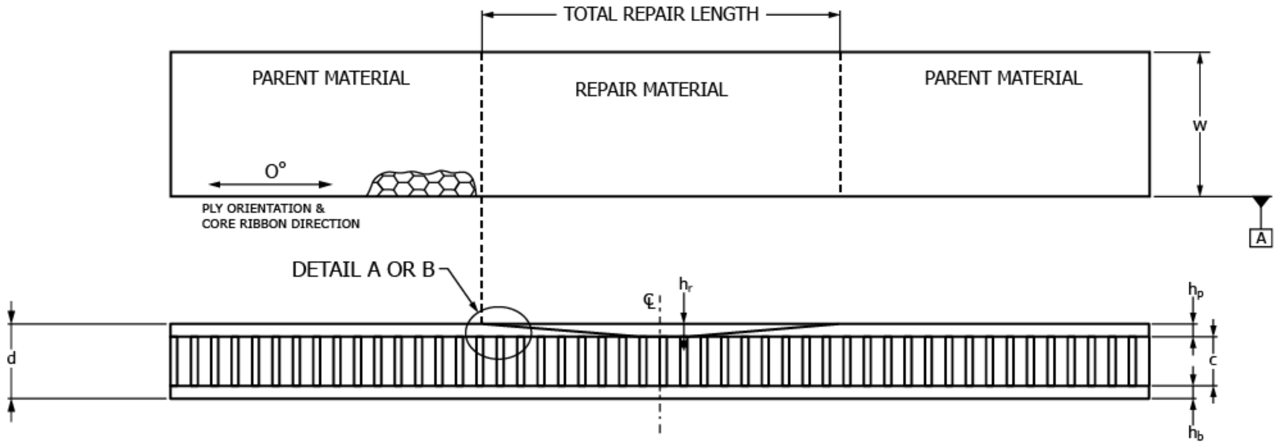
5. Significance and Use

5.1 Flexure tests on flat sandwich panel construction may be conducted to determine facesheet scarf or step joint compressive strength.

5.2 This practice is limited to obtaining the compressive strength of the sandwich panel scarf and step joint facesheets. Due to the curvature of the flexural test specimen when loaded, facesheet compression strength from this test may not be equivalent to the facesheet compression strength of sandwich structures subjected to pure edgewise (in-plane) compression.

5.3 Factors that influence the compressive response and should therefore be reported include the following: materials (laminate facesheet, core, and adhesive); methods of material fabrication; methods of material preparation, including surface preparation prior to bonding, lay-up, specimen facesheet stacking sequence, and overall thickness; core geometry (cell size); core density; adhesive thickness; joint taper ratio or step

[3] Available from SAE International (SAE), 400 Commonwealth Dr., Warrendale, PA 15096, http://www.sae.org.



DRAWING NOTES:

1. INTERPRET DRAWING IN ACCORDANCE WITH ANSI Y14.5M-1982, SUBJECT TO THE FOLLOWING:
2. ALL DIMENSIONS IN MILLIMETERS WITH DECIMAL TOLERANCES AS FOLLOWS:

NO DECIMAL	.X	.XX
± 0.1	± 0.03	± 0.01

3. PLY ORIENTATION DIRECTION TOLERANCE RELATIVE TO -A- WITHIN ± 0.5°.
4. FINISH ON MACHINE EDGES NOT TO EXCEED 64√ (SYMBOLOGY IN ACCORDANCE WITH ASA B46.1, WITH ROUGHNESS HEIGHT IN MICROINCHES.)
5. REFER TO TABLES 1 AND 2 FOR ADDITIONAL STANDARD SPECIMEN GEOMETRY DEFINITIONS.
6. REFER TO FIGS. 5 AND 6 FOR DETAILS A AND B.
7. CORE RIBBON DIRECTION PARALLEL TO 0° DIRECTION.

FIG. 1 Compressive Sandwich Beam Tapered and Stepped Joint Specimen – Overall Geometry (SI)

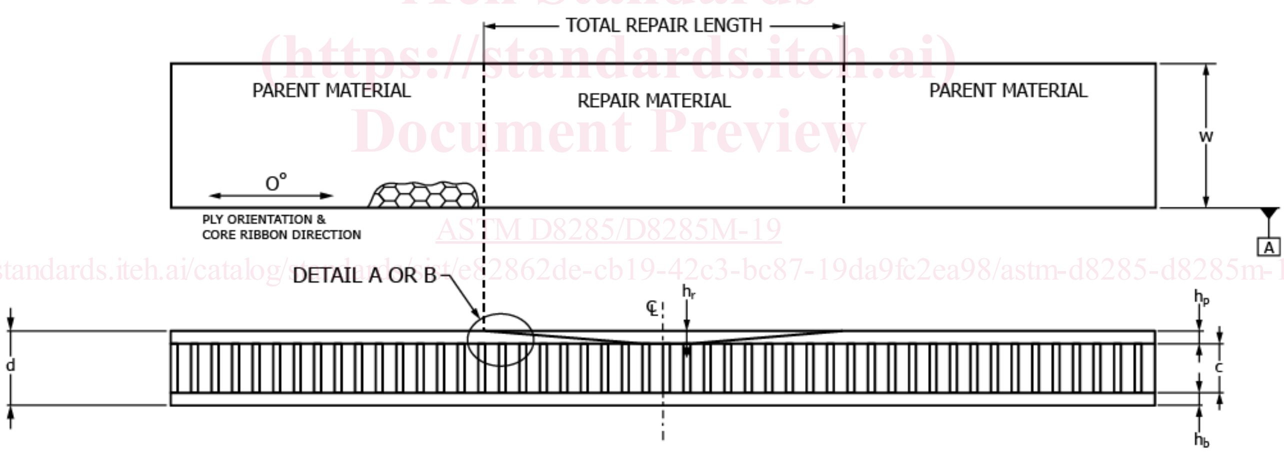


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FIG. 2 Compressive Sandwich Beam Tapered and Stepped Joint Specimen – Overall Geometry (Inch-Pound)

length; ply overlap length; relative thickness and stiffness of parent and repair laminates; adhesive bond stiffness; specimen preparation; specimen conditioning; environment of testing; specimen alignment; speed of testing; time at temperature; void content; and volume percent reinforcement. Properties, in the test direction, which may be obtained from this practice, include the following:

5.3.1 Ultimate compressive strength (based on the nominal repair material thickness), (F_r^{cu}).

5.3.2 Ultimate running load per ply, (N_j).

NOTE 2—Concentrated forces on beams with thin facesheets and low density cores can produce results that are difficult to interpret, especially close to the failure point. Wider loading blocks and rubber pads may assist in distributing the forces.

NOTE 3—To ensure that simple sandwich beam theory is valid, a good rule of thumb for the four-point bending test is the support span length divided by the sandwich thickness should be greater than 20 ($S/d > 20$) with the ratio of repair material facesheet thickness to core thickness less than 0.1 ($h_r/c < 0.1$).

6. Interferences

6.1 *Material and Specimen Preparation*—Poor material fabrication practices, lack of control of fiber alignment, and damage induced by improper coupon machining are known causes of high material data scatter in composites. For the bonded joint specimens, the quality of the co-cured laminate (ply positioning, lengths, impregnation for wet lay-up material system), lack of orientation control of the parent laminate or pre-cured patch, and quality of the bond between the parent and pre-cure or co-cured bonded laminates will have significant effects on the test results.

6.2 *Geometry*—Specific geometric factors that affect sandwich facesheet strength include facesheet thickness, core cell geometry, out-of-plane curvature and facesheet surface flatness (toolside or bagside surface in compression).

6.3 *Specimen Design*—The bonded joint test specimen involves a parent and a repair laminate. These two laminates typically do not use the same material system. There are a number of variables and factors which influence the selection of the repair laminate lay-up relative to the parent laminate. Generally the repair lay-up is designed to match or slightly exceed the stiffness of the parent laminate, and ideally the repair material type (fabric or tape) and the ply thicknesses are the same as for the parent material. When they are different, repair design compromises are necessary to obtain sufficient repair stiffness and strength while not making the repair thicker than the parent laminate. Details of repair design are beyond the scope of this practice. The results from this practice are reported as simple stress and force-per-width values; the joint specimen design will influence the validity of these reported results for use with bonded repair analysis methods. All details of the repair design and fabrication process shall be documented in the test report.

6.3.1 In order to support the extended total length of the joint repair region on the sandwich beam, the overall standard specimen length is 813 mm [32 in.] for this practice. Typical joint total repair length is 254 mm [10.0 in.]. See Figs. 1 and 2 and Tables 1 and 2 for more definition of specimen geometries. Alternate non-standard repair designs may allow shorter overall specimen lengths. The location of the tool or bag side of the parent sandwich panel shall be specified by the test requestor and documented in the test report.

6.3.2 *Step Joint Filler Plies*—The stepped joint specimen should have a filler ply to avoid waviness in the repair plies. The filler ply should ideally be the same thickness as the bottom ply of the parent laminate. The standard test specimen configuration in this practice for unidirectional tape materials uses a +45 ply as a filler ply. If an equivalent thickness fabric ply repair material is available, that could be used for the filler ply to provide a balanced lay-up.

6.3.3 In baseline final mechanical property calculations, it is recommended that the filler ply thickness be omitted, so that the calculated stress and load/ply values are consistent with the number of parent plies and repair plies. If the test requester elects to use the filler ply thickness in the calculations, then this should be clearly documented in the test report.

6.4 *Edge Effects in Angle Ply Laminates*—Premature failure can occur as a result of edge softening in laminates containing off-axis plies. Because of this, the strength for angle ply laminates can be lower than expected. For multidirectional laminates containing significant axial fiber, the effect is not as significant.

6.5 *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. Where 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 post-mortem inspection of the specimen as the failed specimens look very similar for both sequences.

6.6 *Environment*—Results are affected by the environmental conditions under which the tests are conducted. Specimens tested in various environments can exhibit significant differences in both failure force and failure mode. Experience has demonstrated that elevated-temperature, humid environments can be critical for laminate facesheet compressive strength. The critical environmental condition for bonded joint specimens is complicated by having multiple materials in the test specimen geometry. The failure modes may change between laminate facesheet compressive modes, bondline modes, and laminate interfacial modes as environmental conditions change. Critical environments must be assessed independently for each specific combination of material systems (parent material, repair material, adhesive (if used), core, and core-to-facesheet interfacial adhesive used) that is tested.

6.7 *Failure Mode*—For a valid test, final failure of the specimen must occur within the gauge section. Which failure

TABLE 1 Compressive Tapered Joint Standard Specimen Geometry Requirements

Specimen Type	Specimen Lay-Up – Parent and Repair	Taper Ratio	Repair Ply Overlap Length[A]	Specimen Width	Total Repair Length[B]
Tapered	[+45°/0°/90°/-45°]s (Tape) or [+45°/0°/90°/-45°]sf (Fabric)	50:1	13 ± 2 mm [0.5 ± 0.08 in.]	80 ± 3 mm [3.0 ± 0.1 in.]	254 ± 3 mm [10.0 ± 0.10 in.]

[A] The standard repair ply overlap length is designed for a repair ply material thickness less than or equal to 0.2 mm [0.008 in.]. For repair materials with significantly different ply thicknesses, the repair ply overlap length should be adjusted accordingly.
[B] For the standard specimen, the Total Repair Length shall be approximately 254 mm [10 in.].