Designation: D7249/D7249M − 18

Standard Test Method for Facesheet Properties of Sandwich Constructions by Long Beam Flexure[1]

This standard is issued under the fixed designation D7249/D7249M; 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 determination of 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).

1.2 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, each system shall be used independently of the other. Combining values from the two systems may result in non-conformance with the standard.

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.*

NOTE 1—Alternate procedures for determining the compressive strength of unidirectional polymer matrix composites materials in a sandwich beam configuration may be found in Test Method D5467/D5467M.

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]

C273/C273M Test Method for Shear Properties of Sandwich Core Materials
C393/C393M Test Method for Core Shear Properties of Sandwich Constructions by Beam Flexure
D3410/D3410M Test Method for Compressive Properties of Polymer Matrix Composite Materials with Unsupported Gage Section by Shear Loading
D3878 Terminology for Composite Materials
D5229/D5229M Test Method for Moisture Absorption Properties and Equilibrium Conditioning of Polymer Matrix Composite Materials
D5467/D5467M Test Method for Compressive Properties of Unidirectional Polymer Matrix Composite Materials Using a Sandwich Beam
D7250/D7250M Practice for Determining Sandwich Beam Flexural and Shear Stiffness
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
E251 Test Methods for Performance Characteristics of Metallic Bonded Resistance Strain Gages
E456 Terminology Relating to Quality and Statistics
E1237 Guide for Installing Bonded Resistance Strain Gages

3. Terminology

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

3.2 *Symbols:*

[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.

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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.

b = specimen width
c = core thickness
CV = coefficient of variation statistic of a sample population for a given property (in percent)
d = sandwich total thickness
$D^{F,nom}$ = effective sandwich flexural stiffness
E^f = effective facesheet chord modulus
ε = measuring strain in facesheet
F^u = facesheet ultimate strength (tensile or compressive)
F_s = core shear allowable strength
F_c = core compression allowable strength
k = core shear strength factor to ensure facesheet failure
l = length of loading span
L = length of support 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_{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 Test Method

4.1 This test method 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. Deflection and strain versus force measurements are recorded.

4.2 The only acceptable failure modes for sandwich facesheet strength are those which are internal to one of the facesheets. Failure of the sandwich core or the core-to-facesheet bond preceding failure of one of the facesheets is not an acceptable failure mode. 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 construction may be conducted to determine the sandwich flexural stiffness, the core shear strength, and shear modulus, or the facesheets' compressive and tensile strengths. Tests to evaluate core shear strength may also be used to evaluate core-to-facesheet bonds.

5.2 This test method is limited to obtaining the strength and stiffness of the sandwich panel facesheets, and to obtaining load-deflection data for use in calculating sandwich beam flexural and shear stiffness using Standard Practice D7250/D7250M. 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 Core shear strength and shear modulus are best determined in accordance with Test Method C273/C273M provided bare core material is available. Test Method C393/C393M may also be used to determine core shear strength. Standard Practice D7250/D7250M may be used to calculate the flexural and shear stiffness of sandwich beams.

5.4 This test method can be used to produce facesheet strength data for structural design allowables, material specifications, and research and development applications; it may also be used as a quality control test for bonded sandwich panels.

5.5 Factors that influence the 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, specimen preparation, specimen conditioning, environment of testing, specimen alignment, loading procedure, speed of testing, facesheet void content, adhesive void content, and facesheet volume percent reinforcement. Further, facesheet strength may be different between precured/bonded and co-cured facesheets of the same material.

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 pressure 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 span length divided by the sandwich thickness should be greater than 20 ($L/d > 20$) with the ratio of facesheet thickness to core thickness less than 0.1 ($t/c < 0.1$).

6. Interferences

6.1 *Material and Specimen Preparation*—Poor material fabrication practices and damage induced by improper specimen machining are known causes of high data scatter in composites and sandwich structures in general. A specific material factor that affects sandwich cores is variability in core density. 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.

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

6.3 *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. Critical environments must be assessed independently for each specific combination of core material, facesheet material, and core-to-facesheet interfacial adhesive (if used) that is tested.

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

7. Apparatus

7.1 *Micrometers and Calipers*—A micrometer having a flat anvil interface, or a caliper of suitable size, shall be used. The instrument(s) shall have an accuracy of ±25 µm [±0.001 in.] for thickness measurement, and an accuracy of ±250 µm [±0.010 in.] for length and width measurement.

NOTE 4—The accuracies given above are based on achieving measurements that are within 1 % of the sample length, width and thickness.

7.2 *Loading Fixtures*

7.2.1 *Standard 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.].

7.2.2 *Non-Standard 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. Figs. 3-5 show typical test fixtures. Non-standard 3- and 4-point loading configurations have been retained within this standard a) for historical continuity with previous versions of Test Method C393/C393M, b) because some sandwich panel designs require the use of non-standard loading configurations to achieve facesheet failure modes, and c) load-deflection data from non-standard configurations may be used with Standard Practice D7250/D7250M to obtain sandwich beam flexural and shear stiffnesses.

7.2.3 *Support and Loading Bars*—The bars shall be designed to allow free rotation of the specimen at the loading and support points. The bars shall have sufficient stiffness to avoid significant deflection of the bars under load; any obvious bowing of the bars or any gaps occurring between the bars and the test specimen during loading shall be considered significant deflection. The recommended configuration has a 25 mm [1.0 in.] wide flat steel loading block to contact the specimen (through rubber pressure pads) and is loaded via either a cylindrical pivot (see Fig. 3) or a V-shaped bar riding in a V-groove in the top of the flat-bottomed steel loading pad. The tips of the V-shaped loading bars shall have a minimum radius of 3 mm [0.12 in.]. The V-groove in the loading pad shall have a radius larger than the loading bar tip and the angular opening of the groove shall be such that the sides of the loading bars do not contact the sides of the V-groove during the test. Loading bars consisting of 25 mm [1.0 in.] diameter steel cylinders may also be used, but there is a greater risk of local specimen crushing with cylindrical bars. Also, the load and support span lengths tend to increase as the specimen deflects when cylindrical loading bars without V-grooved loading pads are used (e.g., rolling supports).

7.2.4 *Pressure Pads*—Rubber pressure pads having a Shore A durometer of 60, a width of 25 mm [1.0 in.], a nominal thickness of 3 mm [0.125 in.] and spanning the full width of the specimen shall be used between the loading bars and specimen to prevent local damage to the facesheets.

7.3 *Testing Machine*—The testing machine shall be in accordance with Practices E4 and shall satisfy the following requirements:

7.3.1 *Testing Machine Configuration*—The testing machine shall have both an essentially stationary head and a movable head.

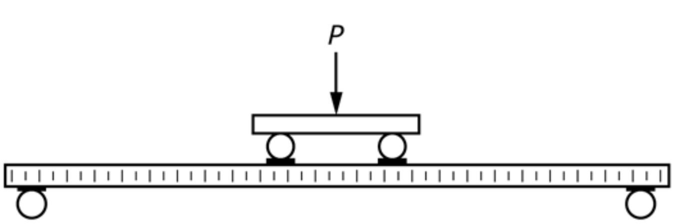
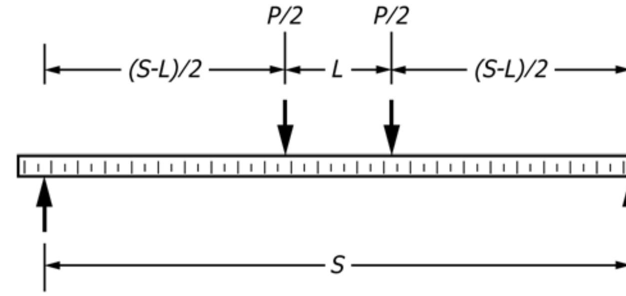


FIG. 1 Test Specimen and Fixture



Configuration		Support Span (*S*)	Load Span (*L*)
Standard	4-Point	560 mm [22.0 in.]	100 mm [4.0 in.]
Non-Standard	3-Point (Mid-span)	*S*	0.0
	4-Point (Quarter-Span)	*S*	*S/2*
	4-Point (Third-Span)	*S*	*S/3*

FIG. 2 Loading Configurations

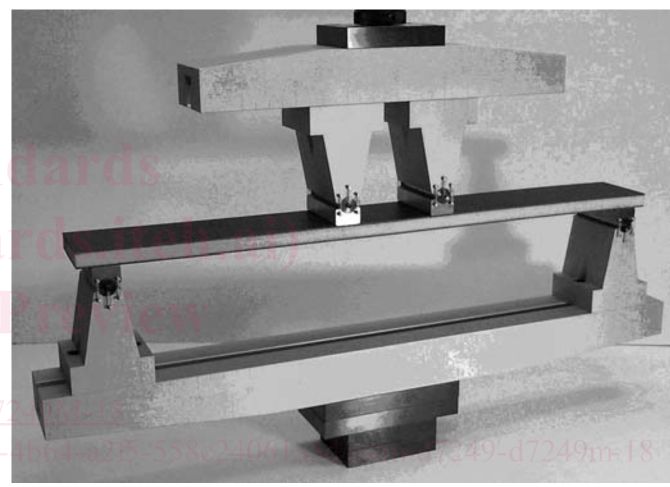


FIG. 3 Standard 4-Point Loading Configuration

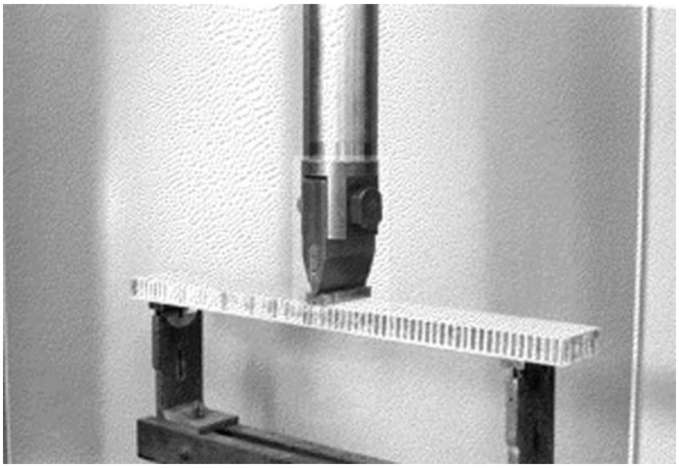


FIG. 4 3-Point Mid-Span Loading Configuration (Non-Standard)

7.3.2 *Drive Mechanism*—The testing machine drive mechanism shall be capable of imparting to the movable head a controlled velocity with respect to the stationary head. The velocity of the movable head shall be capable of being regulated in accordance with 11.4.

7.3.3 *Force Indicator*—The testing machine force-sensing device shall be capable of indicating the total force being carried by the test specimen. This device shall be essentially free from inertia-lag at the specified rate of testing and shall indicate the force with an accuracy over the force range(s) of interest of within ±1 % of the indicated value.

7.4 *Deflectometer (LVDT)*—The deflection of the specimen shall be measured in the center of the support span by a properly calibrated device having an accuracy of ±1 % or better.

NOTE 5—The use of crosshead or actuator displacement for the beam mid-span deflection produces inaccurate results; the direct measurement of the deflection of the mid-span of the beam must be made by a suitable instrument.

7.5 *Strain-Indicating Device*—Strain data, when required, shall be determined by means of bonded resistance strain gages. One axial gage element shall be located on each face at the center of the specimen, with the gage aligned with the specimen length axis. Strain gages cannot be used on the non-standard 3-point loading configuration due to interference with the center loading bar.

7.5.1 *Bonded Resistance Strain Gage Selection*—Strain gage selection is based on the type of material to be tested. An active gage length of 1.5 mm [0.062 in.] is recommended for composite laminates fabricated from unidirectional layers. Larger strain gage sizes may be more suitable for some textile fabrics. Gage calibration certification shall comply with Test Method E251. Strain gages with a minimum normal strain range of approximately 3 % are recommended. When testing textile fabric laminates, gage selection should consider the use of an active gage length that is at least as great as the characteristic repeating unit of the fabric. Some guidelines on the use of strain gages on composite materials follow. A general reference on the subject is Tuttle and Brinson.[3]

7.5.1.1 Surface preparation of fiber-reinforced composites in accordance with Guide E1237 can penetrate the matrix material and cause damage to the reinforcing fibers, resulting in improper coupon failures. Reinforcing fibers should not be exposed or damaged during the surface preparation process. The strain gage manufacturer should be consulted regarding surface preparation guidelines and recommended bonding agents for composites, pending the development of a set of standard practices for strain gage installation surface preparation of fiber-reinforced composite materials.

7.5.1.2 Consideration should be given to the selection of gages having larger resistances to reduce heating effects on low conductivity materials. Resistances of 350 Ω or higher are preferred. Additional consideration should be given to the use of the minimum possible gage excitation voltage consistent with the desired accuracy (1 to 2 V is recommended) to reduce the power consumed by the gage. Heating of the coupon by the gage may affect the performance of the material directly or it may affect the indicated strain as a result of a difference between the gage temperature compensation factor and the coefficient of thermal expansion of the coupon material.

7.5.1.3 Consideration of some form of temperature compensation is recommended, even when testing at standard laboratory atmosphere. Temperature compensation may be required when testing in non-ambient temperature environments.

7.5.1.4 Consideration should be given to the transverse sensitivity of the selected strain gage. The strain gage manufacturer should be consulted for recommendations on transverse sensitivity corrections and effects on composites.

7.6 *Conditioning Chamber*—When conditioning materials at non-laboratory environments, a temperature/vapor-level controlled environmental conditioning chamber is required that shall be capable of maintaining the required temperature to within ±3°C [±5°F] and the required relative humidity level to within ±3 %. Chamber conditions shall be monitored either on an automated continuous basis or on a manual basis at regular intervals.

7.7 *Environmental Test Chamber*—An environmental test chamber is required for test environments other than ambient testing laboratory conditions. This chamber shall be capable of maintaining the gage section of the test specimen at the required test environment during the mechanical test.

8. Sampling and Test Specimen

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 section

[3] Tuttle, M. E., and Brinson, H. F., "Resistance-Foil Strain-Gage Technology as Applied to Composite Materials," *Experimental Mechanics*, Vol 24, No. 1, March 1984, pp. 54–65; errata noted in Vol 26, No. 2, June 1986, pp. 153–154.

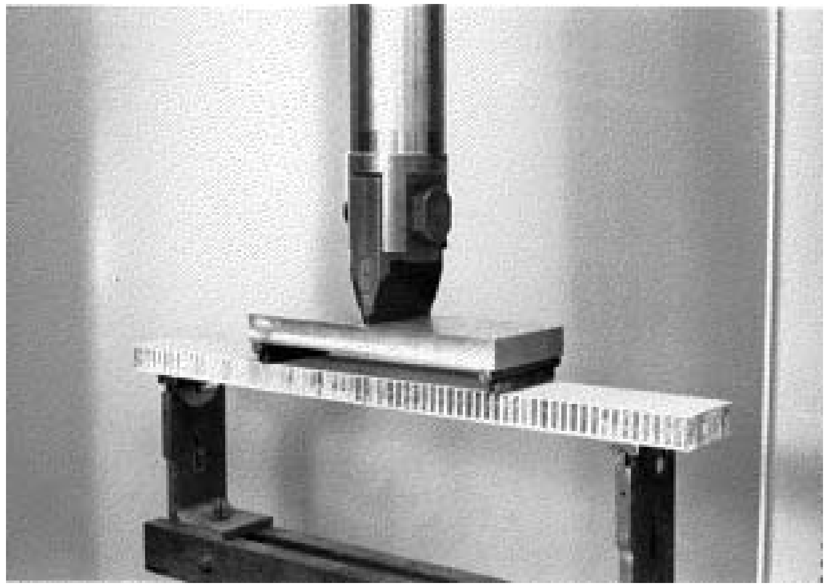


FIG. 5 4-Point Quarter-Point Loading Configuration (Non-Standard)

8.2.3 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 Configuration*—The standard test specimen shall be rectangular in cross section, with a width of 75 mm [3.0 in.] and a length of 600 mm [24.0 in.]. The depth of the specimen shall be equal to the thickness of the sandwich construction.

8.2.2 *Non-Standard Configurations*—For non-standard specimen geometries 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.

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 following equations can be used to size the test specimen (these equations assume that both facesheets have the same thickness and modulus, and that the facesheet thickness is small relative to the core thickness [t/c £ ≤ ~0.10]):

The support span length shall satisfy: $$S \geq \frac{2\sigma t}{kF_s} + L \quad (1)$$

or, the core shear strength shall satisfy: $$F_s \geq \frac{2\sigma t}{k\,(S-L)} \quad (2)$$

The core compression strength shall satisfy: $$F_c \geq \frac{2(c+t)\sigma t}{(S-L)L_{pad}} \quad (3)$$

where:

S = support span length, mm [in.],
L = loading span length, mm [in.] (L = 0 for 3-point loading),
σ = expected facesheet ultimate strength, MPa [psi],
t = facesheet thickness, mm [in.],
c = core thickness,
F_s = core shear allowable strength, MPa [psi],
k = core shear strength factor to ensure facesheet failure (recommend k = 0.75),
L_{pad} = dimension of loading pad in specimen lengthwise direction, mm [in.], and
F_c = core compression allowable strength, Mpa [psi].

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 (e.g. intra-cell dimpling) than is facesheet tension strength.

NOTE 6—Tensile failures rarely occur unless the tensile facesheet is thinner or of different material than the compression facesheet. Failure in the compression facesheet may occur by actual crushing, yielding causing unduly large deflection, wrinkling of the facesheet into the core, the facesheet disbonding from the core, or the facesheet dimpling into the honeycomb core cells.

8.3.2 *Layup*—The apparent flexural strength, effective facesheet moduli, and flexural stiffness obtained from this method may be dependent upon the facesheet stacking sequence, albeit to a much lesser degree than is typical for laminate flexure. For the standard test configuration, facesheets consisting of a laminated composite material shall be balanced and symmetric about the sandwich beam mid-plane.

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 provided 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. 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. 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 The accuracy of all measuring equipment shall have certified calibrations that are current at the time of use of the equipment.

10. Conditioning

10.1 The recommended pre-test specimen condition is effective moisture equilibrium at a specific relative humidity per Test Method D5229/D5229M; however, if the test requestor does not explicitly specify a pre-test conditioning environment, conditioning is not required and the test specimens may be tested as prepared.

10.2 The pre-test specimen conditioning process, to include specified environmental exposure levels and resulting moisture content, shall be reported with the test data.

NOTE 7—The term moisture, as used in Test Method D5229/D5229M, includes not only the vapor of a liquid and its condensate, but the liquid itself in large quantities, as for immersion.

10.3 If no explicit conditioning process is performed the specimen conditioning process shall be reported as "unconditioned" and the moisture content as "unknown".

11. Procedure

11.1 *Parameters to Be Specified Before Test:*

11.1.1 The specimen sampling method, specimen geometry, and conditioning travelers (if required).

11.1.2 The properties and data reporting format desired.

11.1.3 The environmental conditioning test parameters.

11.1.4 The nominal thicknesses of the facesheet materials.

NOTE 8—Determine specific material property, accuracy, and data reporting requirements prior to test for proper selection of instrumentation and data recording equipment. Estimate the specimen strength to aid in transducer selection, calibration of equipment, and determination of equipment settings.

11.2 *General Instructions:*

11.2.1 Report any deviations from this test method, whether intentional or inadvertent.

11.2.2 Condition the specimens as required. Store the specimens in the conditioned environment until test time, if the test environment is different than the conditioning environment.

11.2.3 Before testing, measure and record the specimen length, width, and thickness at three places in the test section. Measure the specimen length and width with an accuracy of ±250 µm [±0.010 in.]. Measure the specimen thickness with an accuracy of ±25 µm [±0.001 in.]. Record the dimensions to three significant figures in units of millimetres [inches].

11.2.4 If strain is to be measured, apply one longitudinal strain gage to each facesheet at the center of the specimen.

11.3 Measure and record the length of the support and loading spans.

11.4 *Speed of Testing*—Set the speed of testing so as to produce failure within 3 to 6 min. If the ultimate strength of the material cannot be reasonably estimated, initial trials should be conducted using standard speeds until the ultimate strength of the material and the compliance of the system are known, and speed of testing can be adjusted. The suggested standard speeds are:

11.4.1 *Strain-Controlled Tests*—A standard strain rate of 0.01 min^{-1}.

11.4.2 *Constant Head-Speed Tests*—A standard cross head displacement of 6 mm/min [0.25 in./min].

11.5 *Test Environment*—If possible, test the specimen under the same fluid exposure level used for conditioning. However, cases such as elevated temperature testing of a moist specimen place unrealistic requirements on the capabilities of common testing machine environmental chambers. In such cases, the mechanical test environment may need to be modified, for example, by testing at elevated temperature with no fluid exposure control, but with a specified limit on time to failure