Designation: D8067/D8067M – 17

Standard Test Method for In-Plane Shear Properties of Sandwich Panels Using a Picture Frame Fixture[1]

This standard is issued under the fixed designation D8067/D8067M; 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 apparent in-plane shear strength and stiffness properties of flat sandwich constructions with composite face sheets. 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 square test specimen with corner notches is mechanically fastened to a pinned metal frame along each edge. The frame is loaded in uni-axial tension which produces tensile forces in the frame elements at a 45° angle to the applied tension. These tensile forces act along the edges of the specimen to cause a state of predominately shear stress to transfer the applied force through the specimen. Procedure A uses a specimen without edge doublers; Procedure B uses a specimen with four discrete edge doublers; Procedure C uses a specimen with a continuous edge doubler.

1.3 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.

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

2. Referenced Documents

2.1 *ASTM Standards:*[2]

D883 Terminology Relating to Plastics
D3878 Terminology for Composite Materials
D5229/D5229M Test Method for Moisture Absorption Properties and Equilibrium Conditioning of Polymer Matrix Composite Materials
E4 Practices for Force Verification of Testing Machines
E6 Terminology Relating to Methods of Mechanical Testing
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

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.

3.2 *Acronyms:*

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

3.2.2 F^{su}—face sheet ultimate shear stress

3.2.3 G_f—effective face sheet chord shear modulus

3.2.4 γ—measured engineering shear strain in face sheet

3.2.5 *L*—length of specimen between doubler edges

3.2.6 *n*—number of specimens

3.2.7 *P*—applied force

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

[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.

3.2.9 *q*—running shear force per unit width along specimen edge

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

3.2.11 τ—face sheet shear stress

3.2.12 *t*—face sheet thickness

3.2.13 x_1—test result for an individual specimen from the sample population for a given property

3.2.14 $\bar{x}$—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 square panel of sandwich construction to a set of forces along the panel edges such that the applied force is transferred through the panel via a state of predominately shear stresses. The tensile forces are applied using a picture-frame loading fixture. By placing two strain gage rosettes in the center of the specimen, the apparent shear stress-strain response of the panel can be measured. Out-of-plane panel deflection can be measured to assist in detecting panel buckling. It is noted that engineering shear strain, as opposed to tensorial shear strain, is used throughout this standard.

NOTE 1—Tensorial shear strain may be used in analysis and reporting of results from tests using this standard, but requires the appropriate inclusion of the factor of 2, and clear documentation shall be made in the test report.

4.2 Procedure A uses a specimen without edge doublers. Procedure B uses a specimen with four discrete edge doublers; the data analysis for this procedure assumes that the doublers do not carry significant shear force. Procedure C uses a specimen with a continuous edge doubler; the data analysis for this procedure assumes that the doublers carry some shear force, and a correction is made to the applied force before calculating the shear stress in the panel.

4.3 The acceptable failure modes are face sheet fracture, face sheet dimpling, face sheet wrinkling or core shear instability. Failure of the sandwich core-to-face sheet bond preceding one of the previous listed modes is not an acceptable failure mode. Failure originating at the panel corner notches is not an acceptable failure mode. Buckling of the panel prior to face sheet or core failure is not an acceptable failure mode, unless otherwise specified as an acceptable response by the test requestor. The test specimen face sheet thicknesses, core thickness, core material and adhesive material must be selected to avoid the unacceptable failure modes.

5. Significance and Use

5.1 In-plane shear loading tests on flat sandwich constructions may be conducted to determine the sandwich panel in-plane shear stiffness, the face sheets' in-plane strength, the core shear instability strength, or panel buckling response.

5.2 This test method can be used to produce face sheet 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.

5.3 Factors that influence the panel strength and shall therefore be reported include the following: face sheet material, core material, adhesive material, methods of material fabrication, face sheet stacking sequence and overall thickness, core geometry (cell size), core shear and compressive strength, core shear and compressive stiffness, adhesive thickness, specimen geometry, specimen preparation, specimen conditioning, environment of testing, specimen alignment, loading procedure, speed of testing, face sheet void content, adhesive void content, and face sheet volume percent reinforcement. Further, face sheet strength may be different between precured/bonded and co-cured face sheets of the same material.

6. Interferences

6.1 *Fixture Geometry*—The basic configuration with through-pins and corner notches may exhibit large deviations from uniform stress. For example, in a configuration relative close in geometry to Method C, the shear stress at the center was predicted by finite element analysis (FEA) to be more than 25 % lower than the value obtained from Eq 2, while the shear stress increases near the edges and corners so that local buckling or material failure is likely to originate at the periphery of the gage area. Farley and Baker reported on the strong influence of the location of the pivot pins on the stress distribution.[3] Moving the pivots to the corners of the gage area, while requiring a significantly more complicated test fixture, provides a greatly improved stress distribution. Furthermore it was reported that stiff edge doublers (e.g. steel rather than composite) increased the uniformity of the stresses.

6.2 *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.

6.3 *Geometry*—Specific geometric factors that affect sandwich face sheet strength include face sheet thickness, core cell geometry, and face sheet surface flatness. This test has been mainly used on panels with relatively thin face sheets (0.5 mm [0.020 in.]). The reliability of testing panels with thicker face sheets is unknown.

6.4 *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

[3] 1. G.L. Farley and D.J. Baker, "In-Plane Shear Test of Thin Panels," *Experimental Mechanics*, Vol. 23, No. 1, 1983, pp. 81–87.

combination of core material, face sheet material, and core-to-face sheet interfacial adhesive (if used) that is tested.

6.5 *Elastic Modulus Measurement*—Shear modulus calculations in this test method assume a uniform distribution of shear stress and engineering shear strain in the center region of the specimen. The actual uniformity is dependent on the material orthotropy, the panel geometry, and doubler material and thickness.

6.6 *Potting*—Edge potting of open cell cores (filling the core cells with resin type material) may be used in the areas under the loading bars. The use of potting may be necessary to avoid crushing the panel when the edge fasteners are installed.

6.7 *Edge Doublers*—These are used to increase the thickness of the face sheets to avoid bearing failures in the face sheets at the edge fastener holes.

6.8 *Edge Doubler Adhesive*—A suitable adhesive shall be selected for the test environment. The cure temperature of the adhesive should not exceed the face sheet material dry glass transition temperature, *Tg*, to avoid changes to the face sheet material. The limitation on cure temperature should also consider any exothermic temperature increases in the adhesive during cure (exothermic reactions are not unusual for adhesives used in secondary bonding).

7. Apparatus

7.1 *Micrometers and Calipers*—A micrometer with a 4 to 7 mm [0.16 to 0.28 in.] nominal diameter ball-interface or a flat anvil interface shall be used to measure the specimen thickness. A ball interface is recommended for thickness measurements when face sheets are bonded to the core and at least one surface is irregular (e.g. the bag-side of a thin face sheet laminate that is neither smooth nor flat). A micrometer or caliper with a flat anvil interface is recommended for thickness measurements when face sheets are bonded to the core and both surfaces are smooth (e.g. tooled surfaces). A micrometer or caliper with a flat anvil interface shall be used for measuring length and width. The use of alternative measurement devices is permitted if specified (or agreed to) by the test requestor and reported by the testing laboratory. The accuracy of the instruments shall be suitable for reading to within 1 % of the sample dimensions. For typical specimen geometries, an instrument with an accuracy of ±0.025 mm [±0.001 in.] is adequate for the length, width, and thickness measurements.

NOTE 2—The accuracies given above are based on achieving measurements that are within 1% of the sample length, width, and thickness.

7.2 *Loading Fixture*—The loading fixture shall be self-aligning and shall not apply eccentric forces. A satisfactory type of apparatus for testing relatively thin face sheet panels is shown in Fig. 1. It consists of a steel frame with four corner pins and 40 panel mounting fastener holes, see Fig. 2. Before using the test fixture, a stress analysis of the entire fixture should be performed, using a conservative estimated failure load for the panel to be tested.

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

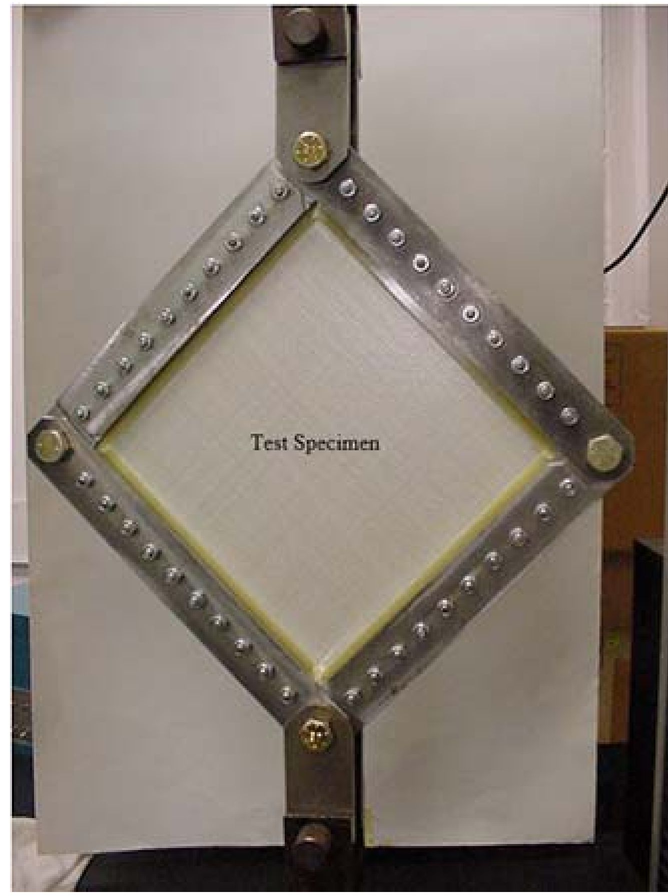


FIG. 1 Panel In-Plane Shear Test Specimen and Test Fixture - Procedure C shown
(Procedure A is the same except without the doublers Procedure B is the same except with discrete doublers on each edge)

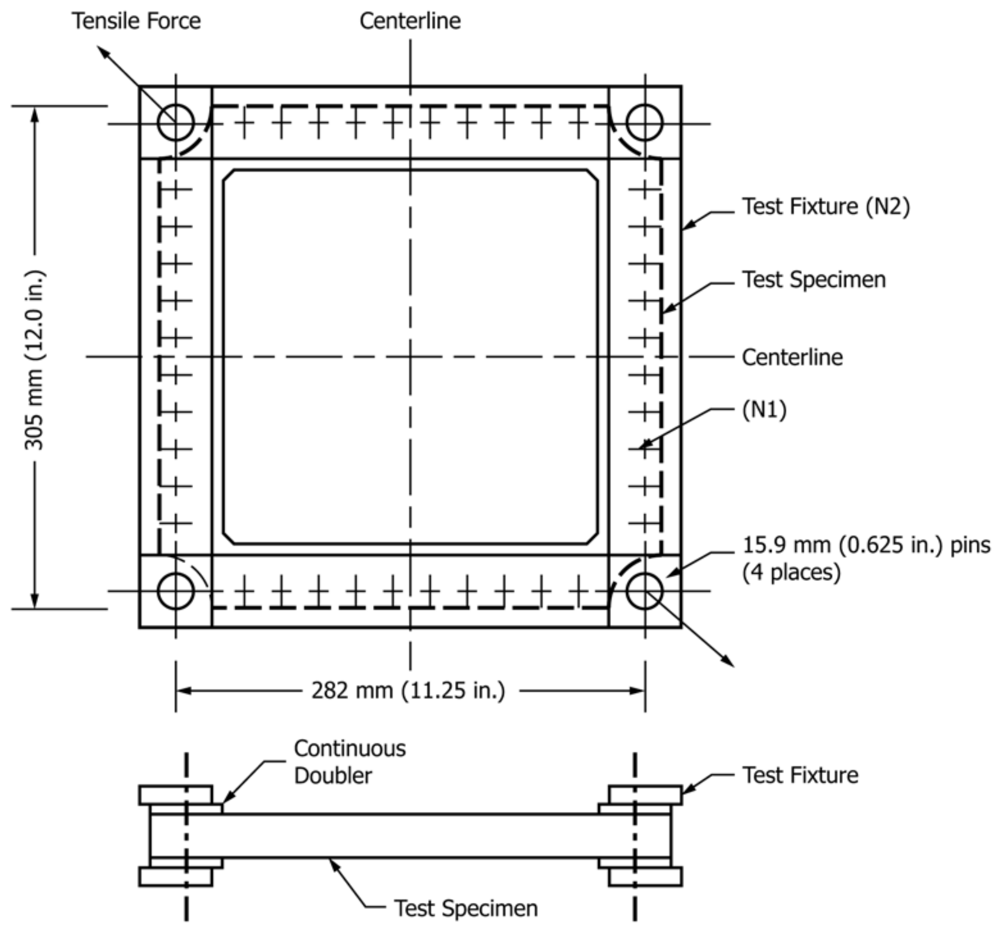
7.3.1 *Testing Machine Configuration*—The testing machine shall have both an essentially stationary head and a movable head.

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*—When required by the test requestor, the out-of-plane deflection shall be measured in the center of the specimen by a properly calibrated device having an accuracy of ±1 % or better of the indicted value.

7.5 *Strain-Indicating Device*—When required by the test requestor, strain data shall be determined by the specified means. When using bonded resistance strain gages, one tri-axial gage rosette shall be located on each face at the center of the specimen. Full field digital image correlation or laser strain measurement methods may be used.



N1. Locate and drill through test specimens and doublers to match fixture:
6.1 – 6.2 mm (0.250-0.254 in.) dia holes
24 mm (0.95 in.) center – center distance between holes
6 mm (0.250 in.) diameter bolts; tighten to 4 +/– 0.6 N-m (35 +/– 5 in.-lbs) torque
(10 places each side)

N2. Test fixture made from steel (recommend 4130 Rockwell C40 for RTA testing; stainless steel for elevated temperature testing)
330 mm long by 43 mm wide by 8.6 mm thick (13 in. long by 1.7 in. wide by 0.34 in. thick)
8 parts required

FIG. 2 Panel In-Plane Shear Test Specimen and Test Fixture - Procedure C

7.6 *Out-of-Plane Displacement*—When required by the test requestor, for cases where panel buckling response is to be measured, moire fringe methods or Digital Image Correlation may be used to provide images of the panel buckle shape. An applied force readout visible in the recorded images or video is required.

7.7 *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.

7.8 *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 Specimens

8.1 *Sampling*—Test at least five specimens per test condition (plus when using Procedure C one additional specimen with the center portion removed, according to 8.6) 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 E251. Report the method of sampling.

8.2 *Geometry*—The standard specimen configuration should be used whenever the specimen design will produce a material fracture prior to panel buckling. In cases where the standard specimen configuration may buckle prior to fracture, a non-standard specimen may be designed.

8.2.1 *Standard Configuration*—The standard test specimen shall be of constant thickness (face sheets and core), with a width and a length of 305 mm [12.0 inch], as in Fig. 3. The depth of the specimen (not including any doublers) shall be equal to the thickness of the sandwich construction.

8.2.2 *Non-Standard Configurations*—Larger or smaller non-standard specimens using correspondingly sized test fixtures may be tested using the procedures of this method.

8.3 *Face Sheets*

8.3.1 *Material*—The face sheets may be any continuous, constant thickness composite laminate.

8.3.2 *Composite Layup*—The apparent shear strength and stiffness obtained from this method may be dependent upon the face sheet stacking sequence. For the standard test configuration, face sheets consisting of a laminated composite material shall be balanced and symmetric about the sandwich panel mid-plane.

8.3.3 *Stiffness*—For the standard specimen, the two face sheets shall be the same material, thickness, and layup. The calculations assume constant and equal face sheet stiffness properties. This assumption may not be applicable for certain face sheet materials which exhibit significant non-linear stress-strain behavior.

8.3.4 *Face Sheet Thickness*—Accurate measurement of face sheet thickness is difficult after bonding or co-curing of the face sheets and core. The test requestor is responsible for specifying the face sheet thicknesses to be used for the calculations in this test method. For precured composite face sheets that are secondarily bonded to the core, the face sheet thickness should be measured prior to bonding. In these cases

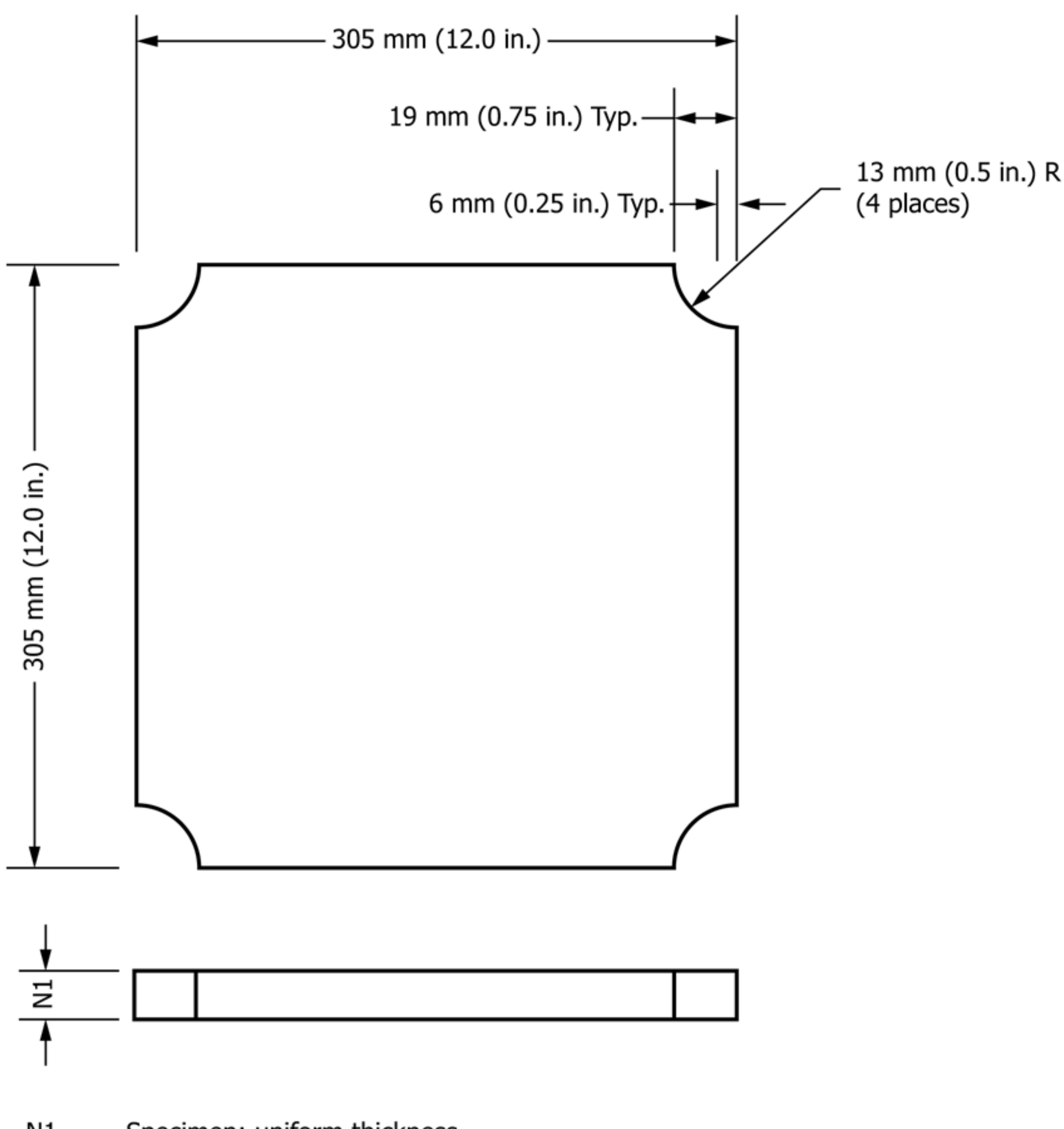


FIG. 3 Standard Specimen Dimensions

the test requestor may specify that either or both measured and nominal thicknesses be used in the calculations. For co-cured composite face sheets, 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 specified by the test requestor on the specimen drawing. The ribbon direction is typically oriented parallel to one of the specimen edges.

8.5 *Potting*—The use of potting in the areas under the loading bars may be necessary to avoid crushing the panel when the edge fasteners are installed. The potting may be installed in the core prior to bonding the face sheets to the core, or the core on the edges of the panel may be machined out and replaced with solid potting compound or metallic bars. The test requestor must specify any required edge potting procedure to be used. The standard test procedure does not require potting.

8.6 *Edge Doublers*—May be used to increase the thickness of the face sheets to avoid bearing failures at the edge fastener holes. The test requestor may specify a different doubler configuration or material from the standard doublers specified below.

8.7 *Specimen Preparation and Machining*

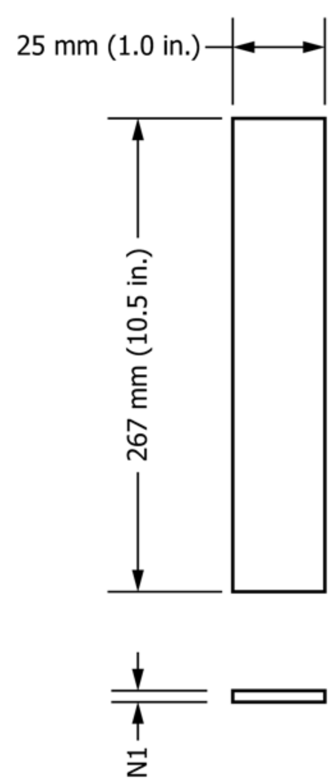
8.7.1 *Doublers—Procedure B*—Four fiberglass doublers 267 ± 1 mm by 25 ± 1 mm wide (10.5 ± 0.04 in. by 1.0 ± 0.04 in. wide) (see Fig. 4) shall be bonded to each side of the test panel specimen with a suitable adhesive (a total of eight (8) doublers are required). A room temperature curing adhesive shall be used unless otherwise specified by the test requestor.

8.7.2 *Doublers—Procedure C*—Fiberglass doublers 305 ± 1 mm by 40 ± 1 mm wide (12.0 ± 0.04 in. by 1.5 ± 0.04 in. wide) (see Fig. 5) shall be bonded to each side of the test panel specimen with a suitable adhesive. See Fig. 6. A room temperature curing adhesive shall be used unless otherwise specified by the test requestor.

8.7.3 *Machining*—After the doubler adhesive has cured, the test specimen shall be machined according to Fig. 6.

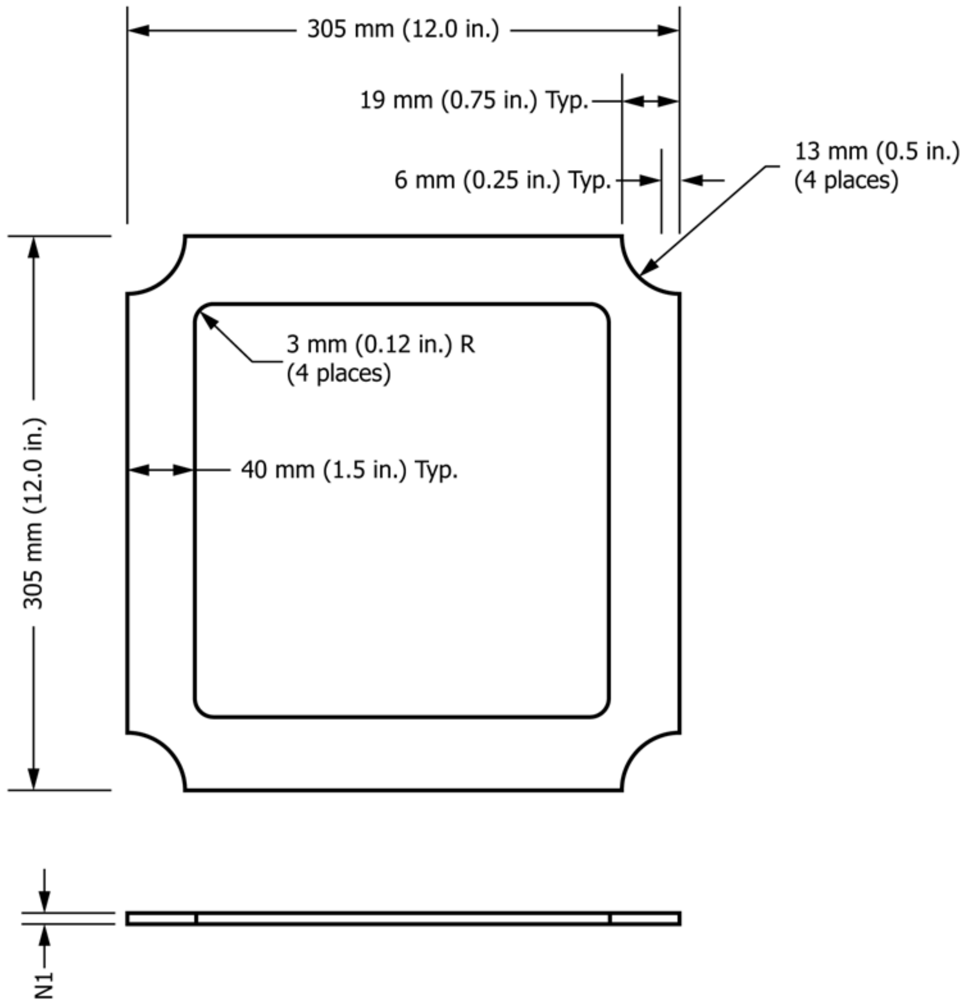
8.7.4 *General Preparation*—Specimen preparation is extremely important for this test method. Take precautions when cutting specimens from large panels to avoid notches, undercuts, rough or uneven surfaces, or delaminations due to inappropriate machining methods. Obtain final dimensions by water-lubricated 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.

8.8 *Procedure C—Frame Load Specimen*—When using Procedure C, one additional specimen from each test group shall have the panel in-between the fiberglass doublers cut out. Machine along the inner edges of the doublers leaving a square "ring" specimen, see Fig. 7. This modified specimen is used to



N1. Doubler 2.5 mm (0.10 in.) thick fiberglass (recommend 181 style cloth and epoxy resin)
One doubler on each specimen edge, both faces (8 total doublers)
Bond doublers to specimen

FIG. 4 Procedure B Doubler Dimensions



N1. Doubler 2.5 mm (0.10 in.) thick fiberglass (recommend 181 style cloth and epoxy resin)
Continuous around specimen, both faces
Bond doubler to specimen

FIG. 5 Procedure C Doubler Dimensions

FIG. 6 Typical Procedure C Test Specimen with Doublers

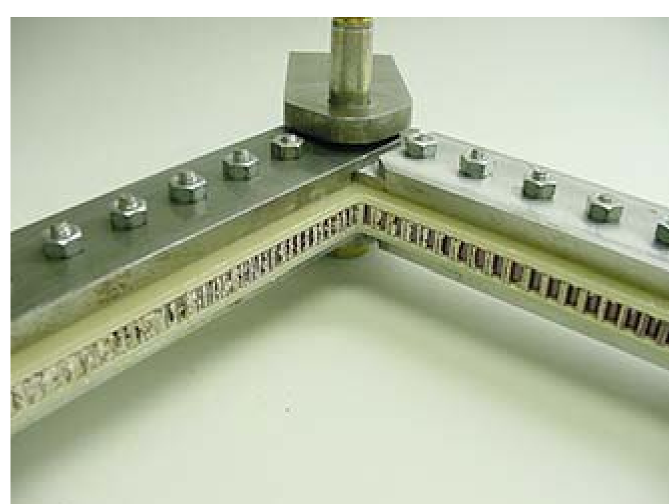


FIG. 7 Modified Procedure C Specimen with Center Cut Out

determine the force the frame withstands and is subtracted from the test panel force.

8.9 *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 according to 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 3—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 procedure and doubler configuration.

11.1.3 The doubler material, layup, thickness, and adhesive.

11.1.4 The properties and data reporting format desired, including strain measurement and LVDT requirements.

11.1.5 The pre-test environmental conditioning test parameters.

11.1.6 The test environmental conditions.

11.1.7 The nominal thicknesses of the face sheet materials.

NOTE 4—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 Before specimen conditioning and testing, measure and record the specimen thickness at three places in the test section. Measure the specimen thickness with an accuracy of ±25 µm [±0.001 in.]. Record the dimensions to three significant figures in units of millimeters [inches].

11.2.3 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.

11.2.4 If strain is to be measured, apply one rosette strain gage to each face sheet at the center of the specimen. The orientation of the rosette legs shall be recorded.

11.3 *Fixture Dimensions*—Measure and record the distance between specimen attachment fastener lines for each of the two opposite edges, and the distance between pin centerlines on each of the four fixture bars. Measure the distances with an accuracy of ±250 µm [±0.010 in.].

11.4 *Speed 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.

NOTE 5—A suggested rate of cross-head movement is 25 mm per minute (1.0 in. per minute).

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 from withdrawal from the conditioning chamber. Record any modifications to the test environment.

NOTE 6—When testing a conditioned specimen at elevated temperature with no fluid exposure control, the percentage moisture loss of the specimen prior to test completion may be estimated by placing a conditioned traveler coupon of known weight within the test chamber at the same time the specimen is placed in the chamber. Upon completion of the test, the traveler coupon is removed from the chamber, weighed, and the percentage weight calculated and reported.

11.6 *Specimen Attachment*—Attach the specimen to the steel frame with 40 bolts. Tighten bolts to 4 ± 0.6 N-m (35 ±5 in.-lbs) torque.

11.7 *Fixture Installation*—Mount the steel frame to the test machine.

11.8 *Transducer Installation*—If required, attach the strain-recording instrumentation to the strain gages on the specimen. If required, attach the deflection transducer to the specimen, and connect to the recording instrumentation. Remove any remaining preload, zero the strain gages and balance the deflection transducer.

11.9 *Loading*—Apply a tensile force to the fixture at a constant rate of movement of the testing machine cross-head at the specified rate while recording data. Load the specimen until failure.

11.10 *Data Recording*—Record force versus head displacement, force versus strain, and force versus deflection data continuously, or at frequent regular intervals (on the order of two to three recordings per second, with a target minimum of 100 recorded data points per test). If any initial failures are noted, record the force, displacement, and mode of damage at such points. Record the method used to determine the initial failure (visual, acoustic emission, etc.). If panel buckling is noted, record the force, displacement and measured strains at the onset of buckling. Record the maximum force (P_{max}), the failure force, measured strains, the head displacement and the deflection at, or as near as possible to, the moment of ultimate failure.

NOTE 7—Determination of the exact force at the onset of buckling can often be difficult due to large displacement rather than bifurcation response of the panel. In cases where a clear buckling force is not evident, reporting of an approximate buckling force with an accompanying note is acceptable.

11.11 *Ultimate Failure Modes*—Record the mode, area, and location of ultimate failure for each specimen. Use the failure identification codes shown in Table 1.

11.11.1 *Acceptable Failure Area*—The acceptable failure area is inside the doubler inner edges.

11.11.2 *Acceptable Failure Modes*—The acceptable failure modes are face sheet fracture, face sheet dimpling, face sheet wrinkling, core shear instability. Failure of the sandwich core-to-face sheet bond preceding one of the previous listed modes is not an acceptable failure mode. Failure originating at the panel corner notches is not an acceptable failure mode. Buckling of the panel prior to face sheet or core failure is not an acceptable failure mode, unless otherwise specified as an acceptable response by the test requestor.

11.12 *Procedure C—Frame Load Specimen*—When using Procedure C, test the modified test specimen (with center cut out) to failure using the same procedures as for the standard test specimens. Record force versus head displacement. Record the maximum force (P_{m_max}) and head displacement.

12. Validation

12.1 Values for ultimate properties shall not be calculated for any specimen *a)* that breaks at some obvious flaw, unless such flaw constitutes a variable being studied, *b)* that initiates failure at the core-to-face sheet bond, *c)* that obviously initiates failure at the corner notches, or *d)* buckles prior to failure unless this is specified as an acceptable response by the test requestor. Retests shall be performed for any specimen on which values are not calculated.

13. Calculation

13.1 *Force-Displacement Behavior*—Plot and examine the force-displacement data to determine if there is any evidence of panel buckling. Buckling can be indicated by a compliance change (change in slope of the force-displacement curve) prior to ultimate failure, although material non-linear response can also produce compliance changes.

13.2 *Force-Strain Behavior*—If strain measurements are obtained, plot and examine the force-strain data to determine if there is any evidence of panel buckling. Buckling can be indicated by a significant change in slope of the force-strain curves where the gages on opposite sides of the panel deviate from the initial linear trend in opposite directions.

13.3 *Procedure C—Corrected Panel Failure Force*—For Procedure C, determine the corrected panel shear failure force for each test specimen using Eq 1 and report the results to three significant figures.

$$P_{corrected} = P_{max} - P_{m\_max} \tag{1}$$

where:

$P_{corrected}$ = corrected maximum force prior to failure for the test specimen, N (lb),
P_{max} = maximum force prior to failure for the test specimen, N (lb), and
P_{m_max} = maximum force prior to failure for the modified test specimen, N (lb).

NOTE 8—If the head displacement at failure of the modified test specimen is greater than the head displacement at failure for the test specimen, then P_{m_max} shall be the force from the modified test specimen force-displacement curve at a displacement value equal to the head displacement at failure for the test specimen.

13.4 *Panel Ultimate Shear Force Resultant*—Determine the panel shear ultimate force per unit width for each test specimen using Eq 2 and report the results to three significant figures.

$$\text{Procedure A or B:} \quad q = (0.707)P_{max}/L \tag{2}$$

$$\text{Procedure C:} \quad q = (0.707)P_{corrected}/L$$

where:

q = apparent panel shear ultimate force per unit width, N/mm (lb/in) and
L = distance between inner edges of doublers, mm (in.).

13.5 *Apparent Face Sheet Ultimate Shear Stress*—Calculate the apparent face sheet ultimate stress for each test specimen using Eq 3 and report the results to three significant figures.

$$F^{su} = q/2t \tag{3}$$

where:

F^{su} = apparent face sheet ultimate shear stress, MPa (psi) and
t = nominal face sheet thickness, mm (in.).

NOTE 9—Accurate measurement of face sheet thickness is difficult after bonding or co-curing of the face sheets and core. The test requestor is responsible for specifying the face sheet thicknesses to be used for the

TABLE 1 Sandwich Panel Face Sheet Three-Part Failure Identification Codes

First Character		Second Character		Third Character	
Failure Type	Code	Failure Area	Code	Failure Location	Code
skin-to-core Delamination	D	Gage	G	Bottom face sheet	B
Face sheet fracture	F	from Corner	C	Top face sheet	T
face sheet Wrinkling	W	Unclear	U	both Face sheets	F
face sheet diMpling	M			Core	C
Core crimpling	C			core-face sheet bond	A
Multi-mode	M(xyz)			Various	V
Buckling	B			Unknown	U
Other	O				

calculations in this test method. For pre-cured composite face sheets that are secondarily bonded to the core, the face sheet 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 face sheets, the thicknesses are generally calculated using nominal per ply thickness values.

13.6 *Face Sheet Shear Strength*—Calculate the maximum shear strain value at each measured strain point from the strain rosette values. The rosette gage legs are numbered according to Fig. 8.

13.6.1 For a rectangular rosette (gages at 45 degrees to each other), use:

$$\varepsilon_P = \frac{\varepsilon_1+\varepsilon_3}{2}+\frac{1}{\sqrt{2}}\sqrt{(\varepsilon_1 - \varepsilon_2)^2+(\varepsilon_2 - \varepsilon_3)^2} \quad (4)$$

$$\varepsilon_Q = \frac{\varepsilon_1+\varepsilon_3}{2}-\frac{1}{\sqrt{2}}\sqrt{(\varepsilon_1 - \varepsilon_2)^2+(\varepsilon_2 - \varepsilon_3)^2}$$

$$\gamma = \varepsilon_P - \varepsilon_Q$$

where:

γ = engineering shear strain,
ε_1 = rosette leg 1 measured strain,
ε_2 = rosette leg 2 measured strain, and
ε_3 = rosette leg 3 measure strain.

13.6.2 For a delta rosette (gages at 120 degrees to each other), use:

$$\varepsilon_P = \frac{\varepsilon_1+\varepsilon_2+\varepsilon_3}{3}+\frac{\sqrt{2}}{3}\sqrt{(\varepsilon_1 - \varepsilon_2)^2+(\varepsilon_2 - \varepsilon_3)^2+(\varepsilon_3 - \varepsilon_1)^2} \quad (5)$$

$$\varepsilon_Q = \frac{\varepsilon_1+\varepsilon_2+\varepsilon_3}{3}-\frac{\sqrt{2}}{3}\sqrt{(\varepsilon_1 - \varepsilon_2)^2+(\varepsilon_2 - \varepsilon_3)^2+(\varepsilon_3 - \varepsilon_1)^2}$$

$$\gamma = \varepsilon_P - \varepsilon_Q$$

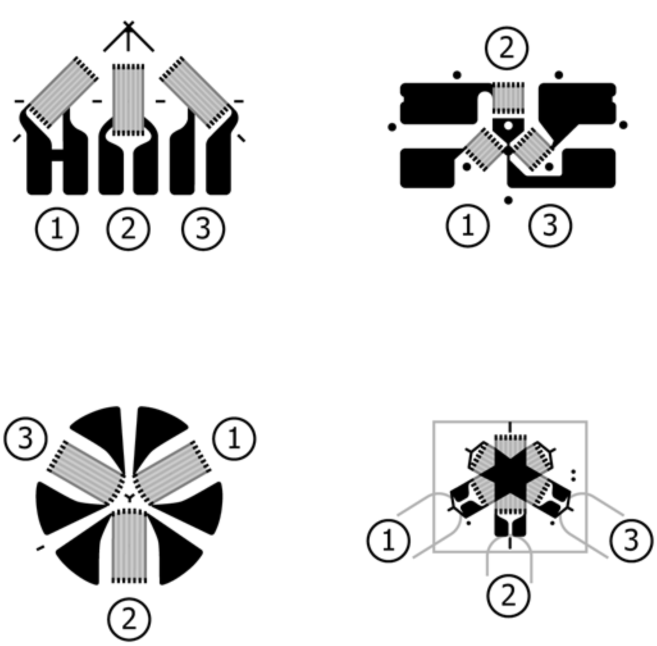


FIG. 8 Strain Gage Rosette Numbering

13.7 *Apparent Effective Face Sheet Chord Shear Modulus*—Calculate the apparent effective chord modulus of each face sheet and report the results to three significant figures. First calculate the measured engineering shear strain from the rosette strain gage data for each face sheet according to 13.6, then average the two face sheet shear strains at each force level to produce a single force-shear strain curve. For Procedure C, correct the force values by subtracting from each test specimen force the modified specimen force at the same head displacement value, to obtain a corrected force-strain curve. For both procedures, use Eq 3-5 to calculate a shear stress-strain curve. Then use Eq 6 to calculate the effective shear modulus.

$$G_f = \frac{(\tau_{6000} - \tau_{2000})}{(\gamma_{6000} - \gamma_{2000})} \quad (6)$$

where:

G = effective face sheet chord shear modulus, Pa [psi],
τ_{6000} = face sheet shear stress corresponding to γ_{6000}, Pa [psi],
τ_{2000} = face sheet shear stress corresponding to γ_{2000}, Pa [psi],
γ_{6000} = recorded engineering shear strain value (magnitude) closest to 6000 micro-strain, and
γ_{2000} = recorded engineering shear strain value (magnitude) closest to 2000 micro-strain.

13.8 *Statistics*—For each series of tests calculate the average value, standard deviation, and coefficient of variation (in percent) for ultimate strength and modulus:

$$\bar{x} = \left(\sum_{i=1}^{n} X_i\right)/n \quad (7)$$

$$S_{n-1} = \sqrt{\left(\sum_{i=1}^{n} x_i^2 - n\bar{x}^2\right)/(n - 1)} \quad (8)$$

$$CV = 100 \times S_{n-1}/\bar{x} \quad (9)$$

where:

$\bar{x}$ = sample mean (average),
S_{n-1} = sample standard deviation,
CV = sample coefficient of variation, %,
n = number of specimens, and
x_1 = measured or derived property.

14. Report

14.1 Report the following information, or references pointing to other documentation containing this information, to the maximum extent applicable (reporting of items beyond the control of a given testing laboratory, such as might occur with material details or panel fabrication parameters, shall be the responsibility of the requestor):

14.1.1 The revision level or date of issue of this test method.

14.1.2 The name(s) of the test operator(s).

14.1.3 Any variations to this test method, anomalies noticed during testing, or equipment problems occurring during testing.

14.1.4 Identification of all the materials constituent to the sandwich panel specimen tested (including face sheet, adhesive and core materials), including for each: material specification, material type, manufacturer's material designation, manufacturer's batch or lot number, source (if not from manufacturer), date of certification, and expiration of certification.

14.1.5 Description of the core orientation.

14.1.6 Description of the fabrication steps used to prepare the sandwich panel including: fabrication start date, fabrication end date, process specification, and a description of the equipment used.

14.1.7 Method of preparing the test specimen, including specimen labeling scheme and method, specimen geometry, sampling method, and specimen cutting method.

14.1.8 Method of bonding the doublers to the specimens; adhesive, cure cycle, and pressure.

14.1.9 Results of any nondestructive evaluation tests.

14.1.10 Calibration dates and methods for all measurements and test equipment.

14.1.11 Details of the test fixture, including dimensions of frame pieces and fasteners, and the frame and fastener materials.

14.1.12 Details of the doublers, including dimensions, materials, adhesive, and bonding process.

14.1.13 Type of test machine, alignment results, and data acquisition sampling rate and equipment type.

14.1.14 Type, range, and sensitivity of displacement transducer.

14.1.15 Measured dimensions and thicknesses for each specimen.

14.1.16 Weight of specimen, if requested.

14.1.17 Conditioning parameters and results.

14.1.18 Relative humidity and temperature of the testing laboratory.

14.1.19 Environment of the test machine environmental chamber (if used) and soak time at environment.

14.1.20 Number of specimens tested.

14.1.21 Speed of testing.

14.1.22 Face sheet thicknesses used in the calculations.

14.1.23 Individual ultimate face sheet strengths and average value, standard deviation, and coefficient of variation (in percent) for the population.

14.1.24 Individual effective face sheet shear modulus values and average value, standard deviation, and coefficient of variation (in percent) for the population.

14.1.25 Force versus crosshead displacement data for each specimen.

14.1.26 Force versus deflection data for each specimen.

14.1.27 Force versus strain data for each strain gage on each specimen.

14.1.28 Failure mode and location of failure.

15. Precision and Bias

15.1 *Precision*—The data required for the development of a precision statement is not available for this test method.

15.2 *Bias*—Bias cannot be determined for this method as no acceptable reference standards exist.

16. Keywords

16.1 face sheet modulus; face sheet strength; face sheet stress; sandwich construction; shear stiffness; shear stress