Standard Test Method for
Shear Properties of Sandwich Core Materials[1]

This standard is issued under the fixed designation C 273/C 273M; 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.

This standard has been approved for use by agencies of the Department of Defense.

1. Scope

1.1 This test method covers the determination of shear properties of sandwich construction core materials associated with shear distortion of planes parallel to the facings. It covers the determination of shear strength parallel to the plane of the sandwich, and the shear modulus associated with strains in a plane normal to the facings. The test may be conducted on core materials bonded directly to the loading plates or the sandwich facings bonded to the plates. 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. Within the text the inch-pound units are shown in brackets. The values stated in each system are not exact equivalents; therefore, each system must be used independently of the other. Combining values from the two systems may result in nonconformance with the standard.

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

2. Referenced Documents

2.1 *ASTM Standards:* [2]

C 271/C 271M Test Method for Density of Core Sandwich Materials

C 274 Terminology of Structural Sandwich Constructions

C 393 Test Method for Flexural Properties of Sandwich Constructions

D 792 Test Methods for Density and Specific Gravity (Relative Density) of Plastics by Displacement

D 883 Terminology Relating to Plastics

D 2584 Test Method for Ignition Loss of Cured Reinforced Resins

D 2734 Test Methods for Void Content of Reinforced Plastics

D 3171 Test Methods for Constituent Content of Composite Materials

D 3878 Terminology for Composite Materials

D 5229/D 5229M Test Method for Moisture Absorption Properties and Equilibrium Conditioning of Polymer Matrix Composite Materials

D 5687/D 5687M Guide for Preparation of Flat Composite Panels with Processing Guidelines for Specimen Preparation

D 5961/D 5961M Test Method for Bearing Response of Polymer Matrix Composite Laminates

E 4 Practices for Force Verification of Testing Machines

E 6 Terminology Relating to Methods of Mechanical Testing

E 122 Practice for Calculating Sample Size to Estimate, With a Specified Tolerable Error, the Average for a Characteristic of a Lot or Process

E 177 Practice for Use of the Terms Precision and Bias in ASTM Test Methods

E 456 Terminology Relating to Quality and Statistics

E 1309 Guide for Identification of Fiber-Reinforced Polymer-Matrix Composite Materials in Databases

E 1434 Guide for Recording Mechanical Test Data of Fiber-Reinforced Composite Materials in Databases

E 1471 Guide for Identification of Fibers, Fillers, and Core Materials in Computerized Material Property Databases

3. Terminology

3.1 *Definitions*—Terminology D 3878 defines terms relating to high-modulus fibers and their composites. Terminology C 274 defines terms relating to structural sandwich constructions. Terminology D 883 defines terms relating to plastics. Terminology E 6 defines terms relating to mechanical testing. Terminology E 456 and Practice E 177 define terms relating to statistics. In the event of a conflict between terms, Terminology D 3878 shall have precedence over the other terminologies.

3.2 *Symbols*:

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[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 = width of specimen

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

G = core shear modulus

L = length of specimen

P = force on specimen

$S = \Delta P / \Delta u$, slope of initial portion of force-deflection curve

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

t = thickness of core

u = displacement of loading plates

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

γ = core engineering shear strain

τ = core shear stress

4. Summary of Test Method

4.1 This test method consists of subjecting a sandwich core or sandwich panel to monotonically increasing shear force parallel to the plane of its faces. The force is transmitted to the specimen through bonded loading plates that are subjected to opposing tensile or compressive displacements that result in a shear force on the sandwich core. Core shear modulus, stress, and strength are reported in terms of the nominal shear area of the core.

4.2 The only acceptable failure mode is shear failure of the core material. Adhesive or cohesive failures, or both, at the core-to-facesheet, facesheet-to-load-plate, or (if no facesheets are used) core-to-load-plate interface are not acceptable failure modes.

5. Significance and Use

5.1 The core shear properties are fundamental properties that are used in the design of sandwich panels. This test method provides information on the force-deflection behavior of sandwich constructions or cores when loaded in shear parallel to the plane of the facings. From a complete force-deflection curve, it is possible to compute core shear stress at any force (such as the shear stress at proportional limit, at yield, or at maximum force) and to compute an effective core shear modulus.

5.2 The test does not produce pure shear, but the specimen length is prescribed so that secondary stresses have a minimum effect. Approximate shear properties can also be obtained from a sandwich flexure test (see Test Method C 393).

5.3 This test method provides a standard method of obtaining sandwich core shear data for material specifications, sandwich panel design, research and development applications, and quality assurance.

5.4 Factors that influence core shear strength and shall therefore be reported include the following: facing material, core material, adhesive material, methods of material fabrication, core geometry (density, cell size, orientation, etc.), adhesive thickness, specimen geometry and associated measurement accuracy, specimen preparation, specimen conditioning, environment of testing, specimen alignment, loading procedure, speed of testing, and adhesive void content. Further, core-to-facing strength may be different between precured/ bonded and co-cured facings in sandwich panels with the same core and facing material.

6. Interferences

6.1 *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 data scatter in composites in general. Specific material factors that affect sandwich composites include variability in core density and degree of cure of resin in both facing matrix material and core bonding adhesive. Important aspects of sandwich panel specimen preparation that contribute to data scatter are incomplete or nonuniform core bonding to facings, misalignment of core and facing elements, the existence of joints, voids or other core and facing discontinuities, out-of-plane curvature, facing thickness variation, and surface roughness. For this particular core shear test, thickness of the adhesive bond to honeycomb core (adhesive-filled depth into the honeycomb core cells) may affect the core shear strength and modulus values depending on the core thickness.

6.2 *System Alignment*—Unintended loading eccentricities will cause premature failure. Every effort should be made to eliminate undesirable eccentricities from the test system. Such eccentricities may occur as a result of misaligned grips, poor specimen preparation, or poor alignment of the bonded loading plates.

6.3 *Geometry*—Specific geometric factors that affect core shear behavior of sandwich panels includes core cell geometry (shape, density, orientation), core thickness, and adhesive thickness.

6.4 *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 static strength and failure mode. Critical environments must be assessed independently for each sandwich construction tested.

7. Apparatus

7.1 *Micrometers*—The micrometer(s) shall use a 4 to 6-mm [0.16 to 0.25-in.] nominal diameter ball-interface on irregular surfaces such as the bag-side of a facing laminate, and a flat anvil interface on core material alone, machined edges, or very smooth-tooled surfaces. The accuracy of the instrument(s) shall be suitable for reading to within 1 % of the sample length, width and thickness. For typical specimen geometries, an instrument with an accuracy of ±25 µm [±0.001 in.] is desirable for thickness, length and width measurement.

7.2 *Test Fixtures*—Either a tensile or compressive loading mode may be used. In either case, the test specimen shall be rigidly supported by means of steel plates bonded to the facings (see Note 1) as shown in Fig. 1. The thickness of the plates may be varied in accordance with the strength of the sandwich (see Note 2), but the plate length shall be such that the line of action of the direct tensile or compressive force shall pass through the diagonally opposite corners of the sandwich as shown in Fig. 1. A correct line of load action may also be obtained by modifying the core length to thickness ratio provided the specimen dimensional requirements noted in 8.2 are fulfilled.
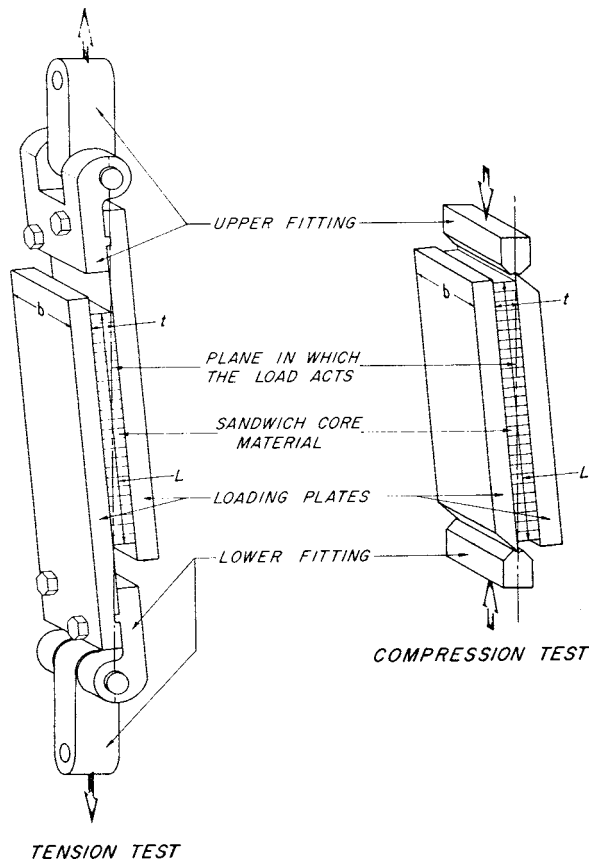
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FIG. 1 Plate Shear Specimens, Force Line of Action

NOTE 1—To ensure a core shear failure on some honeycomb cores, two plies of adhesive must be used to bond the honeycomb to the steel plates. This provides deeper adhesive fillets on the honeycomb cell walls.

NOTE 2—It has been found that loading plates having a bending stiffness per unit width, $D = EI / b$, not less than 2.67 MN - mm²/mm width per millimeter of core thickness (600 000 lb-in.²/in. per inch of core thickness) have performed satisfactorily.

7.2.1 *Tension Loading*—Either pinned or bolted load plate-to-universal-joint test fixtures, as shown in Fig. 2, may be used. The overall load-train shall be of the suspended, self-aligning type.

7.2.2 *Compression Loading*—Load plates shall taper to a knife-edge and fit into V-notch loading blocks, as shown in Fig. 3. V-notch loading blocks shall be rigidly attached to the test machine and aligned flat and parallel to within ±0.02 mm [±0.001 in.].

7.3 *Testing Machine*—The testing machine shall be in accordance with Practices E 4 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.

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 11.6.

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.

7.3.4 *Deflectometer, Compressometer, or Extensometer*—The deflection measurement device shall be capable of measuring the displacement with a precision of at least ±1 %.

7.4 *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.

7.5 *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 entire 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 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 E 122. Report the method of sampling.

8.2 *Geometry*—The test specimens shall have a thickness equal to the thickness of the sandwich, a width not less than 50 mm [2.0 in.], and a length not less than twelve times the thickness.

8.3 *Specimen Preparation and Machining*—Guide D 5687/D 5687M provides recommended specimen preparation practices and should be followed where practical.

8.4 *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.
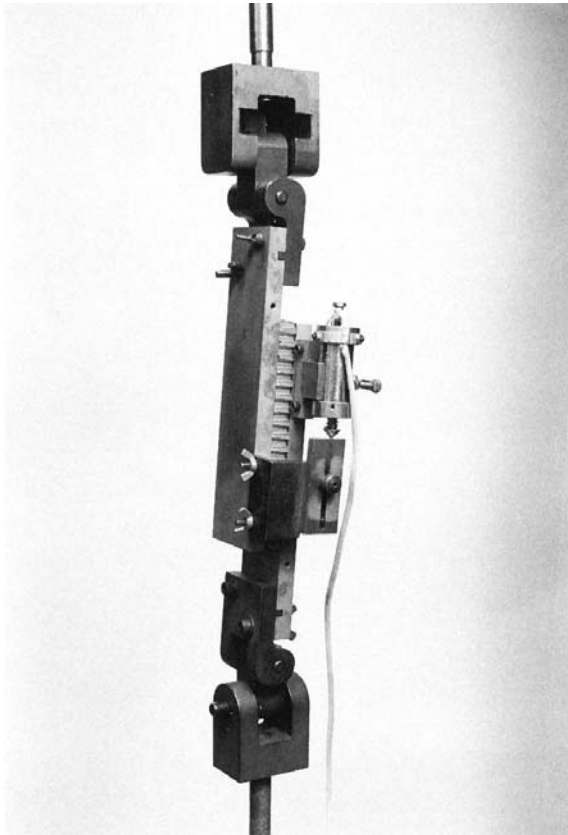
10. Conditioning

10.1 The recommended pre-test specimen condition is effective moisture equilibrium at a specific relative humidity as established by Test Method D 5529/D5229M; however, if the test requester does not explicitly specify a pre-test conditioning environment, conditioning is not required and the test specimens may be tested as prepared.

NOTE 3—The term *moisture*, as used in Test Method D 5229/D5229M, includes not only the vapor of a liquid and its condensate, but the liquid itself in large quantities, as for immersion.

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

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

(a) Bolted Specimen
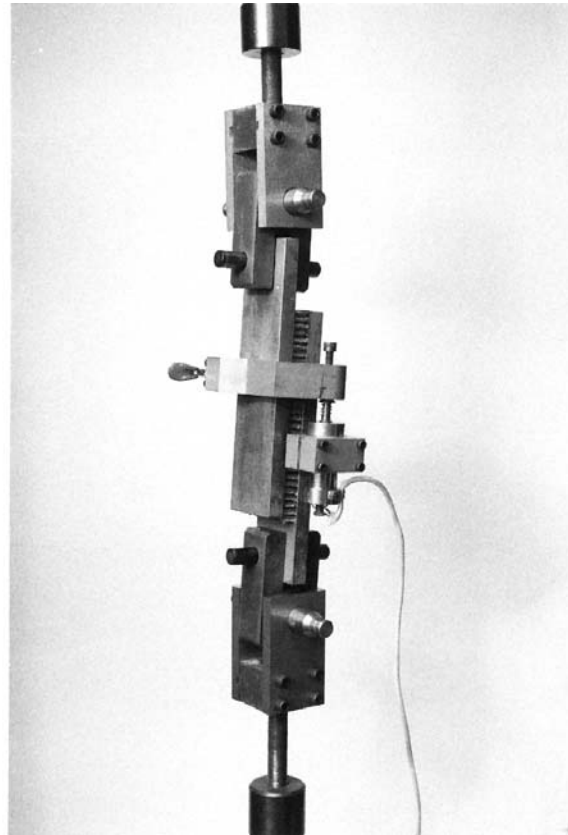
(b) Pinned Specimen

FIG. 2 Tensile Plate Shear Test Set Up

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.

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.

11.1.3 The environmental conditioning test parameters.

11.1.4 If performed, sampling method, specimen geometry, and test parameters used to determine facing density and reinforcement volume.

11.2 *General Instructions*:

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

11.2.2 If core density is to be reported, then obtain these samples from the same sheet of core being tested. Density may be evaluated in accordance with Test Method C 271/C 271M.

11.2.3 If specific gravity, density, facing reinforcement volume, or facing void volume are to be reported, then obtain these samples from the same panels being tested. Specific gravity and density may be evaluated in accordance with Test Methods D 792. Volume percent of composite facing constituents may be evaluated by one of the matrix digestion proce-

dures of Test Method D 3171, or, for certain reinforcement materials such as glass and ceramics, by the matrix burn-off technique in accordance with Test Method D 2584. The void content equations of Test Method D 2734 are applicable to both Test Method D 2584 and the matrix digestion procedures.

11.2.4 Following final specimen machining, but before conditioning and testing, measure the specimen length and width. The accuracy of these measurements shall be within 1 % of the dimension. Measure the overall specimen thickness; the accuracy of this measurement shall be within ±25 mm [±0.001 in.]. Record the dimensions to three significant figures in units of millimeters [inches].

11.3 Bond the specimen to the loading plates, in accordance with the requirements of 7.2, 8.2, and 8.3.

11.4 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.

11.5 Following final specimen conditioning, but before testing, re-measure the specimen length and width as in 11.2.3.

11.6 *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 head displacement rate is 0.50 mm/min [0.020 in./min].
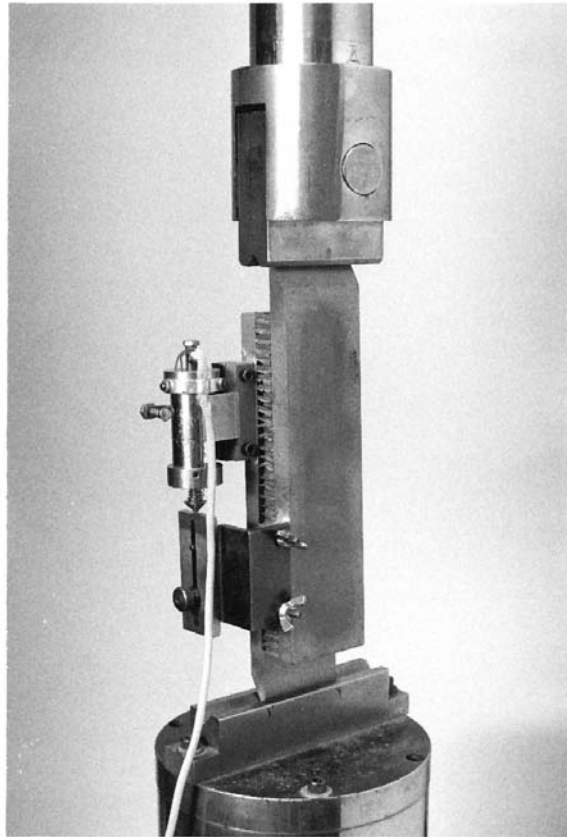
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FIG. 3 Compressive Plate Shear Test Set Up

11.7 *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.

11.8 *Specimen Installation*—Install the specimen/loading-plates assembly into the test machine test fixture, as shown in Figs. 1-3.

11.9 *Displacement Gage Installation*—Install the displacement gage such that it measures the relative displacement between the two steel loading plates. The gage may be mounted on either the specimen side or back. The contact point at which the relative motion between the loading plates is measured shall be centered along the length of the core material (see Figs. 2 and 3).

11.10 *Loading*—Apply a tensile or compressive force to the specimen at the specified rate. Load the specimen until rupture.

11.11 *Data Recording*—Record force versus head displacement and force versus axial displacement, continuously, or at frequent regular intervals; for this test method, a sampling rate of 5 to 10 data recordings per second, and a target minimum of 300 data points per test are recommended. If a compliance change or initial damage event are noted, record the force, displacement, and damage mode at such points. Record the yield force (if any), the maximum force, the failure force, and the displacement at, or as near as possible to, the moment of rupture.

11.12 *Failure Modes*—Record the mode and location of failure for each specimen. Three-place failure mode descriptors, summarized in Table 1, shall be used. This notation uses the first character to describe the failure type, the second

TABLE 1 Three-Place Failure Mode Codes

First Character		Second Character		Third Character	
Failure Type	Code	Failure Area	Code	Failure Location	Code
Core Shear	S	At End	A	Top	T
Interface failure	I	Gage (within core)	G	Middle	M
Explosive	X	One Corner	C	Bottom	B
Other	O	Various	V	Entire Length	E
		Unknown	U	Various	V
				Unknown	U

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character the failure area, and the third character the failure location. Adhesive and/or cohesive failures at the core-to-facesheet, facesheet-to-load-plate, or (if no facesheets are used) core-to-load-plate interface are not acceptable failure modes and the data shall be noted as invalid. The core shear failure mode is considered to be acceptable.

12. Validation

12.1 Values for ultimate properties shall not be calculated for any specimen that breaks at some obvious flaw, unless such flaw constitutes a variable being studied. Retests shall be performed for any specimen on which values are not calculated.

12.2 A significant fraction of failures in a sample population occurring at the ends shall be cause to reexamine the means of force introduction into the material. Factors considered should include the fixture alignment, bondline quality and integrity, specimen thickness, specimen length-to-thickness ratio, and machining accuracy/quality.

13. Calculation

13.1 *Shear Stress*—Calculate the instantaneous core shear stress as follows:

$$\tau = P / (L\,b) \tag{1}$$

where:
τ = core shear stress, MPa [psi],
P = instantaneous force on specimen, N [lbf],
L = length of specimen, mm [in.], and
b = width of specimen, mm [in].

13.2 *Engineering Shear Strain*—Calculate the instantaneous effective core shear strain as follows:

$$\gamma = u / t \tag{2}$$

where:
γ = core engineering shear strain, mm/mm [in./in.],
u = instantaneous displacement between loading plates, mm [in.], and
t = thickness of core, mm [in.].

13.3 *2 % Offset Shear Strength*—For core materials that yield more than 2 % shear strain, calculate the 2 %-Offset core shear strength, denoted τ_{os}, using Eq 1, with $P = P_{os}$, where P_{os} is the 2 % offset yield force. Report the τ_{os} results to three significant figures.

NOTE 5—Determine the 2 % offset yield force, P_{os}, using a data reduction method that results in repeatability, and at least 3-significant-figure precision, such as that described in Test Method D 5961/D 5961M, section 13.8.

13.4 *Ultimate Shear Strength*—Calculate the ultimate core shear strength using Eq 1, with $P = P_{max}$, where P_{max} is the maximum recorded force on the specimen, and report the results to three significant figures.

13.5 *Core Shear Modulus*—Calculate the effective core shear modulus as follows, and report the results to three significant figures:

$$G = (\Delta P/\Delta u)\,t / (L\,b) \tag{3}$$

where:

$\Delta P/\Delta u$ = slope of the force-displacement curve, in N/mm [lbf/in.], from 0.002 mm/mm to 0.006 mm/mm effective engineering shear strain.

13.6 *Statistics*—For each series of tests calculate the average value, standard deviation, and coefficient of variation (in percent) for ultimate core shear strength, core shear modulus, and (if applicable) 2 % offset shear strength:

$$\bar{x} = \left(\sum_{i=1}^{n} x_i \right) / n \tag{4}$$

$$S_{n-1} = \sqrt{\left(\sum_{i=1}^{n} x_i^2 - n\left(\bar{x}\right)^2 \right) / \left(n - 1 \right)} \tag{5}$$

$$CV = 100 \times S_{n-1} / \bar{x} \tag{6}$$

where:
$\bar{x}$ = sample mean (average),
S_{n-1} = sample standard deviation,
CV = sample coefficient of variation, %,
n = number of specimens, and
x_i = 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):

NOTE 6—Guides E 1309, E 1434, and E 1471 contain data reporting recommendations for composite materials and composite materials mechanical testing.

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 Mode of loading (tension or compression) and whether or not face sheets were used.
14.1.5 Identification of all the materials constituent to the sandwich panel specimen tested, 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.
14.1.6 Description of the fabrication steps used to prepare the sandwich panel including: fabrication start date, fabrication end date, process specification, cure cycle, consolidation method, and a description of the equipment used.
14.1.7 If requested, report measured density, volume percent reinforcement, and void content of face-sheets; measured core density; and associated test methods, specimen sampling method and geometries, test parameters and test results.
14.1.8 Sandwich core and adhesive properties, such as nominal thickness, density, and (if honeycomb) cell size, and ribbon direction.
14.1.9 Results of any nondestructive evaluation tests.
14.1.10 Method of preparing the test specimen, including specimen labeling scheme and method, specimen geometry, sampling method, and specimen cutting method.

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

14.1.12 Details of loading plates and apparatus, including dimensions and material used.

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

14.1.14 Measured length, width, and overall thickness for each specimen (prior to and after conditioning, if appropriate).

14.1.15 Conditioning parameters and results.

14.1.16 Relative humidity and temperature of the testing laboratory.

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

14.1.18 Number of specimens tested.

14.1.19 Speed of testing.

14.1.20 Individual core shear modulus values, ultimate shear strengths, 2 % offset core shear strengths, and average value, standard deviation, and coefficient of variation (in percent) for the population.

14.1.21 Force versus crosshead displacement data, and force versus displacement gage data (for each specimen so instrumented).

14.1.22 Failure mode and location of failure for each specimen.

15. Precision and Bias

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

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

16. Keywords

16.1 core; honeycomb; sandwich; sandwich construction; shear modulus; shear strength