**Designation: C393/C393M – 06**

# Standard Test Method for
# Core Shear Properties of Sandwich Constructions by Beam Flexure[1]

This standard is issued under the fixed designation C393/C393M; 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 determination of the core shear properties of flat sandwich constructions subjected to flexure in such a manner that the applied moments produce curvature of the sandwich facing planes. 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]

C273 Test Method for Shear Properties of Sandwich Core Materials
C274 Terminology of Structural Sandwich Constructions
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
D7249/D7249M Test Method for Facing Properties of Sandwich Constructions by Long Beam Flexure
D7250/D7250M Practice for Determining Sandwich Beam Flexural and Shear Stiffness
E4 Practices for Force Verification of Testing Machines
E6 Terminology Relating to Methods of Mechanical Testing
E122 Practice for Calculating Sample Size to Estimate, With Specified Precision, the Average for a Characteristic of a Lot or Process
E177 Practice for Use of the Terms Precision and Bias in ASTM Test Methods
E456 Terminology Relating to Quality and Statistics
E1309 Guide for Identification of Fiber-Reinforced Polymer-Matrix Composite Materials in Databases
E1434 Guide for Recording Mechanical Test Data of Fiber-Reinforced Composite Materials in Databases

## 3. Terminology

3.1 *Definitions*—Terminology D3878 defines terms relating to high-modulus fibers and their composites. Terminology C274 defines terms relating to structural 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 *Symbols*:

$b$ = 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 facing chord modulus
$\varepsilon$ = measuring strain in facing
$F^u$ = facing ultimate strength (tensile or compressive)
$F_c$ = core compression allowable strength
$F_s$ = core shear allowable strength
$F_s^{ult}$ = core shear ultimate strength
$F_s^{yield}$ = core shear yield strength
$k$ = core shear strength factor to ensure core failure

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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.

$L$ = length of loading span
$S$ = 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
$F_Z^{ftu}$ = ultimate flatwise tensile strength
$P_{max}$ = maximum force carried by test specimen before failure
$S_{n-1}$ = standard deviation statistic of a sample population for a given property
$\sigma$ = facing stress or strength
$t$ = facing thickness
$x_1$ = test result for an individual specimen from the sample population for a given property
$x$ = 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 beam of sandwich construction to a bending moment normal to the plane of the sandwich. Force versus deflection measurements are recorded.

4.2 The only acceptable failure modes are core shear or core-to-facing bond. Failure of the sandwich facing preceding failure of the core or core-to-facing bond is not an acceptable failure mode. Use Test Method D7249/D7249M to determine facing strength.

## 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 facings compressive and tensile strengths. Tests to evaluate core shear strength may also be used to evaluate core-to-facing bonds.

5.2 This test method is limited to obtaining the core shear strength or core-to-facing shear strength and the stiffness of the sandwich beam, and to obtaining load-deflection data for use in calculating sandwich beam flexural and shear stiffness using Practice D7250/D7250M.

NOTE 1—Core shear strength and shear modulus are best determined in accordance with Test Method C273 provided bare core material is available.

5.3 Facing strength is best determined in accordance with Test Method D7249/D7249M.

5.4 Practice D7250/D7250M covers the determination of sandwich flexural and shear stiffness and core shear modulus using calculations involving measured deflections of sandwich flexure specimens.

5.5 This test method can be used to produce core shear strength and core-to-facing shear 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.

5.6 Factors that influence the shear strength and shall therefore be reported include the following: facing material, core material, adhesive material, methods of material fabrication, core geometry (cell size), core density, adhesive thickness, specimen geometry, 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.

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

## 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 core shear strength include core orthotropy (that is, ribbon versus transverse direction for honeycomb core materials) and core cell geometry.

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, facing material, and core-to-facing 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 facing failure due to local stresses. In other cases, facing failure can cause local core crushing. When there is both facing 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. For some core materials, the shear strength is a function of the direction that the core is oriented relative to the length of the specimen.

## 7. Apparatus

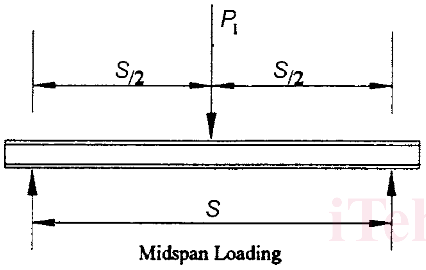
7.1 *Micrometers and Calipers*—A micrometer having a flat anvil interface, or a caliper of suitable size, shall be used. The instrument(s) shall have an accuracy of ±25 mm [±0.001 in.] for thickness measurement, and an accuracy of ±250 mm [±0.010 in.] for length and width measurement.

NOTE 3—The accuracies given above are based on achieving measurements that are within 1 % of the sample length, width and thickness.

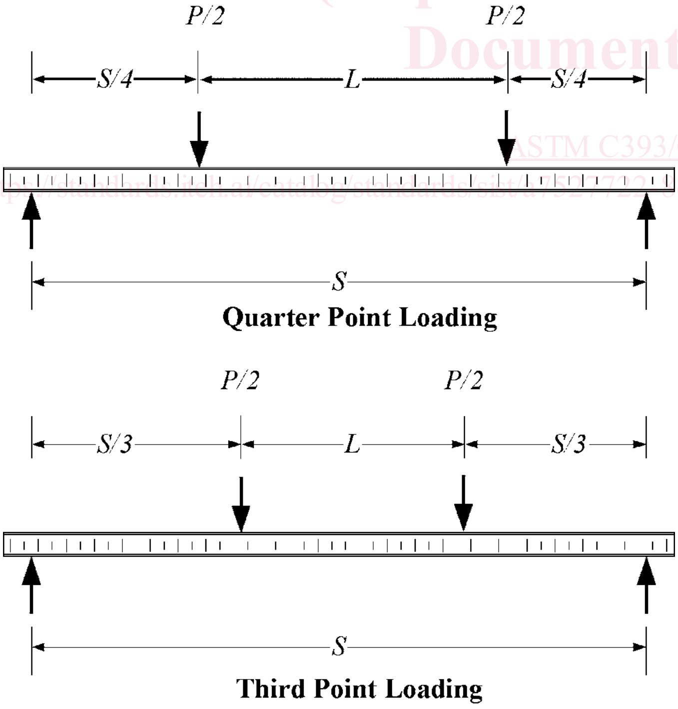
7.2 *Loading Fixtures*—The loading fixture shall consist of either a 3-point or 4-point loading configuration with two support bars that span the specimen width located below the specimen, and one or two loading bars that span the specimen width located on the top of the specimen (Fig. 1), The force shall be applied vertically through the loading bar(s), with the support bars fixed in place in the test machine.

7.2.1 *Standard Configuration*—The standard loading fixture shall be a 3-point configuration and shall have the centerlines of the support bars separated by a distance of 150 mm [6.0 in.].

7.2.2 *Non-Standard Configurations*—All other loading fixture configurations are considered non-standard, and details of the fixture geometry shall be documented in the test report. Fig. 3 shows a typical 4-point short beam test fixture. 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, *(b)* because some sandwich panel designs require the use of non-standard loading configurations to achieve core or bond failure modes, and *(c)* load-deflection data from non-standard configurations may be used with Practice D7250/D7250M to obtain sandwich beam flexural and shear stiffnesses.



(a) 3-Point Loading (Standard Configuration)



(b) 4-Point Loading (Non-Standard Configuration)

| | Configuration | Support Span (*S*) | Load Span (*L*) |
|---|---|---|---|
| Standard | 3-Point (Mid-Span) | 150 mm [6.0 in.] | 0.0 |
| Non-Standard | 4-Point (Quarter-Span) | *S* | *S*/2 |
| | 4-Point (Third-Span) | *S* | *S*/3 |

FIG. 1 Loading Configurations

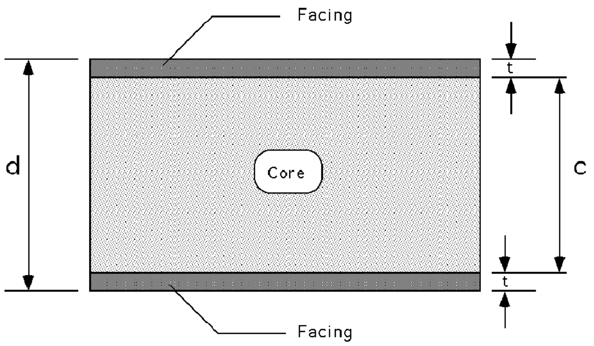


FIG. 2 Sandwich Panel Thickness Dimensions

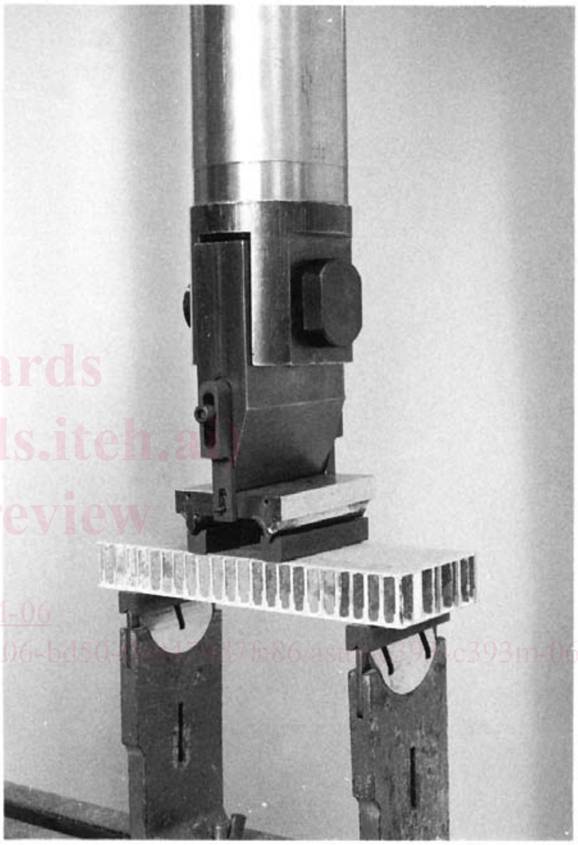


FIG. 3 Short Beam—4-Point (Third-Span) Short Beam Loading Configuration

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 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 (for example, rolling supports).

7.2.4 *Pressure Pads*—Rubber pressure pads having a Shore A durometer of approximately 60, a nominal 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 facings.

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.

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 4—The use of crosshead or actuator displacement for the beam mid-span deflection produces inaccurate results, particularly for 4-point loading configurations; the direct measurement of the deflection of the mid-span of the beam must be made by a suitable instrument.

7.5 *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.

7.6 *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 8.2.3 indicate that the specimen will produce the desired core or core-to-facing bond failure mode. In cases where the standard specimen configuration will not produce a desired failure, a non-standard specimen shall be designed to produce a core or bond failure mode.

8.2.1 *Standard Configuration*—The test specimen shall be rectangular in cross section, with a width of 75 mm [3.0 in.] and a length of 200 mm [8.0 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 half 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 shear strength of the core or core-to-facing bond is required to avoid facing failures. The facings must be sufficiently thick and/or the support span sufficiently short such that transverse shear forces are produced at applied forces low enough so that the allowable facing stress will not be exceeded. However, if the facings are too thick, the transverse shear force will be carried to a considerable extent by the facings, thus leading to a high apparent core shear strength as computed by the equations given in this standard. The following equations can be used to size the test specimen (these equations assume that both facings have the same thickness and modulus, and that the facing thickness is small relative to the core thickness [$t/c \leq \sim 0.10$]):

The support span length shall satisfy:

$$S \leq \frac{2k\sigma t}{F_s} + L \tag{1}$$

or, the core shear strength shall satisfy:

$$F_s \leq \frac{2k\sigma t}{(S - L)} \tag{2}$$

The core compression strength shall satisfy:

$$F_c \geq \frac{2(c + t)\sigma t}{(S - L)l_{pad}} \tag{3}$$

where:

$S$ = support span length, mm [in.],

$L$ = loading span length, mm [in.] ($L = 0$ for 3-point loading),

$\sigma$ = expected facing ultimate strength, MPa [psi],