Designation: C 393 – 00

Standard Test Method for Flexural Properties of Sandwich Constructions[1]

This standard is issued under the fixed designation C 393; 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 the properties of flat sandwich constructions subjected to flatwise flexure in such a manner that the applied moments produce curvature of the sandwich facing planes.

1.2 The values stated in SI units are to be regarded as the standard. The inch-pound units given may be approximate.

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:*

C 273 Test Method for Shear Properties of Sandwich Core Materials[2]

C 480 Test Method for Flexure Creep of Sandwich Constructions[2]

E 4 Practices for Force Verification of Testing Machines[3]

3. Significance and Use

3.1 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.

3.2 These test methods provide a standard method of obtaining the sandwich panel flexural strengths and stiffness.

3.3 Core shear strength and shear modulus are best determined in accordance with Test Method C 273.

3.4 The sandwich stiffness and core shear modulus may be determined by calculations involving measured deflections of sandwich flexure specimens. Tests can be conducted on short specimens and on long specimens or on one specimen loaded in two ways, and the flexural stiffness and shear modulus can be determined by simultaneous solution of the complete deflection equations for each span or each loading. If the facing modulus values are known, a short span beam can be tested and the calculated bending deflection subtracted from the beam's total deflection. This gives the shear deflection from which the core shear modulus can be determined (Notes 1-3).

NOTE 1—For cores with high shear modulus, the shear deflection will be quite small and ordinary errors in deflection measurements will cause considerable variations in the calculated shear modulus.

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.

NOTE 3—To insure 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 facing thickness to core thickness less than 0.1 ($t/c < 0.1$).

4. Apparatus

4.1 *Testing Machine*, capable of maintaining a controlled loading rate and indicating the load with an accuracy of ±1 % of the indicated value. The accuracy of the test machine shall be verified in accordance with Practices E 4.

4.2 *Loading Fixtures*,

4.3 *Transducer, Deflectometer, Dial Gage,* capable of measuring the displacement with a precision of at least ±1 %.

4.4 *Micrometer, Gage, or Caliper*, capable of measuring accurately to 0.025 mm (0.001 in.).

5. Test Specimen

5.1 The test specimen shall be rectangular in cross section. The depth of the specimen shall be equal to the thickness of the sandwich construction, and the width shall be not less than twice 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 span length plus 50 mm (2 in.) or plus one half the sandwich thickness whichever is the greater.

5.2 To determine core shear strength, it is necessary to design the test specimen so that the moments produced at core failure do not stress the facings beyond the compressive or tensile proportional limit stress of the facing material. This requires thicker facings and shorter support spans. If the facings are too thick, the shear load will be carried to a

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[2] *Annual Book of ASTM Standards*, Vol 15.03.

[3] *Annual Book of ASTM Standards*, Vol 03.01.

considerable extent by the facings, thus leading to a high apparent core shear strength as computed by the usual approximate methods.

5.3 Proper design of a test specimen for determining compressive or tensile strength of the facings is obtained by a reverse of considerations for determining core shear strength. The facings are thinner and the span is lengthened so that greater moments are produced at loads low enough so that the allowable core shear stress will not be exceeded. Tensile failures rarely occur unless the tensile facing is thinner or of different material than the compression facing. Failure in the compression facing may occur by actual crushing, yielding causing unduly large deflection, wrinkling of the facing into the core or the facing popping off the core, or the facing dimpling into the honeycomb cells.

6. Conditioning

6.1 When the physical properties of the component materials are affected by moisture, the test specimens shall be brought to constant weight (±1 %) before testing, preferably in a conditioning room with temperature and humidity control. The test, preferably, should be made in a room under the same conditions. A temperature of 23 ± 3°C (73 ± 5°F) and a relative humidity of 50 ± 5 % are recommended for standard control conditions.

7. Procedure

7.1 Arrange the loading fixtures as shown in the appropriate Fig. 1 or Fig. 2. Apply the load to the specimen through steel bars or knife edges with loading pads. If after a trial test, it is found that local core crushing failure occurs under a load point, it is permissible to place narrow plates under the steel pads to prevent such failures. Rubber pads can also be used to distribute the load.

7.1.1 Fig. 3, Fig. 4, and Fig. 5 show test fixtures that have been found to be satisfactory (Note 4).

NOTE 4—Other loading configurations besides the quarter- and third-point loading may be used, but must be specified in the report.

7.2 Measure the dimensions of the specimens and span length in mm (in.) to a precision of ±0.5 %.

7.3 Apply the load at a constant rate that will cause the maximum load to occur between 3 to 6 min. Record the maximum load.

7.4 Load-deflection curves can be taken to determine the sandwich stiffness and core shear modulus. A transducer, deflectometer, or dial gage can be used to measure the midspan deflection.

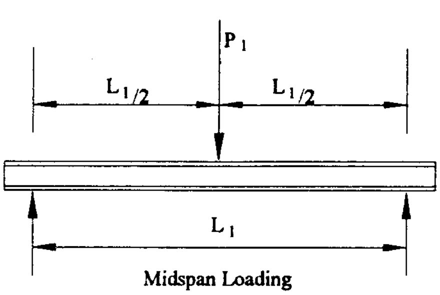

FIG. 1 Single-Point Load

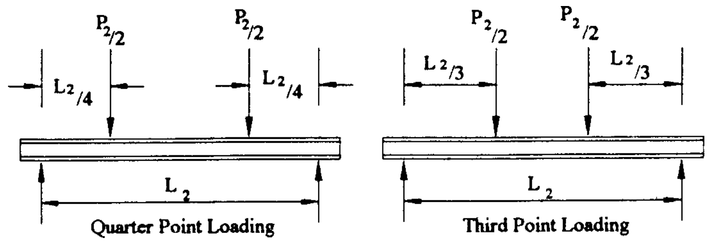

FIG. 2 Two-Point Load

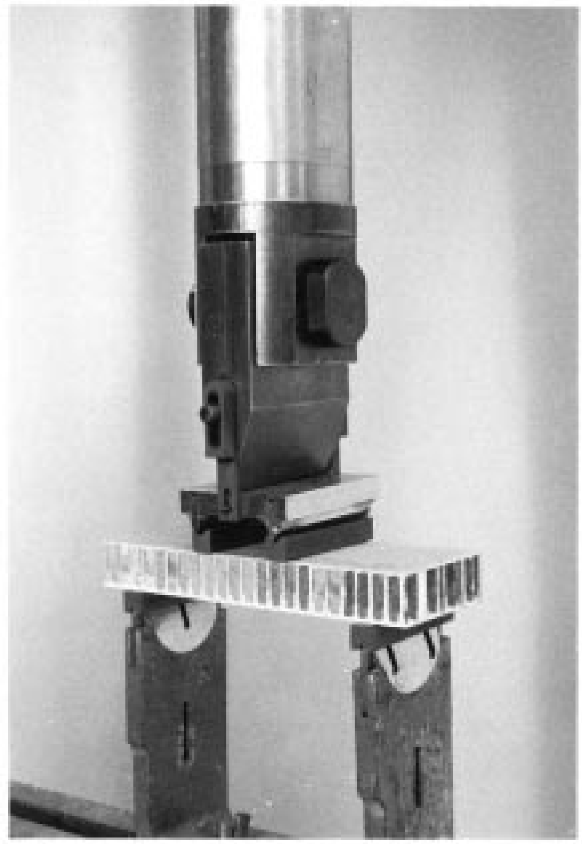

FIG. 3 Short Beam—Two-Point Load (Third Point)

8. Calculation

8.1 *Core Shear Stress (Single-Point Midspan Load)*—Calculate the core shear stress as follows:

$$\tau = \frac{P}{(d + c)b} \quad (1)$$

where:

τ = core shear stress, MPa (psi);
P = load, N (lb);
d = sandwich thickness, mm (in.);
c = core thickness, mm (in.); and
b = sandwich width, mm (in.).

8.1.1 Obtain the ultimate shear strength using Eq 1 where P equals the maximum load; the shear yield strength where P equals the yield load for core materials that yield more than 2 % strain using the 2 % offset method for the yield strength.

8.2 *Facing Bending Stress (Midspan Load)*—Calculate the facing bending stress as follows:

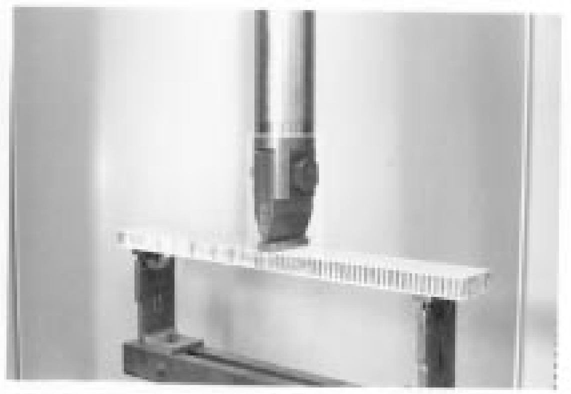

FIG. 4 Long Beam—Long Beam Single-Point Load (Midspan)

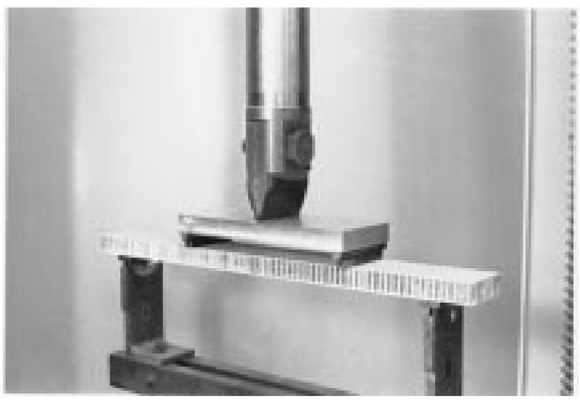

FIG. 5 Long Beam—Quarter-Point Loading

$$\sigma = \frac{PL}{2t(d + c)b} \tag{2}$$

where:

σ = facing bending stress, MPa (psi);
t = facing thickness, mm (in.); and
L = span length, mm (in.).

8.3 *Sandwich Beam Deflection (Midspan Load)*—Calculate the midspan deflection as follows:

$$\underset{\text{total}}{\Delta} = \underset{\text{bending}}{\frac{PL^3}{48\,D}} + \underset{\text{shear}}{\frac{PL}{4\,U}} \tag{3}$$

where:

Δ = total beam midspan deflection, mm (in.);
G = core shear modulus, MPa (psi);
E = facing modulus, MPa (psi); and
D = panel bending stiffness, N-mm^2 (lb-in.^{2}).

$$D = \frac{E(d^3 - c^3)b}{12} \quad \text{same facings} \tag{4}$$

$$D = \frac{E_1 t_1 E_2 t_2 (d + c)^2 b}{4(E_1 t_1 + E_2 t_2)} \quad \text{different facings} \tag{5}$$

$$U = \frac{G(d + c)^2 b}{4\,c} \tag{6}$$

U = panel shear rigidity, N (lb)

8.4 Core shear stress (two-point load; one-quarter or one-third span)—calculate the core shear stress as follows:

$$\tau = \frac{P}{(d + c)b} \tag{7}$$

8.5 Facing bending stress (two-point load; one-quarter span)—calculate the facing bending stress as follows:

$$\sigma = \frac{PL}{4t(d + c)b} \tag{8}$$

8.6 Sandwich panel deflection (two-point load, one-quarter span)—calculate the midspan deflection as follows:

$$\underset{\text{total}}{\Delta} = \underset{\text{bending}}{\frac{11\,PL^3}{768\,D}} + \underset{\text{shear}}{\frac{PL}{8\,U}} \tag{9}$$

8.7 *Flexural Stiffness and Core Shear Modulus*—If deflections of the same sandwich are determined under central load, P on span L_1 and also under total load P applied at quarter-span L_2, the flexural stiffness D and core shear modulus G may be determined from simultaneous solution of the deflection equations as follows:

$$D = \frac{P_1 L_1^3 [1 - (11 L_2^2 / 8 L_1^2)]}{48 \Delta_1 [1 - (2 P_1 L_1 \Delta_2 / P_2 L_2 \Delta_1)]} \tag{10}$$

$$G = \frac{P_1 L_1 c [8\, L_1^2 / 11\, L_2^2 - 1]}{\Delta_1 b (d + c)^2 [(16\, P_1\, L_1^3 \Delta_2 / 11\, P_2\, L_2^3 \Delta_1) - 1]} \tag{11}$$

9. Report

9.1 The report shall include the following:

9.1.1 Description of the test specimens; core material, facings, and adhesive,

9.1.2 Dimensions of the test specimens, core orientation,

9.1.3 Type of loading and span,

9.1.4 Specimens conditioning, if any,

9.1.5 Test temperature and specimens time at temperature,

9.1.6 Test machine cross-head loading rate,

9.1.7 Strengths and stiffness; individual and average values,

9.1.8 Load-deflection curves, if required,

9.1.9 Description of specimen failure mode; whether failure occurred in facings, core or facing-to-core bond.

10. Precision and Bias

10.1 *Precision*—The precision of the procedure in Test Method C 393 for measuring sandwich construction flexural properties is not available.

10.2 *Bias*—Since there is no accepted reference material suitable for determining the bias for the procedures in this test method, bias has not been determined.

11. Keywords

11.1 bending stress; core modulus; core stress; facing modulus; facing stress; flexural stiffness; sandwich construction; sandwich deflection; shear stress