METHODS OF TEST FOR DETERMINING STRENGTH PROPERTIES OF CORE MATERIAL FOR SANDWICH CONSTRUCTION AT NORMAL TEMPERATURES

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# Table of Contents

<table>
<thead>
<tr>
<th>Section</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>Introduction</td>
<td>1</td>
</tr>
<tr>
<td>Compression flatwise</td>
<td>5</td>
</tr>
<tr>
<td>Compression edgewise</td>
<td>7</td>
</tr>
<tr>
<td>Tension flatwise</td>
<td>8</td>
</tr>
<tr>
<td>Shear test for the determination of the modulus of rigidity</td>
<td>9</td>
</tr>
<tr>
<td>Torsion pendulum shear test for the determination of the modulus of rigidity in any plane</td>
<td>11</td>
</tr>
<tr>
<td>Shear strength and stress-strain curves of core materials</td>
<td>13</td>
</tr>
<tr>
<td>The determination of moisture content and specific gravity</td>
<td>15</td>
</tr>
</tbody>
</table>

Report No. 1555, revised
METHODS OF TEST FOR DETERMINING STRENGTH PROPERTIES
OF CORE MATERIAL FOR SANDWICH CONSTRUCTION AT
NORMAL TEMPERATURES

Introduction

Foreword

1. Sandwich construction may be defined as a composite assembly of materials, consisting of a comparatively lightweight core to the opposite faces of which are bonded relatively thin facings of a denser and stronger material. Methods of testing core materials here outlined are based on experience obtained in testing a large number of specimens and have proven satisfactory.

The core materials that are used in sandwich construction fall into several categories, including natural materials, such as balsa; synthetic foamed materials, such as cellular cellulose acetate, foamed resins, and hard rubber; and honeycomb-type cores fabricated from paper, fabric, glass cloth, and metal foil, with varying ratios of honeycomb-cell size to wall thickness. Many of these core materials are nonisotropic, and their properties and the properties of the sandwich in which they are used will vary with the core orientation. It may be necessary, therefore, to make investigations of the strength properties of the core for two or three mutually perpendicular directions. Most of these core materials, however, do not have specific identification for the various strength axes, so that it may be necessary to describe the core material in detail in order to provide complete information on the test direction. In some instances, parallel or perpendicular to the flutes for honeycomb material or parallel or perpendicular to the machine direction may be descriptive enough to identify the direction in which the property is obtained. In these test procedures terms such as the "flatwise direction" perpendicular to the plane of the sandwich and "edgewise direction" parallel to the plane of the sandwich are used to describe directions of load application. This description refers, of course, to directions that are established once an orientation of the core material in the sandwich is assumed, and for orthotropic core materials the test procedures would have to be repeated for other assumed core orientations to provide a complete evaluation of the core material.

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Report No. 1555, revised.
General information is included on gluing procedures that have been found satisfactory, as well as descriptions of fabrication methods and jigs that may be helpful to the user of this report in preparation of specimens.

Scope

2. These methods cover procedure for determining the following strength properties of core materials:

(a) Compression:
   (1) In the flatwise direction (perpendicular to the plane of the sandwich),
   (2) In the edgewise direction (parallel to the plane of the sandwich).

(b) Tension:
   (1) In the flatwise direction (perpendicular to the plane of the sandwich).

(c) Shear:
   (1) Shear test for the determination of the modulus of rigidity associated with shearing strains in planes parallel to the faces of the plate.
   (2) Torsion pendulum shear test for the determination of the modulus of rigidity in any plane.
   (3) Shear strength in the flatwise plane (parallel to the plane of the sandwich).

Test Specimen

3. (a) Selection of test specimens.--The number of test specimens to be chosen for test and the method of their selection depend on the purpose of the particular tests under consideration, so that no general rule can be given to cover all cases. However, with the exception of the plate shear test, no less than five specimens of a type shall be tested. A minimum of two specimens shall be tested for the determination of the modulus of rigidity by the plate shear method unless the results of the two tests do not agree, then more tests shall be required. Any natural skin the core material may have from the manufacturing process shall be removed before the specimens are tested. If desired, supplemmental tests may be made on specimens that do not have the natural skin removed, but when this is done, the records of the test shall indicate this clearly.

Report No. 1555, revised. -2-
Note: Surfacing techniques for use in preparing balsa, cellular cellulose acetate, cellular hard rubber, and paper, glass-fabric, and cotton-fabric honeycomb cores are described in Forest Products Laboratory Report No. 1574, "Fabrication of Lightweight Sandwich Panels of the Aircraft Type."

(b) Control of moisture content and temperature:—The strength properties of some core materials may depend on the moisture content and temperature at time of test. When this is the case, all core material for test shall be preferably conditioned to approximately constant weight and be tested in a room of controlled temperature and humidity. In any event, where moisture content or temperature differences may affect results of tests, the tests shall be conducted so that the conditions will be uniform throughout the thickness, and so that changes will not occur during test. A temperature of 75° F. and a relative humidity of 64 percent or a temperature of 75° F. and a relative humidity of 50 percent are recommended.

(c) Adhesive processes and alining jigs for use in specimen fabrication.—The adhesive process to be used in bonding the core specimens to test fixtures will depend on the mechanical and chemical properties of the core materials. For cores low in strength, room-temperature-setting resorcinol-resin adhesives can be used. If the solvents in these adhesives affect the core material, they may be replaced by room-temperature-setting urea-resin adhesives or intermediate-temperature-setting phenol-resin adhesives. A medium spread of adhesive should be applied to both the core and the fixture surface, and an open-assembly period of 5 to 10 minutes be allowed, followed by assembly and pressing. Maximum allowable pressure (15 p.s.i. has been found satisfactory for a number of core materials) that will not damage the core should be applied and allowed to remain on the specimen for at least 6 hours at room temperature. If the intermediate-temperature-setting phenol-resin adhesives are used, a glue-line temperature of 180° F. for 30 minutes should result in sufficient curing of the joint. When the fixtures are of metal, application of a heat-curing priming adhesive to the metal and its curing are required prior to the bonding of the core to the primed metal.

For high-strength and all honeycomb-type cores, special hot-setting adhesives, of the type formulated for bonding to metal, shall be used for bonding the core materials to the metal fixtures. Manufacturers' directions shall be followed in the use of these adhesives. Maximum allowable pressure without damage to the core material shall be used (15 p.s.i. has been used with honeycomb cores, and as high as 100 p.s.i. with end-grain balsa). Sufficient time should be allowed for the heat to penetrate any alining jig and metal fixtures to insure proper curing of the adhesive.

The metal fixtures shall be cleaned to remove any surface contamination prior to bonding to the core material. A recommended procedure for aluminum is first to remove as much contamination as possible by wiping with an acetone-soaked cloth and then to immerse it for 10 minutes at 140° to 160° F. in a solution of 10 parts by weight of concentrated sulphuric acid, one part by weight of sodium dichromate, and 30 parts by weight of water, and then to wash it in hot water and air dry. Steel plates have been cleaned by abrading with No. 1/2 emery cloth and washing off the particles with hot water and steam, and then quickly air drying.

Report No. 1555, revised
Aluminum cubes, used in the tension test, can be reused by sanding off adhesive and core materials and resurfacing to a uniform thickness on a milling machine. In some instances, adhesives have been removed through the use of solvent chemicals or hot molten salts. The cubes shall not be reused when more than 0.100 inch of thickness has been removed during reuse. Steel plates can be reused by scraping off as much adhesive and core material as possible, and by applying heat if necessary, and then sanding off the remainder with emery cloth.

Since alinement of specimen and fixtures is an important factor if accurate test results are to be obtained, it is recommended that an alinement jig be used in the fabrication of test specimens. Alinement jigs that have been used satisfactorily in the preparation of tension and shear specimens are shown in figures 1 and 2. The tension specimen jig will permit preparation of as many as 25 test specimens on a single core sample. Specimens are fabricated in this jig by placing the cubes, with adhesive spread on their upper surface, in the lower alining holes; laying the core material, with adhesive on both surfaces, on the cubes; insertion of upper alining bars on top of the jig; and then placing cubes, with adhesive on the lower surface, in the upper holes of the jig. The assembly is then pressed under proper conditions. Following the curing of the specimens, the jig is taken apart and the specimen assembly removed. Individual specimens are cut from the group with the use of a bandsaw.

The shear-specimen jig shown in figure 2 has a number of adjustments to permit its use with several thicknesses and lengths of plates. In assembly the lower plate is positioned with the loading end against the movable end of the jig and with the adhesive-spread surface up; the core, spread on both faces with adhesive, is placed on top of the plate; hinges are inserted at the ends of the core; and then the top plate is placed with the adhesive-spread surface down and loading end against the fixed end of the jig on top of the core. The movable end of the jig is then tightened until the distance between the upper stops is equal to the length of the plate. In a properly designed jig, the distance between the middle stops will be equal to the length of the core plus the thickness of the two hinges, and the core will be properly positioned between the plates. The specimen is then pressed and cured and the finished specimen removed from the jig.

Report

4. The report of each test shall include a complete description of the material, including its origin and kind. The type of test and any details pertaining to the fabrication of the specimens shall be given. When specimens have received any special conditioning prior to test, this shall be stated. Dimensions of the finished specimens shall be given, as well as any other factors that might have affected the results of the tests. These shall include: glues, temperatures, and pressures used in fabricating specimens, direction of grain or other orientation data, and type of extensometer used. A complete description of type of failure shall be included in the report.
Compression Flatwise

Scope

5. This method shall be used to test the core material in compression in the direction perpendicular to the plane of the sheet of the finished sandwich.

Test Specimen

6. The test specimen shall be 2 inches square by 5 to 8 inches in height. The cut edges shall be smooth and free of burs. The width, depth, and thickness shall be measured to the nearest 0.001 inch. If the available thickness of core material is less than 5 inches, a group of identical test pieces having all surface irregularities removed shall be stacked one on top of the other without bonding to a height not less than 5 inches. If stress-strain data are desired, the minimum practical height of individual test piece will be 1/2 inch.

Loaded Surfaces Parallel

7. Care shall be taken to prepare the test specimens so that the loaded faces (2- by 2-inch) will be parallel to one another and perpendicular to the edges of the specimen. Where additional support of the bearing surfaces is necessary, the ends of the specimen shall be cast in a suitable molding material (plaster of Paris or cast resin) so that the ends will be flush with the exterior surface of the cast base as shown in figure 3.

Loading Procedure

8. The load shall be applied to the specimen through a spherical loading block, preferably of the suspended, self-aligning type. The load shall be applied with a continuous movement of the movable head of 0.003 inch per inch of height of specimen per minute, with a permissible variation of ± 25 percent.

Stress-strain Curves

9. (a) Data for stress-strain curves may be taken to determine the modulus of elasticity, proportional limit, and yield strength at 0.2 percent offset. Increments of load shall be so chosen that approximately 12 readings of load and deformation are taken to the proportional limit. Deformations shall be read to at least the nearest 0.0001 inch by means of a compressometer having a gage length not exceeding two-thirds of the height of the specimen, or two-thirds the height of the test piece in a built-up specimen. The compressometer shall measure the strain over the central portion of the thickness of the specimen, or the central portion of the middle test piece in a built-up specimen, and, if of the lever type, shall have adequate support.
to permit free motion of the knife edges. The compressometer shall be light in weight, require a minimum force to operate, and shall be attached in such a way that it will not damage the specimen nor affect the test results.

Figure 4 presents a set-up for the compression flatwise test using a built-up specimen, and shows the specimen, spherical loading block, and a Tuckerman-type compressometer for strain measurements. Also shown is the dial indicator that may be used to obtain the total deformation in the specimen (note). In figure 5 is presented a third method using a specimen identical with that of figure 4, but using a method of measuring strain that eliminates the effects due to the weight of the suspended extensometer. The deformations shall be measured on a test specimen that conforms to the specifications of paragraph 6. The Marten’s mirror type of strain gage shown in figure 3 or the Tuckerman strain gage shown in figure 4 gives consistent results on a given material, but the weight of the gage tends to affect the magnitude of the strain measurements on weak materials. It was found that the weight of the gage suspended on 7/8 inch long brads, which protruded 3/8 inch outside the specimen, significantly affected the strain measurements on cellular cellulose acetate of about 6 pounds per cubic foot density. The moduli of elasticity obtained in this manner was 80 percent higher than that obtained by the method presented in figure 5 in which the strain is measured by means of Filar microscopes focused on a specific point (highlights have been found satisfactory) of 0.017-inch-diameter needles that penetrate the specimen to a depth of 1 inch. Electric-type strain gages are usually not considered satisfactory because of their stiffness.

Note: The use of dial gages for measuring head travel is not so accurate as, nor exactly comparable to, the use of strain gages mounted on the specimen, but is permissible for preliminary evaluation of core material.

Definition of Ultimate

10. Ultimate stress shall be the maximum stress attained on the specimen or the stress on the specimen at 2 percent strain, whichever occurs first. If the ultimate stress occurs below 2 percent strain, the strain at ultimate shall be reported (note).

Note: It has been necessary to define failure because some core materials continue to yield almost indefinitely, with the load increasing with the yield.

Moisture Content and Specific Gravity

11. The moisture content and specific gravity of each specimen shall be determined as outlined in section 42.

Report No. 1555, revised -6-
Compression Edgewise

Scope

12. This method shall be used to test the core material in compression in the direction parallel to the plane of the sheet of the finished sandwich.

Test Specimen

13. The test specimen shall be 2 inches wide by 2 inches high by 1/2 inch in thickness measured perpendicular to the plane of the sandwich (note). The cut edges shall be smooth and free of burs. The width, height, and thickness shall be measured to the nearest 0.001 inch.

Note: If a specimen 1/2 inch in thickness cannot be obtained, a specimen 1 inch wide by 4 inches in height by the thickness of the material shall be obtained and tested with lateral support in a jig as shown in figure 6.

End Surfaces Parallel

14. Care shall be taken to prepare the test specimen so that the end surfaces will be parallel and be perpendicular to the faces of the specimen.

Loading Procedure

15. The load shall be applied to the specimen through a spherical loading block, preferably of the suspended self-aligning type. The load shall be applied with a continuous movement of the movable head of the testing machine of 0.003 inch per inch of height of specimen with a permissible variation of ± 25 percent.

Stress-strain Curves

16. (a) Data for stress-strain curves shall be taken to determine the modulus of elasticity, proportional limit, and yield strength at 0.2 percent offset. Increments in load shall be so chosen that approximately 12 readings of load and deformation are taken to proportional limit. Deformations shall be measured to the nearest 0.0001 inch by means of a compressometer having a gage length not exceeding two-thirds of the height of the specimen. The compressometer shall measure the strain over the central portion of the height of the specimen. The apparatus for test and the limits thereon shall be the same as specified for the compression flatwise test in section 9.

Report No. 1555, revised
(b) If the edgewise-compression specimen deflects laterally before ultimate load (as defined in section 17) is reached, the height of the specimen shall be reduced so that failure will result in some manner other than in column bending.

Definition of Ultimate

17. Ultimate stress shall be the maximum stress attained on the specimen or the stress on the specimen at 2 percent strain, whichever occurs first. If the ultimate stress occurs below 2 percent strain, the strain at ultimate shall be reported.

Moisture Content and Specific Gravity

18. The moisture content and specific gravity of each specimen shall be determined as outlined in section 42.

Tension Flatwise

Scope

19. This method of test shall be used to determine the tensile strength of the core material in the direction normal to the plane of the sandwich.

Test Specimen

20. The specimen shall be a 1-inch square section of the core material and have the same thickness as will be used in the finished panel. One-inch cubes of wood or metal (17ST aluminum alloy is recommended for use with high-strength cores, but hardwood cubes, bonded to the side-grain surface will test most core materials having tensile strengths to 350 pounds per square inch) shall be bonded to both surfaces of the core material. One hole, 1/4 inch in diameter, shall be drilled in each cube. The axis of the hole shall be parallel to the bonding face (with wood cubes the holes shall be drilled into the side grain), 0.375 ± 0.02 inches from the face opposite the bonding face, and equidistant (tolerance ± 0.02 inch) between the adjacent sides. The specimen shall be assembled so that the holes in the two cubes on opposite sides of the core material will be oriented at 90° to each other, and the sides of the two cubes be in alignment (maximum offset tolerance, 0.015 inch). The dimensions of the cross section shall be measured to the nearest 0.001 inch. The completed specimen and fittings that apply the load are shown in figure 7. With cellular-type core materials having cell openings in excess of 3/8 inch, the section of core material shall be increased to 2 by 2 inches, and corresponding changes shall be made in the test specimen.
Loading Procedure

21. The specimen shall be loaded to failure in the fitting as shown in figure 8. The fittings for applying load to the specimen shall be made as shown in figure 9. The load shall be applied to the specimen by continuous motion of the movable head of the testing machine. The rate of head travel shall be 0.035 inch per minute with a permissible variation of ± 25 percent.

Test Data

22. This specimen will fail in tension in the core material or at the glue lines, whichever is weakest. The stress at failure shall be obtained by dividing the ultimate load by the cross-sectional area. If the failure is in or partially in the glue bond between core and test fixture, the test shall be considered unsatisfactory.

Moisture Content and Specific Gravity

23. The moisture content and specific gravity of each specimen shall be determined as specified in section 42.

Shear Test for the Determination of the Modulus of Rigidity

Scope

24. This method of test shall be used to determine the modulus of rigidity associated with shearing strains in the plane of the plate or planes parallel thereto (notes 1 and 2).

Note 1: The modulus of rigidity as determined by this test method is the same in all directions if the material is isotropic. If not, it is the modulus associated with the shear distortion in the planes parallel to the faces of the plate.

Note 2: This method of test can be used instead of the method described in sections 30 to 34, inclusive, for determining the modulus of rigidity in any of the planes of elastic symmetry by suitably cutting the material and edge gluing the strips obtained to provide a plate whose faces are parallel to the plane for which the modulus of rigidity is desired.

2Further description and discussion of this method of test may be obtained from Forest Products Laboratory Report No. 1301, June 1942. This testing procedure is described in and is a part of ASTM Specification D805-47, "Methods of Testing Plywood, Veneer, and Other Wood and Wood-base Materials."
**Test Specimen**

25. The test specimen shall be square with the thickness equal to the thickness of the material (note). The length of the edges shall be not less than 20 nor more than 40 times the thickness. The thickness shall be measured to the nearest 0.001 inch, and the length and width to the nearest 0.01 inch.

**Note:** The specimens shall not have any appreciable initial curvature; otherwise, results of test may be variable. If specimens have initial curvature, it will be permissible to surface the faces of the plate to remove the curvature.

**Loading Procedure**

26. Diagonal lines shall be drawn on the face of the specimen connecting opposite corners. The test specimen shall be supported on pointed or rounded supports at two diagonally opposite corners, and shall be loaded at the other two diagonally opposite corners as shown in figure 10. Metal plates shall be attached at the corners of the specimen so that the load can be applied at corners. Small impressions may be made in these plates if desired to locate ball bearings of a diameter not to exceed 1/4 inch, which may be used to provide the necessary pivots at the corners. The loading and supporting frames shall be rigid. Load shall be applied to the specimen by a continuous and uniform movement of the movable head of the testing machine at a rate of 0.003 inch per minute per inch of length of the specimen, with a permissible variation of ± 25 percent.

**Load-deformation Data**

27. Deformations shall be measured to the nearest 0.001 inch at points on each diagonal equidistant from the center of the plate. The testing apparatus shown in figure 10 shows a yoke arrangement by which the average deformation at two points along one diagonal with respect to the deformation at two points along the other diagonal is obtained. Dial readings taken with this equipment give twice the average deflection of the four points. Gage points shall be rounded sufficiently so that they will not penetrate the plate. These measurements preferably shall be measured at the quarter points of the diagonals, but if other points than these are chosen, care shall be taken to avoid locations near the corners of the plate because of load and reaction effects. The plate shall not be stressed beyond its elastic limit, and increments of load shall be so chosen that at least 10 readings of load and deformation are taken. To eliminate the effects of any initial curvature, at least two, and preferably four, sets of data shall be obtained. Successive sets of data shall be taken with the plate rotated 90° from the previous set about an axis through the center of the plate and perpendicular to the plane of the plate. The results of the different runs shall be averaged to obtain the values that will be used to calculate the modulus of rigidity.
Calculations

28. The modulus of rigidity shall be calculated from the averaged data by the formula:

\[ G = \frac{3U^2 P}{2L^3 W} \]

where \( G \) = modulus of rigidity, in pounds per square inch

\( P \) = load applied to each corner, in pounds

\( L \) = thickness of the plate, in inches

\( W \) = deflection of the plate at a point along the diagonal with reference to the center, in inches, and

\( U \) = distance from the center of the plate to the point where the deflection is measured, in inches.

Generally, values of \( P/W \) are taken from the slopes of the load-deflection curves, which give averaged values. It can be noted from the test set-up shown in figure 10 that \( P \) is one-half the load indicated by the testing machine and \( W \) is one-half the deflection indicated by the dial. However, the ratios of the two sets of readings are identical.

Moisture Content and Specific Gravity

29. The moisture content and specific gravity shall be determined for each specimen as specified in section 42.

Torsion Pendulum Shear Test for the Determination of the Modulus of Rigidity in any Plane

Scope

30. This method of test, though not so accurate as the method of test described in sections 24 to 28, may be used for preliminary evaluations or where for any reason that method is not feasible. The modulus of rigidity associated with shear distortion in any specified plane in an anisotropic material can be obtained by having the length-width plane of the specimen under test parallel to the specified plane.

Test Specimen

31. The test specimen shall be a long rectangular strip. The width of the specimen shall be at least four times the thickness. The length of the specimen shall be at least 20 times the width. The other dimensions of the
specimen shall be such that the period of oscillation of the system (when oscillated as specified in the following section) shall be approximately 2 seconds or more. The width and thickness of the specimen shall be measured to the nearest 0.001 inch, and the clear length between clamps to the nearest 0.01 inch.

Test Equipment

32. The specimen shall be suspended vertically and be rigidly clamped at the upper end. A bob shall be clamped to the free end perpendicular to the wide plane of the specimen with the center of gravity of the bob at the centerline of the thickness of the specimen. This bob shall be a round tube or cylinder and may be of steel, alloy, or plastic. The bob must be held rigidly in the clamp so that there is no play in the clamp when the specimen is oscillating. The bob may be from 1 to 3 feet long and from 0.1 to 3 pounds in weight. The weight of the specimen shall be negligible when compared to the weight of the bob. The weight of the bob shall not exert a damaging tensile force on the specimen. A suitable test set-up is shown in figure 11.

Test Procedure

33. When making the test, oscillating of the system is started by twisting the specimen with the bob and then releasing it so that the bob rotates about an axis through the center of the specimen. Care shall be taken to avoid any kind of vibration other than torsion. The time required for 5 or 10 complete oscillations shall be obtained with a stop watch. This procedure shall be repeated several times, and the results be averaged to obtain the period of vibration. This shall be repeated several times on each of two or more specimens, preferably of different lengths.

Calculations

34. The moduli for the specimens shall be calculated individually, and the results be averaged. The following approximate formula shall be used to calculate the modulus of rigidity:

\[
G = \frac{5.33 \pi^2 w d^2 L}{gt^2 ab^3 \left(\frac{16}{3} - K \frac{b}{a}\right)}
\]

where

- \(a\) = width of specimen, in inches
- \(b\) = thickness of specimen, in inches
- \(G\) = modulus of rigidity in the a-L plane, in pounds per square inch
- \(w\) = weight of bob, in pounds

Report No. 1555, revised
\[ d = \text{length of bob, in inches} \]

\[ L = \text{length of specimen between clamps, in inches} \]

\[ g = \text{acceleration of gravity} = 386.4 \text{ inches per second}^2 \]

\[ t = \text{period of oscillation, in seconds (time from one end of swing to the other and back again), and} \]

\[ K = \text{constant} = 3.361 \text{ when } a/b \text{ is greater than 2.5.} \]

**Moisture Content and Specific Gravity**

35. The moisture content and specific gravity shall be determined for each specimen as specified in section 42.

**Shear Strength and Stress-strain Curves of Core Materials**

**Scope**

36. The shear strength obtained in this test procedure is the strength parallel to the length-width plane of the specimen in the test jig and can be varied for any core material by varying the specimen orientation. The modulus of rigidity obtained is that associated with the strains in a plane normal to the plates of the test jig and parallel to the direction of the applied forces.

**Test Specimen**

37. The test specimen shall be 2 inches wide and 12 times the thickness in length. The thickness shall be approximately 1/2 inch. The thickness shall be measured to the nearest 0.01 inch, and the length and width to the nearest 0.01 inch. The test specimen shall be rigidly supported by means of steel plates bonded to the faces and ends as shown in figure 12. The thickness of the plates may be varied in accordance with the strength of the sandwich, but the plate dimensions 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 figure 12.

**Loading Procedure**

38. The load shall be applied to the edge of the rigid plates in compression or tension through a spherical bearing block or universal joint so as to distribute the load uniformly across the width of the specimen. The load shall be applied by a continuous motion of the movable head of the testing machine at a rate of application of 0.005 inch per inch of length of specimen diagonal per minute, with a permissible variation of ± 25 percent.

Report No. 1555, revised -13-
Deformation Data

39. Data for load-deformation curves may be taken to determine the modulus of rigidity, proportional limit, and 0.2 percent offset yield strength. Increments of load shall be taken to obtain approximately 12 readings of load and deformation below the proportional limit. Deformations shall be read to the nearest 0.0001 inch by means of an optical-lever system, dial gage, or any other suitable means. Figure 13 shows a shear test set-up using a dial gage for measuring deformations.

Calculations

40. The shear stress shall be computed in accordance with the following formula:

\[ \tau_s = \frac{P}{2bL} \]

where \( \tau_s \) = shear stress, in pounds per square inch
\( P \) = load on specimen, in pounds
\( L \) = length of specimen, in inches, and
\( b \) = width of specimen, in inches.

The maximum shear strength is, of course, obtained by this formula when \( P \) equals the maximum load. It should be noted that if the failure at maximum load is due to a poor bond between the core and face plates, the test shall be considered unsatisfactory. However, care must be exercised in judging the effectiveness of the bond by observing the location of the failure, because a shear failure in the core occurs over a relatively short length of the specimen and a subsequent failure, which may be interpreted as being in the bond but really is adjacent to it, occurs in the remaining length of the specimen.

The shear strains shall be computed as the angular movement of one plate of the test jig with respect to the other about an axis located on the inside face of one plate, perpendicular to the length-thickness plane and, therefore is:

\[ \theta = \frac{r}{t} \]

where \( \theta \) = angular strain in radians
\( r \) = dial reading or movement of one plate with respect to another, in inches, and
\( t \) = thickness of core or distance between plates, in inches.

Report No. 1555, revised
The modulus of rigidity shall be obtained by computing the slope of the initial straight line portion of the stress-strain curve.

Moisture Content and Specific Gravity

41. The moisture content and specific gravity shall be determined for each specimen as specified in section 42.

The Determination of Moisture Content and Specific Gravity

42. (a) The strength properties of some core materials are dependent on moisture content. When this is the case, the moisture content at time of test must be determined. In any case, it will be necessary to remove all moisture from the coupon before weighing to determine the specific gravity. Because the volume of the core materials is usually changed or the specimen otherwise damaged by test, separate coupons for this determination shall be prepared from the same material as is used in preparing the specimen. These coupons shall be kept with the specimen until time of test. Immediately after test the coupon shall be weighed and measured. The thickness of the sample shall be measured to the nearest 0.001 inch, and the length and width to at least the nearest 0.01 inch. The sample shall be dried in an oven at 100° C. until approximately constant weight is attained. After drying, the sample shall be weighed immediately. The weight of the sample shall be determined to an accuracy of not less than 0.2 percent.

(b) The moisture content shall be calculated as follows:

\[ M = \frac{W - F}{F} \times 100 \]

where \( M \) = moisture content, in percent
\( W \) = initial weight, and
\( F \) = final weight, when oven-dry

(c) The apparent specific gravity shall be computed as follows

\[ \text{Apparent specific gravity} = \frac{F \times 0.061}{L \times w \times t} \]

where \( F \) = final weight, when oven-dry, in grams
\( L \) = length of coupon, in inches
\( t \) = thickness of coupon, in inches, and
\( w \) = width of coupon, in inches.

Note: The specific gravity as determined above is based on volume at test and weight when oven-dry.
Figure 2.—Alignment jig for fabrication of shear-test specimens showing components prior to assembly and a completely assembled specimen in the jig ready for bonding.
Figure 3.--Compression test of honeycomb-type sandwich core material showing method of providing additional end support at the bearing surface through the use of a plaster-of-Paris cast base. A Marten's mirror type of compressometer is attached to the specimen for obtaining deformation readings.
Figure 4.--Test set-up for compression flatwise test of core material for sandwich-type construction. Several layers of core material are stacked together to minimize the effects of end restraint.
Figure 5.—Test set-up for compression flatwise test of core material showing use of Filar microscopes to measure deformations.
Figure 6.--Lateral-support jig of a type suitable for use in making compression-edgewise tests on materials less than 1/2 inch in thickness.
Figure 8.--Test set-up for tension flatwise test of core material for sandwich-type construction showing specimen and fitting for applying load.
Figure 9.—Details of construction of the fittings for tension flatwise test of core material for sandwich-type construction.
Figure 11.--Torsion pendulum test for the determination of the modulus of rigidity for core materials for sandwich construction.
Figure 12.--Shear test for sandwich material.
Figure 13.—Apparatus for shear test showing steel plates, specimen, and dial arrangement for measuring deformations between plates.