PRELIMINARY REPORT ON THE STRENGTH OF FLAT SANDWICH PLATES IN EDGEWISE COMPRESSION

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PRELIMINARY REPORT ON THE STRENGTH OF FLAT SANDWICH PLATES IN EDGEWISE COMPRESSION[1]

By

KENNETH H. BOLLER, Engineer

Summary

This report presents data on the edgewise compressive strength of short columns of flat sandwich plates. It contains the results of a limited number of tests that were made on sandwich constructions to determine the failing stress of the facing material. This report also presents some mechanical properties of the core and facing materials used in the sandwich plates, and describes the methods employed to obtain them.

Introduction

In the design of sandwich constructions the maximum stress of the facings that is obtained in an edgewise compression test of the construction is an important criterion in the determination of the suitability of the component materials. The data on the strength and related properties of sandwich plates are presented in this report to provide assistance in the development of theories and formulas for this criterion.

These data are the results of tests for maximum strength on 169 sandwich constructions. The results were obtained by testing six facing materials in 29 combinations with 10 core materials. In some of the 29 combinations the thicknesses of the component materials were varied, resulting in the 169 sandwich constructions.

Data are presented to show a few properties of the facing and core materials that are related to the edgewise compressive strength of the sandwich. The methods that were employed for obtaining these properties are discussed.

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[1] This report is one of a series of progress reports prepared by the Forest Products Laboratory. Results here reported are preliminary and may be revised as additional data become available.

Materials

Facing Materials

The facing materials that were used and tested in the sandwich constructions are (1) rolled metallic sheets, (2) plastic laminates, and (3) veneer laminates. They are described as follows:

Rolled metallic sheets.--24 SH aluminum sheets, 0.005 inch in thickness, and 24 ST alclad aluminum sheets in 0.008, 0.012, 0.018, 0.020, and 0.032 inch thicknesses were employed. The aluminum sheets in each sandwich construction were placed on the two sides of the core with the lengthwise or rolled direction parallel to the direction of the compressive stress applied in the tests.

Plastic laminates.--Cross-laminated glass cloth facings were used in 2-, 4-, 8-, and 16-ply constructions in conjunction with end-grain balsa cores. These facings were impregnated to a resin content of about 55 percent (based on total weight) with a suitable resin. When glass cloth was used with other core materials, 3-, 6-, 10-, and 16-ply constructions were made with about 45 percent resin content. (Note: The higher resin content of the glass cloth laminate employed with the balsa was found necessary for the proper fabrication of the sandwich constructions. In later panels, not reported here, means were found by which the resin content was satisfactorily reduced to 45 percent.) The glass cloth sheet incorporated in these constructions was 0.003 inch thick, 38 inches wide, and weighed 2.09 ounces per square yard. It was of a plain type of weave.

Cross-laminated papreg was used in 0.009, 0.022, 0.027, 0.042, and 0.066 inch thicknesses. The base paper was made from an unbleached black spruce, Mitscherlich type, sulfite pulp. This paper, 2.5 mils thick, was impregnated with 36.3 percent of a thermosetting phenolic resin. The percentage is based on the weight of the treated paper.[2]

These plastic laminates were placed on the two sides of their respective core materials with the machine direction of the outside sheets parallel to the direction of the stress applied in the tests.

Veneer laminates.--Laminated yellow-poplar veneer was used as a facing material on resin-impregnated pulpboard cores. The laminated facings were made of from 1 to 10 sheets of 0.01-inch rotary-cut veneer, bonded with sheets of resin-impregnated paper. The directions of the grain of the individual veneers were parallel to each other.

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[2] Additional information may be found in "Strength and Related Properties of Forest Products Laboratory Laminated Paper Plastic (Papreg) at Normal Temperature." Forest Products Laboratory Report 1319, revised.

Aircraft spruce plywood was made of a three-ply construction having 1/48-inch faces and 1/32-inch core.

Both yellow-poplar and spruce facing materials were placed on the two sides of their respective core materials with the grain direction of the outside plies parallel to the direction of the stress applied in the tests.

Core Materials

The core materials that were used and tested in the sandwich constructions may be placed in four classes, (1) wood and plywood, (2) expanded plastics, (3) pulpboard, and (4) honeycomb structures. They are described as follows:

Wood and plywood.--Balsa wood was used in combination with all of the types of facing material. The balsa that is referred to as "end grain" (E.G.) was placed between the two facings with the longitudinal or grain direction perpendicular to the facings. This was accomplished by first surfacing the rough planks, then cutting the planks across the grain to make blocks of the required thickness of the core in the sandwich. These blocks were glued edge to edge to form the core. In general, a single sandwich plate contained blocks from the same plank, but the orientation of their radial and tangential directions was not confined to one given direction in the plane of the panel.

The balsa that is referred to as "loaded flat, perpendicular to grain" was placed between the two facings with the grain direction parallel to the plane of the facings and perpendicular to the direction of the load applied in the tests. This construction was made by gluing, edge to edge, planks that had been smoothly surfaced to the required thickness of the core material.

The balsa that is referred to as "loaded parallel to grain" was placed between the two facings with the grain direction parallel to the plane of the facings and parallel to the direction of the load applied in the tests. For this construction the planks of the required thickness were glued edge to edge to provide sufficient width.

The spruce plywood that was used as a core material with aluminum facings was made in the following constructions: (1) the 3/16-inch thick plywood was made of 1/32-inch faces and core and with 1/20-inch cross bands; (2) 3/8-inch thick plywood was made of seven plies of 1/16-inch veneer; (3) 7/8-inch thick plywood was made of seven plies of 1/8-inch veneer. The grain direction of the outer ply in each construction was placed parallel to the direction of the load applied in the tests.

Expanded plastics.--The expanded plastics consisted of solid materials that had been foamed, or expanded, to produce a large number of small voids in the mass thereby reducing the over-all specific gravity. Each of the core materials of this group had a fairly uniform cell structure and an over-all specific gravity of about 0.10. The individual cells varied in size from about 0.01 to 0.04 inch in diameter.

Core materials of calcium alginate, cellular cellulose acetate, cellular hard rubber, British hard rubber, and special sponge rubber were used. They were in the form of flat plates that ranged in thickness from 1/2 inch to 1-1/2 inches, and in width from 2-5/8 inches to 24 inches and in length from 1 to 10 feet. The natural skin that covered the manufactured product was removed from all faces of these materials in their preparation for use as cores. The original direction of the thickness dimension was used as the thickness direction of the core in the sandwich. The other two directions, lengthwise and crosswise, were placed indiscriminately in the direction of the stress applied in the tests.

Pulpboards[3].--The impregnated pulpboards used consisted of irregularly arranged wood fibers that adhered to each other and were formed into sheets of low density, porous core material. The quality of the adhesion and strength of the pulpboards were increased by the addition of resin. The resin-impregnated pulpboards used had resin contents ranging from 0 to 70 percent. The percentage is based on the total weight of the impregnated board when dry. The specific gravities as well as the strengths of the core materials increase with increases in resin content. These boards were not stripped of their outer skin, prior to their use as cores, as were the expanded plastics. This skin prevented excessive penetration into the core material of the glue to affix the facings. The boards were manufactured in thicknesses of 3/8 and 3/4 inch and were used unaltered.

Honeycomb structures.--The honeycomb material that was used in this study was made of either resin-impregnated glass cloth or paper sheets. The glass cloth sheets were the same as those used in making the facings. The paper sheets were made of 4-mil kraft paper, corrugated, and pretreated with 10 percent of phenolic resin. Both kinds of sheeting were impregnated with a contact type of resin and assembled in large separate blocks. The crest of one corrugated sheet was placed on the crest of another forming tubes about 0.18 inch in diameter. The cores for the sandwich were sliced from the blocks so that the thickness dimension of the sandwich was parallel to the axes of the tubes. This core material was oriented in the sandwich so that planes of the corrugated sheets were perpendicular to the direction of loading.

Fabrication of Sandwich Plates

Facing and core materials were combined to form 169 different sandwich constructions. Each construction consisted of sheets of facing material glued to a core to form flat sandwich plates. In some cases more than one layer of core material was required to form the core so that several layers were glued together. The thicknesses of the core and facing materials in these plates are listed in tables 1 through 5.

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[3] Additional information may be found in "Resin Treated Pulpboard Core Material for Sandwich Construction." Forest Products Laboratory Report R1623.

Three sizes of sandwich plates were made: (1) square, 12 inches on a side, (2) rectangular, 12 inches long and 4 times the thickness plus 1 inch in width, (3) rectangular, 2 inches wide and 4 times the thickness plus 1 inch in length. In the fabrication of the rectangular plates, 12 inches long, strips of wood were placed between the facings in conjunction with the core material. These strips, 1/2 inch wide, 12 inches long, and the same thickness as the core material, were located at both 12-inch edges as shown in figure 1.

Methods of Test

Tests of Sandwich Constructions

Compression and tension tests of sandwich constructions were made, except for a few modifications, according to the tentative methods described in Forest Products Laboratory Report 1556.[4]

Compression edgewise.--The compression tests in the edgewise direction were made according to the procedure given in section 6 of report 1556.[4] Although this method was used and found satisfactory for a majority of the specimens, some of them failed adjacent to one of the loaded edges. These failures were subsequently prevented in two different ways, (1) by the addition of wooden strips, shown in figure 1, to provide internal support of the facings at the loaded edges in conjunction with the steel clamps described in report 1556,[4] and (2) by the adoption of plaster disks, as shown in figure 2. The specimens equipped with the plaster disks were prepared by grinding the bearing edges of the facings smooth and parallel and removing 1/4 inch of the core material at each bearing end. The protruding edges of the facing material were cast in plaster disks so that the bearing surfaces of the facings were flush with the surfaces of the disks.

The particular specimens that were modified in each of these ways are indicated by footnotes in tables 1 through 5.

Tension flatwise.--The tension tests in the flatwise direction were made according to the procedure given in section 8 of report 1556.[4] The sandwich material for the specimens used in these tests was obtained from the 12-inch square plates as shown by the cutting diagram (fig. 3).

Compression flatwise.--The compression tests in the flatwise direction were made according to the procedure given in section 7 of report 1556.[4] The sandwich specimens used for these tests were also obtained from the 12-inch square plates.

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[4] Tentative Methods for Conducting Mechanical Tests of Sandwich Constructions. Forest Products Laboratory Report 1556.

Tests of Core Material

Compression and shear tests of the core materials were made according to the tentative methods described in Forest Products Laboratory report 1555[5] with an additional method for determining the modulus of rigidity.

Compression flatwise.--Compression tests of the special sponge rubber were made in the flatwise direction according to the procedure described by paragraphs 5 through 10 and figure 2 of report 1555.[5]

Compression tests of honeycomb materials were made on specimens 2 inches square by 6 inches long (length parallel to axes of cells). These specimens were tested between the heads of a testing machine by applying the load in a direction parallel to the axes of the cells. A 2-inch Marten's mirror arrangement was used for measuring the deformations.

Other core materials were tested in compression flatwise as sandwich constructions as previously described.

Compression edgewise.--Compression tests in the edgewise direction were made according to the procedure described in paragraphs 12 through 17 of Forest Products Laboratory report 1555.[5] Materials for these tests were matched with those used as cores of the sandwich constructions tested in edgewise compression. Core materials from the square plates, which were 3/4 of an inch in thickness or thicker, were prepared by removing the facings from that portion of the plate marked "core, edgewise compression," as indicated in figure 3. Plates that were thinner than 3/4 of an inch did not provide material of sufficient thickness for testing.

Shear.--The modulus of rigidity was determined by one of three methods, (1) plate shear, (2) torsion pendulum, or (3) frame shear. Balsa, cellular cellulose acetate, and cellular hard rubber were tested by the plate shear method, which is described in paragraphs 33 through 37 of Forest Products Laboratory report 1555.[5] Calcium alginate, pulpboards, British hard rubber, and sponge rubber were tested by the torsion pendulum method; paragraphs 39 through 43 of report 1555.

The frame shear method of test was used to determine the modulus of rigidity for honeycomb structures because the other methods were considered not to be applicable. Figure 4 shows the dimensions of the assembly of specimen and frame used for this test. Figure 5 shows the assembly with dial located between the heads of a testing machine. The axes of the cells in the honeycomb are perpendicular to the plates and the planes of the corrugated sheets are parallel to the 6-inch dimension. Loads were applied through either a spherical head (fig. 5) or shimmed bearing blocks and thus distributed uniformly across the width of the specimen.

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[5] Tentative Methods of Test for Determining Strength Properties of Core Material for Sandwich Construction. Forest Products Laboratory Report 1555.