BUCKLING LOADS OF FLAT SANDWICH PANELS IN COMPRESSION

Buckling of Flat Sandwich Panels with Loaded Edges Simply Supported and the Remaining Edges Clamped

Original report dated September 1947

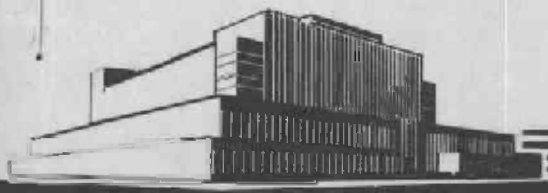
Information Reviewed and Reaffirmed August 1962

No. 1525-B

LOAN COPY

Please return to:

Wood Engineering Research
Forest Products Laboratory
Madison, Wisconsin 53705



FOREST PRODUCTS LABORATORY
MADISON 5, WISCONSIN

UNITED STATES DEPARTMENT OF AGRICULTURE
FOREST SERVICE
In Cooperation with the University of Wisconsin

BUCKLING LOADS OF FLAT SANDWICH PANELS IN COMPRESSION[1]

Buckling of Flat Sandwich Panels with Loaded Edges Simply Supported and the Remaining Edges Clamped[2]

(Cores of End-grain Balsa or Cellular Cellulose Acetate and Facings of Aluminum or Glass Cloth Laminate)

By

K. H. BOLLER, Engineer

Forest Products Laboratory,[3] Forest Service
U.S. Department of Agriculture

Summary and Conclusions

This report presents the results of edgewise compression tests to determine the critical buckling loads of flat sandwich panels having the loaded edges simply supported and the remaining edges clamped. The tests were conducted to confirm the theoretical analysis presented in Forest Products Laboratory Report No. 1525,[4] and modifications introduced to take into account the effect of transverse shear and of stresses greater than the proportional limit.

Tests were made on sandwich constructions that consisted of cores of either end-grain balsa or cellular cellulose acetate and facings of either aluminum or glass cloth laminate. Panels were tested in various sizes to provide as wide a range in stresses as possible.

---

[1]This report is one of a series of progress reports prepared by the Forest Products Laboratory relating to aircraft. Results here reported are preliminary and may be revised as additional data become available. Original report dated September 1947.

[2]This report is the third of a series of reports dealing with the buckling of flat sandwich panels in compression, tested with various types of edge conditions.

[3]Maintained at Madison, Wis., in cooperation with the University of Wisconsin.

[4]March, H. W., and Smith, C. B. Buckling Loads of Flat Sandwich Panels in Compression--Various Types of Edge Conditions. Forest Products Laboratory Report No. 1525. March 1945. Information reviewed and reaffirmed 1962.

The following formula, No. 11 of Report 1525,[4] was used in the theoretical analysis:

$$P_{cr} = \frac{16\pi^2}{3a^2} \left[D_1 \frac{b^2}{n^2 a^2} + \frac{3}{16} D_2 \frac{n^2 a^2}{b^2} + \frac{K}{2} \right] \qquad (1)$$

where:

The symbols are defined in the appendix under "Notation."

This formula was modified to make it applicable to panels with stresses above the proportional limit and to take into account the effect of shear strains in the core. The values of critical buckling loads obtained by experiment averaged about 92 percent of the values obtained by substituting the mechanical properties of the materials in this formula and its modifications. It is believed that the experimental values were lower than the computed values because (1) the clamped edges of the test panels were not secured so firmly by the testing apparatus as had been assumed in the derivation of the formula and (2) the formulas were derived by the energy method which may sometimes lead to computed buckling loads that are as much as 8 percent too great.

Introduction

As part of an investigation to confirm the mathematical analysis, with modifications introduced to take into account the effect of transverse shear and of stresses greater than the proportional limit, which was previously developed at the Laboratory for determining the critical buckling loads of flat sandwich panels supported by various types of edge conditions, this report presents the experimental data of edgewise compression tests on flat sandwich panels simply supported at the loaded edges and clamped at the remaining edges. Information relative to materials, testing procedures, and results is arranged according to the outline used to present similar information in report 1525-A.[5] Duplication of descriptions was avoided by omitting them and referring to the previous report. Where variations from the previous report were necessary, they are noted and fully described.

---

[5] Boller, K. H. Buckling Loads of Flat Sandwich Panels in Compression--the Buckling of Flat Sandwich Panels with Edges Simply Supported. Forest Products Laboratory Report No. 1525-A. February 1947. Information reviewed and reaffirmed 1960.

Scope

Experiments in this study were designed to furnish the critical buckling loads of flat sandwich panels subjected to edgewise compression when the loaded edges are simply supported and the remaining edges are clamped. Panels of various sizes were tested to provide a wide range of stresses in the facings. Four combinations of materials were employed to provide data on the effect of transverse shearing deformation in the core. The tests were made upon panels approximately 1/4 inch in thickness. Two core materials and two facing materials were employed.

Preparation of Specimens

Materials

The materials used in this study consisted of two facing materials, 0.012-inch 24ST alclad aluminum sheet and six-ply cross-laminated glass cloth, and two core materials, 1/4-inch balsa (end grain) and 1/4-inch cellular cellulose acetate. The aluminum-sheet, glass-cloth laminate, and end-grain balsa were described in report 1525-A. The cellular cellulose acetate is described by the manufacturer as "an unoriented, multicellular form of cellulose acetate containing a small portion of a strength-imparting filler material." The material that was used in conducing these tests weighed from 6 to 7 pounds per cubic foot. It had been manufactured in strips approximately 5/8 inch thick, 2-5/8 inches wide, and 10 feet long. These strips were machined at the Laboratory to 1/4 inch thick and about 2-1/4 inches wide. The finished strips were glued edge to edge prior to assembly in the sandwich plate.

Flat sandwich plates were made of these four materials in the following combinations.

Facing Material	Core Material
0.012-inch aluminum sheet (24ST alclad)	1/4-inch balsa
0.012-inch aluminum sheet (24ST alclad)	1/4-inch cellular cellulose acetate
Six-ply cross-laminated glass cloth	1/4-inch balsa
Six-ply cross-laminated glass cloth	1/4-inch cellular cellulose acetate

Manufacture of Sandwich Plates

The method of fabrication of the sandwich plates having glass cloth facings was the same as that previously reported in Report No. 1525-A, but those having aluminum facings were made by two different processes, neither one of which was described in that report. (1) The aluminum sheets, which were to be used on balsa cores, were cleaned; then a bonding agent, composed of a phenol liquid and a vinyl powder, was applied to the inner surface of the facing. These facings were pressed to the balsa cores at 100 pounds per square inch and 275° F. (2) The aluminum sheets, which were to be used on cellular cellulose acetate cores, were cleaned; then a high-temperature-setting modified thermoplastic resin was applied to the inner surface of the facing. These facings were pressed to the cores at 40 pounds per square inch and 225° F.

Twenty-eight flat sandwich plates were made of each of the listed combinations of materials, except the glass cloth-cellular cellulose acetate combination, of which 16 plates were made. All of the plates made of a given combination were subdivided into groups containing four plates each, identical in size and thickness. The sizes of the plates varied from 16 by 30 inches to 40 by 48 inches. For each of the rectangular plates having glass cloth facings, an additional plate, called a companion plate, was manufactured. It was square, about half the size of the rectangular plate, and made of the same materials and by the same method.

Test Panels and Coupons

Test panels and their representative coupons were obtained from the flat rectangular plates in the same manner as that described in Report No. 1525-A and shown in figure 6 of that report, with two exceptions as follows: (1) the square companion plates previously mentioned were trimmed to provide plate shear coupons in place of using the central portion of the rectangular plates for plate shear coupons; and (2) plate shear coupons for the groups of plates having aluminum facings were not provided. The ratio of the length to the width of each plate was chosen, using preliminary estimates of the mechanical properties, so that the first cusp from the left of the appropriate curve of report 1525 applied. Six flexural coupons and three compression coupons were cut from the plates as shown in figure 6 of Report No. 1525-A. The lengthwise direction of these compression coupons was parallel to the direction of applied stress in the test of that plate.

Methods of Test

Determination of Observed Critical Buckling Loads

The two methods, reversal of strain and point of inflection, as discussed in Report No. 1525-A, were used to determine the observed critical buckling loads of the test panels. However, the apparatus that supported these panels was altered to meet, as nearly as possible, the requirements of the new edge conditions.

Apparatus.--The apparatus used in previous tests in this series was revised to support the new panels so as to simply support the loaded edges and clamp the remaining edges of the panels. The revised apparatus consisted of the same grooved end rods, which rotated on a nest of rollers, that are shown in figure 12 of 1525-A. However, a new upper loading beam was designed and made to support the upper roller assembly. Figure 24[6] shows a cross section of the roller support and the revised loading beam. This loading beam consisted of channel irons which were deeper, longer, and fastened more rigidly than those used in previous tests. The inner surfaces of the present pair were finished and spaced 7.000 inches ±0.001 inch apart. The channel irons also provided a support for the top supporting plates and the wooden alinement blocks, which were used to aline the roller supports.

A complete new arrangement was made to provide a clamped edge condition on the edges that were not loaded. These edges were clamped with as much fixity as was possible without impairing the compressive movement of the panel. Figure 25 shows a cross-sectional sketch of a test panel, guide plates, and the vertical guide plates, and the vertical guide posts that provided this clamped condition. All of the panels were held along each unloaded edge by two guide plates, one fixed and the other adjustable. The latter was adjusted to provide about 0.002-inch clearance between the guide plates and the panel. The guide plates were finished and grooved, as shown, to allow space for metalectric strain gages and their wires. Both the fixed guide plates and the holder for the adjustable guide plates were bolted to the vertical guide post and they were alined by means of keys and keyways. Both types of guide plates were made in various short lengths so that a series of them would provide support for various heights of panels. The vertical guide post was a 7-inch channel iron finished to 6.995 inches ±0.001 inch.

---

[6]The figures and tables in this report are numbered consecutively with those of report 1525 and its supplement 1525-A.

Figures 26 and 27 show a test panel supported in the revised apparatus. Ample space at the corners of the panel where the two types of support are adjacent was provided to allow for compressive shortening of the panel. This space was always less than four times the thickness of the sandwich. Each vertical guide post rests on four springs (not visible in the figures) which are located between the base plate and the double I-beams. The vertical guide posts fit between the channel irons with 0.005-inch clearance, and the 12-inch apron on the base plate of the guide posts straddles the lower double I-beams with 0.005-inch clearance. This design allows freedom of movement in the vertical direction but allows a minimum of torsional movement about a vertical axis.

Load-deformation and load-deflection data were obtained by means of resistance wire strain gages and dials on each panel. Figure 28 shows the equipment that was used. The deformation data were obtained from four strain gages, which were mounted inside the clamps, and two strain gages, which were mounted on opposite sides of the panel at its center. The loads were applied continuously to failure, and the strains and the lateral deflections were recorded at regular intervals.

Determination of Elastic Properties for Use in Formulas

Shear.--The modulus of rigidity, ($\mu_{1,2}$), associated with shearing strains due to flexure and corresponding to the axes x and y (fig. 1 of Report No. 1525) in the plane of the flat panel, was determined for the flat panels faced with glass cloth by the plate-shear method, as developed by the Forest Products Laboratory.[7] Square companion plates were tested as coupons by this method. The length of each side of these square coupons was equal to the length of the simply supported edges of the test panel.

It is realized that the values obtained by this method may be slightly in error due to transverse shear in the cores of these specimens. Only the last term in the parenthesis of equation (3), however, is affected, and the resulting errors in the computed critical loads are therefore negligible.

For the flat panels having aluminum facings, the modulus of rigidity was not determined from tests of plate-shear coupons, because these panels were, for practical purposes, isotropic (stiffness factors D_1, D_2, and K were equal). Therefore plate-shear tests were eliminated and average values of flexural stiffnesses used (see formula 4).

---

[7] American Society for Testing and Materials. Report of Committee D-7 on Wood ASTM Tentative Standard D805-44T. Proposed Methods of Testing Veneer, Plywood, Wood, and Woodbase Laminated Materials. 1944.

Flexure.--The effective flexural stiffness values (D'_1 or D'_2) were determined in the manner described in Report No. 1525-A. The span lengths of the coupons that were oriented in a direction perpendicular to the clamped edges of the panel were arbitrarily chosen equal to one-half of the free distance between those clamps. The measured stiffness values were corrected in accordance with the method previously described[4] to obtain the true values.

Compression of coupons cut from sandwich plates.--Coupons obtained from the sandwich plates were tested in compression according to previously established methods.[8]

Compression of coupons cut from facings.--No additional tests were made to determine stress-strain curves of the facing materials. Values that were obtained from tests and shown in figure 21 and table 9 of 1525-A were used in this report.

Presentation of Data

The experimental data and the results of computations are presented in tables 10 through 13 and on figures 29 through 32. These tables and figures present the data obtained from sandwich panels tested with loaded edges simply supported and the other edges clamped. The tables are identical in form and have the same column headings as tables 1 through 8 of Report No. 1525-A. Therefore, the descriptions given in Report No. 1525-A apply here with the following exceptions:

Column 10.--Values of $P_{cr\ obs}$ were obtained by dividing the total observed critical load by the total panel width, a'. Observations of strains measured at three positions along the width of the panel including gages under the clamps, showed that the load was applied uniformly across the width of the panel until critical buckling occurred.

Column 11.--The observed maximum load, P_m, in pounds per inch of free loaded width, was obtained by the following relationship:

$$P_m = \frac{P - P_{cs}}{a} \qquad (2)$$

where:

P = total observed maximum load on the test panel, in pounds.

[8] American Society for Testing and Materials. ASTM Standard C364-61. Method of Test for Edgewise Compression Strength of Flat Sandwich Constructions.

P_{cs} = load, in pounds, sustained by the material within the clamped support. This load was computed from the strains measured on the material within the clamps.
a = free width of panel.

Columns 14 and 15.--The flexural stiffness factors, D_2 and D_1, were average values computed from data obtained from the flexural coupons according to the elementary beam theory but corrected for deflections due to shear strains in the core. The approximate formulas for these computations are the same as those given in Report No. 1525-A, and the values of $(E_x)_f$, $(E_y)_f$, $(\mu_{xz})_c$, and $(\mu_{yz})_c$, for aluminum, glass cloth, and balsa, which were substituted in these formulas, are the same as those previously used, but an additional value of 3,500 pounds per square inch for $(\mu_{xz})_c$ and $(\mu_{yz})_c$ was used to compute corrections on panels made of cellular cellulose acetate. This value was obtained by plate-shear tests of cellular cellulose acetate.

Columns 16 and 17.--These two columns contain computed stiffness factors, $(\frac{E\sigma}{\lambda})_{1\,2}I$ and experimental stiffness factors $\mu_{1\,2}I$, respectively. The methods of obtaining them, described in Report No. 1525-A, were used in this investigation to determine these values for panels having glass cloth facings. Values of these factors are used to compute K. Since the panels made of aluminum facings can be considered to be isotropic, values of $K = D = \frac{D_1 + D_2}{2}$.

Column 19.--This column presents the computed buckling loads, $P_{cr\ comp}$, obtained from formulas in Report No. 1525. Even though the same symbol, $P_{cr\ comp}$, was used throughout the reports, the critical load was computed differently depending on the manner in which the panel was supported. In this report, the values in column 19 were computed according to the following equations:

(1) For panels faced with glass-cloth laminate

$$P_{cr\ comp} = \frac{16\pi^2}{3a^2}\left[D_1\frac{b^2}{n^2a^2} + \frac{3}{16}D_2\frac{n^2a^2}{b^2} + \frac{1}{2}\left(\frac{E\sigma}{\lambda}\right)_{1,2}I + \mu_{1,2}I\right] \qquad (3)$$

(2) For panels faced with aluminum

$$P_{cr\ comp} = \frac{16\pi^2}{3a^2}\frac{(D_1 + D_2)}{2}\left[\frac{b^2}{n^2a^2} + \frac{3}{16}\frac{n^2a^2}{b^2} + \frac{1}{2}\right] \qquad (4)$$

Column 20.--This column presents the values of the shear reduction factor, $\frac{1}{1 + \eta_2}$, provided the facing stresses are within the elastic range. For panels whose loaded edges are simply supported, and the other edges clamped,[9]

$$\eta_2 = \frac{18\ fc\ P_{cr\ comp}}{(h^3 - c^3)\left[3\,(\mu_{yz})_c + 4\,(\mu_{xz})_c \frac{b^2}{n^2 a^2}\right]} \tag{5}$$

The values of $P_{cr\ comp}$ were computed as shown by equations (3) and (4). The values of the shear moduli of the two core materials were 19,000 pounds per square inch for balsa and 3,500 pounds per square inch for cellular cellulose acetate.

Columns 21 and 22.--The values of M or N in these columns were obtained according to the definitions established in Report No. 1525-A. These values were computed by the same equations as those shown in Report No. 1525-A, except that the proper values of $P_{cr\ comp}$ and η_2, depending on the manner in which the panel was supported, were used. That is:

$$M = \frac{P_{cr\ comp}}{2f\ E_f} \tag{6}$$

$$N = \frac{\eta_2}{E_f} \tag{7}$$

Column 23.--This column presents the values for the computed critical load, that were (1) adjusted by means of the shear reduction ratio when panels had stresses within the elastic range or (2) adjusted by means of the modification for both shear reduction and stresses above the proportional limit. The values were computed in the same manner as shown in Report No. 1525-A, except that the proper formulas applicable to the particular edge conditions were used.

Figures 29 through 32.--These figures present a graphical comparison of the ratios, shown in columns 24 through 26 of the tables, of observed and computed critical values to the edgewise compressive strength of the sandwich

[9]This approximate formula was developed by H. W. March former Forest Products Laboratory mathematician.

constructions. Figures 29 and 30 present the data for panels having aluminum facings, and figures 31 and 32 present the data for panels having glass-cloth facings. Figures 29 and 31 show the relationship of the critical buckling load as computed by formula (1) ($P_{cr\ comp}$) to the observed critical load. Figures 30 and 32 show this relationship when the proper modifications of that formula are employed. The ordinates and the abscissas are the same as those used in Report No. 1525-A.

Analysis of Results

The formula for the critical load of flat sandwich panels having loaded edges simply supported and other edges clamped was given in a previous report[4] under the assumption that the stresses in the facings are less than the proportional limit and that the effect of transverse shear can be neglected. In the present report this formula is modified to apply when these assumptions are not warranted. These modifications were developed in the same manner as those presented in Report 1525-A. Application of the proper formulas for these modifications produced theoretical values that are about 8 percent greater than the observed values.

The following expression was previously derived.[4]

$$P_{cr} = \frac{16\pi^2}{3a^2}\left[D_1\frac{b^2}{n^2a^2} + \frac{3}{16}D_2\frac{n^2a^2}{b^2} + \frac{K}{2}\right] \qquad (1)$$

This formula is applicable to panels which are simply supported at the loaded edges and are clamped at the other edges. Without modifications it is applicable only to panels which are stressed within the elastic range and in which the effect of shear strains in the core is negligible. The values, obtained by substituting in this formula the test data from coupons of each plate, are presented in columns 19 of the tables. The relationship of these values to the observed values are shown in figures 29 and 31. An inspection of the values in these figures show that the average of the observed values below the proportional limit stress is as low as 69 percent of the computed values and that the average of the observed values above the proportional limit stress is as low as 50 percent of the computed values. This, however, is to be expected and the following modifications of formula (1) were used, as they were in Report No. 1525-A.

Modification for shear.--The following modification of the formula allows for the effect of transverse shearing deformations:

$$P_{crs} = \frac{P_{cr\ comp}}{1 + \eta_2} \tag{8}$$

or

$$p_{crs} = \frac{P_{cr\ comp}}{1 + \eta_2}$$

where

$$\eta_2 = \frac{18fc\ P_{cr\ comp}}{(h^3 - c^3)\left[3(\mu_{yz})_c + 4(\mu_{xz})_c \frac{b^2}{n^2 a^2}\right]} \tag{9}$$

Values of the shear reduction ratio, $\frac{1}{1 + \eta_2}$, which shows the magnitude of this modification if applied to panels with buckling stresses below the proportional limit, is presented in column 20. The value of this ratio ranges between 2 and 29 percent for the panels tested. The affect of the application of this modification on $P_{cr\ comp}$ is shown on figures 30 and 32, more especially figure 32, because all of the values plotted are below the proportional limit stress. Comparison with figures 29 and 30 indicates that the modification has shifted the plotted points toward the 45° line.

Modification for shear and for stresses above the proportional limit.--The use of a reduced modulus of elasticity in place of Young's modulus was described in Report No. 1525-A, and it was shown that the critical buckling stress in the facings of a sanwich panel is

$$P_{cr\ r} = M\ E_r \tag{10}$$

where

$$M = \frac{P_{cr\ comp}}{2f\ E_f} \tag{11}$$

This relationship applies to panels in this study because the value of M is equal to the critical buckling stress in the facings divided by the modulus of elasticity of the facings.

Like η_1 in the previous report,[5] η_2 in this study is directly proportional to the reduced modulus, E_r, as follows:

$$\eta_2 = NE_r \tag{12}$$

where

$$N = \frac{18\ fc\ P_{cr\ comp}}{E_f\,(h^3 - c^3)\left[3(\mu_{yz})_c + 4(\mu_{xz})_c \dfrac{b^2}{n^2 a^2}\right]} \tag{13}$$

The combination of the modification for shear and the modification for stresses above the proportional limit is obtained by substituting in equation (8) the expressions for $p_{cr\ comp}$ and η_2, the right-hand members of equations (10) and (12), respectively. The resulting expression for the critical buckling stress in the facing material is

$$p_{cr\ rs} = \frac{M\,E_r}{1 + NE_r} \tag{14}$$

This formula was solved graphically, in the manner described in Report No. 1525-A. The effect of applying this modification can be determined by comparing the computed values, without modifications, to the computed values, with modifications, tabulated in columns 19 and 23, respectively, of tables 10 and 11. This effect can also be determined by a comparison of figures 29 and 30 for those points whose ordinates are greater than 0.5. It may be seen that the plotted points are shifted closer to the 45° line. The observed values are on the average about 92 percent of the computed values. It is believed that the experimental values are too low (1) because the test panels were not rigidly clamped by the apparatus and (2) because the formulas were derived by the energy method and may lead to results that are too great.

APPENDIX

Notation

The symbols that were used in the two previous reports in this series, 1525 and 1525-A, were also used throughout this report, and only the additions and exceptions are listed here.

$K = D_1 = D_2 = D$ (for isotropic facings, that is, aluminum)

$= (1/2)(D_1 + D_2)$ (experimental)

$$M = \frac{P_{cr\ comp}}{2f\ E_f}$$

$$N = \frac{\eta_2}{E_f}$$

$$\eta_2 = \frac{18\ fc\ P_{cr\ comp}}{(h^3 - c^3)\left[3(\mu_{yz})_c + 4(\mu_{xz})_c \frac{b^2}{n^2 a^2}\right]}$$

$P_{cr\ comp}$ = Critical buckling load as computed by the formula of Report 1525 applying to a panel with loaded edges simply supported and remaining edges clamped (pounds per inch of width).

P = Total observed maximum load in pounds on the test panel.

P_{cs} = Load, in pounds, sustained by the material within the clamped supports.

Table 10.—Comparison between experimental and theoretical values of compressive strength of flat sandwich panels of 0.016-inch aluminum sheet and 1/4-inch balsa (loaded edges simply supported, resisting edges clamped)

Panel No.	Dimensions: Thickness: Face	Thickness: Core	Thickness: Total	Width: Free	Width: Total	Height: Free	Height: Total	Density	Observed data: Panel data: Critical load	Panel data: Maximum load	Panel data: Lateral deflection at maximum load	Panel data: Type of failure	Coupon data: Stiffness factors: Bending D_2	Bending D_1	$\left(\frac{E_F}{1-\mu^2}\right)$	Shear μ_{12}	Shear G_{12}	Compression strength F_{2m}	Critical load	Shear reduction ratio	Constants N	$N \times 10^3$	Critical load reduced	Comparative ratios			
	f	c	h	a	a'	b	b'	γ_t	$P_{cr\ obs}$	P_m	w_m							F_{2m}	$P_{cr\ comp}$				$P_{cr\ rs}$	$\frac{P_{cr\ obs}}{P_{2m}}$	$\frac{P_{cr\ comp}}{P_{2m}}$	$\frac{P_{cr\ rs}}{P_{2m}}$	$\frac{P_m}{P_{2m}}$
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)		(18)	(19)	(20)	(21)	(22)	(23)	(24)	(25)	(26)	(27)
	Inch	Inch	Inch	Inches	Inches	Inches	Inches	Lb. per cu. ft.	Lb. per in. width	Lb. per in. width	Inches							Lb. per in. width	Lb. per in. width				Lb. per in. width				
1-1	0.012	0.255	0.279	39.95	45.51	33.02	33.02	0.569	165	399	1.327	Buckle	4,567	4,235				1,090	212	0.980			208	0.162	0.200	0.204	0.365
2	.013	.257	.283	39.88	45.55	33.03	33.03	.666	176	412	1.145	do.	4,673	4,776				1,251	223	.979			218	.141	.176	.174	.329
3	.013	.261	.277	39.98	45.60	33.02	33.02	.577	164	388	1.275	do.	4,343	4,306				824	207	.980			203	.199	.251	.246	.471
4	.012	.252	.276	39.90	45.54	33.02	33.02	.565	165	358	1.080	do.	4,415	4,351				1,061	211	.979			207	.156	.199	.196	.347
2-1	.012	.256	.279	35.95	41.55	23.02	23.02	.594	217	480	1.160	do.	4,827	4,204				1,326	246	.971			239	.164	.186	.180	.340
2	.012	.259	.283	35.82	41.52	23.03	23.03	.636	181	429	1.148	do.	4,484	4,352				1,248	240	.971			241	.145	.192	.193	.344
3	.012	.261	.275	35.90	41.53	23.02	23.02	.585	205	430	1.159	do.	4,375	4,271				1,191	241	.971			234	.172	.202	.196	.361
4	.013	.261	.277	35.94	41.55	23.03	23.03	.585	206	441	1.263	do.	4,347	4,241				1,364	239	.972			232	.150	.175	.170	.323
3-1	.011	.269	.281	28.83	34.53	19.03	19.03	.612	275	507	.940	do.	4,221	4,017				1,333	355	.980			342	.206	.257	.250	.380
2	.012	.249	.273	28.81	34.51	19.02	19.02	.613	304	496	1.030	do.	4,233	4,213				1,331	356	.957			350	.228	.278	.263	.373
3	.012	.244	.268	28.80	34.50	19.01	19.01	.607	290	498	1.069	do.	4,088	4,088				1,233	354	.958			339	.235	.287	.275	.399
4	.011	.252	.274	28.82	34.52	19.01	19.01	.614	275	494	.977	do.	4,173	4,252				1,198	365	.958			350	.230	.308	.292	.412
4-1	.014	.246	.274	23.83	29.53	16.01	16.01	.677	452	534	.636	do.	4,725	4,299				1,354	572	.938			535	.338	.422	.395	.421
2	.012	.251	.275	23.84	29.54	16.02	16.02	.641	423	603	.832	do.	4,452	4,573				1,360	571	.935			534	.311	.420	.393	.443
3	.013	.246	.272	23.84	29.54	16.02	16.02	.633	423	600	.880	do.	4,287	4,393				1,442	548	.938			514	.293	.380	.358	.418
4	.011	.251	.273	23.84	29.54	16.02	16.02	.632	406	652	.700	do.	4,402	4,263				1,454	548	.938			514	.277	.374	.351	.445
5-1	.013	.255	.281	20.82	26.53	14.03	14.03	.658	584	667	.650	do.	4,803	4,425				1,546	749		0.00291	0.880	678	.378	.485	.439	.445
2	.013	.249	.275	20.89	26.53	14.04	14.04	.663	553	528	.540	do.	4,821	4,260				1,292	732		.00284	.879	663	.408	.567	.513	.488
3	.011	.257	.279	20.80	26.46	14.00	14.00	.643	544	643	.595	do.	4,244	4,395				1,288	718		.00330	.852	629	.432	.571	.500	.511
4	.013	.251	.277	20.94	26.54	14.03	14.03	.642	528	548	.590	do.	4,649	4,367				1,621	758		.00294	.906	684	.326	.463	.422	.400
6-1	.013	.253	.279	18.95	24.52	12.02	12.02	.633	652	704	.640	do.	4,529	4,484				1,417	801		.00350	1.116	760	.446	.636	.535	.497
2	.013	.252	.278	18.87	24.52	12.02	12.02	.630	571	680	.700	do.	4,255	4,596				1,223	895		.00348	1.108	760	.467	.752	.621	.556
3	.013	.247	.273	18.95	24.53	12.02	12.02	.620	571	629	.605	do.	3,888	4,242				1,016	816		.00317	1.031	714	.563	.804	.703	.618
4	.014	.248	.276	18.90	24.52	12.02	12.02	.643	571	677	.620	do.	4,175	4,493				1,361	874		.00315	1.088	763	.420	.642	.561	.497
7-1	.013	.248	.274	16.87	22.50	11.02	11.02	.612	567	737	.372	do.	4,302	4,259				1,294	1,107		.00430	1.354	839	.515	.855	.648	.570
2	.013	.253	.279	16.88	22.50	11.01	11.01	.590	711	711	.340	do.	4,474	4,558				1,092	1,184		.00448	1.398	855	.661	1.057	.783	.661
3	.014	.250	.278	16.94	22.50	11.01	11.01	.606	667	743	.406	do.	4,582	4,564				1,348	1,145		.00415	1.296	886	.496	.861	.669	.552
4	.013	.253	.279	16.98	22.50	11.00	11.00	.621	711	748	.400	do.	4,700	4,122				1,440	1,100		.00427	1.359	844	.494	.764	.588	.519

[1] Computed according to formulas in Forest Products Laboratory Report 1525.

[2] Computed by application of modifications to formulas in Forest Products Laboratory Report 1525.

Z M 74137 F

Table 11.—Comparison between experimental and theoretical values of compressive strength of flat sandwich panels of 0.012-inch aluminum sheet and 1/4-inch cellular cellulose acetate (loaded edges simply supported; remaining edges clamped)

Panel No.	Dimensions: Thickness: Face f	Thickness: Core c	Thickness: Total h	Width: Free a	Width: Total a'	Height: Free b	Height: Total b'	Density: Wt.	Observed data: Panel data: Critical load $P_{cr\ obs.}$	Panel data: Maximum load P_m	Panel data: Lateral deflection at maximum load w_m	Panel data: Type of failure	Coupon data: Stiffness factors: Bending D_2	Bending D_1	$\left(\frac{E}{\lambda}\right)_1 12^I$	Shear μ_{12}^I	Compression strength P_{2m}	Computed data: Critical load[1] $P_{cr\ comp.}$	Shear reduction ratio $\frac{1}{1+\nu_2}$	Constants: N	Constants: $N \times 10^6$	Critical load reduced[2] $P_{cr\ re}$	Comparative ratios: $\frac{P_{cr\ obs.}}{P_{2m}}$	$\frac{P_{cr\ comp.}}{P_{2m}}$	$\frac{P_{cr\ re}}{P_{2m}}$	$\frac{P_m}{P_{2m}}$
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)	(18)	(19)	(20)	(21)	(22)	(23)	(24)	(25)	(26)	(27)
	Inch	Inch	Inch	Inches	Inches	Inches	Inches	Lb. per sq. ft.	Lb. per in. width	Lb. per in. width	Inches						Lb. per in. width	Lb. per in. width				Lb. per in. width				
1-1	0.012	0.247	0.271	39.82	45.57	33.00	33.00	0.563	167	322	0.690	Buckle	4,987	4,848			496	233	0.887			207	0.337	0.470	0.417	0.649
2	.013	.247	.273	39.82	45.57	33.04	33.04	.614	167	329	.932	do.	4,652	4,694			779	227	.890			202	.214	.291	.259	.422
3	.012	.248	.272	39.88	45.57	33.03	33.03	.578	140	319	.910	do.	4,638	4,651			723	224	.891			200	.194	.310	.277	.441
4	.013	.246	.272	39.86	45.57	32.44	32.44	.575	176	314	.925	do.	4,709	4,709			658	225	.889			200	.267	.342	.304	.477
2-1	.012	.249	.273	35.88	41.54	23.02	23.02	.595	212	408	.795	do.	4,697	4,841			814	267	.848			236	.260	.328	.275	.501
2	.012	.249	.273	35.84	41.53	23.01	23.01	.604	222	393	.723	do.	4,673	5,192			808	276	.843			233	.275	.342	.288	.486
3	.012	.246	.270	35.88	41.55	23.02	23.02	.588	212	362	.680	do.	4,532	4,866			793	263	.848			223	.267	.332	.281	.456
4	.013	.243	.269	35.98	41.55	23.02	23.02	.589	193	366	.750	do.	4,609	4,761			766	260	.849			221	.252	.339	.289	.478
3-1	.013	.244	.270	28.82	34.52	19.00	19.00	.595	348	431	.420	do.	4,587	4,960			772	413	.784			324	.451	.535	.420	.558
2	.013	.245	.271	28.85	34.53	19.02	19.02	.599	301	465	.425	do.	4,525	5,030			877	413	.784			324	.343	.471	.369	.530
3	.013	.248	.274	28.85	34.51	19.01	19.01	.599	301	483	.660	do.	4,590	5,129			847	420	.783			329	.355	.496	.388	.570
4	.013	.247	.273	28.85	34.51	19.01	19.01	.590	301	404	.595	do.	4,690	5,105			699	423	.782			331	.431	.605	.476	.578
4-1	.013	.243	.269	23.84	29.54	16.02	16.02	.588	379	602	.440	do.	4,525	5,068			875	607	.714			433	.433	.694	.495	.688
2	.013	.241	.267	23.84	29.54	16.00	16.00	.595	379	480	.340	do.	4,591	5,022			737	608	.712			433	.514	.825	.588	.651
3	.013	.238	.264	23.84	29.54	16.00	16.00	.600	406	461	.220	do.	4,443	5,086			852	603	.711			425	.477	.708	.504	.541
4	.013	.245	.271	23.85	29.55	16.00	16.00	.597	447	492	.289	do.	4,838	5,189			829	621	.710			441	.539	.749	.532	.593
5-1	.014	.250	.278	21.13	26.50	14.01	14.01	.609	503	503	.125	do.	4,817	4,834			875	777		0.00280	5.062	513	.575	.888	.586	.575
2	.013	.257	.283	21.20	26.52	14.00	14.00	.617	413	413	.017	Com-pression	5,164	4,895			666	789		.00307	5.081	522	.620	1.185	.784	.620
3	.014	.257	.285	20.80	26.50	14.00	14.00	.619	558	572	.230	Buckle	5,236	5,094			877	859		.00310	5.406	556	.636	.979	.634	.652
4	.013	.256	.282	20.86	26.52	14.00	14.00	.642	483	503	.190	do.	5,153	4,660			834	810		.00315	5.172	533	.579	.971	.639	.603
6-1	.013	.254	.280	18.88	24.53	12.01	12.01	.582	554	616	.290	do.	4,785	4,591			722	947		.00368	6.322	578	.767	1.312	.801	.853
2	.012	.253	.277	18.83	24.51	12.01	12.01	.587	571	577	.150	do.	4,860	4,174			788	917		.00386	6.180	566	.725	1.164	.718	.732
3	.013	.251	.277	18.87	24.51	12.02	12.02	.581	473	531	.142	do.	4,824	4,489			781	942		.00366	6.350	574	.606	1.206	.735	.680
4	.013	.251	.277	18.93	24.53	12.01	12.01	.586	522	574	.230	do.	4,609	4,489			722	914		.00355	6.177	563	.723	1.266	.780	.795
7-1	.013	.252	.278	16.52	22.00	11.00	11.00	.570	535	539	.100	Com-pression	4,765	4,523			587	1,224		.00476	7.968	681	.911	[3]2.085	1.160	.918
2	.013	.253	.279	16.52	22.05	10.98	10.98	.601	502	505	.025	do.	5,173	4,557			761	1,282		.00498	8.317	697	.660	[3]1.625	.916	.664
3	.013	.248	.274	16.62	22.04	10.98	10.98	.588	611	623	.110	do.	4,719	4,337			857	1,185		.00460	7.857	668	.713	1.383	.779	.727
4	.014	.249	.277	16.57	22.02	10.99	10.99	.580	618	618	.165	Buckle	4,772	4,798			883	1,253		.00452	6.195	690	.700	1.419	.761	.700

[1] Computed according to formulas in Forest Products Laboratory Report 1525.

[2] Computed by application of modifications to formulas in Forest Products Laboratory Report 1525.

[3] Values not plotted.

Table 12.--Comparison between experimental and theoretical values of compressive strength of flat sandwich panels of six-ply plywood (walnut and Douglas fir faces) (panel edges simply supported, remaining edges clamped)

Panel No.	Dimensions: Thickness: Face	Thickness: Core	Thickness: Total	Width: Free	Width: Total	Height: Free	Height: Total	Density	Observed data: Panel data: Critical load	Panel data: Maximum load	Panel data: Lateral deflection at maximum load	Panel data: Type of failure	Coupon data: Stiffness factors: Bending D_2	Bending D_1	$\frac{E_{90}}{E_{12}}$ I	Shear $\frac{G_{12}}{I}$	Compression strength	Computed data: Critical load	Shear reduction ratio	Constants: M	Constants: N x 10^5	Critical load residual	Comparative ratios: $\frac{P_{cr\ obs.}}{P_{2m}}$	$\frac{P_{cr\ comp.}}{P_{2m}}$	$\frac{P_{cr\ ft}}{P_{2m}}$	$\frac{P_m}{P_{2m}}$
	f	c	h	a	a'	b	b'	Wt.	$P_{cr\ obs}$	P_m	y_m		D_2	D_1			P_{2m}	$P_{cr\ comp.}$	$\frac{1}{1+\eta_2}$	M	N	$P_{cr\ ft}$	$\frac{P_{cr\ obs.}}{P_{2m}}$	$\frac{P_{cr\ comp.}}{P_{2m}}$	$\frac{P_{cr\ ft}}{P_{2m}}$	$\frac{P_m}{P_{2m}}$
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)	(18)	(19)	(20)	(21)	(22)	(23)	(24)	(25)	(26)	(27)
	Inch	Inch	Inch	Inches	Inches	Inches	Inches	Lb. per sq. ft.	Lb. per in. width	Lb. per in. width	Inches						Lb. per in. width	Lb. per in. width				Lb. per in. width				
2-1	0.016	0.243	0.279	36.90	42.66	25.96	25.96	0.441	86	229	1.242	Buckle	1,568	1,673	270	313	586	74	0.992			73	0.096	0.126	0.126	0.391
2	.020	.241	.281	36.85	42.54	25.96	25.96	.466	80	221	1.281	..do..	1,574	1,681	300	286	661	72	.992			71	.121	.109	.107	.334
3	.018	.246	.282	36.87	42.56	25.97	25.97	.416	78	241	1.335	..do..	1,576	1,630	276	321	682	74	.992			73	.110	.109	.107	.353
4	.016	.244	.280	36.80	42.48	25.96	25.95	.442	75	287	1.281	..do..	1,774	1,702	272	328	668	77	.991			76	.113	.116	.114	.431
2-1	.020	.243	.283	27.96	33.60	18.02	18.02	.440	119	293	.910	..do..	1,642	1,684	306	310	599	129	.988			127	.213	.231	.227	.524
2	.018	.244	.280	27.86	33.52	18.01	18.01	.411	125	314	.885	..do..	1,676	1,618	272	312	699	127	.985			125	.179	.182	.179	.449
3	.018	.246	.282	28.00	33.65	18.02	18.02	.429	107	324	.985	..do..	1,618	1,685	276	294	600	122	.986			120	.178	.203	.200	.557
4	.022	.238	.280	27.86	33.54	17.99	17.99	.437	119	282	.880	..do..	1,721	1,568	323	308	674	129	.986			127	.177	.191	.188	.416
3-1	.019	.242	.280	22.67	28.52	15.00	15.00	.428	154	307	.677	..do..	1,622	1,656	286	267	699	184	.979			180	.237	.307	.301	.613
2	.019	.244	.282	22.86	28.52	15.01	15.01	.441	147	321	.760	..do..	1,641	1,664	290	281	648	183	.979			179	.227	.292	.276	.495
3	.020	.242	.282	22.87	28.51	14.99	14.99	.426	147	327	.715	..do..	1,692	1,584	303	285	645	179	.979			176	.270	.326	.321	.500
4	.019	.243	.281	22.90	28.52	15.00	15.00	.446	147	336	.725	..do..	1,585	1,604	287	290	756	182	.979			178	.192	.236	.232	.441
4-1	.019	.246	.284	18.86	24.50	12.02	12.02	.463	212	410	.650	..do..	1,612	1,541	294	247	640	261	.970			253	.331	.498	.395	.641
2	.018	.246	.282	18.84	24.53	12.01	12.01	.461	204	340	.453	..do..	1,595	1,538	276	256	660	260	.970			252	.364	.464	.450	.607
3	.016	.247	.283	18.90	24.52	12.00	12.00	.474	220	422	.650	..do..	1,611	1,508	278	241	739	256	.970			248	.298	.346	.336	.571
4	.017	.249	.283	18.90	24.54	12.02	12.02	.468	228	440	.640	..do..	1,623	1,499	266	270	603	260	.970			252	.378	.431	.418	.730
5-1	.018	.247	.283	17.00	22.52	11.00	11.00	.418	240	446	.575	..do..	1,588	1,491	276	245	624	312	.964			302	.385	.602	.484	.715
2	.018	.244	.282	16.94	22.53	11.00	11.00	.413	242	384	.430	..do..	1,584	1,516	290	248	486	318	.964			307	.502	.641	.619	.774
3	.019	.245	.283	16.90	22.55	11.00	11.00	.442	256	371	.490	..do..	1,539	1,456	292	239	585	310	.964			299	.455	.530	.511	.634
4	.019	.244	.282	16.88	22.54	11.00	11.00	.435	248	371	.387	..do..	1,615	1,445	290	257	634	320	.964			308	.391	.505	.486	.586
6-1	.017	.249	.283	14.79	20.51	10.01	10.01	.486	322	470	.420	..do..	1,616	1,489	265	276	694	422	.954			403	.464	.608	.581	.677
2	.019	.248	.286	14.88	20.54	10.01	10.01	.487	302	498	.630	..do..	1,606	1,508	298	276	763	421	.954			402	.396	.552	.527	.583
3	.019	.243	.281	14.81	20.50	10.01	10.01	.456	346	539	.450	..do..	1,610	1,487	287	255	823	420	.954			401	.420	.510	.487	.653
4	.019	.244	.282	14.80	20.50	10.01	10.01	.454	332	540	.510	..do..	1,653	1,467	290	261	782	422	.954			403	.425	.540	.515	.691
7-1	.018	.245	.282	13.82	19.48	9.02	9.02	.448	400	567	.460	..do..	1,571	1,471	276	266	691	475	.947			460	.579	.687	.651	.821
2	.019	.245	.284	13.81	19.50	9.02	9.02	.464	354	385	.200	..do..	1,616	1,519	294	287	765	466	.946			450	.463	.635	.601	.603
3	.018	.248	.284	13.84	19.51	9.02	9.02	.456	359	599	.410	..do..	1,590	1,478	291	257	654	474	.947			449	.549	.725	.687	.855
4	.019	.245	.283	13.83	19.51	9.01	9.01	.459	369	586	.375	..do..	1,816	1,431	292	262	699	476	.947			461	.528	.681	.645	.810

[1] Computed according to formulas in Forest Products Laboratory Report 1525.

[2] Computed by application of modifications to formulas in Forest Products Laboratory Report 1525.

Table 13.—Comparison between experimental and theoretical values of compressive strength of flat sandwich panels of six-ply glass cloth laminate and 1/4-inch cellular cellulose acetate (Coated edges simply supported, remaining edges clamped)

Panel No.	Dimensions: Thickness: Face (f)	Thickness: Core (c)	Thickness: Total (h)	Width: Free (a)	Width: Total (a')	Height: Free (b)	Height: Total (b')	Density (Wt.)	Observed data: Panel data: Critical load (P_{cr} obs)	Panel data: Maximum load (P_m)	Panel data: Lateral deflection at maximum load (W_m)	Panel data: Type of failure	Coupon data: Stiffness factors: Bending (D_2)	Bending (D_1)	Shear ($\frac{E^c}{\mu^c}\frac{I}{12}$)	Shear ($\frac{E}{\mu}\frac{I}{12}$)	Compression strength (P_{2m})	Computed data: Critical load[1] (P_{cr} comp.)	Shear reduction ratio $\frac{1}{1+\eta_2}$	Constants: K	Constants: N x 10^6	Critical load reduced[2] (P_{cr} re)	Comparative ratios: $\frac{P_{cr\ obs.}}{P_{2m}}$	$\frac{P_{cr\ obs.}}{P_{2m}}$	$\frac{P_{cr\ re}}{P_{2m}}$	$\frac{P_m}{P_{2m}}$
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)	(18)	(19)	(20)	(21)	(22)	(23)	(24)	(25)	(26)	(27)
	Inch	Inch	Inch	Inches	Inches	Inches	Inches	Lb. per sq. ft.	Lb. per in. width	Lb. per in. width	Inches		Lb. per in. width				Lb. per in. width	Lb. per in. width				Lb. per in. width				
1-1	0.022	0.235	0.281	39.70	43.53	26.04	26.04	0.445	70	124	0.925	Buckle	1,614	1,614	338	275	375	62	0.962			60	0.187	0.165	0.160	0.331
2	.024	.235	.281	39.77	43.52	26.02	26.02	.448	79	172	1.160	...do...	1,562	1,562	350	273	402	60	.983			58	.197	.149	.144	.428
3	.022	.237	.281	39.79	43.52	26.02	26.02	.451	79	176	1.140	...do...	1,693	1,693	325	306	440	64	.961			62	.180	.145	.141	.405
4	.021	.234	.276	39.73	43.52	26.01	26.01	.448	75	180	1.180	...do...	1,582	1,582	301	297	420	61	.962			59	.179	.145	.140	.429
2-1	.021	.235	.277	22.80	28.50	15.00	18.00	.430	195	248	.585	...do...	1,467	1,598	303	244	538	174	.859			166	.364	.323	.289	.460
2	.022	.233	.277	22.82	28.49	15.01	16.01	.453	193	229	.435	...do...	1,608	1,600	316	256	510	178	.897			160	.378	.349	.314	.449
3	.021	.235	.277	22.86	28.50	15.01	15.01	.438	188	190	.280	...do...	1,516	1,598	303	259	459	177	.897			159	.386	.386	.346	.414
4	.023	.231	.277	22.86	28.47	15.01	15.01	.456	183	239	.560	...do...	1,922	1,585	327	249	464	177	.897			159	.394	.381	.343	.515
3-1	.024	.226	.274	16.85	22.50	11.00	11.00	.448	278	301	.420	...do...	1,843	1,683	331	255	460	337	.819			276	.600	.733	.600	.654
2	.025	.226	.276	16.83	22.52	10.98	10.98	.451	275	285	.317	...do...	1,482	1,670	348	252	545	333	.822			274	.606	.611	.503	.525
3	.024	.227	.275	16.85	22.50	11.00	11.00	.469	293	320	.312	...do...	1,598	1,736	334	254	688	346	.815			282	.426	.503	.410	.465
4	.025	.229	.278	16.84	22.51	11.00	11.00	.458	257	291	.340	...do...	1,646	1,738	347	254	540	343	.816			280	.494	.635	.519	.539
4-1	.023	.231	.277	13.64	19.50	9.00	9.00	.476	359	372	.130	...do...	1,556	1,797	327	246	601	511	.750			383	.597	.850	.637	.619
2	.021	.235	.277	13.76	19.50	9.00	9.00	.468	338	394	.320	...do...	1,504	1,848	303	248	500	515	.749			385	.676	1.030	.772	.788
3	.024	.228	.276	13.85	19.51	9.00	9.00	.479	329	403	.400	...do...	1,530	1,796	336	276	649	516	.748			386	.584	.796	.595	.621
4	.021	.231	.273	13.68	19.51	9.00	9.00	.473	338	449	.280	...do...	1,544	1,767	294	287	605	511	.747			382	.559	.845	.651	.742

[1] Computed according to formulas in Forest Products Laboratory Report 1525.

[2] Computed by application of modifications to formulas in Forest Products Laboratory Report 1525.

Z M 74140 F

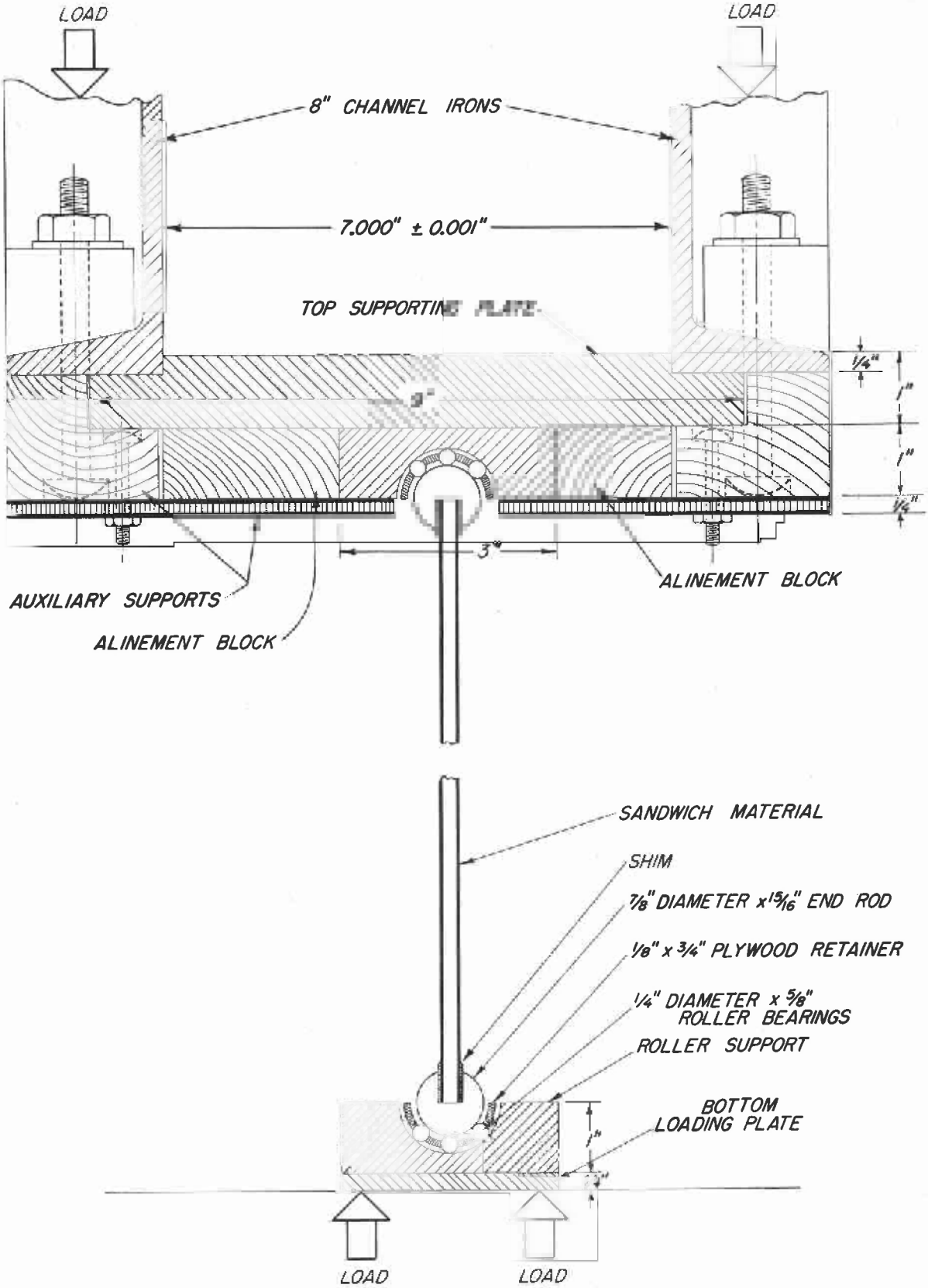


Figure 24.--Details of loading beams and apparatus by which simple support of the loaded edges of sandwich panels was attained.

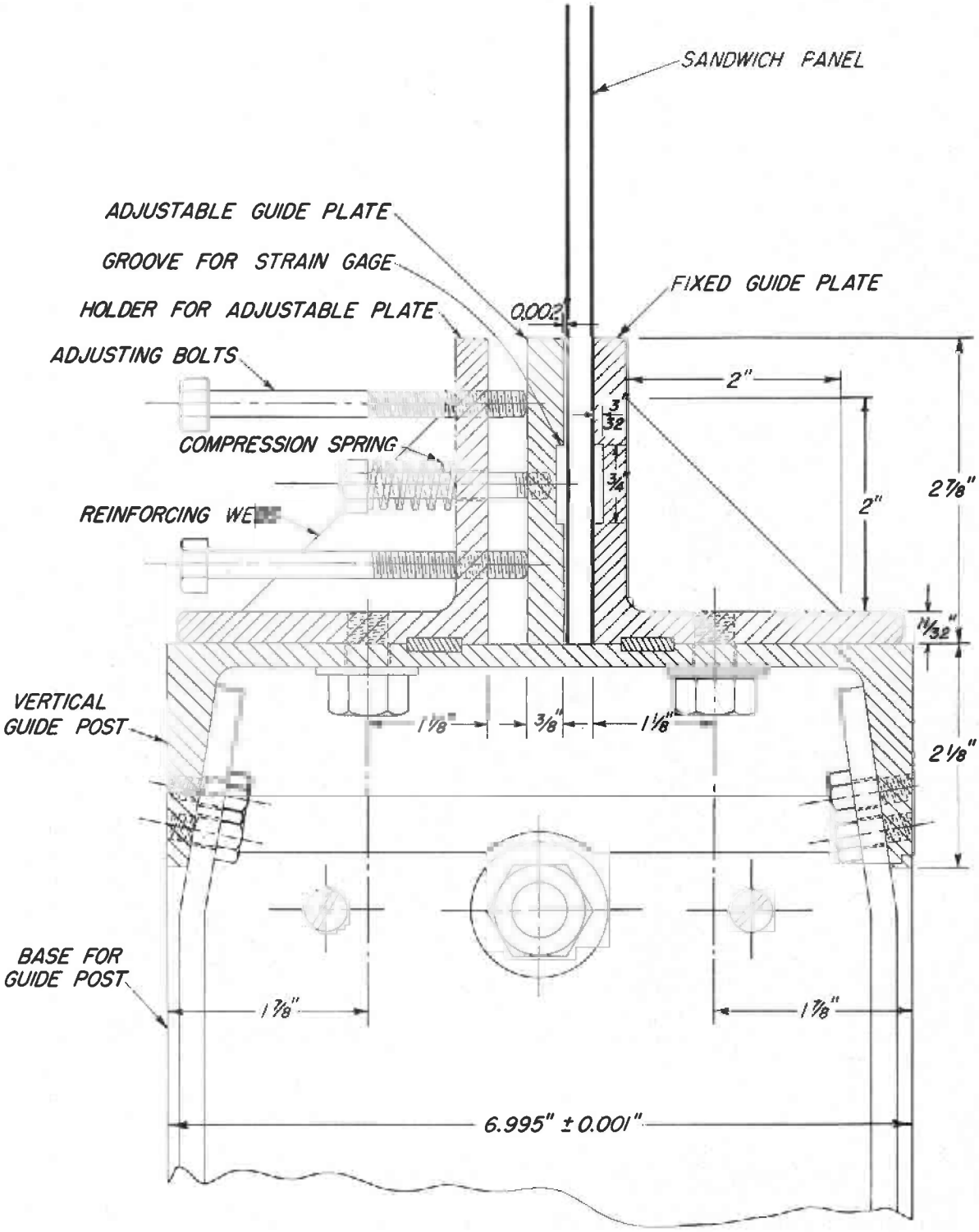


Figure 25.--Details of the fixtures that provided clamped support at the unloaded edges of sandwich panels.

2 M 74131

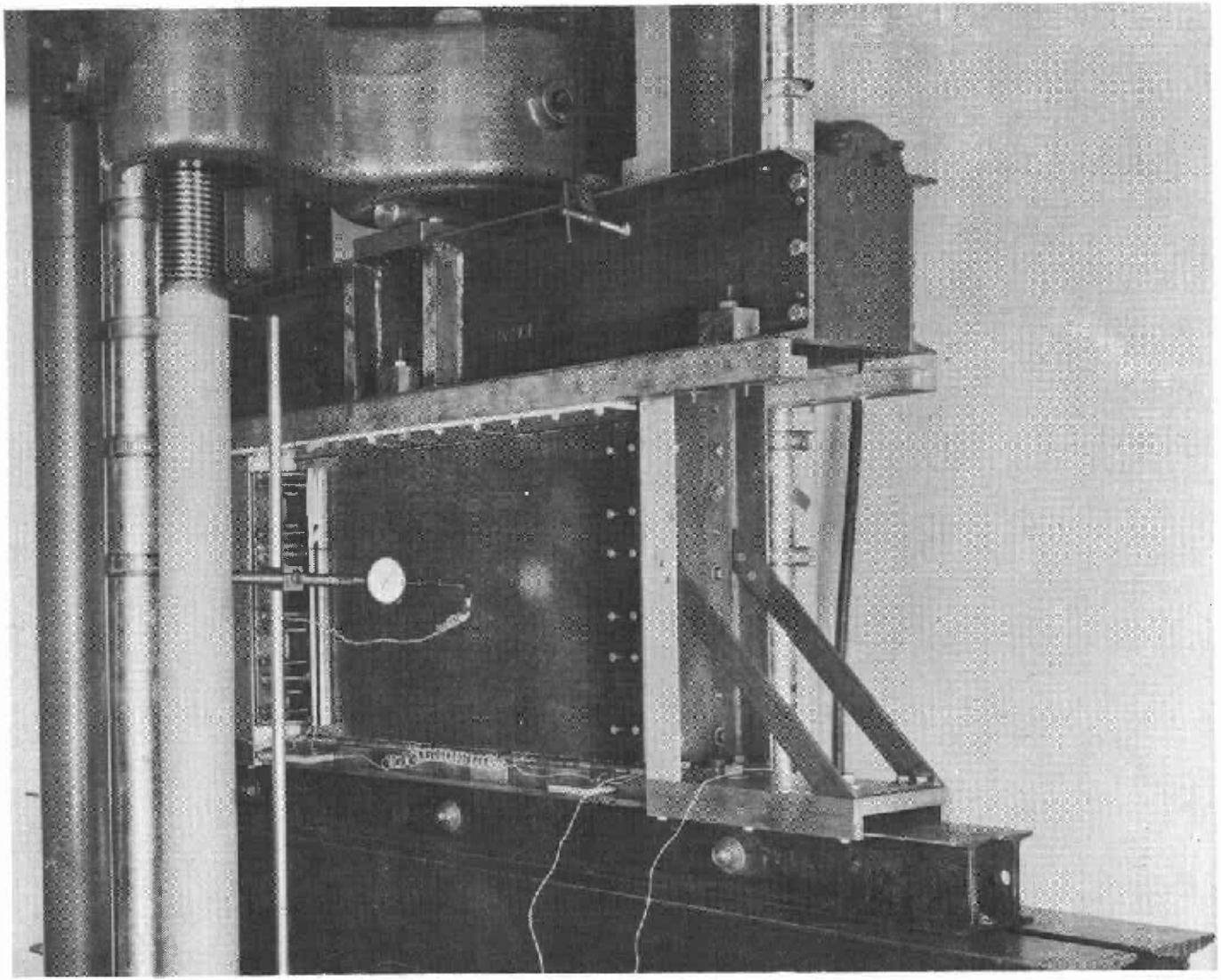


Figure 26.—Apparatus assembly for testing sandwich panels having loaded edges simply supported and the other edges clamped. (View of adjustable guide plates.)

Z X 74716)

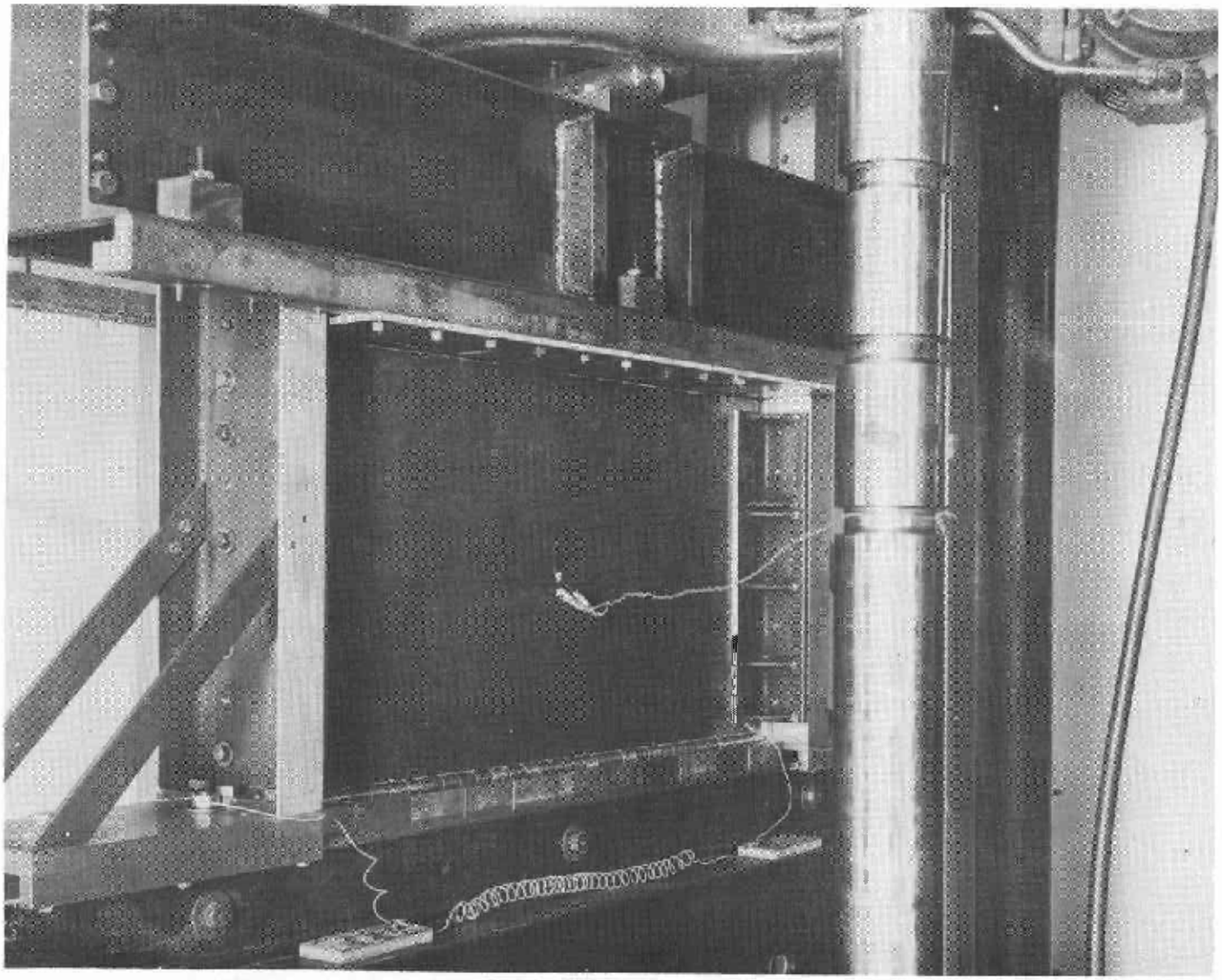


Figure 27.--Apparatus assembly for testing sandwich panels having loaded edges simply supported and the other edges clamped. (View of fixed guide plates.)

Z 74717 F

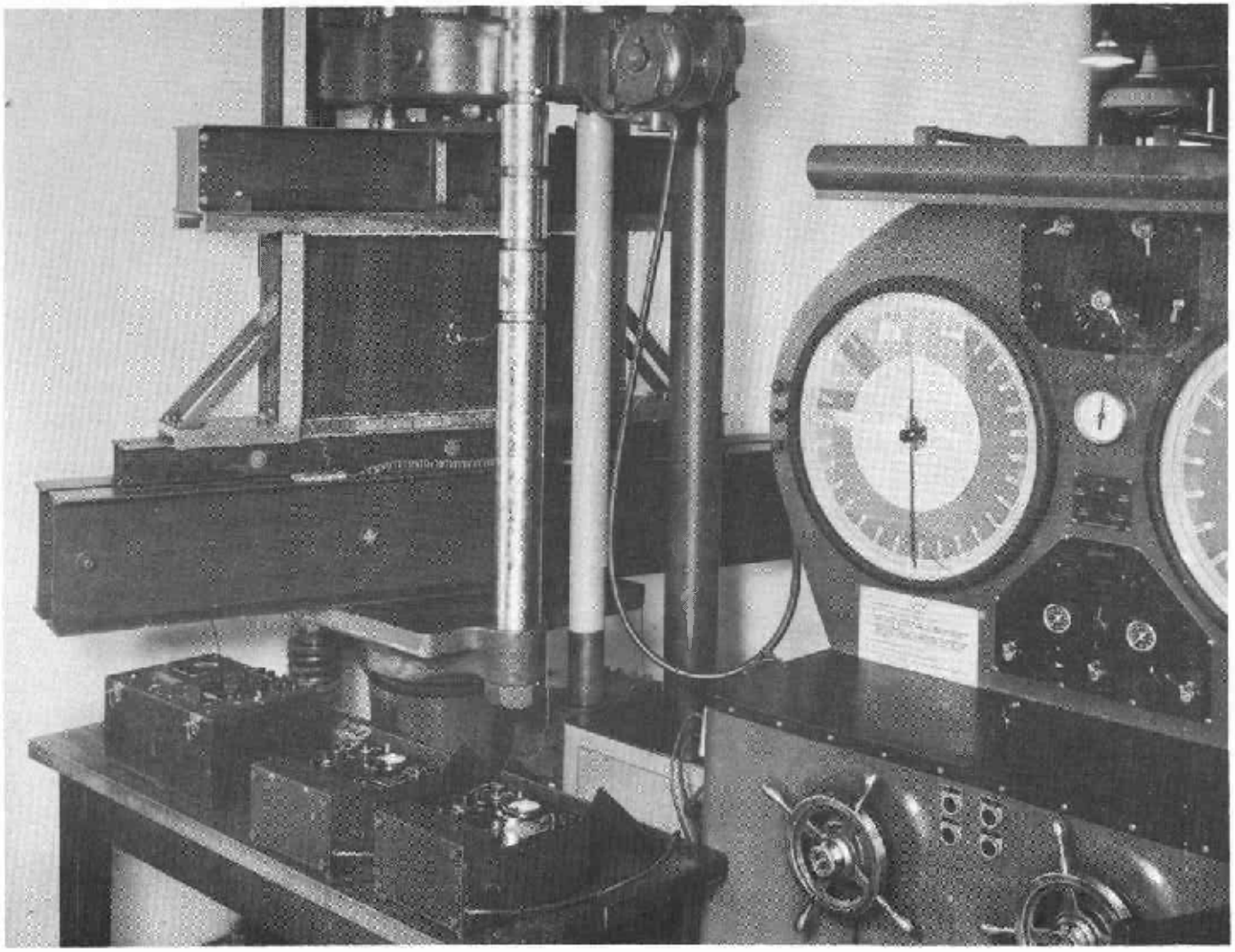


Figure 28.—Apparatus assembly for testing sandwich panels having loaded edges simply supported and the other edges clamped. (View of testing machine and SR-4 strain indicators.)

Z M 74718 F

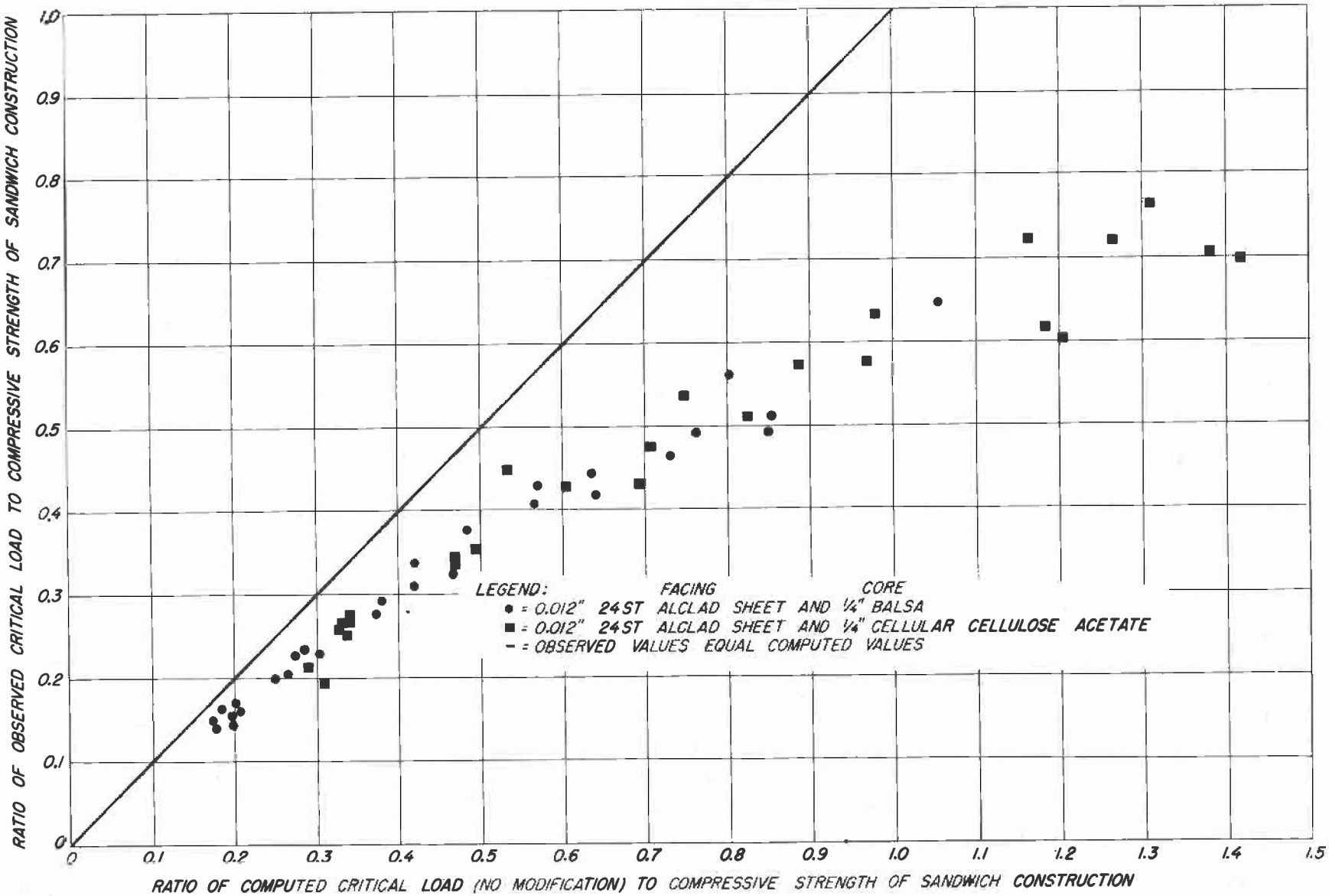


Figure 29.--Observed critical load plotted against the computed critical load (no modification); both expressed as ratios of the compressive strength of the sandwich construction. Critical buckling of panels faced with aluminum, simply supported on the loaded edges and clamped on the remaining edges.

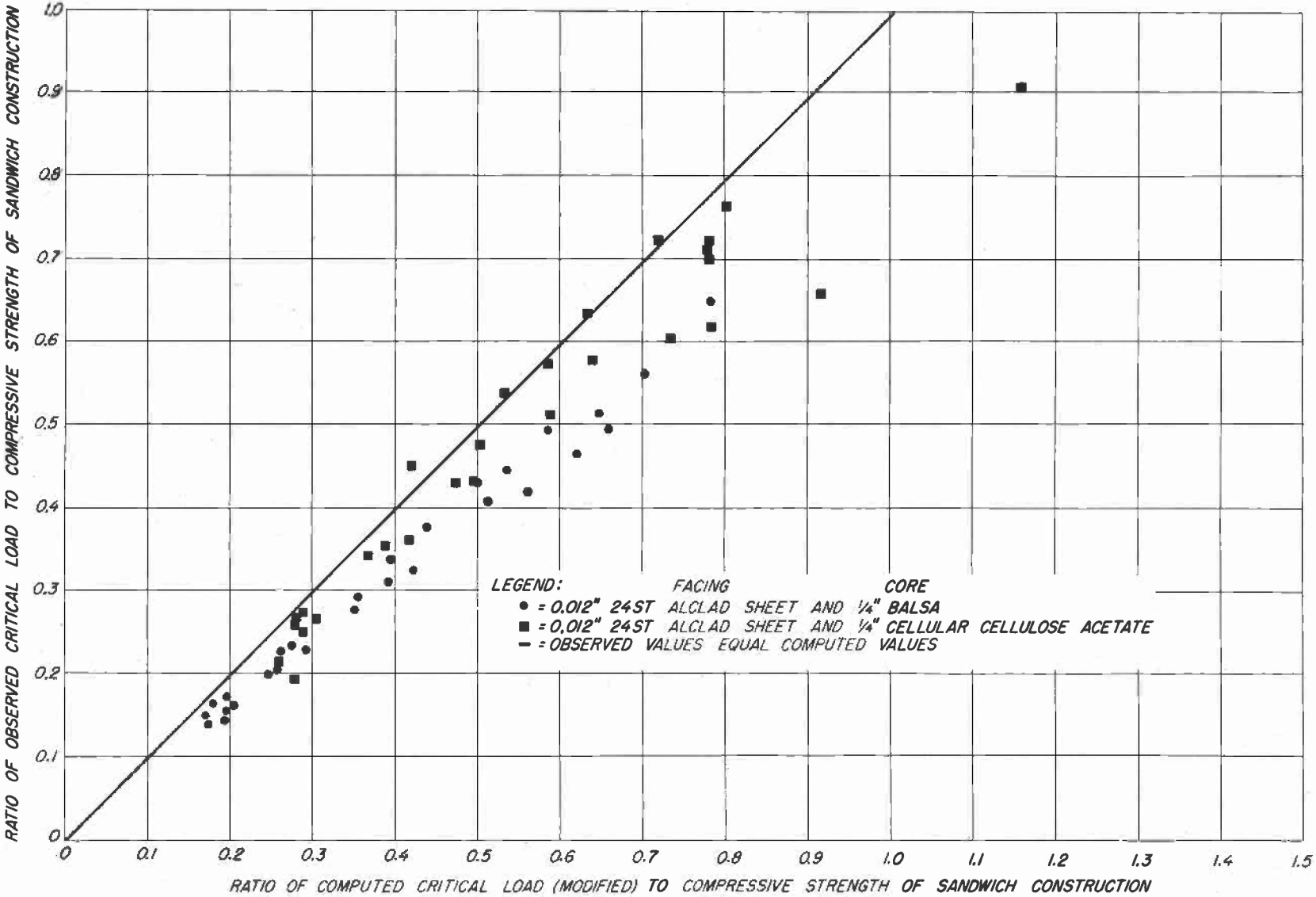


Figure 30.--Observed critical load plotted against the computed critical load (modified for reduced modulus and shear); both expressed as ratios of the compressive strength of the sandwich construction. Critical buckling of panels faced with aluminum, simply supported on the loaded edges and clamped on the remaining edges.

2 M 74134 F

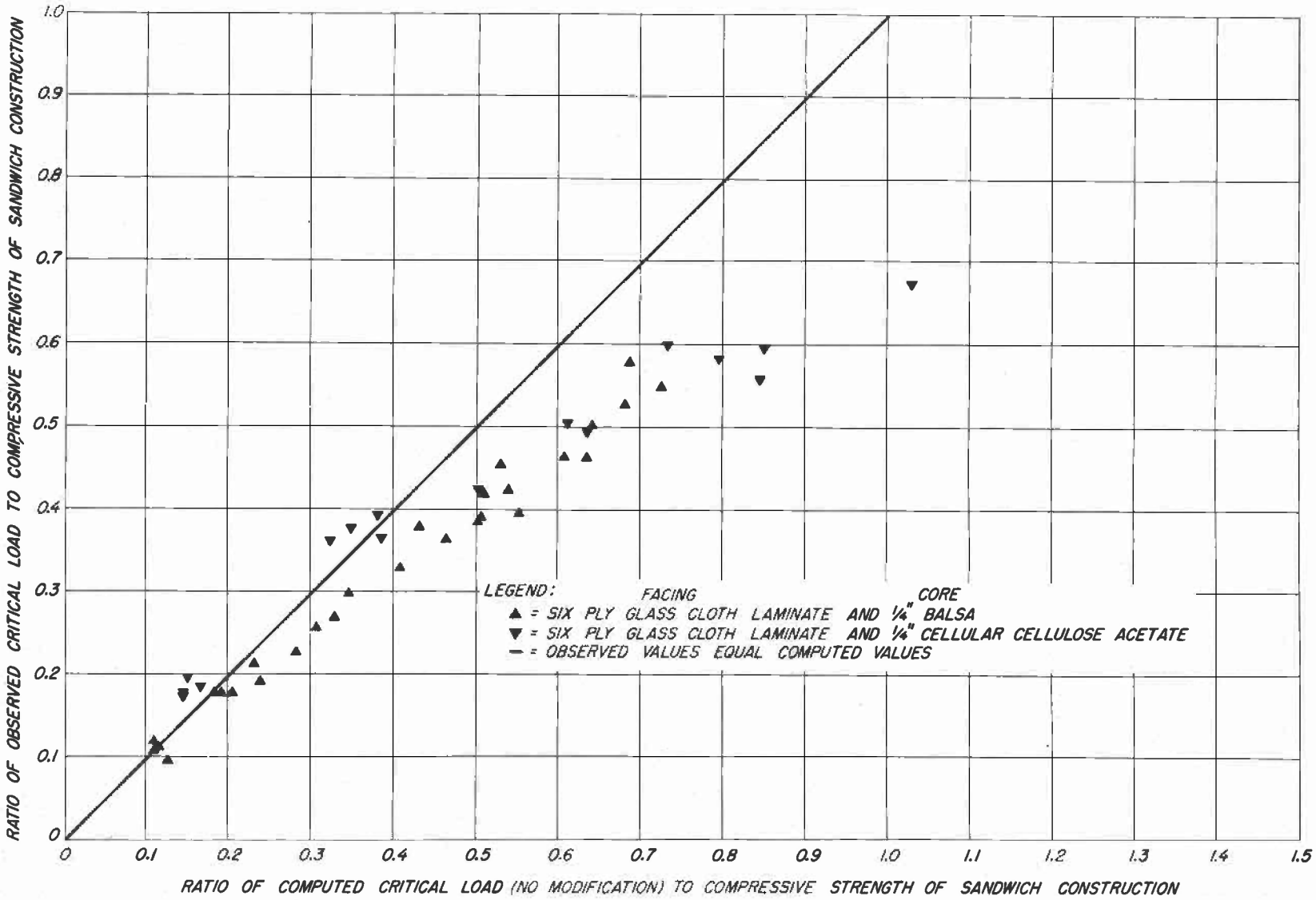


Figure 31.--Observed critical load plotted against the computed critical load (no modification); both expressed as ratios of the compressive strength of the sandwich construction. Critical buckling of panels faced with glass cloth laminate, simply supported on the loaded edges and clamped on the remaining edges.

2 M 74135 F

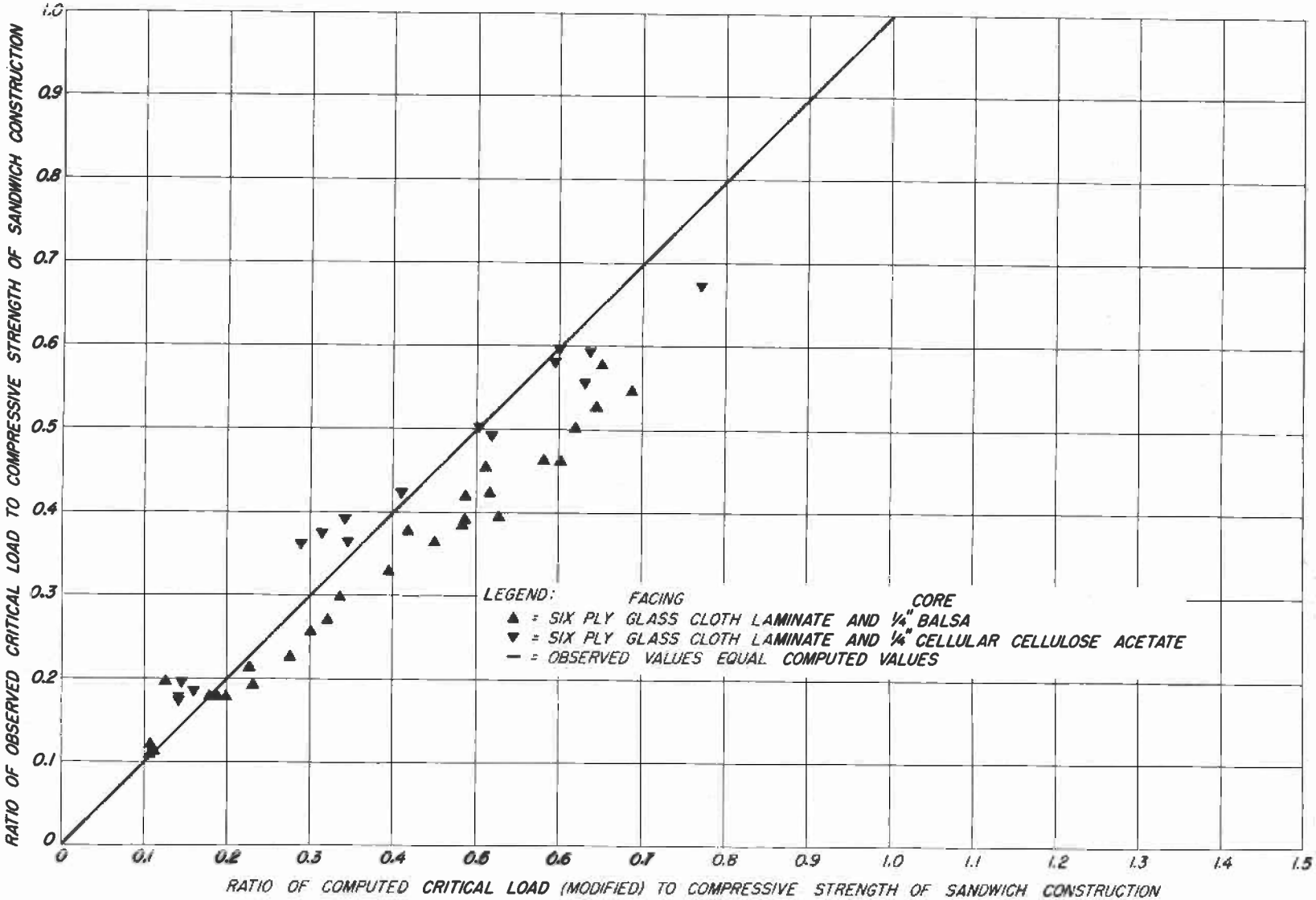


Figure 32.--Observed critical load plotted against the computed critical load (modified for shear); both expressed as ratios of the compressive strength of the sandwich construction. Critical buckling of panels faced with glass cloth laminate, simply supported on the loaded edges and clamped on the remaining edges.

Z M 74136 F

FPL FILING SYSTEM DESIGNATION--S-5-4

Boller, Kenneth Harold
Buckling loads of flat sandwich panels in compression. Buckling of flat sandwich panels with loaded edges simply supported and the remaining edges clamped. (Cores of end-grain balsa or cellular cellulose acetate and faces of aluminum or glass cloth laminate) 2d ed. Madison, U. S. Forest Products Laboratory, 1962.
13 p., illus. (F.P.L. rpt. no. 1525-B)

Experimental data are presented to confirm the theories presented in Forest Products Laboratory Report No. 1525.

Boller, Kenneth Harold
Buckling loads of flat sandwich panels in compression. Buckling of flat sandwich panels with loaded edges simply supported and the remaining edges clamped. (Cores of end-grain balsa or cellular cellulose acetate and faces of aluminum or glass cloth laminate) 2d ed. Madison, U. S. Forest Products Laboratory, 1962.
13 p., illus. (F.P.L. rpt. no. 1525-B)

Experimental data are presented to confirm the theories presented in Forest Products Laboratory Report No. 1525.

Boller, Kenneth Harold
Buckling loads of flat sandwich panels in compression. Buckling of flat sandwich panels with loaded edges simply supported and the remaining edges clamped. (Cores of end-grain balsa or cellular cellulose acetate and faces of aluminum or glass cloth laminate) 2d ed. Madison, U. S. Forest Products Laboratory, 1962.
13 p., illus. (F.P.L. rpt. no. 1525-B)

Experimental data are presented to confirm the theories presented in Forest Products Laboratory Report No. 1525.

Boller, Kenneth Harold
Buckling loads of flat sandwich panels in compression. Buckling of flat sandwich panels with loaded edges simply supported and the remaining edges clamped. (Cores of end-grain balsa or cellular cellulose acetate and faces of aluminum or glass cloth laminate) 2d ed. Madison, U. S. Forest Products Laboratory, 1962.
13 p., illus. (F.P.L. rpt. no. 1525-B)

Experimental data are presented to confirm the theories presented in Forest Products Laboratory Report No. 1525.