Supplement to

COMPRESSION, TENSION, AND SHEAR TESTS ON YELLOWPOPLAR PLYWOOD PANELS OF SIZES THAT DO NOT BUCKLE WITH TESTS MADE AT VARIOUS ANGLES TO THE FACE GRAIN

COMPRESSION TESTS

November 1943

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Note: There will be four reports in this series to be published in the following order:

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COMPRESSION TESTS[1]

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Summary

This report presents the results of 575 compression tests on yellow-poplar plywood, wherein the angle between the face grain and the applied stress varied from 0° to 90°, in 15° increments. Two thicknesses of veneer, 1/16 and 1/32 inch, were used in making the plywood. The 1/16-inch veneer was made into plywood of three, five and seven plies. The 1/32-inch veneer was made into plywood of five, seven, and nine plies. A plywood construction such that all plies were the same thickness, with the grain of adjacent plies at right angles, was used in all tests. Specimens were made with heights of 1-3/8 to 2-5/8 inches and widths of 2 to 6 inches. The height-thickness ratio was between six to one and seven to one.

A preliminary series of 190 tests to determine the effects of the width of the specimen on the compressive strength is also reported.

Introduction

In many of the structural uses of plywood, particularly in aircraft, compressive stresses are applied at an angle to the direction of the face grain of the material. In designing for these uses a knowledge of the ultimate compressive strength, the stress at the proportional limit, and the modulus of elasticity of plywood at such angles is required by the designer. The purpose of these tests was to secure this information. It is believed that the data presented will be useful in estimating the strength and modulus of elasticity of wide plywood panels providing that buckling is prevented. In addition to these data, information is being obtained, and will be discussed in a later report, on the shear and tensile strengths of specimens matched with those used in these compression tests.

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[1] This mimeograph is one of a series of progress reports prepared by the Forest Products Laboratory to further the Nation's war effort. Results here reported are preliminary and may be revised as additional data become available.

Description of Material

The veneers used in the major series of tests (tables 2 to 7) were rotary cut from a single yellowpoplar log and were selected from a restricted region in that log. Thus the strength properties of each sheet of veneer were as closely matched to those of the other sheets as was possible. These veneers were cut in two thicknesses, 1/16 and 1/32 inch. The veneers used in the preliminary series of tests (table 1) were cut 1/8 inch thick from another yellowpoplar log and a yellow birch log.

The plywood was fabricated from these veneers by the hot press method, using Tego glue film. Each panel was made of veneers of a single thickness and species. The 1/16- and 1/8-inch veneers were made into 24- by 24-inch panels of three, five, and seven plies, and the 1/32-inch veneers into panels of five, seven, and nine plies.

The compression specimens for the initial study of the effect of width were obtained from the panels made of the 1/8-inch veneers and were all cut at an angle of 45° to the direction of the face grain. Each panel yielded a number of specimens cut to heights of 2, 3, or 4 inches and widths which ranged from 1 to 8 inches, inclusive, in 1-inch increments. The specimens were cut sufficiently short to avoid column failure. All of the specimens of the same construction were cut from the same panel.

The panels for the main series of tests made of the 1/16-inch veneers and those made of the 1/32-inch veneers were each divided into three groups according to number of plies. Each of these groups was subdivided into seven smaller sub groups designated A to G, inclusive.

All specimens of sub group A were cut with the face grain parallel to the sides (and load axis). Specimens of sub group B had face grain at 15° to the sides, C at 30°, D at 45°, E at 60°, F at 75° and G at 90°.

Three specimens of widths 2, 4, and 6 inches were cut from each panel.

The specimen number is a key to its classification; for example, the numbering of specimen 5-E-2-3 indicates:

Number of plies	5
Sub group	E (face grain is 60° to load axis)
Width, inches	2
Panel number	3 in sub group E

No distinction was made for veneer thickness. Hence one panel made of 1/16-inch veneer and another of 1/32-inch veneer bore the above number.

The heights of the specimens (dimensions parallel to load axis) were such that the height-thickness ratio was between 7 to 1 and 6 to 1. Excessively short specimens were avoided in five-ply 1/32-inch veneer pieces by gluing two panels together formingpanels with the grain of the two central plies parallel.

Only a part of each panel was cut into compression specimens. The remainder of the panel was retained to furnish matched tension and shear specimens.

Method of Testing

All specimens in the preliminary and major programs were tested in a manner similar to the standard Laboratory method using a hydraulic testing machine.

According to the standard methods for compression tests in solid wood (U. S. Department of Agriculture Technical Bulletin 479), the rate of compressive strain is 0.003 inch per inch per minute. In testing plywood specimens in compression at an angle to the face grain direction, it was necessary to deviate slightly from the standard rate in order to obtain a sufficient number of readings below the proportional limit.

On the three-, five-, and seven-ply specimens made of 1/16-inch veneer, strains were applied at the rates of 0.007, 0.004, and 0.002 inch per inch per minute, respectively. For the five-, seven-, and nin-ply specimens made of 1/32-inch veneer, strains were applied at the rates of 0.006, 0.004, and 0.003 inch per inch per minute, respectively.

A Martens Mirror compressometer with a 1-inch gage length was attached to the specimen to measure its deformation. Figure 1 illustrates a specimen under test with the compressometer attached.

The testing procedure was as follows: Immediately prior to test, the compressometer was attached to the specimen and centered horizontally and vertically. The specimen was then placed in the machine and centered under the loading head. Rate of strain in inches per inch per minute and increments of load to be used were determined prior to test. An initial load, equal to one-half of the load increment to be used was applied to the specimen, and initial load and deformation readings taken. Load was then applied at a constant rate of deformation until maximum load was reached. Deformations were recorded for each increment of load, from the initial to the maximum.

Tables and Charts

Table 1 presents the summarized results of the preliminary series of compression tests on yellow-birch and yellowpoplar plywood at 45° to face grain.

In this table, columns 1 and 7 show the number of specimens tested in the various width classifications. The various widths are shown in columns 2 and 8. The values of ultimate compressive stress and ultimate compressive load in columns 4, 5, 10, and 11 are the average values for the tests in each width classification. The maximum deviations of individual specimens from the average maximum crushing strength are shown in columns 6 and 12.

Values of moisture content for each group of tests, columns 3 and 9, are the average values of all the specimens within that particular group. The moisture content is expressed as a percentage of the weight of the oven-dry plywood.

Tables 2 to 7, inclusive, present the results obtained from individual tests of the major series. In these tables, columns 1, 7, and 13 identify individual specimens. Fiber stress at proportional limit, maximum crushing strength, and modulus of elasticity are shown in columns 2, 3, 4; 8, 9, 10; and 14, 15, 16 respectively.

Moisture content, columns 5, 11, and 17, is expressed as a percentage of the oven-dry weight of the plywood.

Specific gravities, columns 6, 12, and 18, are based on volume of the plywood at the time of test.

Average values of fiber stress at proportional limit, maximum crushing strength, and modulus of elasticity are shown in columns 19, 20, and 21, respectively. These values, based on test data, were computed by the method of least squares.

Column 22 presents values for rate of strain in inches per inch per minute used in testing.

Figures 2 and 3 present curves from data obtained in the preliminary series of compression tests on yellow birch and yellowpoplar plywood, made up of three-, five-, and seven-ply veneer, 1/8 inch thick. The curves show the relation of width of specimen to ultimate load. The values for plotted curves are from table 1.

Figures 4 and 5 contain graphs that illustrate how the variation of the angle between face grain and the applied stress affects the mechanical properties under discussion.

Average values for plotting the curves in figures 4 and 5 are found in columns 14, 15, 16, 19, 20, and 21, tables 2 to 7 inclusive.

Analysis of Results

From figures 2 and 3 it is evident that the ultimate load is not directly proportional to the specimen width. A straight line relationship does exist, however, for widths greater than 2 inches. Evidently the material near the sides of the specimen carries less than an average stress.

If wide panels are used in design, the slopes of the straight portions of these curves give the ultimate compressive loads per inch of width with sufficient accuracy.

The straight lines of figures 2 and 3 were drawn to best fit the points plotted for each thickness of plywood. The slopes of these lines represent the ultimate loads per inch of width for the various plywood thicknesses.

The selection of the various widths of specimens to be tested in the major series of tests was based on the results of the preliminary series. As evidenced by the results of the preliminary series, a straight line relationship between load and width occurs for any width of panel greater than 2 inches, provided that buckling does not occur. Since the designer is most concerned with plywood in relatively wide panels, it becomes necessary to determine the strength-width ratio for the plywood of given type and thickness. This determination was made for each type of plywood tested in the major program by applying the method of least squares to the individual test values.

In the preliminary series of tests, consideration was given only to maximum stresses, and straight line determinations made for those stresses. In addition to maximum stresses in the major series, however, moduli of elasticity and stress at proportional limit were also considered, and the slopes were similarly determined by the method of least squares. It seems reasonable to assume that the slopes for all three mechanical properties can be computed on the same basis.

It is evident from figures 4 and 5 that the average stress values, as computed by the method of least squares, agree reasonably well with those obtained from specimens 6 inches wide. An approximate straight line relationship exists between the maximum crushing strength and the inclination of the face grain, but such relationship does not hold for the other properties.

Conclusions

The crushing strengths of wide plywood panels of the types tested, not subject to buckling, may be estimated from the average maximum crushing strength values given in column 20 of tables 2 through 7 in connection with the values of moisture content at test as given in the same tables.

Tentatively, for plywood made of equal thicknesses of plies of other species it appears reasonably safe to assume that the maximum crushing strength varies linearly from a minimum when the face grain is inclined 90° from the applied stress to a maximum when the face grain is parallel to the applied stress.

Table 1.--Results of compression tests on plywood at 45° to face grain (plywood made of 1/8-inch veneer).

Yellow birch						Yellowpoplar					
Number of specimens tested	Width of specimens	Average moisture content at test	Average ultimate compressive stress[1]	Average ultimate compressive load[1]	Maximum deviation from the mean ultimate compressive stress[2]	Number of specimens tested	Width of specimens	Average moisture content at test	Average ultimate compressive stress[1]	Average ultimate compressive load[1]	Maximum deviation from the mean ultimate compressive stress[2]
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
	In.	Percent	Lb. per sq. in.	Lb.	Percent		In.	Percent	Lb. per sq. in.	Lb.	Percent
3-ply--nominal height 2 inches						3-ply--nominal height 2 inches					
7	1	8.8	3,920	1,360	5.9	7	1	8.4	2,190	795	8.9
7	2	8.6	4,040	2,730	9.0	7	2	8.9	2,260	1,640	8.4
7	3	7.2	3,670	3,820	7.3	7	3	8.6	2,560	2,780	4.4
7	4	7.9	4,050	5,660	5.9	6	4	7.7	2,660	3,850	11.0
7	5	8.1	4,080	7,160	4.7	6	5	7.6	2,770	5,020	5.6
6	6	8.7	4,730	9,940	4.6	6	6	8.4	3,100	6,790	8.6
6	8	7.8	4,310	12,060	3.9	6	8	8.9	2,970	8,600	4.3
5-ply--nominal height 3 inches						5-ply--nominal height 3 inches					
5	1	8.9	3,260	1,890	16.8	5	1	8.1	1,820	1,090	11.0
5	2	8.4	4,040	4,680	2.0	5	2	7.7	2,300	2,750	9.8
6	3	8.2	4,170	7,250	3.2	5	3	8.1	2,470	4,390	12.2
5	4	8.3	4,300	10,000	1.2	4	4	7.8	2,660	6,360	10.4
6	6	7.6	4,280	14,960	3.4	5	6	7.4	2,710	9,780	8.1
5	8	8.8	4,380	20,300	2.3	5	8	8.2	2,850	13,600	2.5
7-ply--nominal height 4 inches						7-ply--nominal height 4 inches					
4	1	8.7	4,120	3,340	1.3	4	1	8.4	2,165	1,800	5.4
4	2	8.2	4,210	6,810	2.9	4	2	7.7	2,080	3,480	6.1
5	4	7.9	4,320	14,070	1.1	5	4	7.8	2,330	7,780	5.9
5	6	7.0	4,280	20,950	1.5	5	6	6.8	2,450	12,280	3.4
4	8	6.9	4,700	30,050	2.8	4	8	7.0	2,675	17,800	3.8

[1] Values adjusted to 8 percent moisture content using the factors for maximum crushing strength of wood as given in table 2-2 ANC Handbook (1942) on the Design of Wood Aircraft Structures.

[2] Deviation of individual value (before moisture adjustment) from average.

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Table 2.--Results of compression tests on three-ply yellowpoplar plywood (plywood was made up of 1/16-inch veneer; nominal height of specimens was 1-3/8 inches).

Specimen number	Fiber stress at proportional limit	Maximum crushing strength	Modulus of elasticity	Moisture content	Specific gravity	Specimen number	Fiber stress at proportional limit	Maximum crushing strength	Modulus of elasticity	Moisture content	Specific gravity	Specimen number	Fiber stress at proportional limit	Maximum crushing strength	Modulus of elasticity	Moisture content	Specific gravity	Average fiber stress at proportional limit[2]	Average maximum crushing strength[2]	Average modulus of elasticity[2]	Rate of strain
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)	(18)	(19)	(20)	(21)	(22)
	Lb. per sq. in.	Lb. per sq. in.	1,000 lb. per sq. in.	Percent			Lb. per sq. in.	Lb. per sq. in.	1,000 lb. per sq. in.	Percent			Lb. per sq. in.	Lb. per sq. in.	1,000 lb. per sq. in.	Percent		Lb. per sq. in.	Lb. per sq. in.	1,000 lb. per sq. in.	In. per in. per minute
Specimens 2 inches wide						Specimens 4 inches wide						Specimens 6 inches wide									
θ[1] = 0°						θ = 0°						θ = 0°									
3-A-2-1	2,330	5,270	1,522	9.8	0.456	3-A-4-1	4,720	5,660	1,349	Not determined		3-A-6-1		5,160	1,058	8.4	0.470				
2	4,110	5,100	1,407	9.6	.458	2	4,920	5,620	1,516	do.		2		5,260	1,114	8.7	.474				
3	3,880	5,420	1,411	9.9	.471	3	4,170	5,160	1,322	do.		3	4,760	5,460	1,238	8.9	.481				
4	3,100	4,710	1,292	9.5	.442	4		4,630	936	do.		4	4,030	4,760	1,128	8.8	.439				
Average..	3,355	5,125	1,408	9.7	.457	Average..	4,603	5,268	1,281			Average..	4,395	5,160	1,134	8.7	.466	5,027	5,178	998	0.004
θ = 15°						θ = 15°						θ = 15°									
3-B-2-1	2,620	4,380	837	9.9	.455	3-B-4-1	3,430	4,740	763	do.		3-B-6-1	2,000	4,720	786	8.7	.467				
2	2,840	4,660	860	10.1	.448	2	3,920	5,400	876	do.		2	3,240	4,650	669	8.8	.452				
3	3,170	4,600	820	9.8	.448	3	2,610	4,560	815	do.		3	3,480	4,520	590	9.0	.458				
4	2,520	4,360	876	9.5	.440	4	3,090	4,470	770	do.		4	3,350	4,490	713	9.0	.452				
Average..	2,788	4,500	848	9.8	.448	Average..	3,262	4,792	806			Average..	3,018	4,595	690	8.9	.457	3,132	4,642	610	.004
θ = 30°						θ = 30°						θ = 30°									
3-C-2-1	1,800	3,350	418	9.8	.442	3-C-4-1	1,530	3,540	459	do.		3-C-6-1	1,840	3,570	404	7.9	.453				
2	1,550	3,160	375	9.9	.442	2	1,580	3,680	476	do.		2	1,980	3,620	452	7.9	.452				
3	1,250	3,200	380	9.8	.417	3	2,160	3,540	422	9.7	0.427	3	1,980	3,460	390	7.8	.410				
4	1,360	3,400	417	9.9	.435	4	1,990	3,500	447	9.4	.435	4	1,840	3,580	479	8.5	.441				
Average..	1,490	3,278	398	9.8	.434	Average..	1,815	3,565	451	9.6	.431	Average..	1,910	3,558	431	8.0	.439	2,120	3,698	448	.004
θ = 45°						θ = 45°						θ = 45°									
3-D-2-1	1,100	2,520	259	9.7	.447	3-D-4-1	1,660	2,740	313	9.9	.440	3-D-6-1	1,550	2,770	418	9.8	.434				
2	1,400	2,620	251	10.0	.450	2	1,590	2,980	279	9.5	.470	2	1,430	3,010	474	9.7	.467				
3	1,430	2,740	236	9.8	.487	3	1,670	2,800	299	9.7	.479	3	1,520	2,940	442	9.5	.476				
4	1,540	2,860	202	9.7	.450	4		3,190	320	9.3	.464	4	1,560	3,230	542	8.7	.467				
Average..	1,368	2,685	257	9.8	.458	Average..	1,640	2,928	303	9.6	.465	Average..	1,515	2,988	469	9.4	.461	1,589	3,139	575	.007
θ = 60°						θ = 60°						θ = 60°									
3-E-2-1	1,580	2,790	343	8.9	.493	3-E-4-1	1,960	3,030	356	9.4	.486	3-E-6-1	1,490	2,870	528	9.6	.476				
2	1,340	2,400	301	9.6	.439	2	1,610	2,640	351	9.3	.451	2	1,390	2,710	499	9.6	.437				
3	1,530	2,530	336	9.5	.436	3	1,780	2,550	356	9.2	.449	3	1,080	2,620	542	9.8	.445				
4	1,220	2,390	295	9.6	.469	4	2,020	2,700	374	9.1	.428	4	1,390	2,700	520	9.7	.433				
Average..	1,418	2,528	319	9.4	.459	Average..	1,842	2,730	359	9.2	.454	Average..	1,338	2,725	522	9.7	.448	1,298	2,824	624	.007
θ = 75°						θ = 75°						θ = 75°									
3-F-2-1	1,870	2,650	639	9.7	.459	3-F-4-1	1,880	2,810	633	9.1	.458	3-F-6-1	1,300	2,760	939	8.8	.470				
2	1,320	2,430	664	10.0	.468	2	1,730	2,420	506	9.4	.472	2	1,200	2,530	906	9.0	.460				
3	1,340	2,480	560			3	1,820	2,530	484	9.4	.461	3	1,300	2,630	606	8.6	.459				
4	1,510	2,490	480			4	2,240	2,790	534	9.0	.465	4	1,050	2,320	774	8.8	.456				
Average..	1,510	2,512	586	9.8	.464	Average..	1,918	2,638	539	9.2	.464	Average..	1,212	2,560	806	8.8	.461	1,064	2,584	916	.007
θ = 90°						θ = 90°						θ = 90°									
3-G-2-1	2,220	2,770	676	9.6	.451	3-G-4-1		2,460	794	9.7	.452	3-G-6-1	1,400		839	9.1	.467				
2	1,310	2,370	538	9.8	.432	2		2,490	794	9.4	.449	2	1,150	2,040	874	9.4	.452				
3	1,380	2,290	725	9.8	.428	3	1,800	2,200	539	9.4	.418	3	1,060	1,980	782	9.2	.435				
4	1,850	2,490	677			4	1,260	2,280	613	9.5	.431	4	1,680	2,240	630	9.4	.430				
Average..	1,690	2,480	654	9.7	.437	Average..	1,530	2,358	685	9.5	.438	Average..	1,322	2,087	781	9.3	.446	1,139	1,908	845	.004

[1] θ is the angle between face grain and applied stress.

[2] Averages in these columns computed by method of least squares.

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Table 3.--Results of compression tests on five-ply yellowpoplar plywood (plywood was made of 1/16-inch veneer; nominal height of specimens was 1-7/8 inches)

Specimen number	Fiber stress at proportional limit	Maximum crushing strength	Modulus of elasticity	Moisture content	Specific gravity	Specimen number	Fiber stress at proportional limit	Maximum crushing strength	Modulus of elasticity	Moisture content	Specific gravity	Specimen number	Fiber stress at proportional limit	Maximum crushing strength	Modulus of elasticity	Moisture content	Specific gravity	Average fiber stress at proportional limit[2]	Average maximum crushing strength[2]	Average modulus of elasticity[2]	Rate of strain
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)	(18)	(19)	(20)	(21)	(22)
	Lb. per sq. in.	Lb. per sq. in.	1,000 lb. per sq. in.	Percent			Lb. per sq. in.	Lb. per sq. in.	1,000 lb. per sq. in.	Percent			Lb. per sq. in.	Lb. per sq. in.	1,000 lb. per sq. in.	Percent		Lb. per sq. in.	Lb. per sq. in.	1,000 lb. per sq. in.	In. per in. per minute
		Specimens 2 inches wide						Specimens 4 inches wide						Specimens 6 inches wide							
		[1]$\theta = 0°$						$\theta = 0°$						$\theta = 0°$							
5-A-2-1	2,690	4,160	1,051.0	8.6	0.428	5-A-4-1	2,380	4,040	908.0	9.9	0.408	5-A-6-1	2,750	4,000	868.0	10.3	0.405				
2	2,590	4,080	984.0	9.1	.440	2	2,740	4,730	945.0	10.0	.446	2	2,880	4,380	1,066.0	10.2	.445				
3	2,700	4,330	1,088.0	10.4	.436	3	2,450	4,660	1,098.0	9.8	.454	3	3,420	4,250	909.0	10.2	.440				
4	2,690	4,360	978.0	8.2	.468	4	2,840	4,300	1,049.0	9.6	.464	4	2,800	4,120	980.0	10.1	.462				
Average..	2,670	4,230	1,025.0	9.1	.443	Average..	2,600	4,430	1,000.0	9.8	.443	Average..	2,960	4,190	956.0	10.2	.438	3,110	4,165	921	0.002
		$\theta = 15°$						$\theta = 15°$						$\theta = 15°$							
5-B-2-1	1,694	3,840	656.0	8.9	.447	5-B-4-1	2,220	3,770	705.0	10.1	.445	5-B-6-1	2,530	4,010	704.0	9.9	.454				
2	2,220	4,040	686.0	9.3	.462	2	1,798	3,640	592.0	10.1	.448	2	2,290	3,490	529.0	10.4	.446				
3	1,726	3,580	612.0	8.8	.424	3	2,230	3,680	617.0	9.5	.438	3	1,900	4,120	616.0	9.9	.458				
4	2,130	3,920	740.0	7.6	.448	4	1,993	3,290	608.0	9.8	.416	4	1,894	3,660	541.0	10.0	.450				
Average..	1,942	3,840	674.0	8.6	.445	Average..	2,060	3,600	630.0	9.9	.437	Average..	2,154	3,820	598.0	10.0	.452	2,259	3,808	560	.002
		$\theta = 30°$						$\theta = 30°$						$\theta = 30°$							
5-C-2-1	1,296	2,980	296.1	9.0	.437	5-C-4-1	1,634	3,100	331.2	9.9	.434	5-C-6-1	1,860	2,840	388.2	10.2	.432				
2	1,492	3,260	331.7	7.8	.478	2	1,080	2,720	385.9	10.2	.463	2	1,772	3,310	412.1	10.2	.460				
3	1,391	2,990	289.9	8.5	.446	3	1,401	2,620	409.9	10.0	.446	3	1,654	3,200	388.1	10.2	.442				
4	1,239	3,330	359.2	9.0	.466	4	1,398	3,300	412.5	10.1	.455	4	1,770	3,240	439.0	10.1	.448				
Average..	1,354	3,140	319.2	8.6	.457	Average..	1,378	2,940	384.9	10.0	.450	Average..	1,764	3,150	406.8	10.2	.446	1,969	3,151	451	.002
		$\theta = 45°$						$\theta = 45°$						$\theta = 45°$							
5-D-2-1	1,033	2,400	204.5	8.4	.420	5-D-4-1	1,325	2,930	307.5	9.8	.421	5-D-6-1	1,659	2,660	368.6	9.8	.420				
2	772	2,650	266.4	10.4	.450	2	1,460	2,980	321.8	10.5	.452	2	1,518	2,980	379.5	10.4	.449				
3	944	2,730	277.8	10.5	.460	3	1,150	2,860	316.0	10.5	.438	3	1,272	3,090	357.2	9.9	.445				
4	900	2,670	241.2	10.4	.452	4	1,315	2,950	355.2	10.1	.450	4	986	3,080	371.0	10.1	.450				
Average..	912	2,610	247.5	9.9	.446	Average..	1,312	2,930	325.1	10.2	.440	Average..	1,359	2,950	369.1	10.0	.441	1,582	3,122	430	.002
		$\theta = 60°$						$\theta = 60°$						$\theta = 60°$							
5-E-2-1	1,219	2,880	300.2	10.5	.470	5-E-4-1	1,226	2,990	340.5	10.1	.470	5-E-6-1	1,480	2,960	377.8	10.0	.456				
2	1,322	2,680	278.4	10.0	.427	2	1,406	2,370	334.0	10.2	.418	2	1,318	2,760	363.2	9.8	.416				
3	1,400	2,770	276.8	8.3	.442	3	1,406	2,770	351.6	9.8	.450	3	1,433	2,950	400.2	9.9	.440				
4	1,482	2,810	301.2	9.8	.444	4	1,320	2,800	410.0	9.6	.456	4	1,536	3,140	458.5	10.3	.459				
Average..	1,356	2,780	289.2	9.6	.446	Average..	1,340	2,730	359.0	9.9	.448	Average..	1,442	2,950	399.9	10.0	.443	1,485	3,036	455	.002
		$\theta = 75°$						$\theta = 75°$						$\theta = 75°$							
5-F-2-1	1,718	2,670	542.0	10.0	.446	5-F-4-1	1,878	2,780	583.0	9.9	.446	5-F-6-1	1,466	2,800	444.4	10.3	.435				
2	1,789	2,730	564.0	10.0	.432	2	1,802	2,620	490.0	10.5	.440	2	1,195	2,820	497.9	10.8	.425				
3	1,818	2,840	582.0	10.0	.470	3	1,238	2,730	548.0	10.2	.456	3	1,980	2,940	556.0	10.0	.464				
4	1,550	2,360	548.0	9.9	.436	4	1,155	2,700	487.0	10.4	.444	4	1,810	2,910	489.0	10.1	.452				
Average..	1,719	2,650	559.0	10.0	.446	Average..	1,518	2,710	527.0	10.2	.446	Average..	1,613	2,870	496.8	10.3	.444	1,560	2,976	466	.002
		$\theta = 90°$						$\theta = 90°$						$\theta = 90°$							
5-G-2-1				10.4	.442	5-G-4-1	1,886	2,960	780.0	10.3	.452	5-G-6-1	1,798	2,700	702.0	10.1	.442				
2	2,071	3,000	680.0	10.1	.462	2	2,160	3,000	812.0	10.3	.473	2	2,100	2,840	714.0	10.3	.474				
3	2,129	2,630	716.0	9.8	.436	3	1,710	2,520	684.0	10.4	.440	3	1,968	2,690	667.0	10.3	.437				
4	1,957	2,650	593.0	10.0	.429	4	1,786	2,520	656.0	10.6	.433	4	1,624	2,190	634.0	10.4	.428				
Average..	2,052	2,760	663.0	10.1	.442	Average..	1,886	2,750	733.0	10.4	.450	Average..	1,872	2,600	679.0	10.3	.445	1,786	2,516	681	.002

[1] θ is the angle between face grain and applied stress.

[2] Averages in these columns computed by method of least squares.

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Table 4.--Results of compression tests on seven-ply yellowpoplar plywood (plywood was made of 1/16-inch veneer; nominal height of specimens was 2-5/8 inches).

Specimen number	Fiber stress at proportional limit	Maximum crushing strength	Modulus of elasticity	Moisture content	Specific gravity	Specimen number	Fiber stress at proportional limit	Maximum crushing strength	Modulus of elasticity	Moisture content	Specific gravity	Specimen number	Fiber stress at proportional limit	Maximum crushing strength	Modulus of elasticity	Moisture content	Specific gravity	Average fiber stress at proportional limit[2]	Average maximum crushing strength[2]	Average modulus of elasticity[2]	Rate of strain
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)	(18)	(19)	(20)	(21)	(22)
	Lb. per sq. in.	Lb. per sq. in.	1,000 lb. per sq. in	Percent			Lb. per sq. in.	Lb. per sq. in.	1,000 lb. per sq. in.	Percent			Lb. per sq. in.	Lb. per sq. in.	1,000 lb. per sq. in.	Percent		Lb. per sq. in.	Lb. per sq. in.	1,000 lb. per sq. in.	In. per in. per minute
Specimens 2 inches wide						Specimens 4 inches wide						Specimens 6 inches wide									
[1]$\theta = 0°$						$\theta = 0°$						$\theta = 0°$									
7-A-2-1	3,140	4,380	1,138.0	9.6	0.479	7-A-4-1	2,190	4,200	1,083.0	9.3	0.476	7-A-6-1	2,760	4,290	960.0	10.1	0.470				
2	3,370	4,280	1,079.0	8.9	.472	2	2,670	4,360	1,068.0	8.1	.472	2	2,830	4,480	944.0	9.7	.466				
3	2,450	3,740	908.0	8.9	.454	3	2,070	4,140	982.0	8.8	.456	3	3,100	4,360	1,033.0	9.8	.462				
4	3,030	3,670	956.0	8.9	.432	4	2,550	3,980	992.0	9.0	.448	4	2,260	3,730	1,220.0	9.7	.447				
Average..	3,000	4,020	1,020.0	9.1	.464	Average..	2,370	4,170	1,031.0	8.8	.463	Average..	2,740	4,220	1,039.0	9.8	.461	2,608	4,314	1,049	0.002
$\theta = 15°$						$\theta = 15°$						$\theta = 15°$									
7-B-2-1	2,300	3,550	662.0	8.7	.454	7-B-4-1	1,955	3,970	728.0	8.4	.458	7-B-6-1	2,270	4,100	827.0	9.3	.460				
2	2,290	3,280	628.0	8.9	.440	2	2,078	3,660	670.0	8.4	.430	2	1,129	3,650	762.0	9.1	.436				
3	1,696	3,030	617.0	8.9	.437	3	1,954	3,710	664.0	8.5	.448	3	1,297	3,850	920.0	9.0	.440				
4	2,260	3,480	626.0	8.7	.447	4	2,162	4,060	669.0	9.0	.460	4	2,391	4,100	844.0	9.0	.466				
Average..	2,136	3,340	633.0	8.8	.444	Average..	2,037	3,850	683.0	8.6	.449	Average..	1,772	3,920	838.0	9.1	.450	1,589	4,220	941	.002
$\theta = 30°$						$\theta = 30°$						$\theta = 30°$									
7-C-2-1	900	3,020	308.5	8.9	.448	7-C-4-1	1,278	3,080	329.4	8.4	.435	7-C-6-1	1,541	3,240	450.5	9.4	.426				
2	1,126	2,510	304.5	9.0	.428	2	1,075	3,190	373.2	7.6	.429	2	1,195	3,390	513.0	9.5	.433				
3	1,241	3,040	275.8	8.7	.430	3	1,237	3,130	348.1	9.0	.435	3	1,151	3,050	390.0	9.6	.428				
4	1,365	2,960	285.6	9.1	.420	4	1,374	3,070	313.9	8.8	.428	4	1,030	3,140	370.5	10.0	.418				
Average..	1,158	2,880	293.6	8.9	.432	Average..	1,241	3,120	341.2	8.4	.432	Average..	1,229	3,200	431.0	9.6	.426	1,265	3,366	500	.002
$\theta = 45°$						$\theta = 45°$						$\theta = 45°$									
7-D-2-1	892	2,280	216.6	9.3	.426	7-D-4-1	1,073	2,710	290.0	8.5	.432	7-D-6-1	1,001	2,970	347.8	9.3	.448				
2	1,550	2,520	469.5	9.7	.437	2	1,184	3,000	275.1	8.9	.444	2	872	3,030	335.4	9.3	.436				
3	614	2,410	216.4	9.6	.390	3	915	2,700	269.2	9.2	.402	3	902	2,810	317.6	9.7	.388				
4	670	2,510	229.4	9.3	.434	4	1,042	2,890	288.0	8.0	.444	4	1,063	3,190	379.6	9.3	.440				
Average..	932	2,430	283.0	9.5	.422	Average..	1,054	2,820	280.6	8.6	.430	Average..	960	3,000	345.1	9.4	.428	974	3,285	376	.002
$\theta = 60°$						$\theta = 60°$						$\theta = 60°$									
7-E-2-1	854	2,690	285.9	9.6	.427	7-E-4-1	1,221	2,920	309.2	9.2	.430	7-E-6-1	1,220	2,970	436.0	9.2	.440				
2	911	2,680	268.0	9.9	.438	2	1,284	2,940	298.5	9.0	.452	2	1,302	3,050	392.3	9.4	.452				
3	1,046	2,320	282.0	9.5	.418	3	1,287	2,810	296.6	8.8	.432	3	1,410	3,050	377.9	9.5	.446				
4	1,035	2,230	266.6	9.4	.402	4	1,210	2,750	302.4	8.8	.424	4	1,518	2,820	337.2	9.7	.421				
Average..	962	2,480	275.6	9.6	.421	Average	1,250	2,860	301.7	9.0	.434	Average..	1,362	2,980	385.8	9.4	.440	1,563	3,222	441	.002
$\theta = 75°$						$\theta = 75°$						$\theta = 75°$									
7-F-2-1	1,705	2,330	479.0	9.2	.422	7-F-4-1	1,475	2,840	501.0	8.8	.435	7-F-6-1	1,580	2,840	603.0	9.6	.420				
2	1,416	2,190	528.0	9.5	.441	2	....	3,120	516.0	9.1	.444	2	1,924	3,070	605.0	9.9	.438				
3	1,590	2,240	452.0	9.1	.420	3	1,550	2,750	502.0	9.1	.424	3	1,117	2,870	628.0	9.6	.412				
4	1,796	2,890	494.0	9.1	.450	4	1,695	3,080	514.0	9.0	.454	4	2,122	3,070	590.0	10.0	.442				
Average..	1,627	2,410	488.0	9.2	.433	Average..	1,573	2,950	508.0	9.0	.439	Average..	1,686	2,960	606.0	9.8	.428	1,715	3,238	666	.002
$\theta = 90°$						$\theta = 90°$						$\theta = 90°$									
7-G-2-1	1,993	2,910	730.0	8.9	.457	7-G-4-1	1,944	3,090	686.0	10.6	.427	7-G-6-1	1,728	2,900	1,217.0	10.1	.428				
2	1,852	2,500	652.0	10.4	.396	2	1,709	2,560	646.0	9.2	.406	2	1,924	2,560	682.0	9.8	.392				
3	1,900	3,090	736.0	9.4	.444	3	1,960	2,660	702.0	9.1	.430	3	1,900	3,090	818.0	9.7	.419				
4	1,960	2,920	740.0	9.0	.419	4	2,010	2,960	744.0	9.1	.412	4	1,502	2,990	1,057.0	9.3	.406				
Average..	1,926	2,860	714.0	9.4	.429	Average..	1,906	2,820	694.0	9.5	.419	Average..	1,764	2,880	944.0	9.7	.411	1,682	2,900	1,058	.002

[1] θ is the angle between face grain and applied stress.

[2] Averages in these columns computed by method of least squares.

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Table 5.--Results of compression tests on five-ply yellowpoplar plywood (plywood was made of 1/32-inch veneer; nominal height[1] of specimens was 1-7/8 inches).

Specimen number	Fiber stress at proportional limit	Maximum crushing strength	Modulus of elasticity	Moisture content	Specific gravity	Specimen number	Fiber stress at proportional limit	Maximum crushing strength	Modulus of elasticity	Moisture content	Specific gravity	Specimen number	Fiber stress at proportional limit	Maximum crushing strength	Modulus of elasticity	Moisture content	Specific gravity	Average fiber stress at proportional limit[2]	Average maximum crushing strength[2]	Average modulus of elasticity[2]	Rate of strain
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)	(18)	(19)	(20)	(21)	(22)
	Lb. per sq. in.	Lb. per sq. in.	1,000 lb. per sq. in.	Percent			Lb. per sq. in.	Lb. per sq. in.	1,000 lb. per sq. in.	Percent			Lb. per sq. in.	Lb. per sq. in.	1,000 lb. per sq. in.	Percent		Lb. per sq. in.	Lb. per sq. in.	1,000 lb. per sq. in.	In. per in. per minute
		Specimens 2 inches wide						Specimens 4 inches wide						Specimens 6 inches wide							
		[3]θ = 0°						θ = 0°						θ = 0°							
5-A-2-1	3,450	4,700	1,015	8.7	0.434	5-A-4-1	2,710	4,230	1,101	9.4	0.433	5-A-6-1	2,480	4,120	928	8.1	0.419	...	...	...	...
2*	2,040	3,620	876	8.8	.353	2	2,050	3,640	866	10.1	.362	2	2,110	3,220	927	9.0	.360	...	...	...	...
3	2,250	3,880	962	8.9	.363	3	2,560	3,760	893	9.8	.374	3	2,260	3,590	986	8.4	.377	...	...	...	...
4	3,050	4,620	1,125	8.7	.412	4	2,890	4,120	1,040	9.5	.409	4	2,380	3,860	1,108	8.9	.409	...	...	...	...
Average..	2,700	4,200	994	8.8	.390	Average..	2,550	3,940	975	9.7	.394	Average..	2,310	3,700	987	8.6	.391	2,103	3,837	1,129	0.004
		θ = 15°						θ = 15°						θ = 15°							
5-B-2-1	2,070	3,460	554	9.0	.372	5-B-4-1	2,390	3,540	558	9.9	.375	5-B-6-1	1,600	3,460	507	9.0	.376	...	...	...	...
2	2,220	3,930	704	9.1	.380	2	1,660	3,650	686	13.2	.369	2	2,080	3,810	714	8.5	.386	...	...	...	...
3	2,810	4,180	708	8.6	.410	3	2,660	3,920	706	9.6	.400	3	2,340	3,520	731	8.6	.398	...	...	...	...
4	2,260	4,090	790	9.0	.408	4	2,110	3,100	694	9.2	.417	4	1,870	3,900	719	8.0	.414	...	...	...	...
Average..	2,340	3,920	689	8.9	.392	Average..	2,200	3,550	661	10.5	.390	Average..	1,970	3,670	668	8.5	.394	1,789	3,551	657	.004
		θ = 30°						θ = 30°						θ = 30°							
5-C-2-1	1,550	3,480	322	8.5	.386	5-C-4-1	1,640	3,860	390	8.5	.405	5-C-6-1	2,070	3,690	450	8.5	.403	...	...	...	...
2	1,640	3,350	369	8.8	.374	2	1,560	3,440	382	9.0	.379	2	1,630	3,420	506	9.0	.369	...	...	...	...
3	1,860	3,760	376	8.5	.399	3	1,860	3,830	407	8.9	.404	3	1,580	3,600	526	8.5	.394	...	...	...	...
4	1,600	3,660	356	8.5	.411	4	2,050	3,670	400	9.0	.419	4	1,780	3,650	552	8.6	.414	...	...	...	...
Average..	1,660	3,560	356	8.6	.392	Average..	1,780	3,700	395	8.8	.402	Average..	1,760	3,590	508	8.6	.395	1,816	3,604	585	.004
		θ = 0°						θ = 0°						θ = 0°							
5-CP-2-A[4]	2,400	3,640	918	8.8	.366	5-CP-4-A	2,550	3,840	920	9.4	.374	5-CP-6-A	1,610	3,620	1,116	9.1	.368	...	...	...	...
C	2,520	4,230	1,119	10.1	.389	C	2,170	3,360	1,002	9.0	.387	C	1,790	3,780	1,162	9.2	.387	...	...	...	...
E	1,390	3,670	1,358	8.5	.400	E	2,960	4,250	964	8.8	.402	E	3,020	4,000	1,048	9.0	.391	...	...	...	...
G	2,180	4,080	1,060	8.8	.390	G	2,530	4,210	1,026	8.8	.393	G	2,530	3,880	1,202	8.9	.420	...	...	...	...
Average..	2,120	3,900	1,114	9.0	.386	Average..	2,550	3,920	978	9.0	.389	Average..	2,240	3,820	1,132	9.0	.392	2,103	3,837	1,129	.004
		θ = 45°						θ = 45°						θ = 45°							
5-D-2-1	1,520	3,330	295	8.6	.400	5-D-4-1	1,440	3,250	316	7.9	.407	5-D-6-1	...	3,390	...	8.7	.389	...	...	...	...
2	1,250	3,360	297	8.6	.407	2	880	3,390	370	8.9	.403	2	...	3,390	...	8.9	.405	...	...	...	...
3	1,440	3,110	298	8.5	.423	3	1,080	3,710	400	12.4	.414	3	1,450	3,530	504	9.1	.427	...	...	...	...
4	1,310	3,110	267	8.6	.395	4	1,400	3,260	286	9.4	.399	4	1,000	3,360	556	9.1	.405	...	...	...	...
Average..	1,380	3,230	289	8.6	.406	Average..	1,200	3,400	343	9.6	.406	Average..	1,220	3,420	530	9.0	.406	1,129	3,512	614	.004
		θ = 60°						θ = 60°						θ = 60°							
5-E-2-1	1,250	2,340	341	19.1	.404	5-E-4-1	1,800	3,180	385	7.8	.404	5-E-6-1	1,460	3,340	502	8.8	.409	...	...	...	...
2	1,380	2,980	349	8.3	.397	2	1,470	3,200	397	8.3	.400	2	1,390	3,280	514	8.9	.396	...	...	...	...
3	1,510	3,120	355	8.7	.396	3	1,340	3,420	455	9.0	.404	3	1,350	3,420	495	8.7	.409	...	...	...	...
4	1,290	3,130	309	12.5	.384	4	...	3,160	...	9.1	.394	4	970	3,070	526	8.4	.394	...	...	...	...
Average..	1,360	2,890	338	12.2	.395	Average..	1,540	3,240	412	8.6	.400	Average..	1,290	3,280	509	8.7	.402	1,260	3,470	595	.004
		θ = 0°						θ = 0°						θ = 0°							
5-CP-2-B[4]	2,600	4,240	1,083	9.0	.403	5-CP-4-B	2,950	4,300	1,046	8.7	.398	5-CP-6-B	...	4,290	1,056	7.7	.402	...	...	...	...
D	2,550	4,360	1,076	9.2	.401	D	2,890	4,250	1,070	8.7	.392	D	2,030	4,180	1,076	8.1	.391	...	...	...	...
F	3,170	4,220	1,073	8.7	.414	F	1,920	4,160	894	8.3	.404	F	2,220	4,330	1,307	8.5	.394	...	...	...	...
H	2,580	4,580	1,192	8.7	.420	H	...	4,330	1,166	8.5	.413	H	2,160	4,440	1,403	8.5	.410	...	...	...	...
Average..	2,720	4,350	1,106	8.9	.410	Average..	2,590	4,260	1,044	8.6	.402	Average..	2,140	4,310	1,210	8.2	.399	2,103	3,837	1,129	.004
		θ = 75°						θ = 75°						θ = 75°							
5-F-2-1	1,450	2,840	500	8.9	.362	5-F-4-1	1,700	2,970	538	8.5	.375	5-F-6-1	1,390	2,790	578	9.2	.362	...	...	...	...
2	1,520	2,820	550	9.0	.393	2	2,120	3,150	582	8.7	.399	2	1,690	3,070	607	9.1	.391	...	...	...	...
3	1,780	3,160	546	8.5	.425	3	1,880	3,240	614	8.4	.422	3	1,680	3,250	658	8.6	.418	...	...	...	...
4	1,520	3,140	610	8.9	.417	4	1,630	3,110	658	8.9	.411	4	1,600	3,320	645	7.5	.417	...	...	...	...
Average..	1,570	2,990	552	8.8	.399	Average..	1,830	3,120	598	8.6	.402	Average..	1,590	3,110	622	8.6	.397	1,601	3,166	657	.007
		θ = 90°						θ = 90°						θ = 90°							
5-G-2-1	1,630	2,500	560	9.5	.353	5-G-4-1	1,310	2,560	574	8.5	.345	5-G-6-1	1,190	2,440	643	7.7	.356	...	...	...	...
2	1,030	2,420	720	9.3	.394	2	1,810	2,840	656	8.4	.399	2	970	2,780	874	7.9	.402	...	...	...	...
3	1,200	2,700	728	9.3	.393	3	1,980	3,070	740	8.6	.396	3	1,380	3,000	890	7.7	.406	...	...	...	...
4	1,660	2,829	756	10.6	.388	4	1,910	2,840	694	9.2	.391	4	1,490	2,840	688	8.0	.395	...	...	...	...
Average..	1,380	2,610	691	9.6	.382	Average..	1,750	2,830	666	8.7	.383	Average..	1,260	2,760	774	7.8	.390	1,196	2,842	815	.007

[1] Test specimens were made of two thicknesses of plywood. Thus a height-thickness ratio could be obtained which precludes buckling during test.

[2] Averages in these columns computed by method of least squares.

[3] θ is the angle between face grain and applied stress.

[4] CP denotes specimens from control panels.

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Table 6.--Results of compression tests on seven-ply yellowpoplar plywood (plywood made of 1/32-inch veneer; nominal height of specimens was 1-1/2 inches).

Specimen number	Fiber stress at proportional limit	Maximum crushing strength	Modulus of elasticity	Moisture content	Specific gravity	Specimen number	Fiber stress at proportional limit	Maximum crushing strength	Modulus of elasticity	Moisture content	Specific gravity	Specimen number	Fiber stress at proportional limit	Maximum crushing strength	Modulus of elasticity	Moisture content	Specific gravity	Average fiber stress at proportional limit[1]	Average maximum crushing strength[1]	Average modulus of elasticity[1]	Rate of strain
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)	(18)	(19)	(20)	(21)	(22)
	Lb. per sq. in.	Lb. per sq. in.	1,000 lb. per sq. in.	Percent			Lb. per sq. in.	Lb. per sq. in.	1,000 lb. per sq. in.	Percent			Lb. per sq. in.	Lb. per sq. in.	1,000 lb. per sq. in.	Percent		Lb. per sq. in.	Lb. per sq. in.	1,000 lb. per sq. in.	In. per in. per minute
		Specimens 2 inches wide						Specimens 4 inches wide						Specimens 6 inches wide							
		[2]θ = 0°						θ = 0°						θ = 0°							
7-A-2-1	1,750	3,790	876	9.4	0.392	7-A-4-1	2,000	3,920	1,262	9.0	0.393	7-A-6-1	1,860	3,920	1,248	9.4	0.388				
2	1,160	3,920	1,067	9.1	.395	2	2,190	3,720	1,072	9.0	.385	2	1,540	3,760	1,169	9.0	.390				
3	2,770	3,630	804	9.5	.380	3	1,630	3,920	1,188	9.6	.398	3	1,700	3,860	1,292	9.9	.396				
4	2,560	4,060	886	8.9	.407	4	1,950	3,850	1,548	9.3	.403	4	1,950	4,000	1,190	9.0	.406				
Average....	2,080	3,850	908	9.2	.394	Average..	1,940	3,850	1,268	9.2	.395	Average..	1,760	3,880	1,225	9.3	.396	1,548	3,813	1,351	0.003 - 0.006
		θ = 15°						θ = 15°						θ = 15°							
7-B-2-1	1,950	3,400	527	9.7	.382	7-B-4-1	2,530	3,650	831	8.1	.389	7-B-6-1	1,680	3,650	817	9.3	.389				
2	2,100	3,640	610	9.4	.387	2	2,700	3,830	680	8.1	.406	2	1,710	3,830	722	9.6	.392				
3	2,440	3,890	723	9.4	.396	3	1,740	3,610	752	8.0	.390	3	1,560	3,790	764	9.3	.393				
4	2,090	3,580	690	10.2	.398	4	2,180	3,380	646	8.6	.388	4	1,540	3,430	624	10.0	.382				
Average....	2,140	3,630	638	9.7	.391	Average..	2,290	3,620	727	8.2	.393	Average..	1,620	3,680	732	9.6	.389	1,361	3,699	779	.003 - .006
		θ = 30°						θ = 30°						θ = 30°							
7-C-2-1	1,760	3,300	336	9.7	.390	7-C-4-1	2,000	3,410	403	7.9	.397	7-C-6-1	1,570	3,680	491	9.5	.394				
2	1,680	3,230	368	10.0	.364	2	1,670	3,320	418	8.4	.390	2	1,590	3,440	496	10.1	.378				
3	1,530	3,210	392	9.4	.385	3	2,000	3,760	461	8.0	.408	3	1,410	3,660	618	9.5	.400				
4	1,460	3,130	425	9.8	.378	4	1,560	3,440	480	8.0	.394	4	1,800	3,400	422	9.7	.384				
Average....	1,610	3,220	380	9.7	.384	Average..	1,810	3,480	440	8.1	.397	Average..	1,590	3,540	507	9.7	.389	1,585	3,709	570	.003 - .006
		θ = 0°						θ = 0°						θ = 0°							
7-CP-2-A[3]	2,390	3,520	948	9.9	.366	7-CP-4-A	2,290	3,750	1,018	8.6	.376	7-CP-6-A	2,210	3,630	984	8.1	.381				
C	2,420	3,810	974	9.7	.392	C	2,510	3,960	1,046	9.2	.392	C	1,670	3,620	1,272	8.8	.388				
E	2,400	3,840	1,034	9.7	.412	E	2,760	3,960	963	9.3	.421	E	1,380	3,960	1,455	9.5	.410				
G	2,140	3,280	849	10.2	.382	G	2,480	3,580	957	9.9	.393	G	1,580	3,660	1,285	10.2	.400				
Average....	2,340	3,810	951	9.9	.388	Average..	2,510	3,810	995	9.2	.396	Average..	1,710	3,720	1,249	9.2	.395	1,548	3,813	1,351	.003 - .006
		θ = 45°						θ = 45°						θ = 45°							
7-D-2-1	1,270	3,030	285	10.1	.391	7-D-4-1	1,740	3,350	334	8.5	.414	7-D-6-1	1,300	3,330	489	8.5	.404				
2	1,200	3,120	301	9.7	.406	2	1,260	3,420	408	8.2	.406	2	1,640	3,340	457	8.2	.408				
3	1,090	3,000	298	9.1	.395	3	1,320	3,160	401	8.7	.398	3	1,360	3,140	384	8.9	.394				
4	1,160	2,860	276	10.0	.368	4	1,530	3,020	330	8.8	.381	4	1,360	2,950	404	9.0	.376				
Average....	1,180	3,000	290	9.7	.390	Average..	1,460	3,240	368	8.6	.400	Average..	1,460	3,190	434	8.6	.396	1,608	3,284	505	.003 - .006
		θ = 60°						θ = 60°						θ = 60°							
7-E-2-1	1,380	2,870	297	10.0	.386	7-E-4-1	1,710	2,980	416	9.0	.397	7-E-6-1	1,220	2,990	522	8.7	.401				
2	1,590	3,060	379	9.9	.438	2	1,370	3,290	445	8.9	.440	2	780	3,200	582	8.9	.445				
3	1,790	2,840	284	9.9	.400	3	1,650	2,970	375	8.9	.395	3	1,180	2,860	472	8.7	.390				
4	1,550	2,860	326	9.8	.390	4	1,300	2,980	383	9.9	.388	4	1,100	2,850	546	9.4	.386				
Average....	1,580	2,910	322	9.9	.404	Average..	1,510	3,060	405	9.2	.405	Average..	1,070	2,980	531	8.9	.406	816	3,009	636	.003 - .006
		θ = 0°						θ = 0°						θ = 0°							
7-CP-2-B	2,220	3,830	1,164	10.2	.399	7-CP-4-B	2,070	3,730	968	10.1	.382	7-CP-6-B	1,950	3,430	1,128	10.5	.392				
D	2,870	3,760	1,040	10.0	.392	D	2,020	3,900	1,064	9.5	.393	D	1,910	3,960	1,294	9.7	.399				
F	2,240	3,670	1,244	10.4	.383	F	1,220	3,670	1,358	9.7	.372	F	1,500	3,690	1,206	10.1	.389				
H	2,090	3,900	1,156	10.1	.410	H	2,430	4,020	1,026	9.4	.404	H	2,170	4,020	1,300	9.5	.406				
Average....	2,360	3,790	1,151	10.2	.396	Average..	1,940	3,830	1,104	9.7	.388	Average..	1,880	3,780	1,232	10.1	.396	1,548	3,813	1,351	.003 - .006
		θ = 75°						θ = 75°						θ = 75°							
7-F-2-1	1,680	2,590	510	10.4	.382	7-F-4-1	1,560	2,860	590	9.6	.384	7-F-6-1	1,260	2,750	662	8.8	.382				
2	...	2,990	...	9.9	.385	2	1,630	2,840	544	9.5	.384	2	1,560	2,790	531	9.2	.397				
3	1,850	2,900	584	9.9	.401	3	1,600	3,160	637	9.4	.404	3	1,300	3,040	698	8.9	.404				
4	1,540	2,540	545	10.1	.371	4	1,210	2,700	603	9.3	.375	4	1,390	2,590	578	9.2	.378				
Average....	1,690	2,760	546	10.1	.385	Average..	1,500	2,890	594	9.4	.387	Average..	1,380	2,790	617	9.0	.390	1,217	2,811	653	.003 - .006
		θ = 90°						θ = 90°						θ = 90°							
7-G-2-1	1,560	3,150	836	10.1	.392	7-G-4-1	2,030	3,160	764	9.7	.390	7-G-6-1	1,360	3,000	1,047	8.7	.392				
2	1,940	2,660	708	10.3	.366	2	1,700	2,740	752	10.0	.367	2	1,740	2,700	744	8.9	.384				
3	1,710	2,760	737	10.4	.388	3	1,340	2,780	838	9.9	.394	3	1,300	2,770	824	9.2	.390				
4	1,940	2,650	706	10.1	.377	4	1,560	2,850	806	9.9	.378	4	1,370	2,720	900	9.0	.379				
Average....	1,790	2,800	747	10.2	.381	Average..	1,660	2,880	790	9.9	.382	Average..	1,440	2,800	879	9.0	.386	1,270	2,794	945	.003 - .006

[1] Averages in these columns computed by method of least squares.

[2] θ is the angle between face grain and applied stress.

[3] CP denotes specimens from control panels.

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Table 7.--Results of compression tests on nine-ply yellowpoplar plywood (plywood made of 1/32-inch veneer; nominal height of specimens was 1-7/8 inches).

Specimen number	Fiber stress at proportional limit	Maximum crushing strength	Modulus of elasticity	Moisture content	Specific gravity	Specimen number	Fiber stress at proportional limit	Maximum crushing strength	Modulus of elasticity	Moisture content	Specific gravity	Specimen number	Fiber stress at proportional limit	Maximum crushing strength	Modulus of elasticity	Moisture content	Specific gravity	Average fiber stress at proportional limit[1]	Average maximum crushing strength[1]	Average modulus of elasticity[1]	Rate of strain
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)	(18)	(19)	(20)	(21)	(22)
	Lb. per sq. in.	Lb. per sq. in.	1,000 lb. per sq. in.	Percent			Lb. per sq. in.	Lb. per sq. in.	1,000 lb. per sq. in.	Percent			Lb. per sq. in.	Lb. per sq. in.	1,000 lb. per sq. in.	Percent		Lb. per sq. in.	Lb. per sq. in.	1,000 lb. per sq. in.	In. per in. per minute
		Specimens 2 inches wide						Specimens 4 inches wide						Specimens 6 inches wide							
		[2]θ = 0°						θ = 0°						θ = 0°							
9-A-2-1	2,910	4,310	1,232	7.9	0.446	9-A-4-1	3,240	4,510	1,203	7.4	0.454	9-A-6-1	3,480	4,660	1,140	8.2	0.441				
2	2,090	4,500	1,504	7.9	.476	2	3,790	4,650	1,141	7.5	.467	2	3,720	4,980	1,252	7.9	.480				
3	3,320	4,530	1,338	7.7	.465	3	3,820	4,930	1,200	7.5	.481	3	3,910	5,230	1,372	8.0	.495				
4	2,570	4,410	1,256	7.7	.455	4	3,890	4,590	1,178	7.5	.456	4	3,500	4,760	1,860	7.9	.466				
Average...	2,720	4,440	1,332	7.8	.460	Average..	3,680	4,670	1,180	7.5	.464	Average..	3,650	4,910	1,406	6.0	.470	2,453	4,524	1,378	0.003
		θ = 15°						θ = 15°						θ = 15°							
9-B-2-1	1,650	3,120	656	8.3	.411	9-B-4-1	2,220	3,460	578	8.2	.402	9-B-6-1	2,520	3,760	573	8.5	.410				
2	2,290	3,850	818	8.1	.464	2	2,380	4,350	798	7.6	.462	2	1,530	4,570	1,010	8.2	.455				
3	2,100	3,680	799	7.9	.453	3	3,060	4,470	800	7.6	.468	3	1,410	4,620	1,174	8.1	.458				
4	2,130	3,490	762	8.2	.415	4	2,700	4,050	700	7.5	.428	4	1,600	4,140	984	8.2	.425				
Average...	2,040	3,540	759	8.1	.436	Average..	2,590	4,080	719	7.7	.440	Average..	1,760	4,270	935	8.2	.437	1,626	4,641	1,024	.003
		θ = 30°						θ = 30°						θ = 30°							
9-C-2-1	1,600	3,340	398	7.7	.428	9-C-4-1	1,890	3,810	441	7.3	.430	9-C-6-1	1,260	3,980	598						
2	1,220	3,060	400	8.1	.416	2	1,900	3,360	407	8.2	.410	2	1,500	3,500	562	8.6	.401				
3	1,790	3,580	417	7.6	.442	3	1,810	3,940	444	7.9	.439	3	1,530	4,150	601	7.7	.437				
4	1,250	3,580	462	7.6	.426	4	1,620	3,930	474	8.2	.430	4	1,820	4,230	686	7.5	.438				
Average...	1,460	3,390	419	7.8	.428	Average..	1,800	3,760	442	7.9	.427	Average..	1,530	3,960	612	7.9	.425	1,559	4,252	708	.003
		θ = 0°						θ = 0°						θ = 0°							
9-CP-2-A[3]	2,690	3,830	980	7.5	.421	9-CP-4-A	2,720	3,880	908	8.3	.406	9-CP-6-A	1,520	4,150	1,516	7.5	.418				
C	2,420	3,820	968	7.6	.429	C	2,520	3,990	884	8.6	.427	C	1,850	3,780	1,000	7.7	.390				
E	2,150	3,770	946	7.6	.410	E	2,820	3,720	842	8.0	.441	E	1,870	3,930	1,008	7.9	.444				
G	2,920	4,410	1,048	7.5	.452	G	1,960	4,020	892	8.3	.417	G	1,760	4,120	1,304	8.0	.418				
Average...	2,540	3,960	986	7.6	.428	Average..	2,510	3,900	882	8.4	.423	Average..	1,750	4,000	1,207	7.8	.418	2,453	4,524	1,378	.003
		θ = 45°						θ = 45°						θ = 45°							
9-D-2-1	1,800	3,910	382	7.9	.468	9-D-4-1	1,990	3,970	398	8.2	.438	9-D-6-1	1,770	4,130	593	8.0	.454				
2	1,790	3,330	284	7.6	.424	2	1,700	3,090	309	8.2	.404	2	1,640	3,430	444	8.0	.422				
3	1,690	3,530	282	7.8	.451	3	1,680	3,590	344	8.2	.442	3	1,760	3,900	476	7.9	.448				
4	1,730	3,620	361	7.2	.436	4	1,930	3,460	342	8.0	.426	4	1,290	3,770	482	7.6	.434				
Average...	1,750	3,600	327	7.6	.445	Average..	1,820	3,530	348	8.2	.428	Average..	1,620	3,810	499	7.9	.440	1,546	3,912	584	.003
		θ = 60°						θ = 60°						θ = 60°							
9-E-2-1	1,830	3,490	365	7.4	.428	9-E-4-1	1,920	3,450	383	8.1	.435	9-E-6-1	1,400	3,650	476	7.1	.426				
2	1,890	3,350	357	7.5	.425	2	2,080	3,500	378	8.4	.425	2	1,520	3,520	524	7.6	.428				
3	1,720	3,470	396			3	2,000	3,340	375	8.5	.424	3	1,400	3,700	662	7.6	.440				
4	1,840	3,500	465	7.4	.440	4	1,640	3,540	455	8.5	.447	4	1,800	3,780	564	7.8	.458				
Average...	1,820	3,450	396	7.4	.431	Average..	1,910	3,460	398	8.4	.433	Average..	1,530	3,660	556	7.5	.438	1,385	3,768	637	.003
		θ = 0°						θ = 0°						θ = 0°							
9-CP-2-B	2,900	3,860	990	7.7	.411	9-CP-4-B	2,860	4,020	970	7.9	.429	9-CP-6-B	2,160	4,100	1,156	7.8	.426				
D	1,660	3,400	913	7.6	.390	D	2,310	3,350	812	8.1	.395	D	1,740	4,020	1,192	8.2	.430				
F	2,820	3,870	924	7.6	.449	F		3,420		8.1	.401	F	1,900	3,880	1,118	8.1	.415				
H	2,530	3,760	872	7.4	.404	H	3,580	4,540	1,120	7.8	.465	H	2,540	4,740	1,430	7.6	.460				
Average...	2,480	3,720	925	7.6	.414	Average..	2,920	3,830	967	8.0	.422	Average..	2,080	4,180	1,224	7.9	.433	2,453	4,524	1,378	.003
		θ = 75°						θ = 75°						θ = 75°							
9-F-2-1	1,990	3,280	611	7.6	.421	9-F-4-1	1,870	2,940	424	8.3	.410	9-F-6-1	1,250	3,070	602	7.7	.431				
2	1,620	3,110	516	7.5	.396	2	1,710	2,910	452	7.8	.397	2	1,260	3,070	624	7.5	.400				
3	1,740	3,220	598	7.7	.380	3	1,830	3,000	532	7.7	.370	3	1,410	3,090	771	7.9	.388				
4	1,770	3,100	642	8.0	.383	4	1,660	2,780	441	8.2	.370	4	1,110	3,150	810	7.9	.396				
Average...	1,780	3,180	592	7.7	.395	Average..	1,770	2,910	462	8.0	.387	Average..	1,260	3,100	702	7.8	.404	996	3,054	757	.003
		θ = 90°						θ = 90°						θ = 90°							
9-G-2-1	1,760	3,120	750	8.1	.410	9-G-4-1	1,620	2,700	473	8.2	.380	9-G-6-1	1,820	2,940	570	8.1	.417				
2	1,890	2,800	486			2	1,430	2,480	459	7.8	.341	2	1,390	2,650	637	7.5	.353				
3	2,180	3,410	864			3	2,350	3,460	830	8.1	.417	3	1,370	3,660	1,144	8.0	.430				
4	1,330	2,300	433			4	1,240	2,280	449	8.1	.323	4	1,390	2,330	418	7.6	.328				
Average...	1,790	2,910	633	8.1	.410	Average..	1,660	2,730	553	8.0	.365	Average..	1,490	2,880	692	7.8	.382	1,344	2,866	722	.003

[1] Averages in these columns computed by method of least squares.

[2] θ is the angle between face grain and applied stress.

[3] CP denotes specimens from control panels.

Z M 49548 F

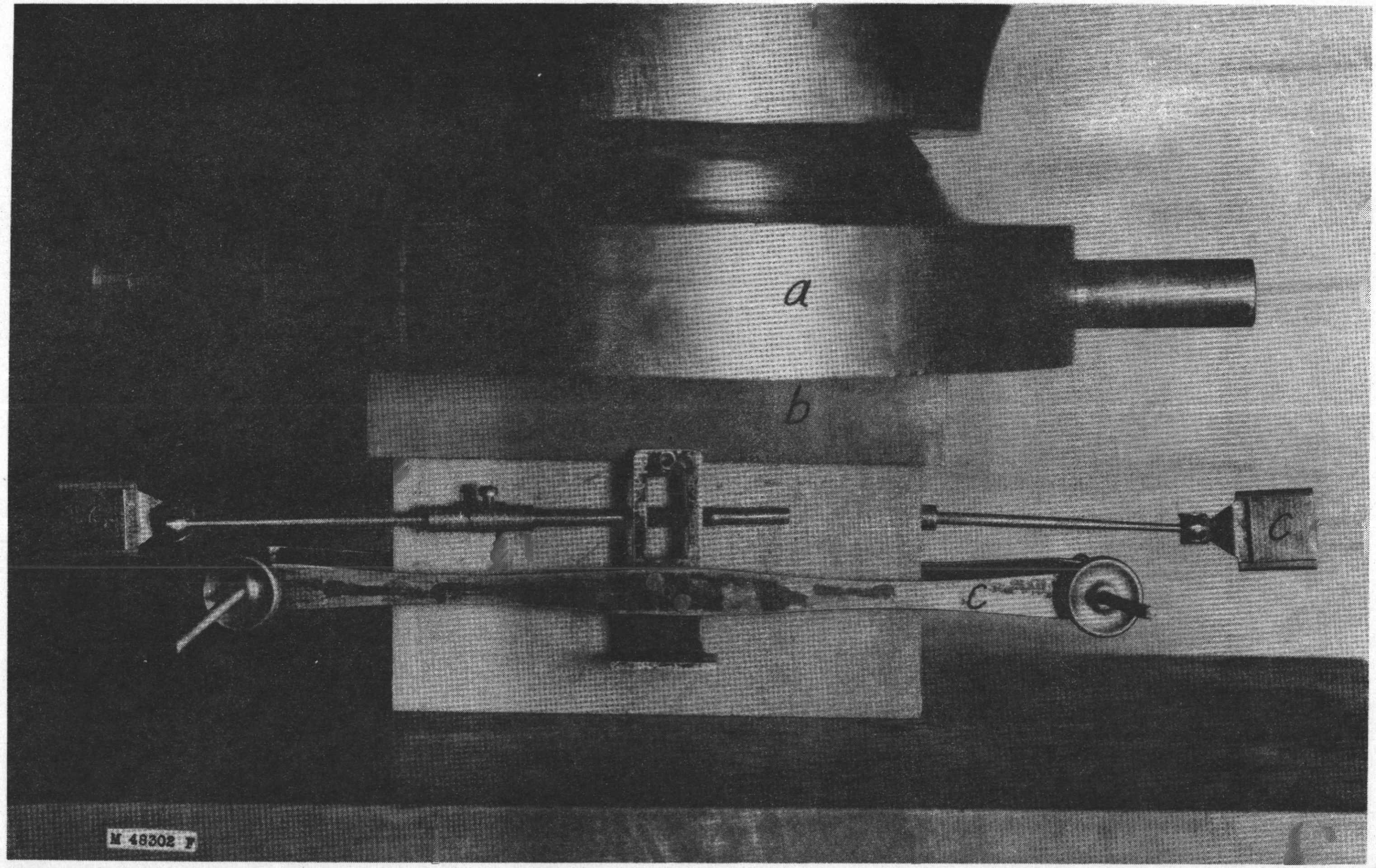

Figure 1.--Method of conducting compression tests at various angles to the face grain, showing (a) the spherical loading block, (b) narrow steel block to transmit load to test specimen and (c) Martens mirror extensometer of 1-inch gage length attached to test specimen to measure deformations.

Z M 50416 F

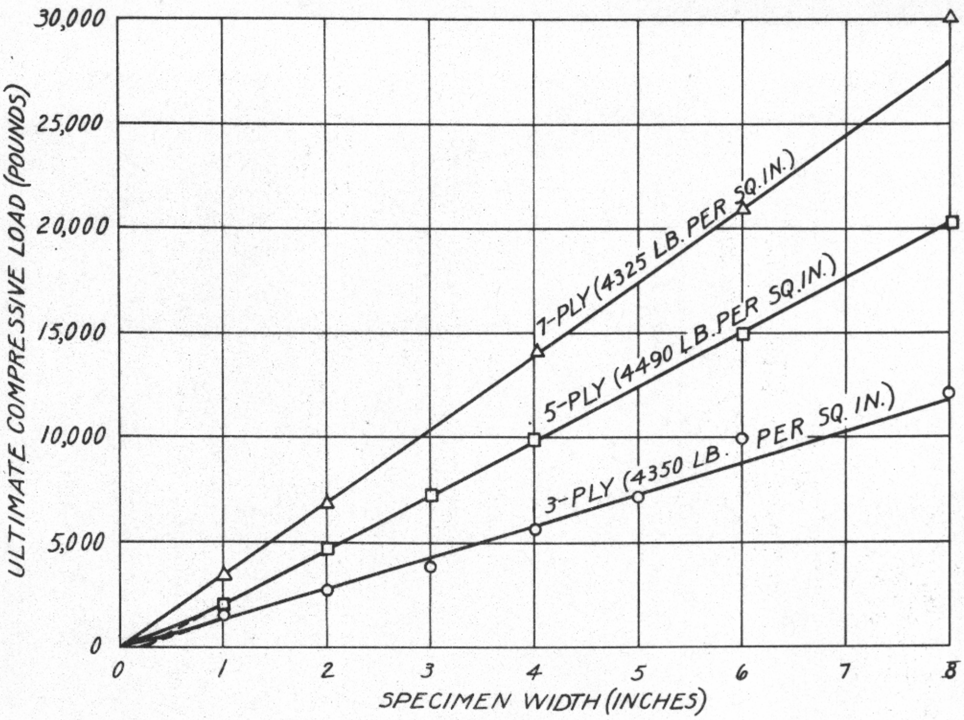

Figure 2.--Compression tests on yellow birch plywood at 45° to face grain, showing relation between specimen width and ultimate load.

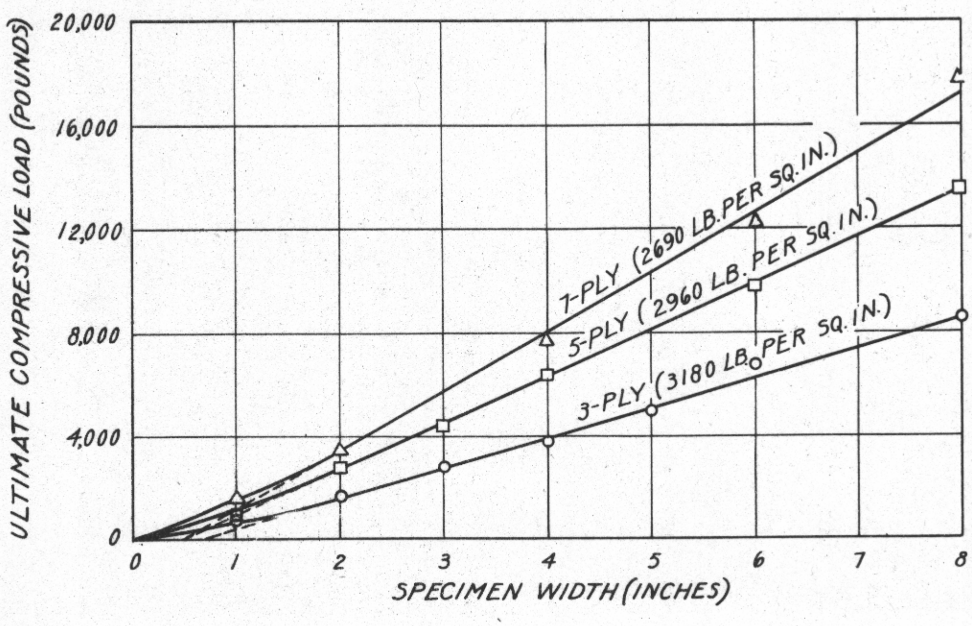

Figure 3.--Compression tests on yellowpoplar plywood at 45° to face grain, showing relation between specimen width and ultimate load.

Z M 49785 F

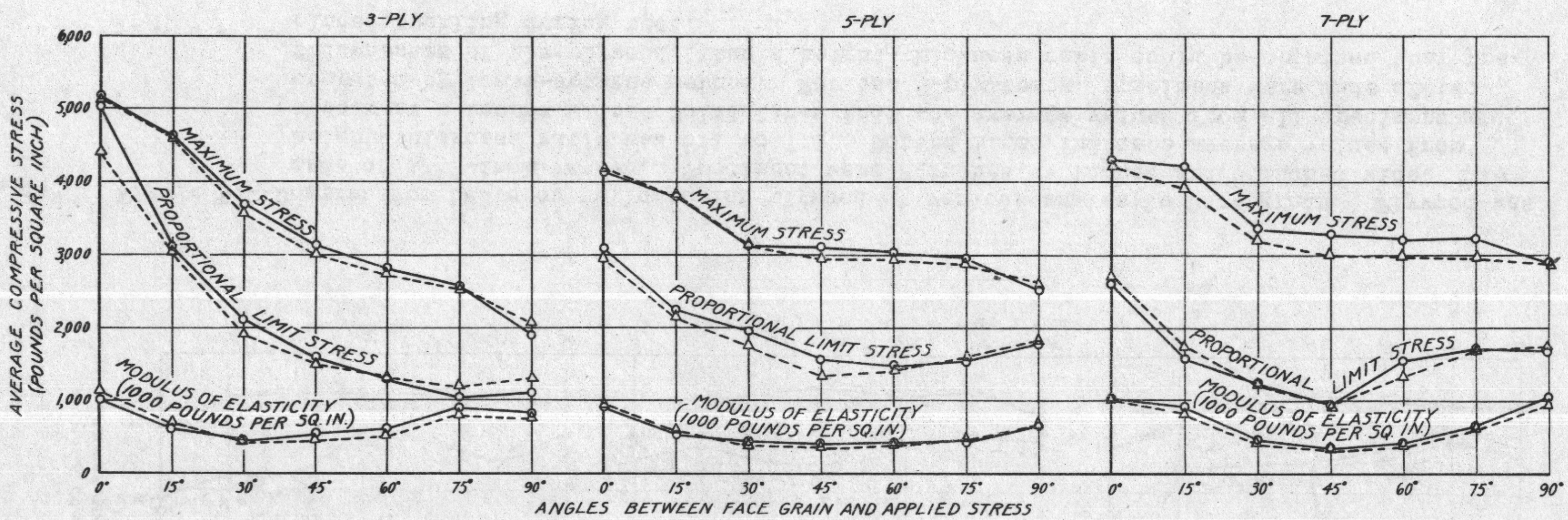

Figure 4.--Compression tests on yellowpoplar plywood at various angles to face grain. Plywood was made of 1/16-inch veneer. Specimens were 2 inches, 4 inches and 6 inches wide. The height-thickness ratio was 6:1 to 7:1. Dotted lines indicate average values from specimens 6 inches wide. Solid lines indicate average values from all specimens as computed by least-squares method.

Z M 49786 F

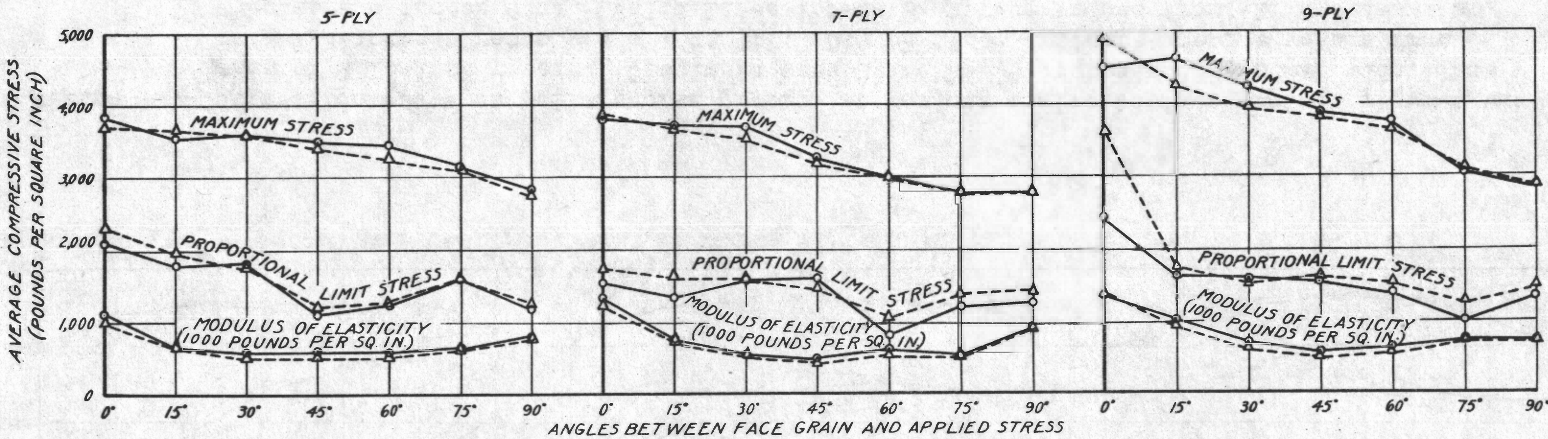

Figure 5.--Compression tests on yellowpoplar plywood at various angles to face grain. Plywood was made of 1/32-inch veneer. Specimens were 2 inches, 4 inches and 6 inches wide. The height-thickness ratio was 6:1 to 7:1. Dotted lines indicate average values from specimens 6 inches wide. Solid lines indicate average values from all specimens as computed by least-squares method. For the 5-ply tests, specimens were made of two thicknesses of the plywood, thus a height-thickness ratio could be obtained that precluded buckling during test.

Z M 49787 F

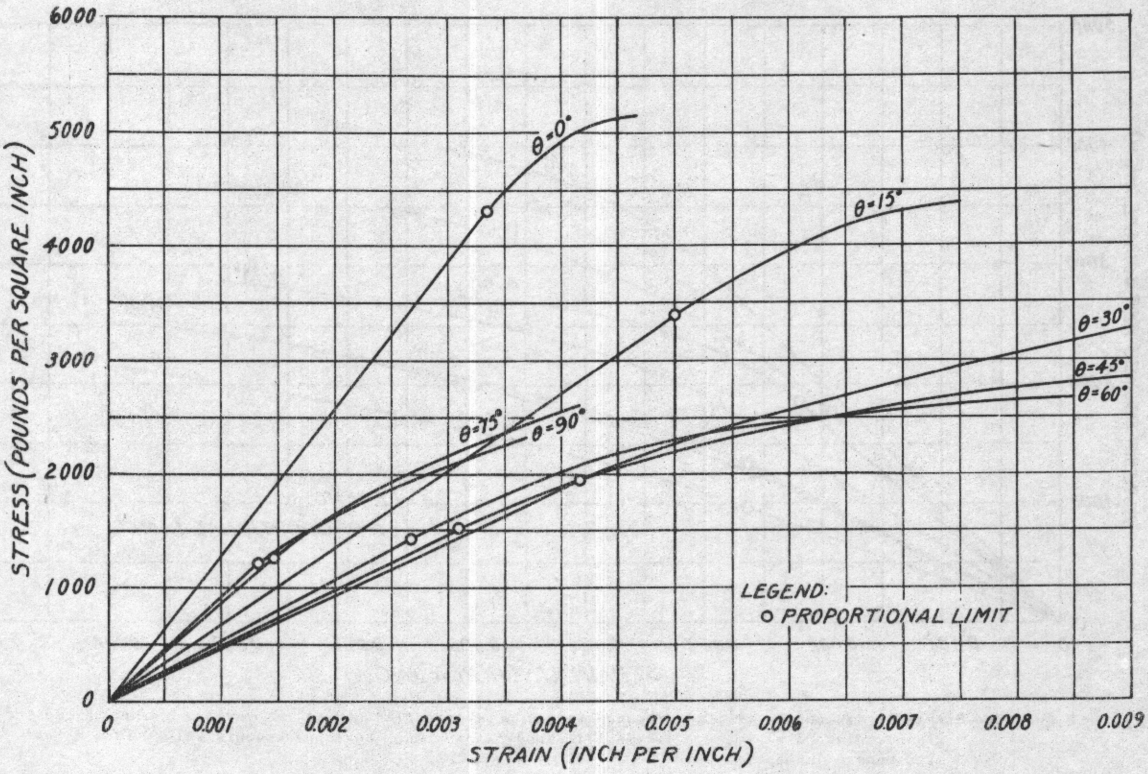

Figure 6.--Stress-strain curves from compression tests on yellowpoplar plywood at various angles to the face grain. Plywood was made of three 1/16-inch plies. Each curve represents values from 4 tests on specimens 6 inches in width.

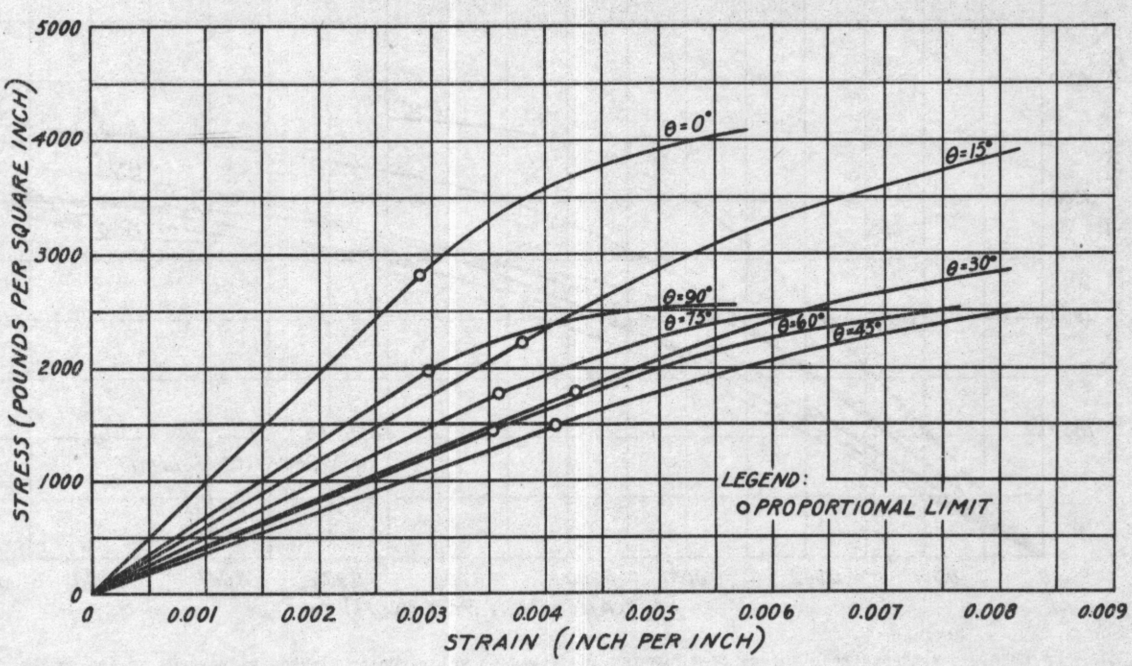

Figure 7.--Stress-strain curves from compression tests on yellowpoplar plywood at various angles to the face grain. Plywood was made of five 1/16-inch plies. Each curve represents values from 4 tests on specimens 6 inches in width.

Z M 50778 F

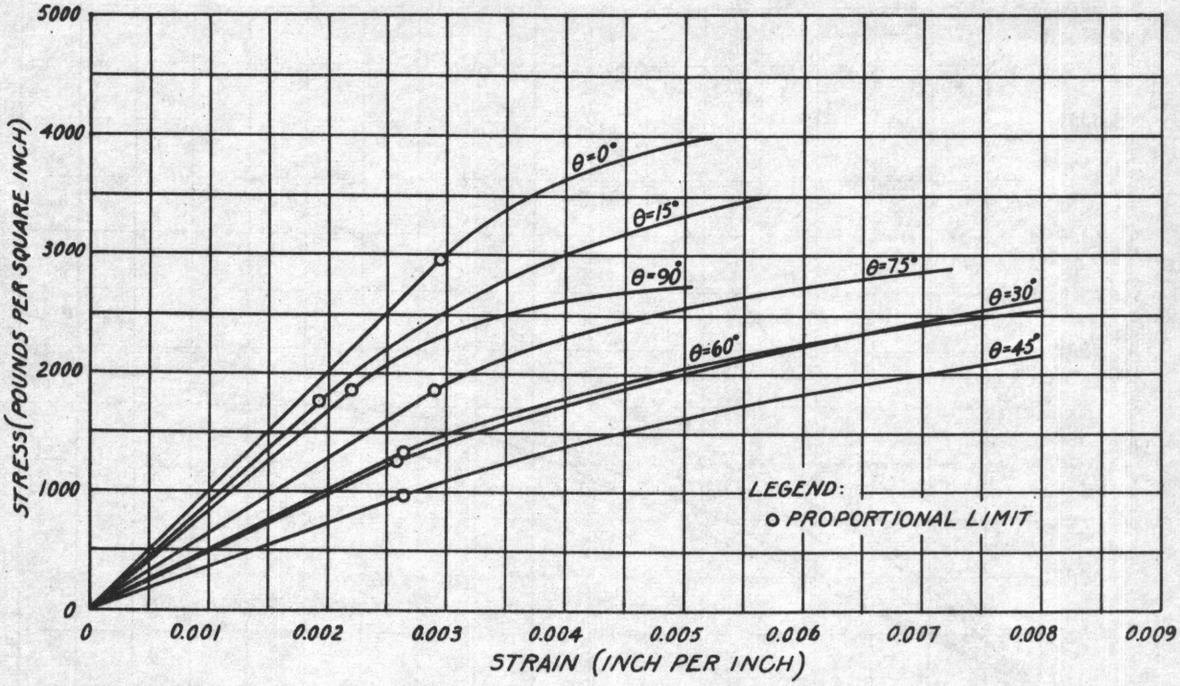

Figure 8.--Stress-strain curves from compression tests on yellowpoplar plywood at various angles to the face grain. Plywood was made of seven 1/16-inch plies. Each curve represents values from 4 tests on specimens 6 inches in width.

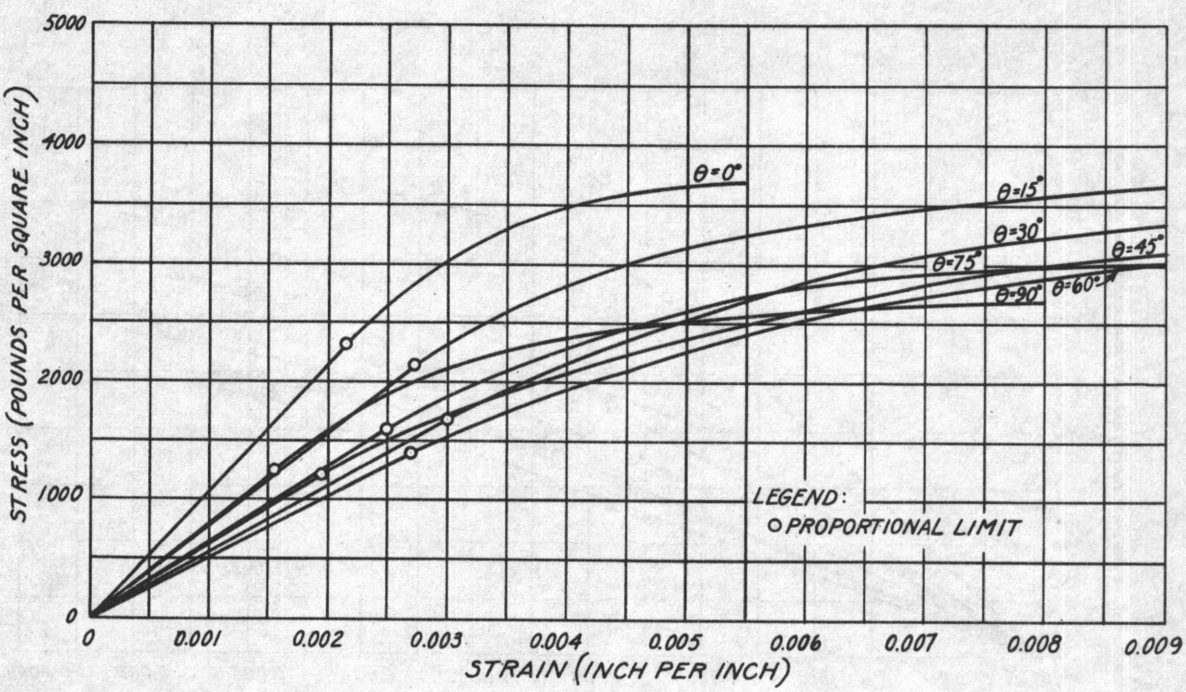

Figure 9.--Stress-strain curves from compression tests on yellowpoplar plywood at various angles to the face grain. Plywood was made of five 1/32-inch plies. The curve for $\theta = 0^\circ$ represents values from 12 tests, each of the remaining curves represent values from 4 tests on specimens 6 inches in width.

Z M 50779 F

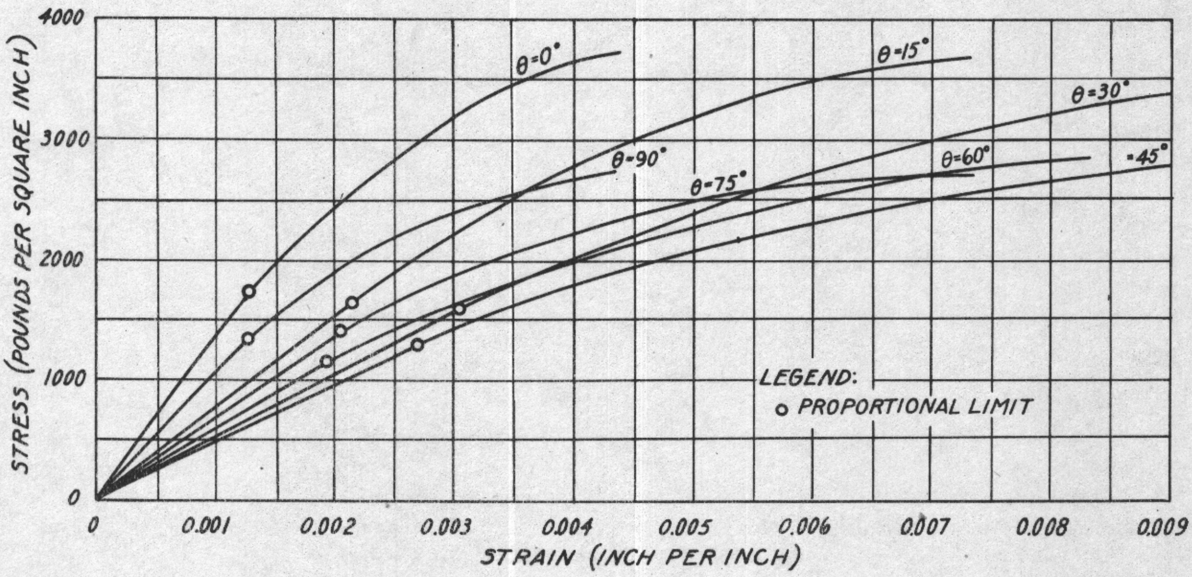

Figure 10.--Stress-strain curves from compression tests on yellowpoplar plywood at various angles to the face grain. Plywood was made of seven 1/32-inch plies. The curve for $\theta = 0°$ represents values from 12 tests, each of the remaining curves represent values from 4 tests. Specimens were 6 inches in width.

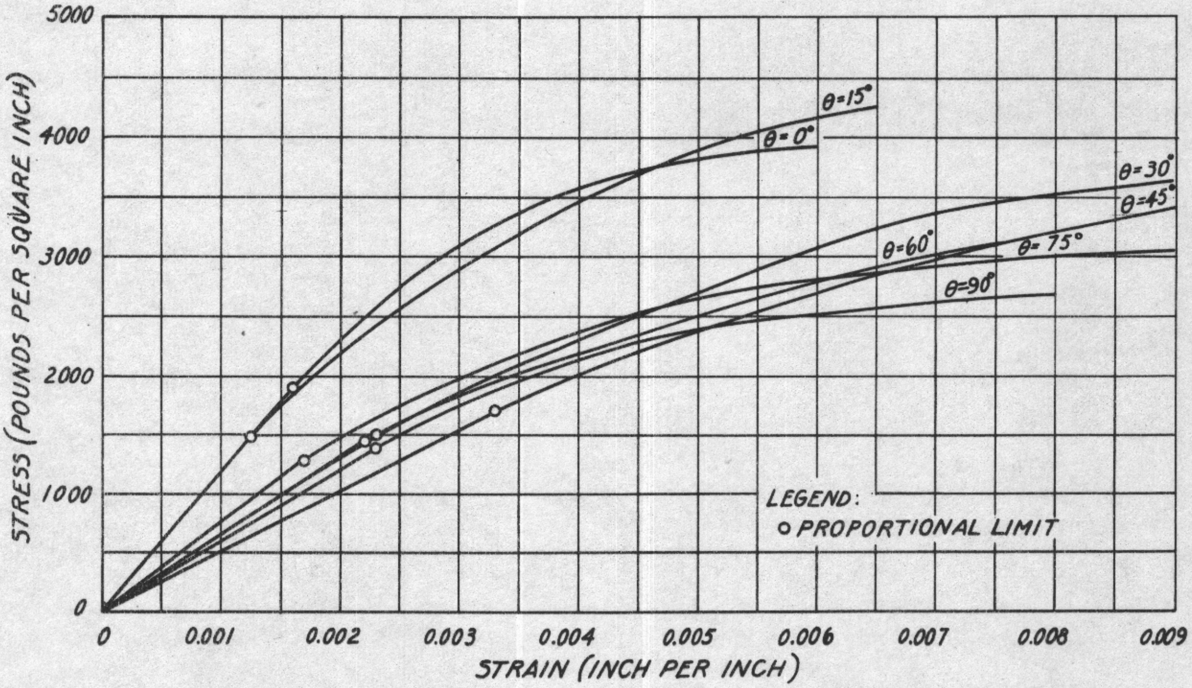

Figure 11.--Stress-strain curves from compression tests on yellowpoplar plywood at various angles to the face grain. Plywood was made of nine 1/32-inch plies. The curve for $\theta = 0°$ represents values from 12 tests, each of the remaining curves represent values from 4 tests. Specimens were 6 inches in width.

Z M 50780 F