DURABILITY OF LOW-DENSITY SANDWICH PANELS OF THE AIRCRAFT TYPE AS DETERMINED BY LABORATORY TESTS AND EXPOSURE TO WEATHER

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In Cooperation with the University of Wisconsin

DURABILITY OF LOW-DENSITY SANDWICH PANELS OF THE AIRCRAFT TYPE AS DETERMINED BY LABORATORY TESTS AND EXPOSURE TO WEATHER[1,2]

PART IV

By

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Summary

Three sandwich constructions, consisting of a facing of glass fabric laminate of 112 fabric, 114 finish, (this finish does not impart the best resistance to moisture) on an alkyd-isocyanate foam core, waffle-type glass-fiber core, and a resin-treated paper honeycomb, were tested for durability to high temperature, high humidity, water immersion, and outdoor weathering.

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[2] This report covers the fourth part of a continuing study, the first, second, and third parts of which were covered in Forest Products Laboratory Reports Nos. 1573, 1573-A, and 1573-B of the same title.

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The effects of these exposures on strength and dimensional stability were ascertained. Results of these tests show that all three constructions withstood most of these exposures without losing more than half of their initial strength, and with very little change in dimensional stability.

Introduction

The purpose of these studies was to obtain information on the durability of low-density core materials and sandwich constructions of the aircraft type. This information is needed because of the increasing use of sandwich-type constructions in high-speed aircraft. The work was done at the U. S. Forest Products Laboratory under the joint direction of the Air Materiel Command, Department of the Air Force; the Bureau of Aeronautics, Navy Department; and the Civil Aeronautics Administration.

The results of various tests on three types of low-density sandwich panels having facings of glass fabric laminates and cores of alkyd-isocyanate foam, cores of glass fibers and resin formed to a waffle shape, and honeycomb cores of resin-treated paper are presented in this report. Results of similar tests on three core materials, balsa, cellular cellulose acetate, and cellular hard rubber, and on sandwich constructions using these cores with facings of aluminum, glass fabric laminates, and plywood are presented in Part I (U. s. Forest Products Laboratory Report 1573).

Specimens of the same core and facing materials as in Part I but involving different adhesives and resins were tested and reported in Part II (U. S. Forest Products Laboratory Report 1573-A). Tests on four honeycomb core materials constructed of paper, cotton cloth, glass cloth, and aluminum foil, and cambinations of these cores with the above three facing materials are presented in Part III (U. S. Forest Products Laboratory Report 1573-B).

The sandwich combinations tested for this report were subjected to the following exposures:

1. Water immersion.
2. High temperature.
3. High humidity.
4. Outdoor weathering.

Fabrication and Description of Panels

Two sandwich panels approximately 30 by 36 inches in size were fabricated of each core and glass fabric laminate facings consisting of eight plies of glass cloth 112, finish 114, impregnated with a low-viscosity polyester resin.

Panels Having Waffle-Type Glass-Resin Core

"he waffle core (Code No. 31) (see fig. 1) used to make 2 panels was 0.310 inch thick. This core is made of chopped glass fibers and resin-formed to a waffle shape. The panels were assembled by laying the glass cloth for one facing, containing about 48 percent of resin, on a cellophane-covered flat metal mold. The blocks of core material were then given 1 roller coat of resin on each side, laid on the impregnated cloth, and covered with impregnated cloth for the other facing. After covering the top facing with a sheet of cellophane, the panel was allowed to stand for about 2 hours to give the resin time to diffuse through the individual sheets of glass cloth. The panel and its mold were then put in a rubber bag and cured in a heated chamber at about 250° F. for 1 hour under vacuum-induced air pressure of about 14 pounds per square inch in the rubber bag.

Panels Having Alkyd-Isocyanate Foam Core

The 2 panels with alkyd-isocyanate foam cores (fig. 2) were obtained from a commercial source and were described by the manufacturer as follows: The facings were void-free premolded glass-fabric laminates made using a low-viscosity polyester resin. The facings were restrained in a rigid flat mold allowing for a half-inch spacing between the facings. The alkyd-isocyanate foamed-in-place material (Code No. 37) consisted of an alkyd resin, meta-tolylene diisocyanate (TDI), and aerosol OT pellets. Ten percent more TDI than was theoretically required to react completely with the alkyd resin was used in the formulation. The formulation also contained 11 percent (based on weight of the alkyd resin) of a 10 percent aerosol-acetone solution. After the foam was poured into the mold, each panel was cured for about 30 minutes at 130° F., and 2 to 2-1/2 hours at 240° to 245° F.

Panels Having Paper-Honeycomb Core

Panels with paper-honeycomb cores (fig. 3) were also obtained from a commercial source. The core (Code No. 40) was impregnated with a polyester resin. The cell size was approximately 1/4 inch and of somewhat irregular hexagonal shape. The overall thickness of the sandwich was approximately 1/2 inch.

Preparation of Test Specimens

From each sandwich construction five types of specimens were prepared for test; small panels each about 5-1/2 by 6 inches; flatwise tension specimens; flatwise compression specimens; edgewise compression specimens; and large weathering panels each approximately 16 by 25 inches.

Two 5-1/2- by 6-inch panels were prepared for each of the various indoor exposures with unprotected edges and two with protected edges. Two 2- by 3-inch edgewise compression and two 2- by 2-inch flatwise campression specimens were cut from each small 5-1/2- by 6-inch exposure panel after it had received the specified indoor exposure.

Six 1-inch-square flatwise tension specimens were prepared for each exposure condition except weathering. In addition, 10 tension specimens, 5 flatwise compression specimens, and 5 edgewise compression specimens were prepared for tests at 75° F. and 64 percent relative humidity which tests were to serve as a standard for comparison with tests of specimens exposed to the various indoor and outdoor exposures.

The specimens were selected for each individual indoor exposure by a sampling method, representing as many different portions of each panel as possible. This was done to determine the average properties of each panel, and to reduce the effect of a possible variation within any one panel.

Two panels of each combination, approximately 16 by 25 inches, were used to determine the effect of weather or distortion, such as cupping and twisting. One was exposed with unprotected edges, while the other had three of the four edges sealed with waterproof fabric tape and 2 coats of aluminized varnish. (The varnish consisted of 1-1/2 pounds of aluminum paste, fine aircraft-use grade, in 1 gallon of phenolic-resin varnish conforming to Specification AN-V-26.) The panels for outdoor weathering were mounted on exposure rack6 with the unprotected edge of the panel downward.

Twenty flatwise tension Specimens, 5 edgewise compression specimens, and 5 flatwise compression specimens were cut from each of the large weathering panels after weathering for 1 year and reconditioning to constant weight at 75° F. and 64 percent relative humidity.

Treatment of Specimens

All specimens were first conditioned to constant weight at 75° F. and 65 percent relative humidity and then divided into groups for the following exposures :

1. Controls -- maintained and tested at 75° F. and 65 percent relative humidity.

2. Water immersion
   a. Immersion in running tap water, approximately 55° F., for 24 hours; specimens tested wet.

   b. Immersion in running tap water for 40 days; specimens tested wet.

   c. Immersion in running tap water for 40 days; specimens tested after being reconditioned to constant weight at 75° F. and 65 percent relative humidity.

3. High temperature
   a. Placed for 240 hours in an insulated box maintained at 200° F., dry heat; specimens tested hot.

   b. Maintained for 240 hours at 200° F., dry heat; specimens tested after being reconditioned to constant weight at 75° F. and 65 percent relative humidity.

4. High humidity
   a. Placed in a room maintained at a temperature of 80° F. and 97 percent relative humidity until weight was constant; specimens tested damp.

   b. Brought to constant weight at 80° F. and 97 percent relative humidity; specimens tested after being reconditioned to constant weight at 75° F. and 65 percent relative humidity.

5. Weathering
   These specimens were placed on racks and fastened at 3 points with a brass spring beneath each point and a screw hook above. This arrangement allowed for free movement and easy removal of specimens. On June 11, 1951, the panels were set up facing south at an angle of 45° from the vertical position.

Description of Test Procedures

In general, the test methods conformed to, or were similar to, those described in Forest Products Laboratory Report No. 1556, "Methods for Conducting Mechanical Tests of Sandwich Construction at Normal Temperatures," revised October 1948.

All tests except those which required a temperature of 200° F. were conducted in a room in which the temperature was maintained at 75° F. and relative humidity at 65 percent. Dimensions and weights of specimens were taken immediately before test. Normal testing techniques or practices were supplemented with the following variations:

1. Specimens that had been immersed for 1 and 40 days were blotted to remove free water, then weighed, measured, and tested immediately.

2. A small insulated plywood box, housing the specimen and necessary apparatus, was used to conduct the tests at 200° F. The box was equipped with a double-glazed door and windows, electric heating coils, thermostat, and a fan for air circulation.

3. The specimens exposed to high relative humidity (97 percent) were transported from the humidity chamber in a closed container (a few at a time) to prevent a change in their moisture content during the interval of time required for weighing, measuring, and awaiting test.

The large panels exposed to outdoor weathering were weighed and measured for warping immediately after removal from the test racks on the Laboratory roof at the end of 3, 6, and 12 months' exposure. During the winter snow or ice was removed from panels with a hand scraper before they were measured. These measurements were taken on one side of each panel with a special measuring bar and dial gage (fig. 4). Deflection readings were taken along each of the four edges and along the diagonals. The deflection dial, which was mounted in the center of the measuring bar, was calibrated in 0.001-inch increments. The gage was placed on the panel in 6 different positions, along each of the edges and along 2 diagonals; and the measurement to the face of the panel at the center of each span was recorded. Measurements concave upwards were given a positive value; those convex upwards were given a negative value. The amount of cupping was determined from the average change in deformation along the edges of the 4 sides of each panel. The amount of twist was determined from the change in the difference in deflection across the 2 diagonals of each panel.

Weights and measurements of thickness were obtained from both the large and small weathered panels after they had been brought indoors.

Presentation of Data

The percentage increases in weight and thickness of the 5-1/2- by 6-inch specimens exposed to 4 controlled conditions with and without protected edges are listed in table 1. These values were obtained by dividing the change in weight and thickness by the original weight and thickness.

Table 2 presents the data obtained from the 16- by 25-inch specimens after 3, 6, and 12 months of exposure outdoors. The information tabulated includes their percentage change in weight, their actual change in thickness, and the amount of cupping and twist panels with and without protected edges underwent,

The data on effects of various exposure conditions on the tensile strength of the various sandwich constructions after reconditioning to 75° F. and 64 percent relative humidity are presented in table 3. The values for specimens exposed to various indoor conditions are for panels with w-protected edges, and the values for specimens exposed outdoors are for panels both with and without protected edges. The strength value presented is given as a percentage of the strength before exposure (control strength). The control values are an average of 10 tests, the exposure values an average of 6 teats, and the outdoor exposures an average of 20 tests. Minimum and maximum tensile strength values are also included in the table for each exposure condition.

Data on edgewise compressive strength are given in table 4 for panels with and without protected edges.

Data on flatwise compressive strength are given in table 5 for specimens with and without protective edges.

A summary of the weather during the period of outdoor exposure, June 1, 1951, to July 8, 1952, is presented in table 6.

Results and Discussion

Effect of Controlled Exposures on Weight and Thickness

The effect of water soaking, high temperature, and high humidity on the thickness (as shown in table 1) of the three sandwich types tested was slight. The greatest change in thickness for all exposures and sandwich types amounted to 3.2 percent, and the majority of the specimens expanded or contracted less than 1 percent considering the changes in thickness due to all exposures, sandwich specimens having cores of alkyd-isocyanate foam showed the greatest variation in thickness.

The effect of the controlled atmospheric conditions on changes in weight (table 1) of the three sandwich constructions was very slight, except for the sandwich constructions containing the waffle-type core that were soaked in water. This may be attributed to the difference in core construction in that the waffle-type core is the only one of the three sandwich constructions tested in which the core is not composed of distinct separate cells but provides continuous passages throughout the sandwich, which therefore can act as a large reservoir for conducting and holding water.

Effect of Water Immersion on Strength

In general, water soaking for 24 hours did not adversely affect the flatwise compressive strength of the three sandwich constructions permanently although it did appreciably lower this property after 40 days of immersion. Strength values for cores of alkyd-isocyanate foam and waffle were about 15 percent lower, and those of paper core about 25 percent lower, than the initial values for specimens tested at 75° F. and 64 percent relative humidity. These reductions were not permanent, however, as the panels regained their initial strength after being returned to normal conditions at 75° F. and 64 percent relative humidity (see table 5).

The effect of water soaking on core tensile strength (table 3) is difficult to evaluate because few of the specimens failed in the core, most of them failing in the bond between the core and facing or the bond between facing and load block. For this reason it is only possible to consider the effect of soaking on the sandwich as a whole. The only thing that may be reported with certainty is that soaking for an additional 39 days beyond the initial 24 hours' had a decided weakening effect on resistance to flatwise tension. The average tensile strength of alkyd-isocyanate foam sandwich after 40 days' soaking was 62 percent of the strength remaining after 24 hours' soaking.

The waffle sandwich, after 40 days' soaking, retained 74 percent of the strength it had after 24 hours' soaking. The paper honeycomb sandwich, after 40 days' soaking, retained 76 percent of its strength after 24 hours' soaking. Values for these sandwich constructions are given in term of their strength after 24 hours' soaking instead of the control strength because their average tensile strength after 24 hours' soaking was actually higher than the control strength. The reason for the increase in strength due to 24 hours' soaking is not positively known.

The edgewise compressive strength (table 4) of sandwich with cores of alkyd-isocyanate foam and paper honeycomb was not adversely affected by immersion in water. The sandwich specimens with waffle-type core appear to have lost 15 to 35 percent of their initial strength, and this was not recoverable upon reconditioning to 75° F. and 65 percent relative humidity.

Effect of High Temperature Exposure on Strength

The exposure of the three sandwich constructions to 200° F. for 10 days resulted in reduced strength values at 200" F. for all combinations of materials tested, except for the tensile strength of the paper honeycomb-core and alkyd-isocyanate foam sandwiches. The tensile strength of the sandwich with paper-honeycomb core tested after 10 days at 200° F. was 156 percent of its initial strength before it was heated. When cooled to room temperature, the paper-honeycomb-core sandwich increased in strength to 168 percent of the strength of unexposed specimens. The tensile strength of sandwich with alkyd-isocyanate foam core tested after 10 days at 200° F. was 107 percent of the initial strength before heating. After reconditioning to room temperature, the strength of foam sandwich was reduced to 85 percent of the strength of unexposed specimens. The tensile strength of the sandwich with waffle-type core tested after 10 days at 200° F. was 69 percent of its initial strength. After being reconditioned, its strength was 79 percent that of unexposed specimens.

The flatwise compression strength of all three constructions was reduced by heating at 200° F. for 10 days. There was no permanent loss in strength when the panels were reconditioned to room temperature, except that some of the alkyd-isocyanate foam core split upon reconditioning to room temperature. The losses in strength at 200° F. amounted to 28 and 17 percent for the foam core, 54 and 60 percent for the waffle core, and 19 and 26 percent for the paper-honeycomb core, depending on whether the edges of the exposure panel were protected or unprotected during exposure.

The edgewise compression strength of all three constructions was reduced by exposure to 200° F. Strength losses after 10 days at 200° F. were 14 and 23 percent for paper honeycomb core, 74 and 74 percent for waffle core, and 67 and 65 percent for alkyd-isocyanate core, depending on whether the edges of the exposed panel were protected or unprotected. These losses were recovered, however, for sandwich specimens having waffle and paper core after reconditioning to 75° F. and 64 percent relative humidity.

Effect of High Humidity on Strength

The effect of high humidity on the strength of sandwich made of paper honeycomb and waffle core was roughly equivalent to the strength lost during the 40-day water immersion. The edgewise and flatwise compression strength of sandwich having an alkyd-isocyanate foam core was reduced more by the high humidity than by 40 days of immersion in water.

Effect of Outdoor Weathering on Weight, Thickness, Flatness, and Strength

A summary of the weather conditions for the period of exposure is presented in table 6. The effects of weathering on the dimensional stability of the panels tested is presented in table 2. Nons of the materials tested underwent excessive dimensional changes when the panel measurements were taken at the end of 3, 6, and 12 months of exposure. In addition, the strength tests on specimens cut from panels exposed to the weather for 1 year and reconditioned to 75° F. and 64 percent relative humidity showed that there were no reductions in strength of paper-honeycomb-core sandwhich as a result of 1 year's outdoor exposure.

The weathering exposure also had no effect on the edgewise and flatwise compression strength of the sandwich with alkyd-isocyanate foam core. The tensile strength of the foam type sandwich was reduced only 10 percent. All strength properties of the waffle-type sandwich appeared to be reduced by 1 year's exposure to the weather, but none exceeded 31 percent.

Table 1.--Weight and thickness changes of 5-1/2 by 6- by 1/2-inch panels of various sandwich constructions subjected to four controlled exposure conditions. Facings consisted of eight-ply glass cloty 112-114 impregnated with polyester resin.

Type of core	Edge protection[1,2]	Change in weight and thickness by exposure[3] to: 24-hour water immersion		40-day water immersion		40-day water immersion reconditioned		200° F. for 10 days		200° F. for 10 days, reconditioned		97% relative humidity until weight was constant		97% relative humidity until weight was constant, then reconditioned	
		Increase in weight	Increase in thickness	Increase in weight	Increase in thickness	Increase in weight	Increase in thickness	Increase in weight	Increase in thickness	Increase in weight	Increase in thickness	Increase in weight	Increase in thickness	Increase in weight	Increase in thickness
		Percent	Percent	Percent	Percent	Percent	Percent	Percent	Percent	Percent	Percent	Percent	Percent	Percent	Percent
Alkyd isocyanate foam	(1)	0.49	0.000	2.12	0.00	0.73	0.18	-2.65	-0.36	-2.34	-3.20	1.46	1.57	1.30	1.43
	(2)	1.43	-.35	1.87	.18	1.54	.00	-2.78	-.54	-2.42	+1.43	1.53	1.05	1.44	1.78
Waffle	(1)	9.8	.30	[4]37.10	.00	25.30	-.30	-1.09	.29	-1.05	-.29	1.31	-.30	1.45	.30
	(2)	5.06	.30	8.08	.00	7.96	-.30	-1.25	1.81	-1.04	.00	1.04	1.20	.89	.00
Paper honeycomb	(1)	.30	-.40	1.02	.00	.99	-.20	-1.82	-.20	-1.70	.00	1.96	.20	2.16	.20
	(2)	1.59	-.20	3.84	.00	3.46	.00	-1.73	-.60	-1.56	.00	2.16	.20	2.26	.40

[1]Three edges of exposed panel sealed with waterproof tape.

[2]Edges of exposed panel unprotected.

[3]All specimens originally conditioned to 75° F., 64 percent relative humidity.

[4]Free water present in exposure panel.

Table 2.--Effect of exposure to weather on weight, thickness and flatness of 16- by 25- by 1/2-inch panels of various sandwich constructions. Facings consisted of eight-ply glass cloth 112-114 impregnated with polyester resin.

Type of core	Edge protection[1, 2]	3 months: Increase in weight	3 months: Increase in thickness	3 months: Change in warp: Cupping[3]	3 months: Change in warp: Twist[4]	6 months: Increase in weight	6 months: Increase in thickness	6 months: Change in warp: Cupping[3]	6 months: Change in warp: Twist[4]	12 months: Increase in weight	12 months: Increase in thickness	12 months: Change in warp: Cupping[3]	12 months: Change in warp: Twist[4]
		Percent	Percent	Inches	Inches	Percent	Percent	Inches	Inches	Percent	Percent	Inches	Inches
Alkyd isocyanate foam	(1)	0.04	1.61	0.000	0.011	0.05	1.25	-0.001	0.000	0.04	1.25	-0.005	0.005
	(2)	.02	1.61	.003	.133	.04	1.61	.006	.143	.01	1.07	.004	.072
Waffle	(1)	-.02	.00	-.003	.040	.03	.29	.000	.061	.01	.00	-.004	.017
	(2)	-.03	.00	.014	.064	.01	.29	.023	.066	.00	-.29	.016	.039
Paper honeycomb	(1)	.01	1.00	-.038	.133	.06	.79	-.041	.142	.02	.60	-.039	.134
	(2)	.03	.40	-.018	.208	.08	.20	-.012	.222	.03	.40	.004	.169

[1] Three of four edges of exposure panel sealed with waterproof tape.

[2] Edges of exposure panel unprotected.

[3] Average of four edge measurements. Minus sign indicates concave upward.

[4] Difference between two diagonal deflection measurements.

Table 3.--Tensile strength of various sandwich constructions subjected to controlled exposure conditiona and to outdoor weathering. Facings consisted of eight-ply glass cloty 112-114 impregnated with polyester resin.

Type of core	Edge protection[1]	Range	Controls[2]		24-hour water immersion[3]		40-day water immersion[2]		40-day water immersion reconditioned[3]		200° F. for 10 days[2]		200° F. for 10 days reconditioned[2]		Equilibrium at 97 percent relative humidity[2]		97 percent relative humidity reconditioned[2]		Exposed to weather[4] Edges unprotected, reconditioned		Exposed to weather[4] Edges protected, reconditioned	
			Average strength	Core failure	Percent average control strength	Core failure	Percent average control strength	Core failure	Percent average control strength	Core failure	Percent average control strength	Core failure	Percent average control strength	Core failure	Percent average control strength	Core failure	Percent average control strength	Core failure	Percent average control strength	Core failure	Percent average control strength	Core failure
			P.s.i.	Percent		Percent		Percent		Percent		Percent		Percent		Percent		Percent		Percent		Percent
Alkyd isocyanate foam	(1)	Max.	--	--	155	100	91	--	145	100	118	100	108	0	98	--	146	100	142	90	115	90
		Min.	--	--	118	100	81	--	100	80	91	100	68	20	71	--	108	85	81	100	68	100
		Av.	148	7	137	100	85	--	132	93	107	83	85	5	83	--	129	71	117	75	90	10
Waffle	(1)	Max.	--	--	106	0	98	--	116	10	85	100	117	0	85	--	64	0	104	100	120	0
		Min.	--	--	57	0	41	--	80	5	55	100	57	0	57	--	37	0	51	0	48	0
		Av.	183	100	83	0	61	--	90	6	69	100	79	0	72	--	52	0	73	0	84	0
Paper honeycomb	(1)	Max.	--	--	182	40	136	--	160	0	190	10	228	0	131	--	146	0	137	0	167	0
		Min.	--	--	122	0	84	--	140	0	133	50	98	0	57	--	79	0	58	0	79	0
		Av.	184	0	151	7	115	--	149	0	156	32	168	7	100	--	124	0	98	0	125	6

[1] Edges of exposed specimen not protected.

[2] Controls - average of 10 tests conducted after conditioning to constant weight at 75° F., 65 percent relative humidity.

[3] Exposure tests - average of 6 tests.

[4] Outdoor exposure tests - average of 20 tests.

Table 4.--Edgewise compressive strength of various sandwich constructions subjected to four controlled exposures and to outdoor weathering. Facings consisted of eight-ply glass cloth 112-114 impregnated with polyester resin.

Type of core	Edge protection[1,2]	Controls[3] Maximum facing stress High	Low	Average	Effect on strength of exposure to-- 24-hour water immersion[4]	40-day water immersion[4]	40-day water immersion reconditioned[4]	200° F. for 10 days[4]	200° F. for 10 days reconditioned[4]	Equilibrium at 97 percent relative humidity[4]	Equilibrium at 97 percent relative humidity reconditioned[4]	Exposed to weather reconditioned[3]
					Percent average control strength	Percent average control strength	Percent average control strength	Percent average control strength	Percent average control strength	Percent average control strength	Percent average control strength	Percent average control strength
		P.s.i.	P.s.i.	P.s.i.								
Alkyd isocyanate foam	(1)	31,470	16,220	26,600	123	116	135	33	42	80	108	100
	(2)	31,470	16,220	26,600	117	103	124	35	0[5]	82	98	100
Waffle	(1)	24,780	21,840	23,330	65	63	65	26	71	58	79	74
	(2)	24,780	21,840	23,330	66	50	85	26	58	68	74	69
Paper honeycomb	(1)	16,080	10,280	14,040	144	94	120	86	160	95	130	143
	(2)	16,080	10,280	14,040	128	103	138	77	142	105	133	138

[1]Three of four edges of exposed panel sealed with waterproof tape.

[2]Edges of exposed panel not protected.

[3]Average of 5 tests conducted after conditioning to constant weight at 75° F., 65 percent relative humidity.

[4]Average of 2 tests.

[5]Core split during heating.

Table 5.--Flatwise compressive strength of various sandwich constructions subjected to four controlled exposures and to outdoor weathering. Facings consisted of eight-ply glass cloth 112-114 impregnated with polyester resin.

Type of core	Edge protection[1,2]	Controls[3] Maximum stress High	Controls[3] Maximum stress Low	Controls[3] Maximum stress Average	Effect on strength[6] of exposure to-- 24-hour water immersion[4]	40-day water immersion[4]	40-day water immersion reconditioned[4]	200° F. for 10 days[4]	200° F. for 10 days reconditioned[4]	Equilibrium at 97 percent relative humidity[4]	Equilibrium at 97 percent relative humidity reconditioned[4]	Exposed to weather reconditioned[3]
					Percent average control strength	Percent average control strength	Percent average control strength	Percent average control strength	Percent average control strength	Percent average control strength	Percent average control strength	Percent average control strength
		P.s.i.	P.s.i.	P.s.i.								
Alkyd isocyanate foam	(1)	295	242	263	104	89	110	72	94	68	103	104
	(2)	295	242	263	111	84	124	83	(5)	59	91	103
Waffle	(1)	874	487	678	102	81	120	46	117	75	126	99
	(2)	874	487	678	84	86	108	40	124	87	117	90
Paper honeycomb	(1)	527	492	512	106	77	98	81	121	79	87	100
	(2)	527	492	512	102	68	99	74	124	67	104	102

[1] Three of four edges of exposed panel sealed with waterproof tape.

[2] Edges of exposed panel not protected.

[3] Average of five tests conducted after conditioning to constant weight at 75° F., 65 percent relative humidity.

[4] Average of two tests.

[5] Core split during heating.

[6] Calculated at 20 percent compression.

Table 6.--Summary of weather conditions June 1, 1951, to August 1, 1952[1]

Month and year	Air temperature				Average relative humidity	Precipitation		Average daily sunshine[2]	
	Maximum	Minimum	Mean	Normal mean		Total	Normal	Mean	Normal
	(°F.)	(°F.)	(°F.)	(°F.)	Percent	Inches	Inches	Percent	Percent
June 1951	84	45	64.9	67.2	71	3.21	3.76	54	63
July	89	54	71.3	72.1	71	3.01	3.88	72	70
August	84	52	67.4	69.8	78	3.74	3.21	56	64
September	84	36	58.6	61.4	76	2.93	3.72	61	57
October	82	27	50.8	49.3	78	5.48	2.43	52	52
November	60	8	29.6	34.2	71	2.05	1.78	52	39
December	61	-12	21.4	22.4	71	1.79	1.63	37	36
January 1952	49	-13	21.4	16.7	76	2.24	1.38	41	43
February	47	8	27.9	19.1	77	.84	1.50	45	48
March	59	4	29.5	30.6	76	3.09	2.07	58	51
April	88	28	50.5	45.4	62	1.37	2.77	63	53
May	89	39	58.4	57.6	68	4.39	3.85	47	57
June	93	50	70.5	67.2	73	4.75	3.76	60	63
July	93	57	74.8	72.1	68	6.94	3.88	74	70

[1] Data from official U. S. Weather Bureau Records for Madison, Wisconsin.

[2] Percentage of total possible.

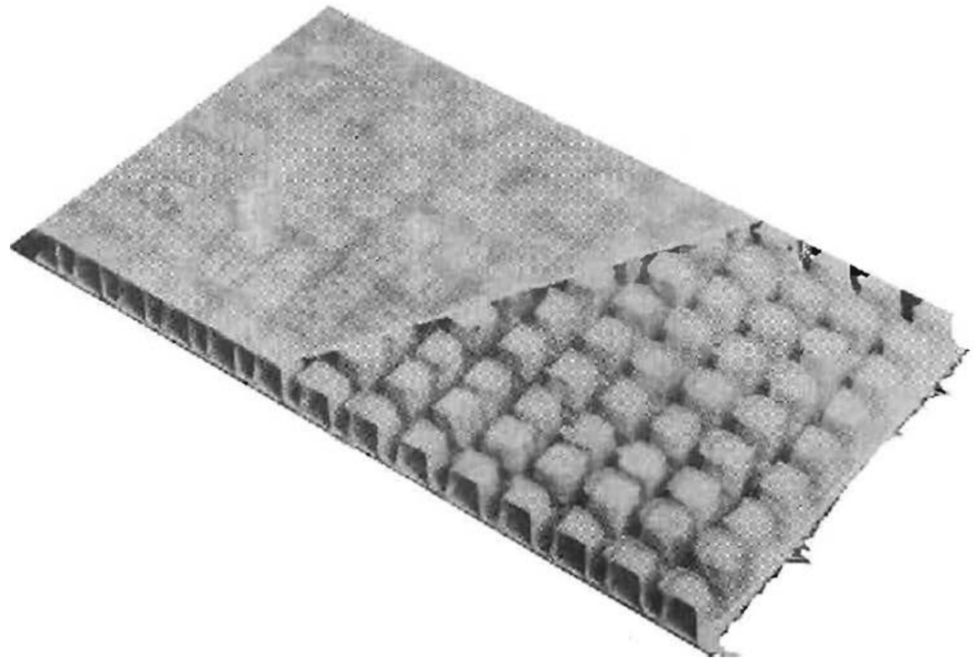

Figure 1.--Photograph of plastic sandwich having waffle-type core and glass cloth facing. One facing partially removed to show core structure.

Z M 97290 F

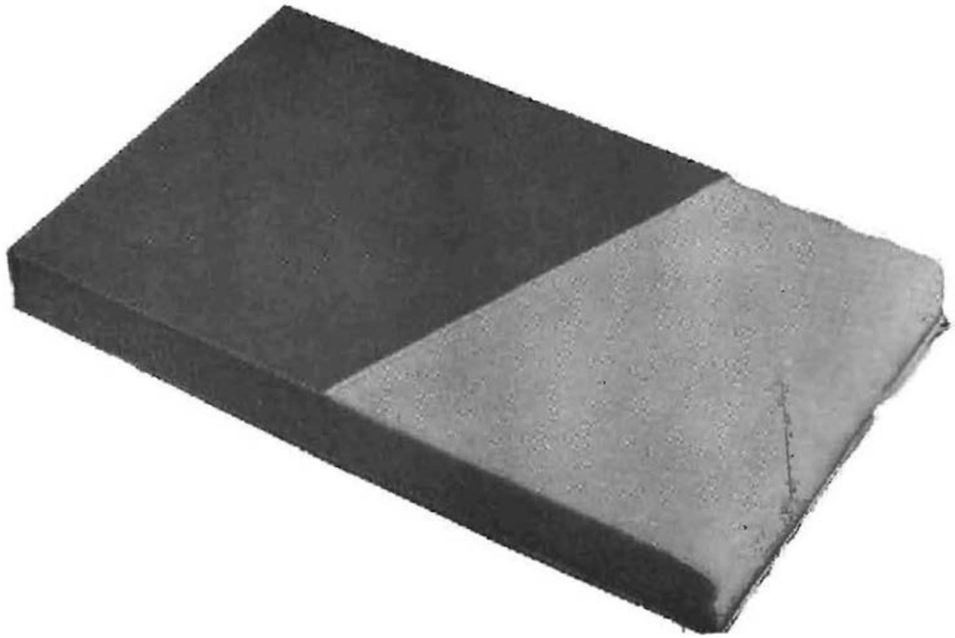

Figure 2.--Photograph of plastic sandwich having alkyd-isocyanate foam core and glass cloth facings. Facing partially removed to show core structure.

Z M 97289 F

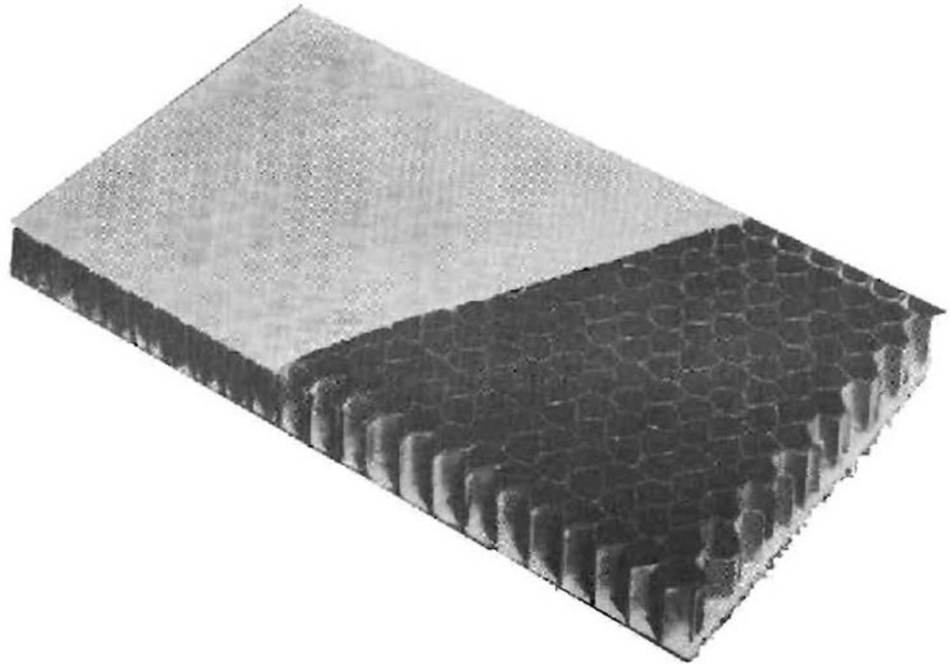

Figure 3.--Photograph of plastic sandwich having paper honeycomb core and glass cloth facings. One facing partially removed to show core structure.

Z M 97288 F

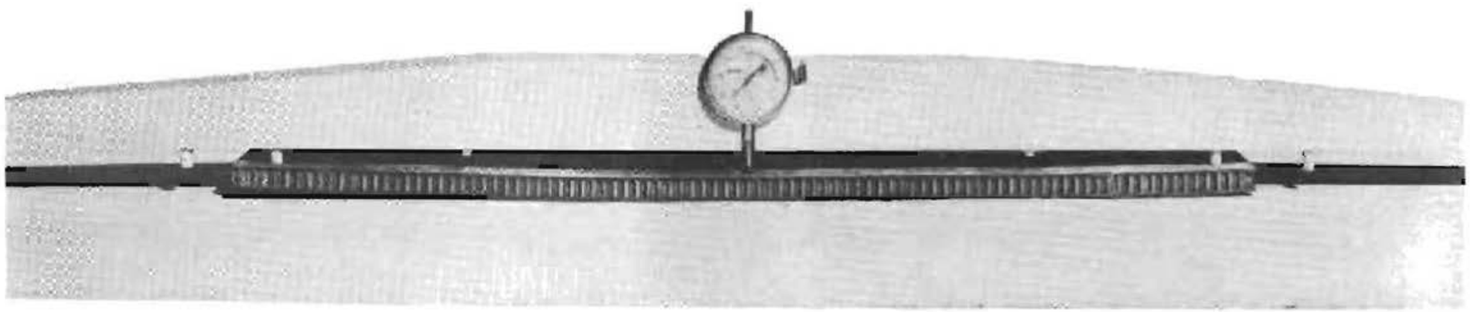

Figure 4.--Warp-measuring device shown in position on the long side of a weathering panel.

Z M 80271 F