COMPRESSIVE AND SHEAR PROPERTIES OF TWO CONFIGURATIONS OF SANDWICH CORES OF CORRUGATED FOIL

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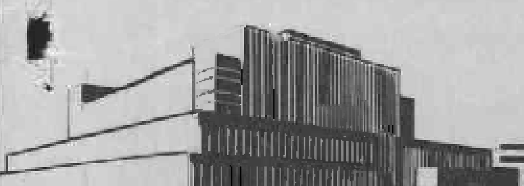

FOREST PRODUCTS LABORATORY
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UNITED STATES DEPARTMENT OF AGRICULTURE
FOREST SERVICE
In Cooperation with the University of Wisconsin

COMPRESSIVE AND SHEAR PROPERTIES OF TWO CONFIGURATIONS[1] OF SANDWICH CORES OF CORRUGATED FOIL

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Summary

Compressive and shear properties were determined for two configurations of sandwich cores of corrugated aluminum foil. The corrugated foil was assembled either with the corrugation flutes parallel, to form the usual honeycomb core with hexagonal cells, or with the corrugation flutes crossbanded and cut so that the corrugation flutes were at 45° to the sandwich facing.

Compressive and shear strength values were lower for the crossbanded core than for the honeycomb core.

Introduction

Lightweight structural panels suitable for use in modern flight vehicles can be produced by bonding facings of a thin strong material to a core of thick low-density material. The need for suitable core material has resulted in the production of honeycomb-like cores of thin sheet materials. Sandwich panels made with cores of this type and the successful application of these panels in structures requiring high strength-to-weight ratios have demonstrated its practicability.

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

This report presents the compressive and shear properties of a core of corrugated aluminum foil where the foils are crossbanded and of a honeycomb core of the same foil. Figure 1 shows a sample of sandwich panel with crossbanded core. In a sandwich panel with crossbanded core, fluids could be circulated in the spaces between the corrugations. The crossbanded core is also not as easily collapsed as the honeycomb core in directions parallel and perpendicular to core ribbons and therefore may be easier to hold when machining certain shapes.

Description of Materials

Samples of honeycomb and crossbanded core were fabricated from corrugated 0.002-inch-thick foil of 5052-H39 aluminum. The corrugations were 1/8 inch deep and were shaped to form either 1/4-inch hexagonal cells for honeycomb core if bonded with the corrugation flutes parallel or crossbanded core when the corrugations were laid at 90° to each other. Three slices 24 inches square and 2 inches thick and one slice 24 inches square and 1/2 inch thick were received of each type of core.

Core samples were weighed and measured and the core density was computed. Computed core densities were 4.4 pounds per cubic foot for the crossbanded core and 4.2 pounds per cubic foot for the honeycomb core.

Preparation of Specimens

Flatwise compression and shear specimens were cut from the core slices with a high-speed bandsaw. Flatwise compression specimens were 2 by 2 inches in cross section by 1/2 and 2 inches in thickness. The top and bottom of the specimens were dipped in an epoxy resin adhesive that formed a 1/16-inch fillet on the foil edges and prevented the edges from rolling and buckling when the specimens were loaded.

Two sizes of shear specimens were prepared. Specimens 2 inches wide by 6 inches long were cut from the 1/2-inch-thick core slices and specimens 4 inches wide by 24 inches long were cut from the 2-inch-thick core slices. An epoxy resin adhesive was used to bond steel loading plates 1/2 inch thick to cores 1/2 inch thick and plates 1 inch thick to cores 2 inches thick (fig. 2). A thin coating of adhesive was spread on the loading plates and the core specimen was pressed through the adhesive until it contacted the plate. The adhesive was cured at room temperature.

Evaluation Procedure

Flatwise compression specimens were supported on a spherical bearing block resting on the lower platen of a mechanically driven testing machine. A small load was applied to the specimen and the spherical bearing block adjusted by tapping lightly with a small hammer. Four adjustable jacks were then placed under the spherical base to prevent its motion when load was applied to the specimen. The movable loading head of the testing machine was driven at a rate of 0.003 inch per minute until maximum load was reached in 3 to 6 minutes for both the 1/2- and 2-inch-thick specimens. After reaching maximum load, the rate of motion of the movable head was increased to 0.01 inch per minute and the test continued until the specimen was crushed to about 10 percent of its original height. An autographic record of the load versus the testing machine head travel was made during the test, using a differential transformer deflectometer to measure head travel.

To determine the modulus of elasticity of the cores 2 inches thick, the deformation in compression was measured with Marten's mirror compressometers over a 1-inch gage length. Deformations were recorded at equal increments of load until maximum load occurred, and load-deformation curves were plotted from which the initial slope was used to compute the modulus of elasticity.

The arrangement of shear specimens and loading plates is shown in the sketches of figure 2. Shear specimens 1/2 inch thick were loaded in tension and the 2-inch-thick specimens were loaded in compression. Shear specimens that were loaded in tension were mounted in a mechanically driven testing machine. The movable head of the machine was driven at a rate of about 0.015 inch per minute, and the specimens reached maximum load in 3 to 6 minutes. Shear specimens 2 inches thick and loaded in compression were placed between notched blocks, one attached to the upper head of the testing machine and the other resting on a spherical loading base. An initial load of about 200 pounds was applied. The loading plates were then firmly and evenly seated in the notched blocks by tapping the spherical base with a hammer and screw jacks placed under the spherical bearing block to prevent movement of the block during loading. The movable head of the testing machine was driven at a rate of about 0.03 inch per minute and the specimen failed in 3 to 6 minutes. A steel chain was attached at the upper end of the specimen to prevent the heavy specimen from falling when failure occurred.

Presentation and Discussion of Results

Flatwise compressive properties for both the honeycomb and crossbanded cores are presented in table 1. Figure 3 presents average compression stress-strain curves based on data from the specimens 2 inches thick. In flatwise compression, the modulus of elasticity for the crossbanded cores was 81,000 pounds per square inch or about 35 percent of the value (230,000 pounds per square inch) of the honeycomb core. The difference between the two modulus of elasticity values is probably due to the differences in the direction of the applied load relative to the direction of the corrugation flutes in the core. The modulus of elasticity and proportional limit stresses were determined for cores of 2-inch thickness only. The compressive stress at the proportional limit for the crossbanded core was 145 pounds per square inch, or about 50 percent of the value of 300 pounds per square inch for the honeycomb core. Maximum stress in compression for the crossbanded core was 210 pounds per square inch, or about 40 percent of the maximum stress of 535 pounds per square inch for the honeycomb core. Cores 1/2 inch thick were about 4 percent stronger than cores 2 inches thick.

The specimens were crushed to fairly large deformations (10 percent of their thickness) to obtain the shape of the load-deformation curve beyond failure. In order to obtain these data, the distance that the movable head of the testing machine traveled was recorded automatically as the compression specimens were loaded.

Curves for four specimens typical of the data obtained are presented in figure 4. This figure shows that the head travel at the minimum compressive stress after failure was about 0.04 inch regardless of core thickness or core configuration. This appears to be reasonable because failure occurs locally and spreads toward the specimen ends as compression is increased.

Core shear properties parallel to the core ribbon direction (TL) and perpendicular to the core ribbon direction (TW) are presented in table 2. Figures 5 and 6 present typical shear stress-strain curves for the honeycomb and crossbanded cores. Curves are presented for cores 1/2 and 2 inches thick. Specimens 1/2 inch thick were evaluated by loading in tension and the 2-inch specimens were evaluated by loading in compression. From a previous study,[2] the results obtained for 1/2-inch core by either tension or compression loading were comparable; therefore, any differences in values between 1/2- and 2-inch core can be attributed to core thickness differences and not type of loading.

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[2] Jenkinson, Paul M. and Kuenzi, Edward W. Effect of Core Thickness on Shear Properties of Aluminum Honeycomb Core. Forest Products Laboratory Report No. 1886, 1962.

The TL shear modulus for the 2-inch honeycomb core was about 16 percent greater than that for the 1/2-inch core. For the crossbanded core, there was only a slight difference in the TL shear modulus values for 1/2- and 2-inch specimens.

The TL shear modulus of the crossbanded core was about 10 percent greater than that for the honeycomb core 2 inches thick and 30 percent greater than that for the honeycomb 1/2 inch thick. The TW shear modulus for the 2-inch honeycomb core was not greatly different from that for the 1/2-inch core; however, for the 2-inch crossbanded core, it was only about 20 percent of that for the 1/2-inch specimen. The TW shear modulus of the crossbanded core 2 inches thick was 7 percent of that for the honeycomb core; the crossbanded core 1/2 inch thick, however, had a TW shear modulus of 33 percent of the honeycomb core.

Maximum and proportional limit stresses were lower for the 2-inch cores than for the 1/2-inch cores. The proportional limit stresses for the 2-inch honeycomb core were about 87 percent (TL) and 69 percent (TW) of corresponding values for 1/2-inch core. For the 2-inch specimens of the crossbanded core, the proportional limit stress was about 56 percent (TL) and 20 percent (TW) of corresponding values for the 1/2-inch core. For both TL and TW shear, the maximum stress for the 2-inch honeycomb core was about 80 percent of the maximum stress for the 1/2-inch core. For the crossbanded core 2 inches thick, the maximum TL stress was about 65 percent and the TW stress about 50 percent of corresponding values for the 1/2-inch core.

Both proportional limit and maximum stress for the crossbanded core were less than for the honeycomb core. The proportional limit stress (TL) and maximum stress (TL) for the 1/2-inch crossbanded core were about 78 percent of stresses for the 1/2-inch-thick honeycomb core. For TW shear of 1/2-inch core, the proportional limit stress of the crossbanded core was about 37 percent and the maximum stress about 50 percent of the values obtained from the honeycomb core. The differences between shear stresses for crossbanded and honeycomb core were larger for 2-inch core than for 1/2 inch core.

Table 1.--Flatwise compressive properties of cores of corrugated 0.002-inch-thick aluminum foil

Core thickness	Proportional limit stress	Maximum stress	Modulus of elasticity	Deformation at minimum stress	Minimum stress	Stress at 10 percent deformation
In.	P.s.i.	P.s.i.	P.s.i.	Percent	P.s.i.	P.s.i.
			HONEYCOMB CORE (4.2 POUNDS PER CU. FT.)			
1/2	....	495	....	7.2	205	230
1/2	....	545	....	7.7	205	220
1/2	....	525	....	7.0	215	240
1/2	....	635	....	6.8	220	245
1/2	....	555	....	6.9	210	235
1/2	....	605	....	6.6	215	235
1/2	....	570	....	6.8	200	225
1/2	....	515	....	7.1	190	215
1/2	....	555	....	6.8	190	225
1/2	....	495	....	7.2	205	225
1/2	....	580	....	6.6	190	230
Average	....	550	....	7.0	205	230
2	270	560	250,000	....	....	....
2	300	525	245,000	2.0	160	235
2	275	500	220,000	....	....	....
2	275	525	230,000	1.9	150	225
2	340	540	210,000	1.9	165	230
2	320	560	230,000	1.9	170	245
Average	300	535	230,000	1.9	160	235
			CROSSBANDED CORE (4.4 POUNDS PER CU. FT.)			
1/2	....	240	....	8.0	94	100
1/2	....	230	....	8.2	87	92
1/2	....	215	....	8.2	93	97
1/2	....	225	....	8.0	87	93
1/2	....	235	....	8.1	91	94
1/2	....	225	....	9.0	84	85
1/2	....	195	....	8.8	79	80
1/2	....	205	....	8.8	87	88
1/2	....	230	....	7.5	91	99
1/2	....	235	....	9.0	93	94
1/2	....	205	....	8.3	73	76
Average	....	220	....	8.4	87	91
2	175	200	72,000	....	....	....
2	140	230	90,500	2.4	75	90
2	150	220	83,500	2.4	72	81
2	180	225	84,500	2.4	74	76
2	90	185	73,000	2.7	68	81
2	140	205	83,500	2.7	83	84
Average	145	210	81,000	2.5	74	82

Table 2.--Shear properties of cores of corrugated 0.002-inch-thick aluminum foil

Core thickness	Shear parallel to core ribbons (TL)			Shear perpendicular to core ribbons (TW)		
	Proportional limit stress	Maximum stress	Shear modulus	Proportional limit stress	Maximum stress	Shear modulus
In.	P.s.i.	P.s.i.	P.s.i.	P.s.i.	P.s.i.	P.s.i.
HONEYCOMB CORE (4.2 POUNDS PER CU. FT.)						
1/2	235	330	52,500	145	190	27,000
1/2	...	330	...	150	185	27,500
1/2	200	335	62,000	150	195	29,000
1/2	235	335	57,500	140	195	29,500
1/2	235	335	60,000	150	200	26,000
1/2	235	350	62,000	150	195	29,000
1/2	235	350	56,500	...	215	...
1/2	215	350	61,500	150	195	29,000
1/2	235	330	62,500	145	200	32,000
1/2	200	355	70,500	150	190	33,000
1/2	...	355	...	125	200	32,000
1/2	...	345	...	145	185	31,500
Average	225	340	60,500	145	195	29,500
2	190	270	66,000	78	155	29,000
2	190	285	73,500	100	153	28,000
2	200	275	75,500	105	155	28,500
2	200	285	68,500	110	155	29,000
2	190	290	73,000	110	160	28,000
2	190	280	66,500	100	155	29,500
Average	195	280	70,500	100	155	28,500
CROSSBANDED CORE (4.4 POUNDS PER CU. FT.)						
1/2	170	275	84,000	59	110	12,000
1/2	175	270	67,500	59	105	12,000
1/2	...	255	...	50	99	9,500
1/2	160	255	74,000	59	100	10,000
1/2	185	265	66,000	59	105	12,500
1/2	150	270	91,000	50	97	8,500
1/2	165	270	83,500	46	97	9,000
1/2	185	265	87,000	50	97	8,500
1/2	200	260	86,000	42	98	8,000
1/2	180	270	84,000	59	105	12,000
1/2	145	275	73,500	59	99	7,500
1/2	...	285	...	51	94	7,500
Average	170	270	79,500	54	100	10,000
2	87	170	97,000	13	50	1,850
2	110	170	80,500	10	48	2,000
2	99	185	76,000	15	50	2,350
2	105	165	71,000	10	49	2,100
2	94	175	70,000	10	50	2,100
2	84	180	74,000	10	49	2,100
Average	96	175	78,000	11	49	2,100

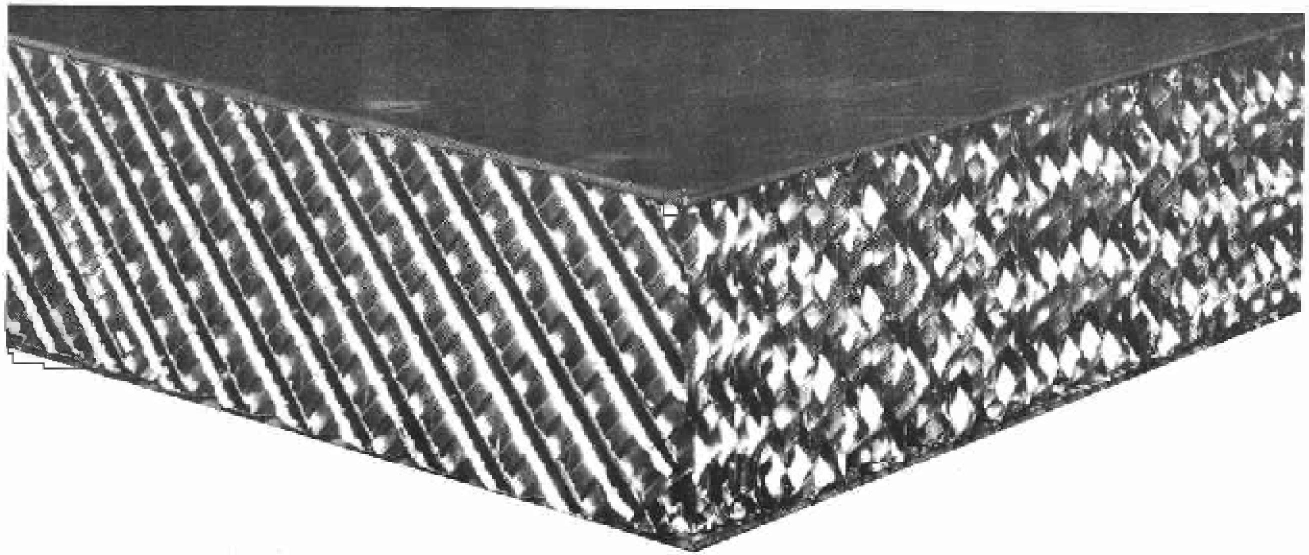

Figure 1. --Aluminum sandwich panel with crossbanded core.

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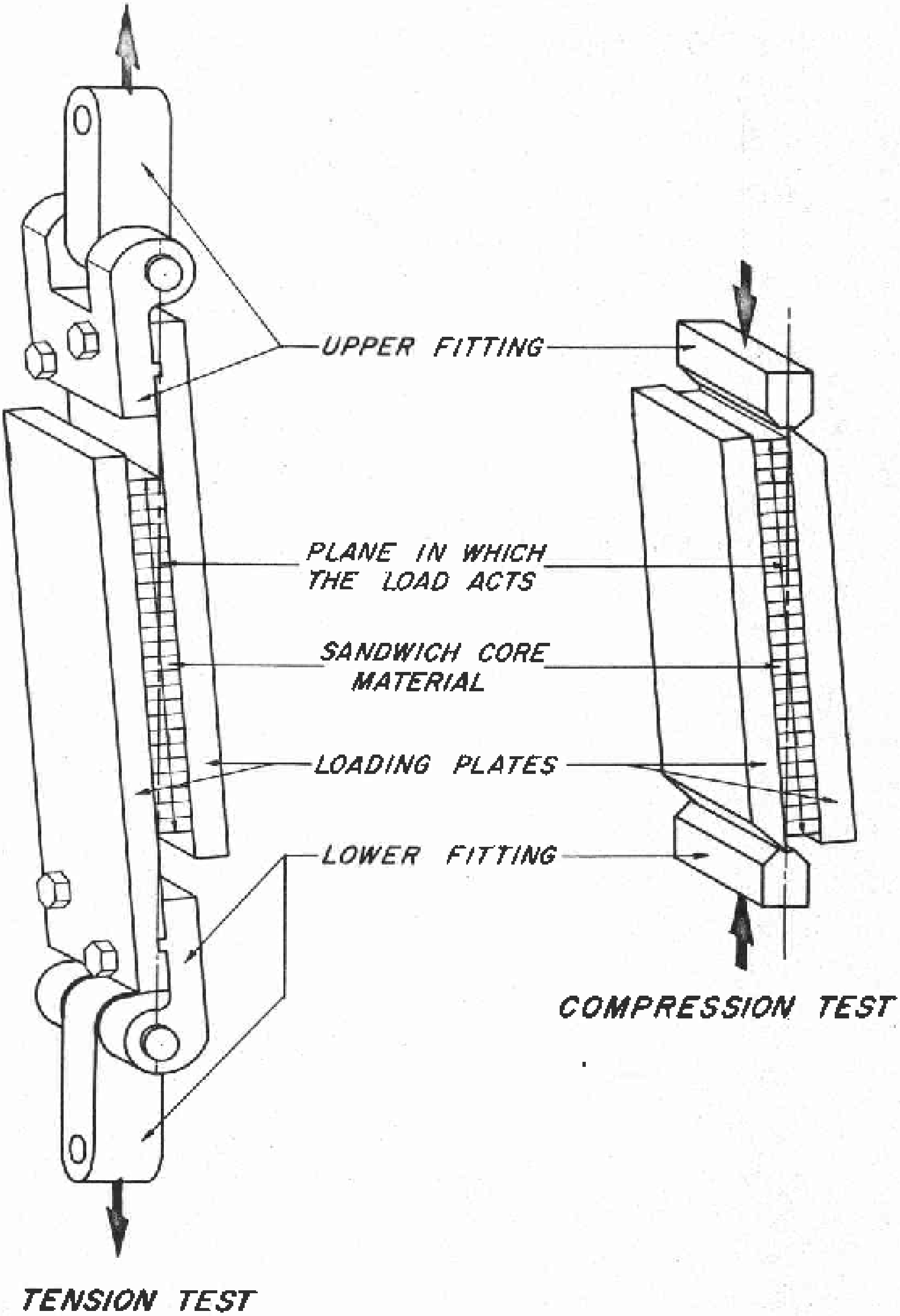

Figure 2.--Sketch showing shear specimens attached to loading plates and plane of action of applied loads.

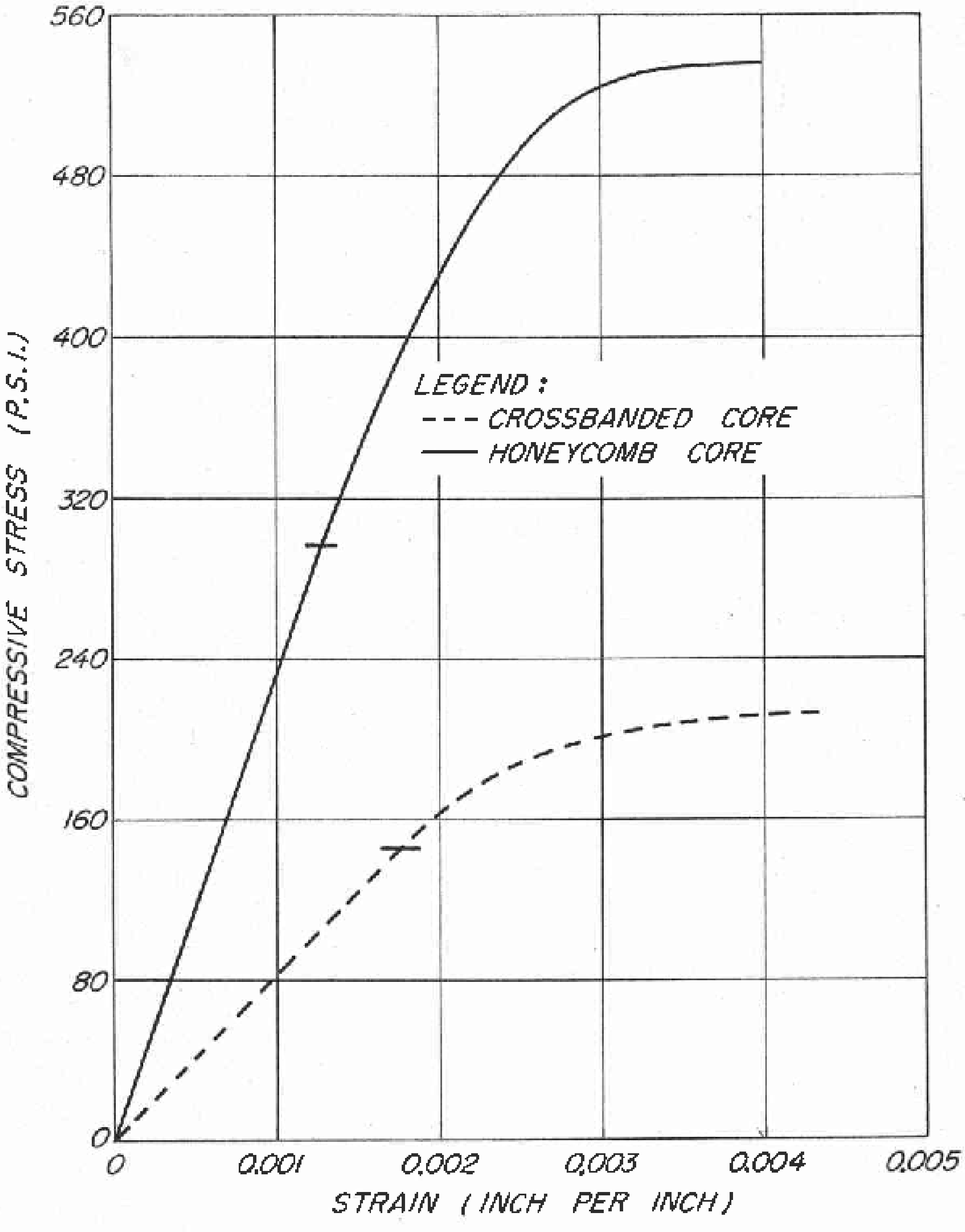

Figure 3.--Average compression stress strain curves for 2-inch-thick 5052 aluminum cores of 0.002 inch corrugated foil.

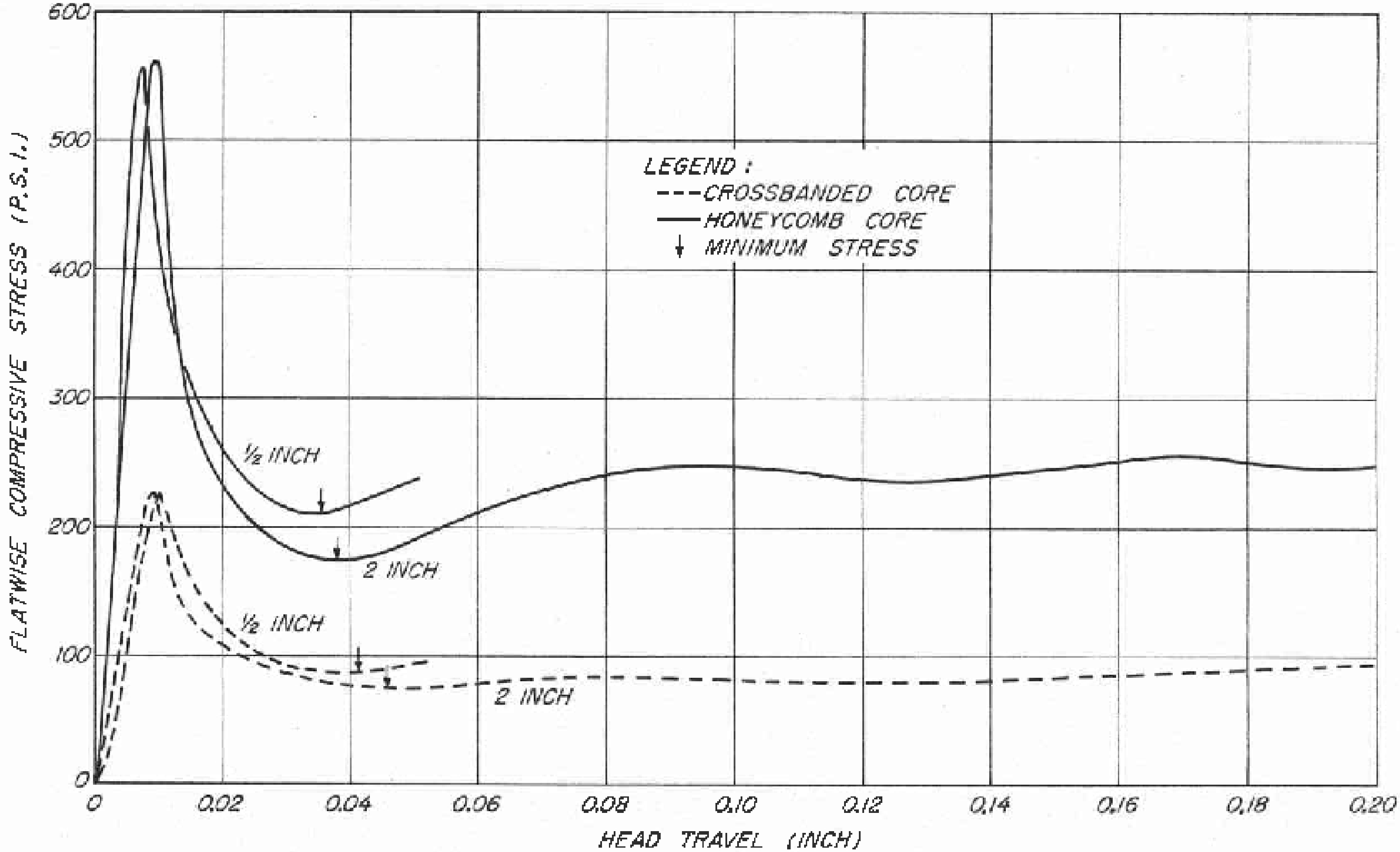

Figure 4.--Autographic record of testing machine head travel and load for flatwise compression of four aluminum cores.

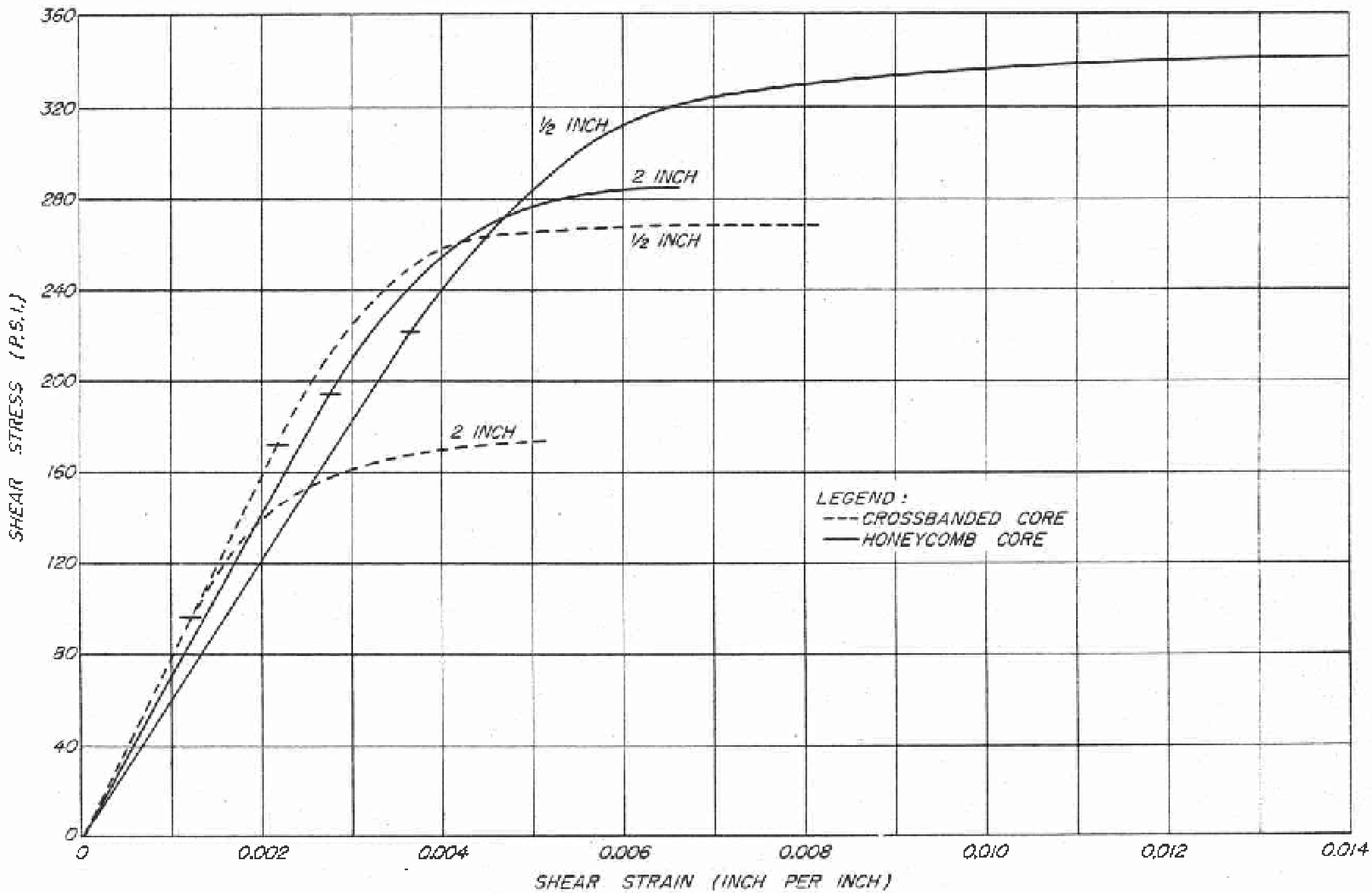

Figure 5. --Shear stress strain curves for honeycomb and crossbanded aluminum cores loaded parallel to the core ribbon direction (TL).

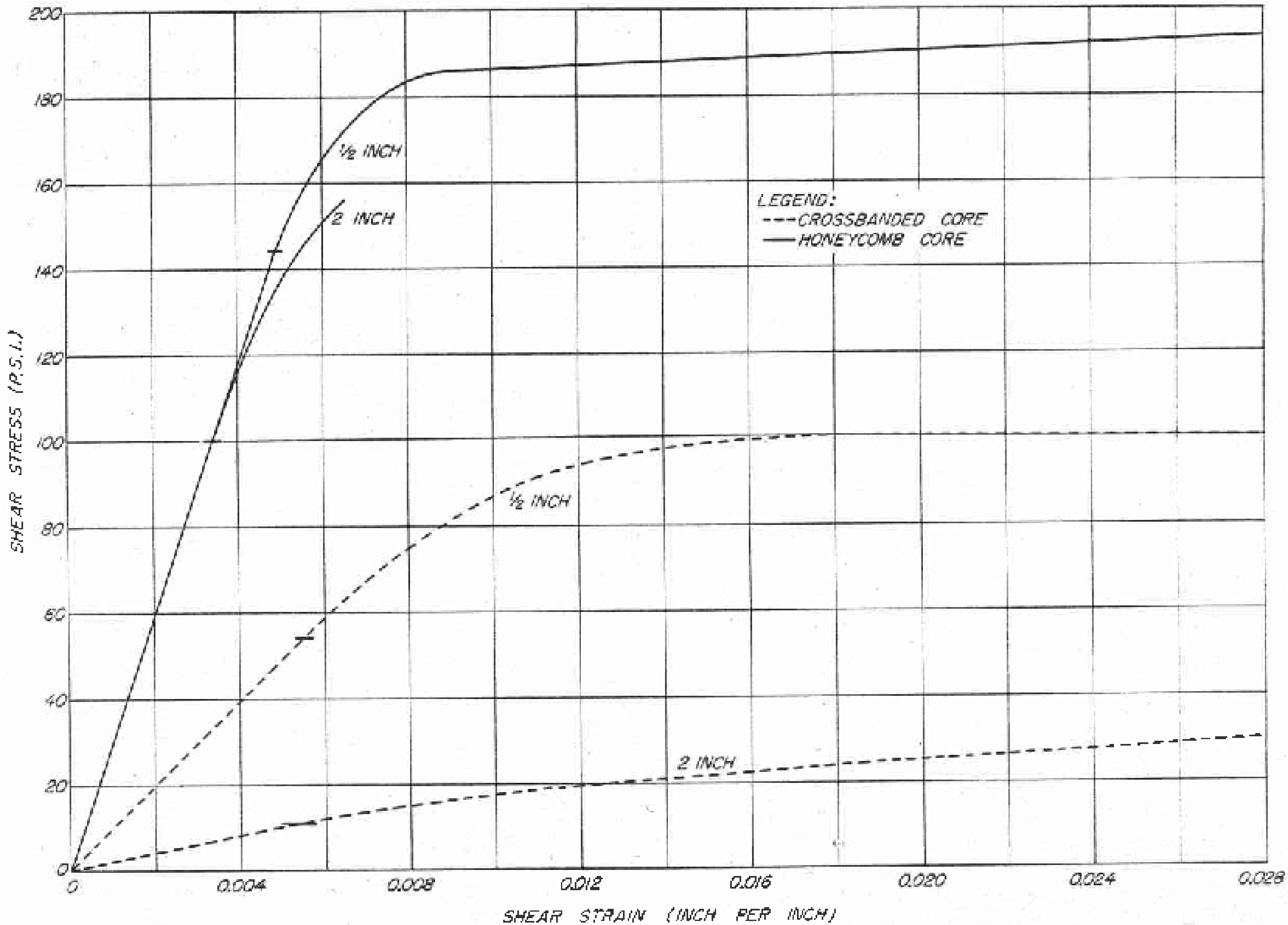

Figure 6.--Shear stress strain curves for honeycomb and crossbanded aluminum cores loaded perpendicular to the core ribbon direction (TW).

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