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EFFECT OF CORE THICKNESS AND  
MOISTURE CONTENT ON MECHANICAL  
PROPERTIES OF TWO RESIN-TREATED  
PAPER HONEYCOMB CORES

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CONSTRUCTION FOR FLIGHT VEHICLES —  
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## ABSTRACT

This report presents the results of compression and shear evaluations of two resin-treated paper honeycomb cores. The cores had densities of 1.7 and 3.7 pounds per cubic foot.

Cores were evaluated in thicknesses of 1/4 to 2 inches and at several moisture contents ranging up to 80 percent.

Compressive strength of 1/4-inch-thick cores was 25 to 80 percent greater than that of 2-inch-thick cores. Compressive strength and modulus of elasticity of cores at 10 percent moisture content were 50 to 70 percent of those at 4 percent moisture content. Cores soaked in water (60 to 80 percent moisture content) had only 20 to 30 percent of the strength and modulus of elasticity of those at 4 percent moisture content.

Core shear strength was two to four times as high for 1/4-inch as for 2-inch-thick cores. Core shear strength and modulus of rigidity at 10 percent moisture content was 50 to 70 percent of that at 4 percent moisture content; cores soaked in water had 20 to 40 percent of the strength and modulus of rigidity of those at 4 percent moisture content. Specimens sheared parallel to the core ribbon direction had about twice the strength and three times the stiffness as those of the same core sheared perpendicular to the core ribbon direction.

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# EFFECT OF CORE THICKNESS AND MOISTURE CONTENT ON MECHANICAL PROPERTIES OF TWO RESIN-TREATED PAPER HONEYCOMB CORES<sup>1</sup>

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## INTRODUCTION

Sandwich constructions, comprised of strong, thin facings bonded to a thick, lightweight core, can be used to produce stiff, lightweight structural panels for use in aircraft and other flight vehicles. Resin-treated paper honeycomb cores have been used for bulkheads, cockpit floors, baggage racks, and other aircraft applications where minimum weight coupled with moderate strength and stiffness are required. The purpose of this study was to determine the compressive and shear properties of two commercially produced paper honeycomb cores.

The cores were of 60- and 125-pound kraft paper formed to 7/16-inch hexagonal cells and then treated with alcohol-soluble phenolic resin to produce core of 1.7 and 3.7 p.c.f. (pounds per cubic foot) density, respectively.

Honeycomb core shear and compressive strengths tend to decrease as core thickness increases. Criteria for buckling of the cell walls predict that core strength of a relatively thin core changes rapidly as core thickness changes: but strength for a core with a thickness greater than the cell size is relatively insensitive to changes in core thickness. Accordingly, a mini-

mum thickness of 1/4 inch was selected as the thinnest core likely to be of practical use, and additional thicknesses of 1/2 and 1 inch were chosen to determine the shape of the curve showing strength as affected by thickness.

A maximum thickness of 2 inches was chosen to determine the lower boundary of the strength-thickness relations because strengths of thicker cores would not be expected to be significantly lower.

Aircraft sandwich panels in service may be exposed to a variety of humidity conditions affecting both strength and stiffness of paper honeycomb cores. Cores were evaluated after conditioning in rooms maintained at 73° to 80° F. and 30, 50, and 90 percent relative humidity, producing core moisture contents ranging from 3 to 11 percent. A more severe moisture exposure, occasionally encountered in service, is infiltration of liquid water into the interior of a sandwich panel. Accordingly, properties of cores immersed in water for 48 to 72 hours (60 to 80 percent moisture content) were evaluated to establish a lower limit for the strength-moisture relations.

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<sup>2</sup>Maintained at Madison, Wis., in cooperation with the University of Wisconsin.

## CORE MATERIALS USED

Cores were produced commercially and were received from the manufacturers in sheets of the required thicknesses. Both cores were made of kraft paper expanded to form 7/16-inch hexagonal cells.

The lighter core was made of 60-pound (per 3,000 square feet) kraft paper treated with about 20 percent alcohol-soluble phenolic resin by weight. Average core density was 1.7 p.c.f. Twelve sheets of core were furnished for each core thickness, each of the 12 sheets being produced on a separate date. Thus, this core may

be considered a representative sample of core produced.

The heavier core was made of 125-pound kraft paper treated with about 35 percent alcohol-soluble phenolic resin. Average core density was 3.7 p.c.f. Twelve sheets of core were furnished for each core thickness, six sheets sampled from the production of each of two dates. Thus, this core sample may be considered as typical of core commercially produced, although not as representative of production as the sample of lighter core.

## PREPARATION OF SPECIMENS

Sheets of core received from the manufacturer were conditioned to constant weight in a room maintained at 73° F. and 50 percent relative humidity. Then each core was weighed and measured and the density calculated. A 4-inch-square sample was cut from each of the sheets of 2-inch-thick core only, to determine conditioning time necessary in each of the humidity rooms used and the moisture content attained. These specimens were measured and equilibrium weights determined in rooms maintained at 80° F. and 30 percent relative humidity, 73° F. and 50 percent relative humidity, and 80° F. and 90 percent relative humidity. Then the specimens were oven-dried, weighed, and the moisture content at each humidity condition calculated. A second set of specimens cut from each sheet of 1-inch-thick core was immersed in water for 48 hours. These were then removed from the water bath and shaken to remove surface moisture. They were then weighed, oven-dried, and weighed again, and the moisture content in the wet condition was calculated.

### Compression Specimens

Four compression specimens, each 4 inches square, were cut from each sheet of core with a bandsaw. Ends of the compression specimens were dipped in epoxy resin to form reinforcing fillets about 1/16 to 1/8 inch deep at each end of the core cells. Fillets on the 1/4-inch-thick specimens were 1/16 inch deep or less. One

specimen from each core sheet was conditioned to constant weight in each of the three conditioning rooms mentioned above. The fourth specimen was immersed in distilled water at 75° F. for 48 hours. Specimens were removed from the conditioning rooms or water bath and tested immediately. The oven-dried specimens cut from 2-inch-thick cores only, had the ends dipped in resin and were dried again in an oven. After cooling in an airtight container containing a desiccant, they were removed and tested immediately.

### Shear Specimens

Eight shear specimens, each 4 inches wide with the length 12 times the core thickness, were cut from each sheet of core. Specimens sheared in the "TL" plane had the core ribbon direction parallel to the specimen length. Specimens sheared in the "TW" plane had the core ribbon direction parallel to the 4-inch specimen width. Shear specimens of the 1/4-inch-thick core were 6 inches long and 4 inches wide. One "TL" and one "TW" specimen from each sheet of core were conditioned in each of the three conditioning rooms prior to bonding of loading plates.

Steel loading plates were bonded to the core with a room-temperature-setting epoxy resin (fig. 1). The core cell ends contacted the loading plates and the resin formed fillets, which bonded the cell walls to the plates.

The bonding plates were stiff enough to resist bending. A stiffness of at least 600,000 p.s.i.

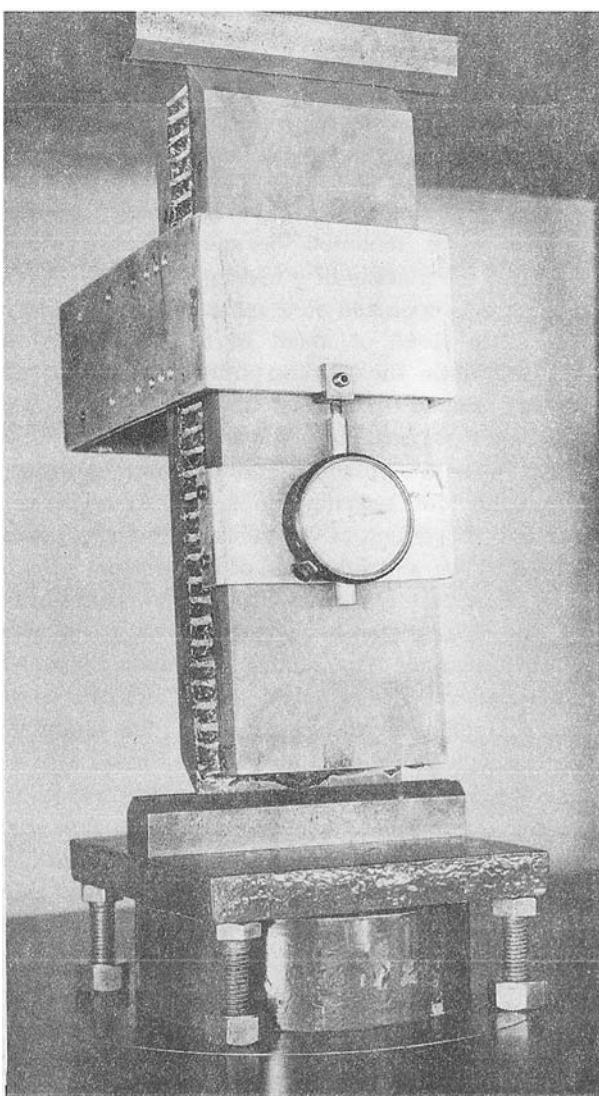


Figure 1.--Core shear apparatus showing specimen with attached loading plates, spherical base, and collar and dial gage used to measure deformations.

(pounds per square inch) for each inch of width and core thickness is recommended.<sup>2</sup> On this basis, required loading plate thicknesses were calculated as follows:

Core thickness	Required loading plate thickness	Loading plate thickness used
<u>In.</u>	<u>In.</u>	<u>In.</u>
0.25	0.39	0.75
.5	.49	.75
1.0	.62	1.00
2.0	.78	1.25

After the adhesive had cured, specimens were removed from the conditioning rooms and tested immediately.

One "TL" and one "TW" specimen from each sheet of core were immersed in distilled water at 75° F. for about 72 hours. The specimens were removed from the water bath and immediately bonded to the steel loading plates. In this way the interior of the specimen retained most of its moisture while the adhesive was curing. After about 12 hours, the specimens with attached loading plates were moved into a second water bath for about 48 hours. Specimens were then removed from the water bath and tested immediately.

## EVALUATION OF SPECIMENS

### Compression Specimens

Compression specimens were mounted between two loading plates, and this assembly was placed between a spherical bearing block and the upper platen of a testing machine. A specimen and loading plates are shown in figure 2. The loading plates were of magnesium tooling plate 4-1/2 by 6 inches by 1/2 inch thick. These plates were chosen because their flatness and thickness are held to very close tolerances in manufacture.

A load of about 50 to 100 pounds was applied while the specimens were aligned. Screw jacks were then placed under each corner of the bearing block to prevent further movement of the block. Load was then applied at a rate such that failure occurred in 3 to 6 minutes. Specimens failed by buckling of the cell walls, followed by crushing and crinkling of the cell corners.

Load-deformation data were obtained for the 2-inch-thick specimens. After the specimens were aligned and the bearing block fixed in place by

<sup>2</sup>American Society for Testing and Materials. Shear test in flatwise plane of flat sandwich constructions on sandwich cores. ASTM Standard C 273-61, 1961.

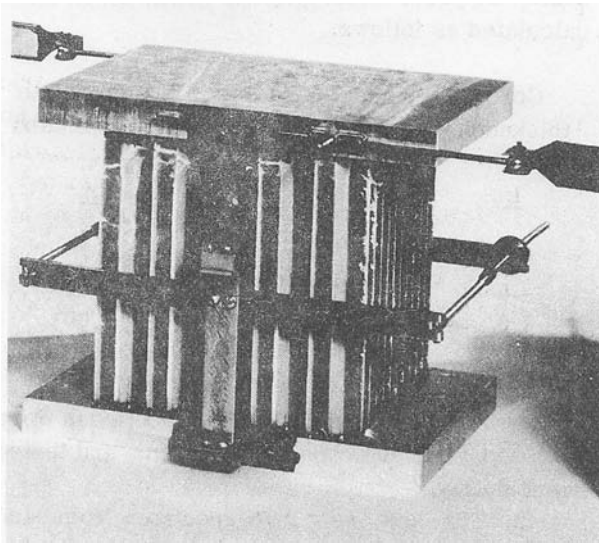


Figure 2.--Core compression apparatus showing specimen, magnesium loading plates, and Marten's mirror compressometers. (M 119 307)

screw jacks, Marten's mirror compressometers were attached to the loading plates, as shown in figure 2. The movable head of the testing machine was driven at a constant speed such that failure of the specimens occurred in 3 to 6 minutes while load-deformation data were obtained.

### Shear Specimens

Apparatus used for core shear tests is shown in figure 1. The specimens with attached loading plates were mounted between notched blocks between the platens of a testing machine, with the lower end supported on a spherical bearing block. An initial load of about 50 to 100 pounds was applied while the loading plates were firmly and evenly seated in the notched blocks by tapping the spherical bearing block with a hammer. Screw jacks were then placed under the four corners of the spherical bearing block (fig. 1) to prevent further movement of the block during application of load. The movable head of the testing machine was driven at a constant speed such that failure of the specimens occurred in 3 to 6 minutes.

Movement of one loading plate with respect to the other was measured to 0.0001 inch by a collar and dial gage, as shown in figure 1. The aluminum collar was attached to one loading plate with set screws, while the dial gage was similarly fastened to the other plate. The spring-loaded dial stem maintained contact with the collar. The collar and dial gage were mounted so that they moved away from each other as the specimen deformed, thus preventing damage to the dial when failure occurred.

Failure occurred by progressive buckling of the core cell walls, followed by crinkling of the cell corners.

## PRESENTATION OF DATA AND DISCUSSION OF RESULTS

### Core Density and Moisture Content

Density of sheets of the lighter core at 73° F. and 50 percent relative humidity ranged from 1.6 to 1.9 p.c.f. and averaged 1.7 p.c.f. Density of sheets of the heavier core under the same conditions ranged from 3.5 to 4.1 p.c.f., with an average density of 3.7 p.c.f.

The effect of relative humidity on core moisture content is shown in figure 3. Samples of the 1.7-p.c.f. core placed in a room maintained at 80° F. and 30 percent relative humidity reached constant weight within 1 day at an average moisture content of 3.7 percent. After a 1-day conditioning at 73° F. and 50 percent relative humidity, an

equilibrium was reached at 5.3 percent moisture content. After an additional 2-day conditioning at 80° F. and 90 percent relative humidity, an equilibrium moisture content of 11.2 percent was reached.

Samples of the 3.7-p.c.f. core reached an equilibrium moisture content of 3.4 percent after 1 day at 80° F. and 30 percent relative humidity. A moisture content of 5.0 percent was reached after 1 day at 73° F. and 50 percent relative humidity, and a moisture content of 9.8 percent after 2 days at 80° F. and 90 percent relative humidity.

Moisture content of specimens of the lighter core after immersion in water for 48 hours

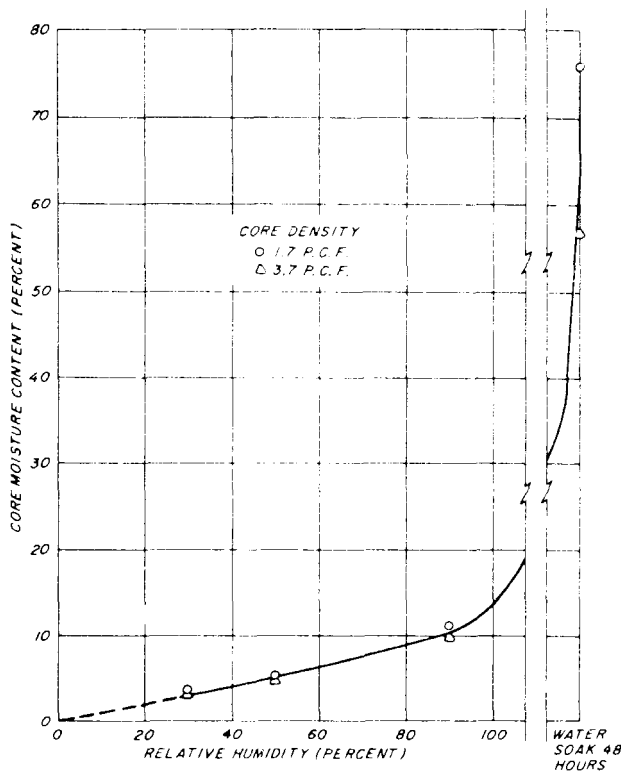


Figure 3.--Effect of relative humidity (at 80°F.) on equilibrium moisture content of resin-treated paper honeycomb core. M 129 079

averaged 76 percent, while specimens of the heavier core had an average moisture content of 57 percent, as shown in figure 3.

### Core Compressive Properties

Average compressive properties of the two resin-treated paper honeycomb cores are summarized in table 1. Compressive properties of individual specimens are presented in table 2. An average value for each group of 12 specimens is given and the standard deviation is listed to indicate the variability of the data.

Figure 4 is a "carpet plot" for the 1.7-p.c.f. core showing the relationship between compressive strength, moisture content, and core thickness. This type of graph is designed to show the relationship between three variables in such a way that interpolation is facilitated. Each point represents the average of 12 specimens. Curves of compressive strength versus moisture content were plotted for each core thickness. Points were displaced horizontally one unit for each 20 percent change in moisture content. Adjacent

curves were displaced horizontally one unit for each 1/2-inch difference in core thickness. The grid was then completed by drawing curves of equal moisture content.

Compressive strengths of cores between grid-lines are easily estimated by interpolation. For example, the strength of a 3/4-inch-thick core at 8 percent moisture content may be estimated as shown in figure 4. Points for a 3/4-inch-thick core are located on the 5 and 10 percent moisture curves halfway (horizontally) between the curves for 1/2- and 1-inch cores. Points for a core at 8 percent moisture content are located on the 1/2- and 1-inch core thickness curves at three-fifths of the horizontal distance from the 5 percent curve to the 10 percent moisture content curve. Curves (shown by dashed lines) are then drawn through the pairs of points roughly parallel to the adjacent curves and the compressive strength desired is found where the two curves intersect (70 p.s.i.).

Figure 5 is a carpet plot of compressive strength versus core moisture content and thickness for the 3.7-p.c.f. core.

The compression data shown in figures 4 and 5 are also presented in the composite carpet plot of figure 6. The strength of 1/4-inch-thick core at 80° F. and 30 percent relative humidity was arbitrarily selected as 100 percent strength, and strengths of all other cores were plotted on a percentage basis. The dashed lines at the top of the graphs are extrapolation to an ovdry condition.

Typical compressive stress-strain curves for 2-inch-thick specimens of the 1.7-p.c.f. core are shown in figure 7. Each curve represents 12 specimens at the moisture content indicated. The proportional limit stresses are indicated by short horizontal lines through the curves. The curves show that as moisture content increases, strength, proportional limit stress, and modulus of elasticity decrease and the core becomes more plastic. Figure 8 shows similar curves for the 3.7-p.c.f. core.

The effect of core moisture content on compression modulus of elasticity is shown in figure 9. Plotted points represent the ratio of the modulus of elasticity to that of an ovdry specimen. The compression modulus at 10 percent moisture content was about half that of ovdry specimens, while specimens soaked in water were only about 20 percent as stiff.

Table 1.--summary of compressive and shear properties of resin-treated paper honeycomb core

Core density <sup>1</sup>	Core thickness	Core moisture content	Compressive properties			Shear properties--TL <sup>2</sup>			Shear properties--TW <sup>3</sup>			
			Maximum stress	Proportional limit stress	Modulus of elasticity	Maximum stress	Proportional limit stress	Modulus of rigidity	Maximum stress	Proportional limit stress	Modulus of rigidity	
P.c.f.	In.	Pct.	P.s.i.	P.s.i.	1,000 p.s.i.	P.s.i.	P.s.i.	1,000 p.s.i.	p.s.i.	P.s.i.	1,000 p.s.i.	
1.7	1/4	4	140	--	--	170	90	12.9	100	30	5.7	
		5	150	--	--	140	50	11.2	90	25	4.2	
		11	90	--	--	90	30	6.8	60	15	2.6	
		76	25	--	--	30	4	4.0	20	5	.9	
	1/2	4	120	--	--	110	55	12.4	60	20	5.0	
		5	100	--	--	80	35	11.1	50	25	4.0	
		11	60	--	--	M	20	7.0	30	10	2.3	
		76	25	--	--	20	4	2.9	10	2	.9	
	1	4	90	--	--	70	35	11.6	35	15	3.6	
		5	90	--	--	70	25	10.3	35	15	3.4	
		11	50	--	--	35	10	6.7	25	10	1.8	
		76	20	--	--	20	3	3.1	9	2	1.1	
2	4 <sup>4</sup>	110	65	25.5	--	--	--	--	--	--	--	
	4	90	60	18.6	60	25	10.0	30	15	3.3		
	5	90	60	20.7	55	30	9.4	30	10	3.3		
	11	50	35	13.6	35	10	6.5	15	5	1.8		
	76	20	15	4.8	15	3	3.2	7	1	1.0		
3.7	1/4	3	520	--	--	410	100	23.6	240	90	9.7	
		5	410	--	--	410	150	22.7	230	70	9.5	
		10	260	--	--	300	80	16.8	160	40	6.0	
		57	130	--	--	120	15	10.3	70	15	2.3	
	1/2	3	420	--	--	320	100	24.3	170	70	8.6	
		5	350	--	--	220	80	16.4	140	45	7.7	
		10	260	--	--	210	40	18.2	100	20	6.0	
		57	110	--	--	80	15	8.0	60	15	2.8	
	1	3	340	--	--	270	110	24.1	140	50	8.3	
		5	350	--	--	250	80	22.2	130	40	7.9	
		10	200	--	--	140	30	14.7	80	20	4.5	
		57	110	--	--	80	10	10.9	40	5	2.8	
	2	4 <sup>4</sup>	420	270	67.4	--	--	--	--	--	--	--
		3	310	200	49.3	210	80	21.5	120	45	7.6	
		5	320	180	53.1	200	55	21.6	110	45	7.5	
		10	180	110	33.2	130	45	14.1	60	20	4.1	
		57	100	60	14.6	70	15	9.6	40	10	2.7	

<sup>1</sup> At 73° F. and 50 percent relative humidity.

<sup>2</sup> "TL" plane is parallel to core ribbon direction and parallel to core flutes.

<sup>3</sup> "TW" plane is perpendicular to core ribbon direction and parallel to core flutes.

<sup>4</sup> Oven-dried at 218° F. for 48 hours.

### Core Shear Properties

Average shear properties for the two resin-treated paper honeycomb cores are summarized in table 1. Shear properties of individual specimens are given in table 3. Average values and the standard deviation are given for each set of 12 specimens.

Shear Strength in TL Plane.--Figures 10 and 11 are carpet plots of shear strength (TL) versus core thickness and moisture content. These graphs are similar to the compressive strength carpet plots given in figures 4 and 5. The data in figures 10 and 11 are also presented on a percentage basis in the composite carpet plot of figure 6.

Shear Strength in TW Plane.--Carpet plots of shear strength (TW) versus core thickness and

moisture content are given in figures 12 and 13. These data are also shown in the composite carpet plot of figure 6.

A plot of shear strength (TL) versus shear strength (TW) is presented in figure 14. The relationship  $\tau_{TL} = 1.78 \tau_{TW} + 2$  was determined by least squares.

Stress-Strain Properties.--Typical shear stress-strain curves are presented in figures 15 through 18. The curves were drawn using average data for the 2-inch-thick cores. The curves show that as moisture content increased, shear strength, proportional limit stress, and shear modulus decreased and failures were less abrupt.

The effect of core moisture content on the shear modulus is shown in figures 19 and 20. Shear moduli at 10 percent moisture content were

Table 2.--Compressive properties of resin-treated paper honeycomb core

Core thickness	Core density 1.7 p.c.f. <sup>1,2</sup>				Core density 3.7 p.c.f. <sup>1,2</sup>					
	Moisture content	Maximum stress	Proportional limit stress	Modulus of elasticity	Moisture content	Maximum stress	Proportional limit stress	Modulus of elasticity		
<u>In.</u>	<u>Pct.</u>	<u>P.s.i.</u>	<u>P.s.i.</u>	<u>1,000 p.s.i.-</u>	<u>Pct.</u>	<u>P.s.i.</u>	<u>P.s.i.</u>	<u>1,000 p.s.i.</u>		
1/4	4	110	--	--	3	490	--	--		
		160	--	--		450	--	--		
		120	--	--		580	--	--		
		130	--	--		540	--	--		
		160	--	--		460	--	--		
		160	--	--		480	--	--		
		160	--	--		590	--	--		
		130	--	--		580	--	--		
		130	--	--		510	--	--		
		150	--	--		500	--	--		
		120	--	--		520	--	--		
		120	--	--		550	--	--		
		Av. 140				Av. 520				
		S.D. 20				S.D. 50				
	5	140	--	--	5	370	--	--		
		130	--	--		310	--	--		
		140	--	--		420	--	--		
		150	--	--		440	--	--		
		160	--	--		380	--	--		
		160	--	--		350	--	--		
		150	--	--		480	--	--		
		150	--	--		420	--	--		
		140	--	--		410	--	--		
		180	--	--		430	--	--		
		140	--	--		420	--	--		
		150	--	--		470	--	--		
		Av. 150				Av. 410				
		S.D. 10				S.D. 50				
11	100	--	--	10	250	--	--			
	80	--	--		220	--	--			
	110	--	--		290	--	--			
	80	--	--		280	--	--			
	90	--	--		240	--	--			
	90	--	--		230	--	--			
	80	--	--		280	--	--			
	80	--	--		280	--	--			
	90	--	--		270	--	--			
	80	--	--		260	--	--			
	70	--	--		280	--	--			
	80	--	--		270	--	--			
	Av. 90				Av. 260					
	S.D. 10				S.D. 20					
76	30	--	--	57	100	--	--			
	20	--	--		80	--	--			
	30	--	--		170	--	--			
	30	--	--		150	--	--			
	30	--	--		100	--	--			
	25	--	--		90	--	--			
	25	--	--		150	--	--			
	25	--	--		150	--	--			
	25	--	--		150	--	--			
	25	--	--		130	--	--			
	25	--	--		150	--	--			
	30	--	--		130	--	--			
	Av. 25				Av. 130					
	S.D. 3				S.D. 30					

Footnotes are listed on page 11

Table 2.--Compressive properties of resin-treated paper honeycomb core--con.

Core thickness	Core density 1.7 p.c.f. <sup>1,2</sup>				Core density 3.7 p.c.f. <sup>1,2</sup>			
	Moisture content	Maximum stress	Proportional limit stress	Modulus of elasticity	Moisture content	Maximum stress	Proportional Limit stress	Modulus of elasticity
<u>In.</u>	<u>Pct.</u>	<u>P.s.i.</u>	<u>P.s.i.</u>	<u>1,000 p.s.i.</u>	<u>Pct.</u>	<u>P.s.i.</u>	<u>P.s.i.</u>	<u>1,000 p.s.i.</u>
1/2	4	110	--	--	3	410	--	--
		120	--	--		420	--	--
110		--	--	440		--	--	
120		--	--	390		--	--	
140		--	--	400		--	--	
130		--	--	410		--	--	
140		--	--	460		--	--	
130		--	--	470		--	--	
120		--	--	400		--	--	
100		--	--	400		--	--	
100		--	--	450		--	--	
110		--	--	450		--	--	
			Av. 120					Av. 420
		S.D. 10				S.D. 30		
1/2	5	110	--	--	5	400	--	--
		100	--	--		300	--	--
		100	--	--		310	--	--
		20	--	--		390	--	--
		110	--	--		320	--	--
		120	--	--		340	--	--
		90	--	--		370	--	--
		100	--	--		350	--	--
		100	--	--		320	--	--
		100	--	--		300	--	--
		90	--	--		370	--	--
		100	--	--		380	--	--
				Av. 100				
		S.D. 10				S.D. 30		
1/2	11	--	--	--	10	210	--	--
		--	--	--		240	--	--
		60	--	--		300	--	--
		60	--	--		280	--	--
		70	--	--		250	--	--
		65	--	--		250	--	--
		60	--	--		280	--	--
		65	--	--		280	--	--
		60	--	--		230	--	--
		65	--	--		220	--	--
		60	--	--		280	--	--
		65	--	--		270	--	--
				Av. 60				
		S.D. 5				S.D. 30		
1/2	76	25	--	--	57	90	--	--
		25	--	--		90	--	--
		35	--	--		140	--	--
		25	--	--		150	--	--
		30	--	--		80	--	--
		25	--	--		90	--	--
		25	--	--		140	--	--
		25	--	--		130	--	--
		20	--	--		80	--	--
		20	--	--		80	--	--
		20	--	--		140	--	--
		30	--	--		130	--	--
				Av. 25				
						S.D. 30		

Footnotes are listed on page 11

Table 2.-Compressive properties of resin-treated paper honeycomb core--Con.

Core thickness	Core density 1.7 p.c.f. <sup>1,2</sup>				Core density 3.7 p.c.f. <sup>1,2</sup>			
	Moisture content	Maximum stress	Proportional limit stress	Modulus of elasticity	Moisture content	Maximum stress	Proportional limit stress	Modulus of elasticity
In.	Pct.	P.s.i.	P.s.i.	1,000 p.s.i.	Pct.	P.s.i.	P.s.i.	1,000 p.s.i.
1	4	90	--	--	3	320	--	--
		90	--	--		390	--	--
		100	--	--		340	--	--
		110	--	--		340	--	--
		100	--	--		340	--	--
		100	--	--		320	--	--
		90	--	--		380	--	--
		80	--	--		340	--	--
		80	--	--		330	--	--
		90	--	--		340	--	--
		90	--	--		350	--	--
		Av. 90				330	--	--
		S.D. 10				Av. 340		
						S.D. 20		
	5	80	--	--	5	310	--	--
		80	--	--		360	--	--
		90	--	--		350	--	--
		100	--	--		350	--	--
		90	--	--		350	--	--
		100	--	--		340	--	--
		80	--	--		400	--	--
		70	--	--		340	--	--
		90	--	--		350	--	--
		100	--	--		340	--	--
		90	--	--		340	--	--
		90	--	--		360	--	--
		Av. 90				Av. 350		
		SD. 10				S.D. 20		
	11	50	--	--	10	210	--	--
		50	--	--		210	--	--
		55	--	--		200	--	--
		55	--	--		210	--	--
		60	--	--		210	--	--
		55	--	--		190	--	--
		50	--	--		230	--	--
		55	--	--		200	--	--
		50	--	--		200	--	--
		50	--	--		200	--	--
		45	--	--		170	--	--
		50	--	--		190	--	--
		Av. 50				Av. 200		
		S.D. 5				S.D. 10		
	76	20	--	--	57	100	--	--
		20	--	--		120	--	--
		25	--	--		90	--	--
		20	--	--		120	--	--
		25	--	--		110	--	--
		20	--	--		100	--	--
		20	--	--		110	--	--
		15	--	--		100	--	--
		20	--	--		100	--	--
		20	--	--		120	--	--
		20	--	--		90	--	--
		25	--	--		110	--	--
		Av. 20				Av. 110		
		S.D. 2				S.D. 10		

Footnotes are listed on page 11

Table 2.--Compressive properties of resen-treated paper honeycomb core--Con.

Core thickness	Core density 1.7 p.c.f. <sup>1,2</sup>				Core density 3.7 p.c.f. <sup>1,2</sup>				
	Moisture content	Maximum stress	Proportional limit stress	Modulus of elasticity	Moisture content	Maximum stress	Proportional limit stress	Modulus of elasticity	
<u>In.</u>	<u>Pct.</u>	<u>P.s.i.</u>	<u>P.s.i.</u>	<u>1,000 p.s.i.</u>	<u>Pct.</u>	<u>P.s.i.</u>	<u>P.s.i.</u>	<u>1,000 p.s.i.</u>	
2	30	100	60	24.0	30	430	200	77.2	
		100	70	27.5		440	300	68.5	
		100	60	24.2		430	260	70.8	
		110	15	23.2		440	310	73.0	
			75	25.4		380	260	61.0	
		110	60	27.0		410	280	65.1	
		90	60	21.3		430	290	67.2	
		100	50	28.2		440	290	69.0	
		110	70	27.0		390	250	59.4	
		120	75	27.1		420	250	65.5	
		90	55	23.4		450	300	67.9	
		110	75	27.2		420	280	64.5	
			Av. 110	65		25.5	Av. 420	270	67.4
			S.D. 10	10		2.2	S.D. 20	30	4.9
		4	4	80		50	17.5	3	340
80	55			20.6	310	160	50.3		
80	55			17.0	320	210	43.5		
90	55			18.5	310	210	51.8		
90	60			21.4	310	220	50.4		
90	50			20.8	310	190	48.0		
80	50			18.0	320	200	50.0		
80	55			17.1	340	200	55.0		
80	50			15.6	290	200	43.0		
110	55			21.2	310	210	46.5		
80	55			14.3	290	180	48.6		
90	60			21.2	300	190	50.5		
	Av. 90			55	18.6	Av. 310	200		49.3
	S.D. 10			5	2.4	S.D. 20	20		3.7
5	5			90	60	21.2	5		330
		90	60	21.0	360	210		58.9	
		90	55	19.5	310	190		60.1	
		90	60	22.0	310	200		51.0	
		100	55	21.6	310	180		48.6	
		90	60	24.6	310	190		49.3	
		80	60	19.1	300	190		48.7	
		80	55	17.5	330	180		54.5	
		80	55	22.1	300	160		52.8	
		90	60	21.0	310	160		51.8	
		80	50	19.1	300	150		51.4	
		80	55	19.9	310	200		53.2	
			Av. 90	60	20.7	Av. 320		180	53.1
			S.D. 5	5	1.8	S.D. 20		20	3.9
		11	11	55	30	13.9		10	190
50	30			14.1	190	120	31.2		
55	30			12.4	180	120	31.8		
50	30			12.4	190	110	34.0		
50	35			13.8	170	110	32.8		
55	40			14.6	180	110	31.8		
50	35			14.5	190	100	34.4		
50	40			14.3	180	110	30.6		
50	40			12.2	180	110	32.0		
55	35			15.7	180	110	32.7		
40	25			10.4	170	110	34.4		
50	35			14.8	210	120	35.1		
	Av. 50			35	13.6	Av. 180	110		33.2
	S.D. 4			4	1.5	S.D. 10	5		1.9

Footnotes are listed on page 11.

Table 2.--Compressive properties of resin-treated paper honeycomb core--Con..

Core thickness	Core density 1.7 p.c.f. <sup>1,2</sup>				Core density 3.7 p.c.f. <sup>1,2</sup>			
	Moisture content	Maximum stress	Proportional limit stress	Modulus of elasticity	Moisture content	Maximum stress	Proportional limit stress	Modulus of elasticity
<u>In.</u>	<u>Pct.</u>	<u>P.s.i.</u>	<u>P.s.i.</u>	<u>1,000 p.s.i.</u>	<u>Pct.</u>	<u>P.s.i.</u>	<u>P.s.i.</u>	<u>1,000 p.s.i.</u>
2	76	20	15	4.8	57	90	60	14.3
		20	15	4.5		90	60	12.2
		25	15	4.9		90	50	14.2
		20	15	5.3		100	69	16.9
		20	20	4.5		80	55	11.9
		20	15	4.9		90	50	15.3
		20	15	5.1		100	60	16.9
		20	15	4.2		100	60	15.6
		20	15	4.1		80	55	12.8
		20	15	3.8		100	55	14.1
		15	10	3.7		100	70	14.7
		<u>20</u>	<u>15</u>	<u>3.9</u>		<u>110</u>	<u>75</u>	<u>16.7</u>
		Av. 20	15			Av. 100	60	14.6
		S.D. 2	1	.5		S.D. 10	5	1.7

<sup>1</sup>At 73° F. and 50 percent relative humidity

<sup>3</sup>Ovendried at 218° F. for 48 hours.

<sup>2</sup>S.D. indicates standard deviation.

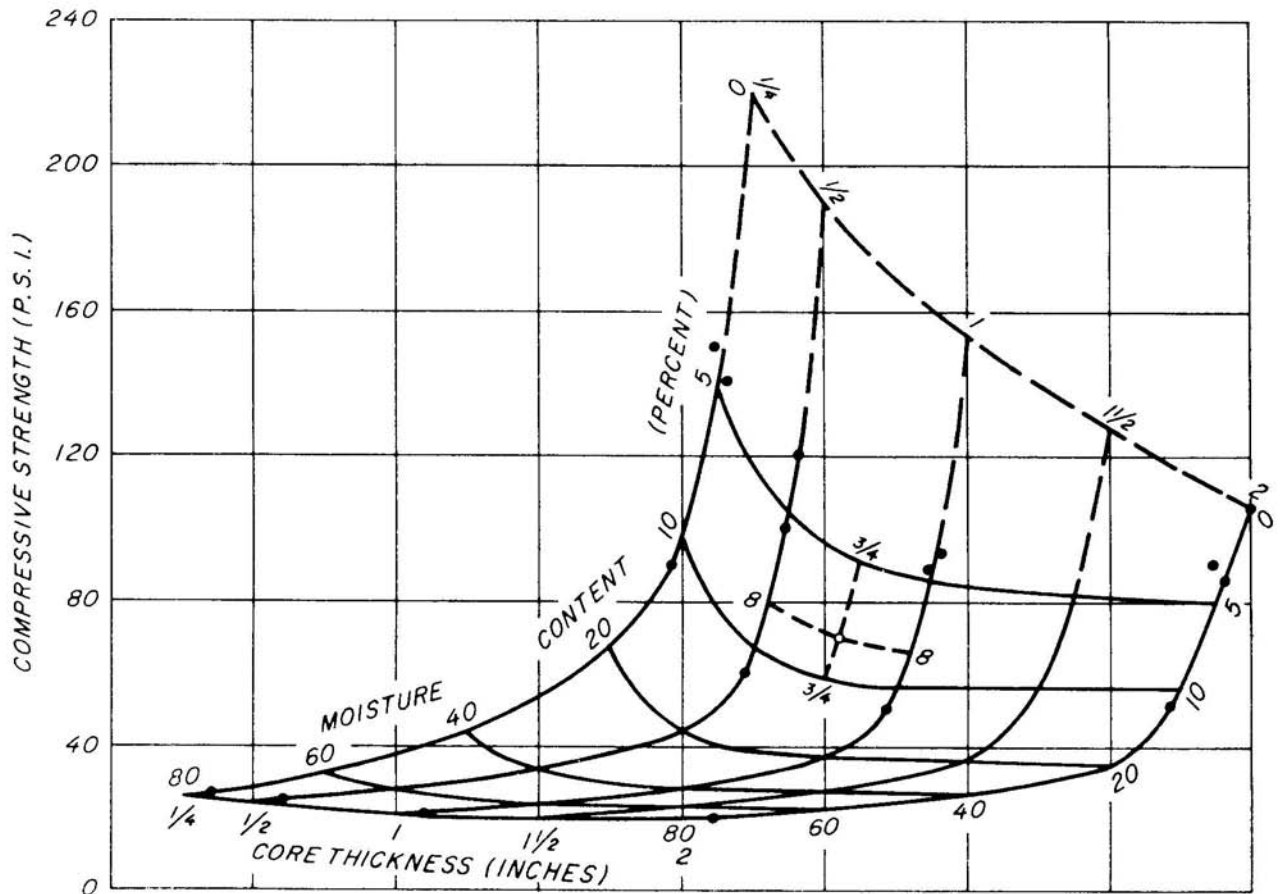


Figure 4.--Compressive strength of 1.7 p.c.f. core plotted as a function of core thickness and moisture content.

M 129 080

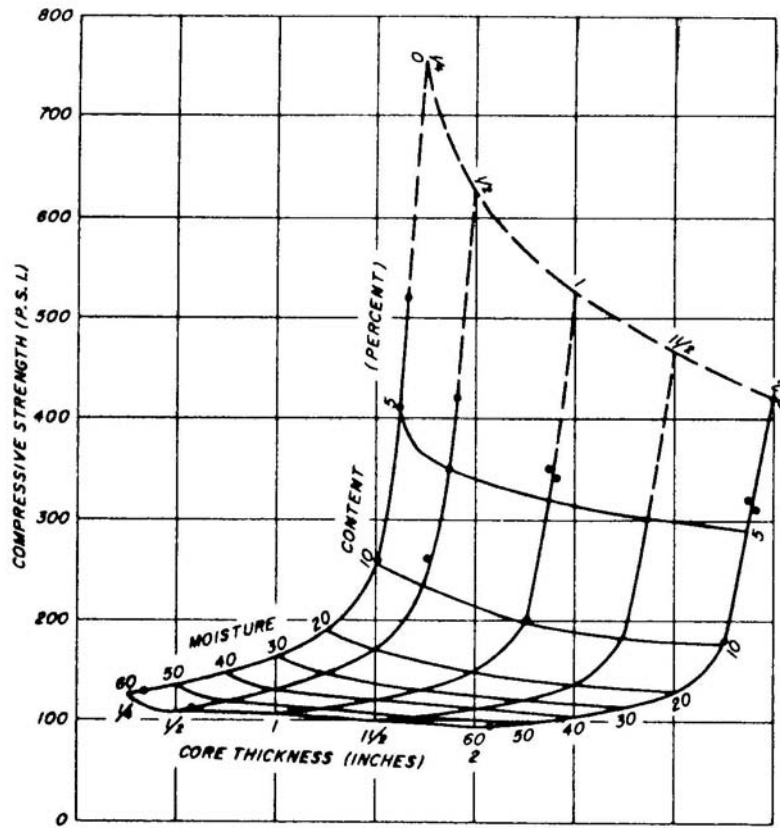


Figure 5.--Compressive strength of 3.7 P.c.f. core plotted as function of core thickness and moisture content.

M 129 081

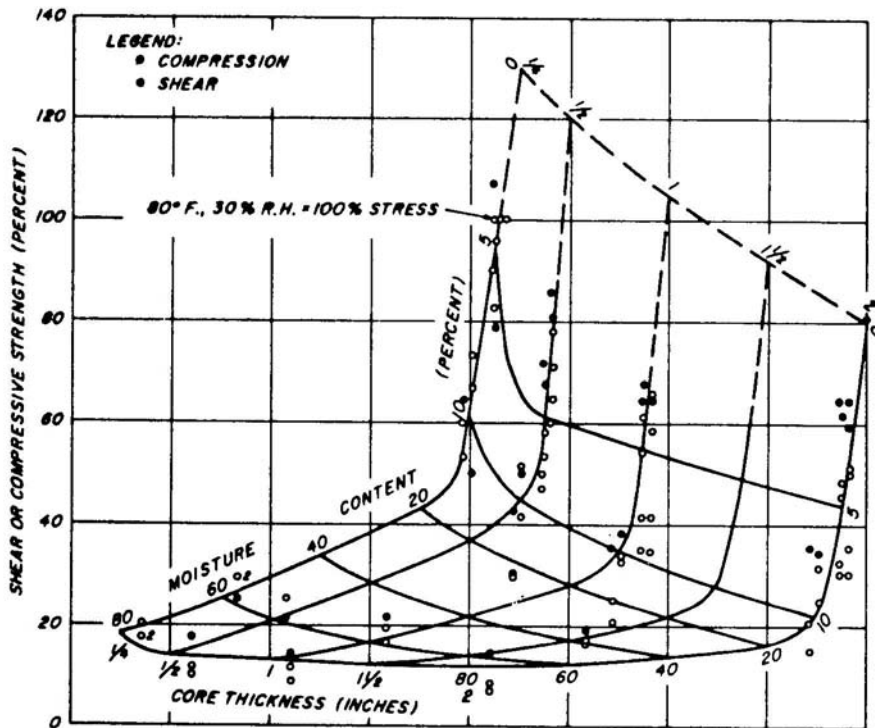
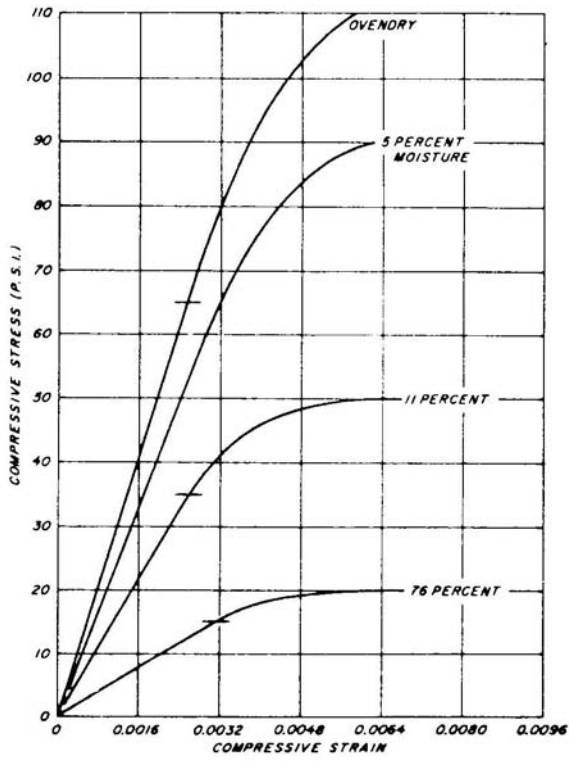


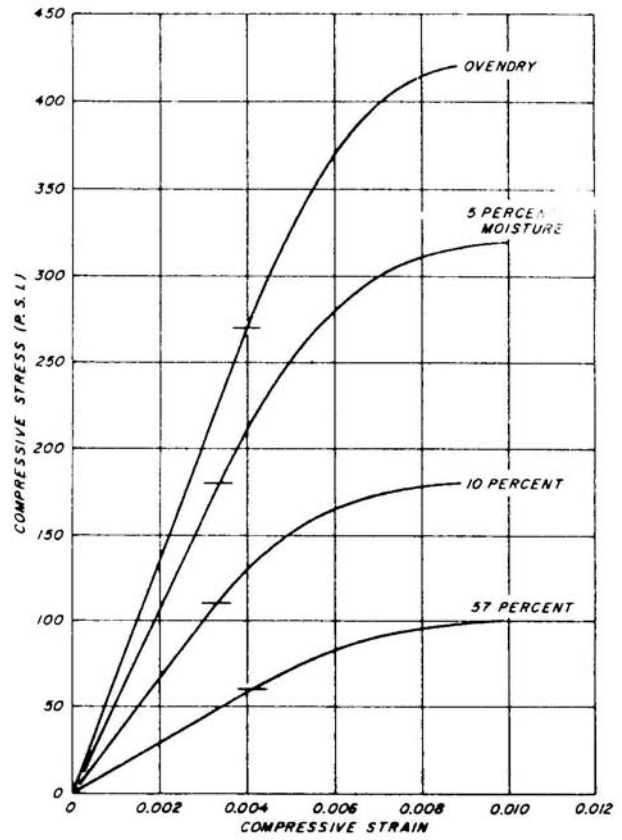
Figure 6.--Compressive or shear strength of resin-treated paper honeycomb core plotted as a function of core thickness and moisture content.

M 129 082



M 129 083

Figure 7.--Compressive stress-strain curves for 1.7 p.c.f. core at several moisture contents.



M 129 084

Figure 8. --Compressive stress-strain curves for 3.7 p.c.f. core at several moisture contents.

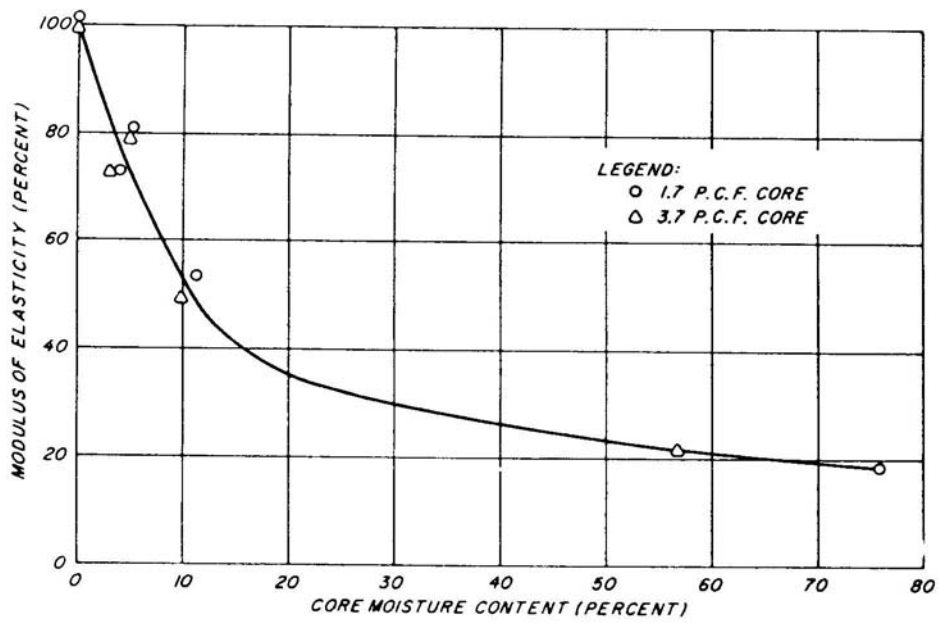


Figure 9.--Effect of core moisture content on compression modulus of elasticity.

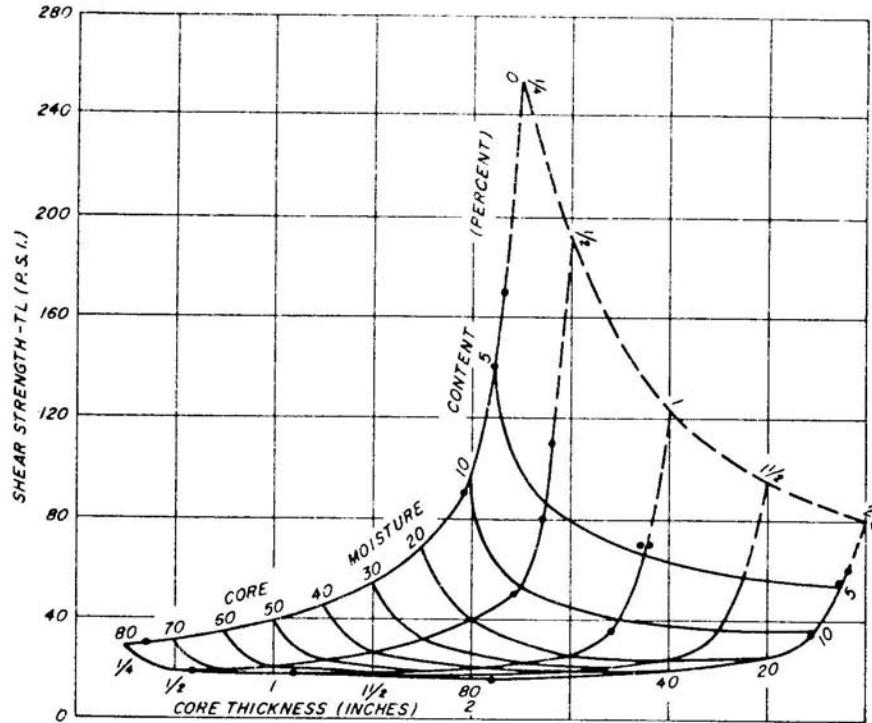


Figure 10.--Shear strength of 1.7 p.c.f. core in TL plane plotted as a function of core thickness and moisture content.

M 129 086

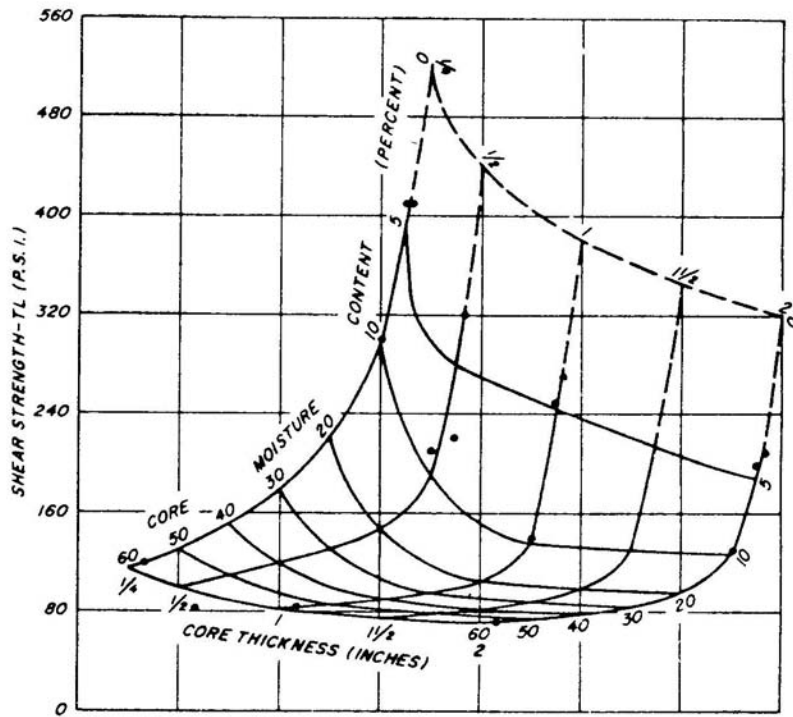


Figure 11.--Shear strength of 3.7 p.c.f. core in TL plane plotted as a function of core thickness and moisture content.

M 129 087

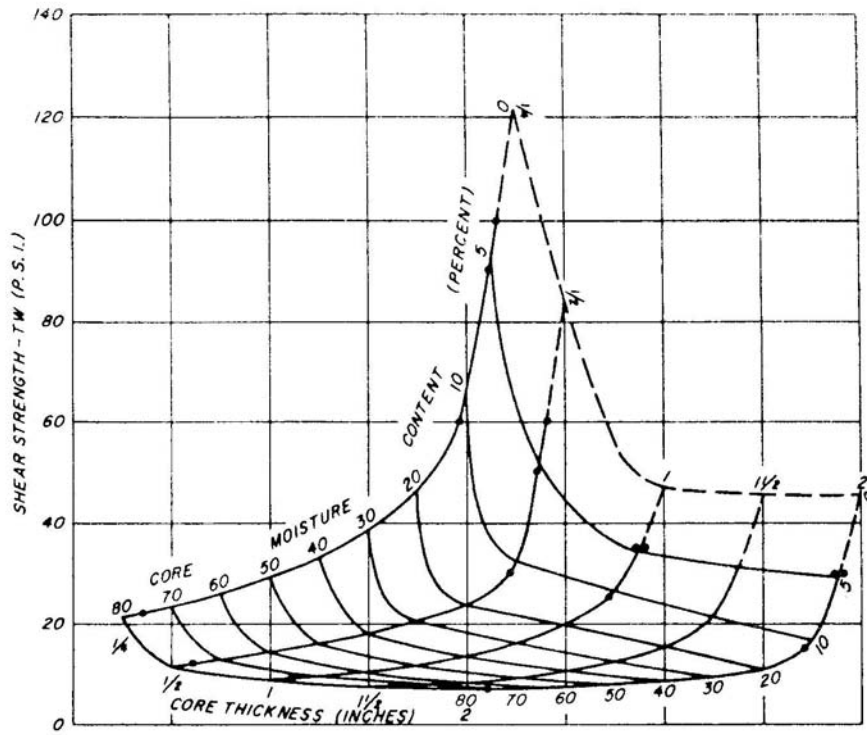


Figure 12.--Shear strength of 1.7 p.c.f. core in TW plane plotted as a function of core thickness and moisture content.

M 129 088

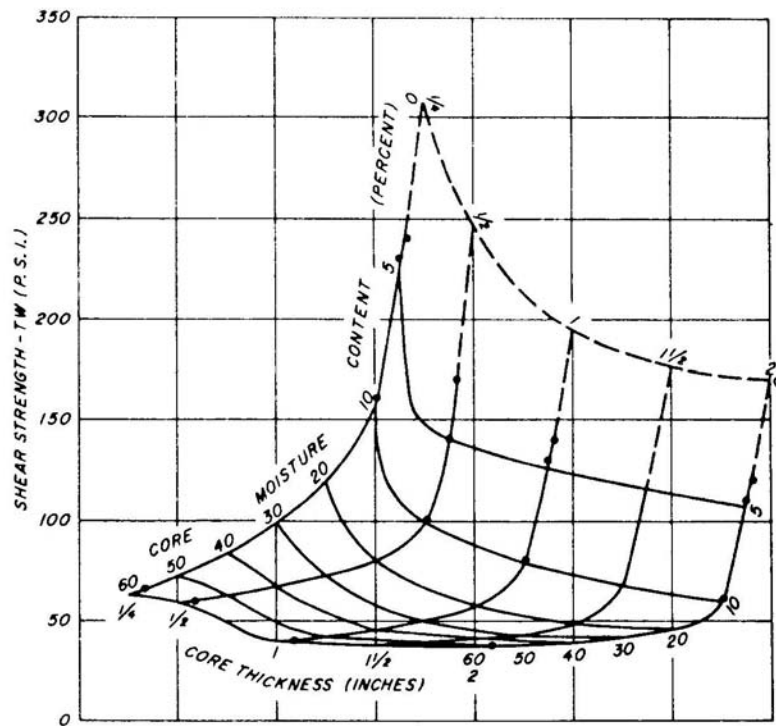


Figure 13.--Shear strength of 3.7 p.c.f. core in TW plane plotted as a function of core thickness and moisture content.

Table 3. --Sheer properties of resin-treated paper honeycomb cord<sup>1,2</sup>

Core thickness	Core density 1.7 p.c.f. <sup>3,4</sup>							Core density 1.7 p.c.f. <sup>3,4</sup>						
	Moisture content	Maximum stress		Proportional limit stress		Modulus of rigidity		Moisture content	Maximum stress		Proportional limit stress		Modulus of rigidity	
		TL	TW	TL	TW	TL	TW		TL	TW	TL	TW	TL	TW
In.	Pct.	P.s.i.	P.s.i.	P.s.i.	P.s.i.	1,000 p.s.i.	1,000 p.s.i.	Pct.	P.s.i.	P.s.i.	P.s.i.	P.s.i.	1,000 p.s.i.	1,000 p.s.i.
1/4	4	170	80	90	35	10.5	4.8	3	450	240	---	90	----	10.0
		150	80	80	30	10.4	4.1		400	240	120	90	23.0	10.7
		180	120	80	30	14.9	7.0		450	250	110	80	22.8	9.8
		200	120	80	40	13.8	6.3		440	250	80	90	25.4	10.7
		210	120	110	30	14.3	6.0		410	230	40	70	26.8	9.5
		190	110	100	40	14.0	5.6		360	210	60	90	22.1	9.9
		150	110	90	40	10.4	5.3		450	240	120	90	23.3	9.4
		160	90	80	25	14.0	4.8		40	250	120	90	23.0	10.2
		170	90	100	20	14.0	5.8		370	230	100	80	23.4	8.9
		160	100	80	35	13.2	5.8		360	220	130	80	21.6	10.1
		140	90	50	20	12.9	6.3		380	220	120	80	23.9	9.2
		150	100	80	25	12.4	6.6		380	210	110	90	24.4	8.1
		Av. 170	100	90	30	12.9	5.7		Av. 410	240	100	90	21.6	9.7
		S.D. 20	10	20	5	1.6	.8		S.D. 30	10	30	10	1.5	.8
		1/4	5	160	100	60	30		10.4	5.0	5	430	220	150
130	80			65	30	10.5	3.8	390	230	170		70	20.8	10.5
140	100			55	30	11.1	5.1	454	250	180		70	25.8	10.3
160	100			60	40	11.4	4.7	440	250	130		90	25.4	9.8
160	100			60	20	11.8	4.8	420	230	170		60	20.8	10.7
140	90			45	25	12.6	4.8	380	210	120		80	19.7	9.1
110	90			35	30	10.1	4.3	450	250	120		90	25.3	8.9
130	70			50	25	13.0	3.1	400	250	150		90	21.6	10.0
120	80			60	30	11.8	1.5	410	230	140		70	23.0	9.1
110	80			40	20	10.6	3.0	400	220	170		70	21.9	9.2
130	70			45	15	10.4	4.1	400	220	110		80	21.2	8.6
130	70			40	20	11.3	4.4	400	210	180		70	21.9	8.5
Av. 140	90			50	25	11.2	4.2	Av. 410	230	150		70	22.7	9.5
S.D. 20	10			10	5	.9	.7	S.D. 20	20	20		10	2.1	.7
1/4	1			100	70	40	20	5.4	2.6	10		290	140	90
		90	55	35	20	6.8	2.1	260	140		80	40	13.0	4.8
		70	65	15	20	5.8	3.0	330	180		110	45	16.3	5.7
		110	70	40	20	8.5	3.0	330	200		110	50	16.5	7.3
		100	60	35	15	7.8	2.6	270	160		80	35	13.9	6.2
		80	60	15	15	7.4	2.0	240	160		80	40	13.6	7.0
		100	55	15	10	8.3	3.1	350	170		90	40	19.1	5.1
		100	50	30	10	1.2	2.2	340	180		60	45	20.3	5.9
		100	50	25	10	7.0	2.3	290	180		40	40	20.8	7.0
		80	50	25	15	5.8	2.6	290	150		60	40	19.2	5.2
		80	50	25	10	4.1	2.4	300	170		70	45	19.0	6.4
		100	55	25	20	7.0	2.9	240	160		70	30	15.0	6.6
		90	60	30	15	6.0	2.6	Av. 300	160		80	40	16.8	6.0
		S.D. 10	10	10	5	1.3	.3	S.D. 40	20		20	5	2.0	.9
		1/4	76	30	25	6	4	3.3	.9		57	---	60	---
25	30			3	4	4.0	.8	90	60	10		10	11.0	2.1
30	25			6	6	4.0	1.3	160	80	20		15	11.2	2.4
30	30			6	6	4.2	1.4	160	70	20		10	11.1	2.6
35	30			5	8	4.3	1.0	80	50	15		15	9.0	1.5
40	25			5	5	3.9	1.0	90	50	10		10	9.3	2.1
35	20			4	7	4.3	1.0	150	70	40		15	10.6	3.0
30	15			2	5	3.8	.5	140	80	15		10	10.0	2.6
45	15			6	3	3.7	.8	120	70	15		10	10.1	2.7
30	15			4	4	4.3	.6	110	m	15		20	10.1	2.2
35	10			4	3	4.0	.7	110	70	15		20	10.1	2.4
30	15			3	5	4.0	1.2	120	70	10		15	10.4	2.3
Av. 30	20			4	5	4.0	.9	Av. 120	70	15		15	10.3	2.3
S.D. 5	5			1	2	.3	.3	S.D. 30	10	8		3	.7	.5
1/2	4			90	55	50	30	11.5	4.7	3		320	160	80
		110	55	60	10	12.0	4.8	120	160		120	60	22.1	8.6
		110	55	M	20	13.1	5.5	350	170		110	60	24.2	8.6
		110	65	55	25	14.4	5.5	340	180		90	60	25.6	9.4
		130	65	65	25	14.5	5.4	300	150		90	70	23.5	8.6
		130	65	50	25	14.9	4.6	290	160		120	60	23.8	8.7
		100	55	60	10	10.8	4.2	330	170		110	80	25.4	7.9
		110	50	55	25	12.4	3.8	160	170		120	80	26.0	8.6
		120	60	60	15	13.4	5.5	310	160		110	70	24.0	8.7
		100	60	60	15	10.7	4.9	100	170		100	80	22.0	0.7
		90	55	60	20	10.1	5.2	330	160		110	70	25.4	8.0
		90	60	60	15	11.0	6.1	330	180		80	70	25.8	9.0
		Av. 110	60	55	20	12.4	5.0	Av. 320	170		100	70	24.3	8.6
		S.D. 10	5	5	5	1.6	.6	S.D. 20	10		20	10	1.4	.4

Footnotes are listed on page 9

Table 3.--Shear properties of resin-treated paper honeycomb core<sup>1,2</sup>-Con.

Core thickness	Core density 1.7 p.c.f. <sup>3,4</sup>							Core density 3.7 p.c.f. <sup>3,4</sup>							
	Moisture content	Maximum stress		Proportional limit stress		Modulus of rigidity		Moisture content	Maximum stress		Proportional limit stress		Modulus of rigidity		
		TL	TW	TL	TW	TL	TW		TL	TW	TL	TW	TL	TW	
In.	Pct.	P.s.i.	P.s.i.	P.s.i.	P.s.i.	$\frac{1,000}{P.s.i.}$	$\frac{1,000}{P.s.i.}$	Pct.	P.s.i.	P.s.i.	P.s.i.	P.s.i.	$\frac{1,000}{P.s.i.}$	$\frac{1,000}{P.s.i.}$	
1/2	5	90	50	35	25	11.5	3.6	5	220	140	80	40	15.5	7.7	
		70	55	30	20	10.4	3.9		210	140	70	60	15.6	7.4	
		100	55	25	25	12.6	4.4		220	160	80	50	16.3	7.9	
		90	60	50	30	11.2	4.4		240	160	80	45	19.3	8.2	
		100	60	45	25	11.9	4.4		180	130	70	55	14.0	7.3	
		90	50	40	25	10.8	3.7		210	140	80	50	15.6	7.0	
		70	50	15	25	9.7	4.3		230	120	80	50	16.6	6.8	
		90	45	45	25	11.5	3.0		230	150	80	40	16.4	8.1	
		80	45	30	25	10.6	3.8		230	130	70	35	17.1	7.2	
		80	45	25	25	12.1	3.7		200	130	70	40	14.5	7.5	
	70	45	35	25	10.2	3.6	220	150	90	35	16.6	8.6			
	80	45	30	25	10.5	4.6	290	160	100	55	19.9	8.2			
	Av.	80	50	35	25	11.1	4.0	Av.	220	140	80	45	16.4	7.7	
	S.D.	10	5	10	3	.9	.5	S.D.	30	10	10	10	1.7	.6	
	11	10	45	30	15	10	6.8	2.1	10	230	100	35	15	18.7	5.9
			40	30	15	10	6.4	2.3		200	90	50	15	15.4	6.9
			50	35	20	10	8.0	3.0		230	110	45	15	18.0	6.4
			60	35	20	10	7.5	2.7		260	110	60	20	20.2	6.1
			65	30	20	10	8.3	2.3		160	80	45	15	14.4	5.8
			60	30	20	10	8.2	2.2		250	80	45	10	21.8	5.3
40			30	20	10	4.9	2.8	210		100	45	25	17.8	5.7	
45			30	15	10	6.6	1.9	210		110	60	15	17.4	6.7	
55			25	20	5	7.8	2.0	200		80	45	15	17.8	5.2	
50			25	15	10	7.4	1.8	170		90	30	15	16.5	6.1	
45	25	20	10	5.7	2.3	230	100	30	25	21.9	5.7				
50	30	20	10	5.9	2.6	220	100	30	25	18.7	5.9				
Av.	50	30	20	10	7.0	2.3	Av.	210	100	40	20	18.2	6.0		
S.D.	8	4	2	1	1.1	.4	S.D.	30	10	10	3	2.3	.5		
76	57	15	10	2	2	3.0	0.7	57	70	35	15	5	6.8	3.0	
		15	10	3	2	3.2	.8		70	45	10	10	7.4	2.2	
		20	15	8	2	2.8	1.1		90	55	10	10	10.2	2.9	
		20	15	5	3	2.8	1.0		100	55	25	15	10.4	2.9	
		20	15	6	2	2.9	1.1		60	55	10	10	6.7	3.0	
		20	10	4	3	2.6	.8		60	80	10	15	6.4	4.2	
		25	10	4	3	4.0	.8		80	65	20	10	6.8	3.2	
		25	10	4	2	3.4	.7		100	65	25	15	9.5	3.1	
		20	10	5	2	2.7	.8		80	50	20	10	6.8	3.0	
		20	10	5	2	2.3	.7		60	60	15	10	5.8	3.5	
20	10	3	2	2.8	1.0	100	80	20	20	9.5	4.0				
15	15	4	2	2.0	1.3	110	75	25	20	9.1	3.8				
Av.	20	10	4	2	2.9	.9	Av.	80	60	15	15	8.0	3.2		
S.D.	3	2	2	0.5	.5	.2	S.D.	20	15	5	5	1.7	.6		
1	4	70	40	40	15	11.0	3.4	3	250	150	70	40	20.2	9.3	
		70	35	40	20	14.7	3.0		280	160	100	40	23.6	9.1	
		70	40	30	15	11.6	4.0		270	140	110	40	22.6	8.4	
		60	40	35	20	11.0	3.7		260	140	160	55	22.8	8.3	
		70	40	40	15	12.4	4.0		270	140	110	40	27.4	8.7	
		70	40	35	15	10.4	3.8		260	130	70	40	23.2	8.1	
		70	35	35	10	10.4	3.6		310	150	90	60	26.0	8.3	
		80	30	35	15	14.1	2.8		270	130	90	40	24.4	7.7	
		60	35	30	20	9.5	3.5		280	140	160	65	22.4	7.5	
		60	35	40	10	15.7	3.5		270	130	120	60	28.0	7.6	
60	35	25	15	8.9	3.5	290	140	100	50	26.0	8.0				
60	35	40	15	9.6	4.0	250	140	150	45	22.4	8.5				
Av.	70	35	35	15	11.6	3.6	Av.	270	140	110	50	24.1	8.3		
S.D.	10	3	4	3	2.2	.4	S.D.	20	10	30	10	2.3	.6		
5	5	70	35	35	15	10.5	3.4	5	240	130	40	40	20.6	9.0	
		70	35	25	20	9.0	3.0		280	140	100	50	22.4	7.8	
		70	40	25	15	9.9	3.6		240	140	70	40	21.7	7.8	
		70	35	25	10	11.8	3.7		240	140	90	45	23.4	7.6	
		70	35	20	15	11.5	3.5		230	120	80	40	21.4	7.8	
		70	40	25	10	10.0	3.6		250	120	80	35	23.0	7.5	
		60	35	20	10	10.0	3.5		260	140	80	40	23.2	8.0	
		80	35	20	5	11.2	3.2		250	120	80	40	22.8	7.5	
		60	35	25	15	10.4	3.3		250	130	70	35	22.6	7.8	
		70	35	40	20	10.9	3.3		240	130	60	35	22.6	8.0	
60	30	25	15	8.9	3.2	250	130	70	40	22.6	7.7				
60	35	25	20	9.8	3.6	230	130	80	40	20.2	8.6				
Av.	70	35	25	15	10.3	3.4	Av.	250	130	80	40	2.2	7.9		
S.D.	5	2	6	4	.9	.2	S.D.	10	10	15	5	1.0	.4		

Footnotes are listed on page 19

Table 3.--Shear properties of certain coated paper honeycomb core<sup>1,2</sup>—Con.

Core thickness	Core density 1.7 p.c.f. <sup>3,4</sup>								Core density 3.7 p.c.f. <sup>3,4</sup>								
	Moisture content		Maximum stress		Proportional limit stress		Modulus of rigidity		Moisture content	Maximum stress		Proportional limit stress		Modulus of rigidity			
	TL	TW	TL	TW	TL	TW	TL	TW		TL	TW	TL	TW	TL	TW		
In.	Pct.	P.s.i.	P.s.i.	P.s.i.	P.s.i.	1,000 P.s.i.	1,000 P.s.i.	Pct.	P.s.i.	P.s.i.	P.s.i.	P.s.i.	1,000 P.s.i.	1,000 P.s.i.			
1	11	35	25	10	10	6.0	1.6	10	120	70	40	20	14.2	5.0			
		35	20	5	5	7.7	1.6		150	90	30	20	15.8	4.8			
		35	25	10	10	6.8	2.0		140	80	20	20	14.9	4.6			
		35	25	10	10	6.1	1.9		140	90	35	25	15.3	5.0			
		45	25	20	10	6.9	1.8		120	70	25	20	13.9	4.6			
		40	25	5	10	7.9	1.9		140	70	40	25	14.6	4.2			
		35	20	10	10	6.4	1.9		150	80	30	20	13.9	4.3			
		35	20	10	5	7.8	1.5		150	80	40	20	15.0	4.7			
		30	20	15	10	6.0	1.7		150	70	30	25	14.2	3.5			
		35	25	10	10	6.8	1.8		150	70	40	25	15.6	3.9			
	30	20	10	10	5.8	1.6	140	70	30	20	15.2	4.1					
	35	25	10	10	6.3	2.4	140	80	30	20	14.3	4.9					
	35	25	10	10	6.7	1.8	140	80	30	20	14.7	4.5					
			Av. S.D.	3	2	4	2	.7			Av. S.D.	10	10	6	2	.7	.5
	76	20	20	7	4	2	2.9	.8	57	80	45	15	8	9.3	2.8		
			20	8	2	2	3.6	.8		100	45	20	3	11.2	3.5		
			20	9	3	2	4.0	1.2		90	40	20	4	9.8	2.6		
			20	11	4	2	3.3	1.4		30	40	5	5	11.1	2.8		
			20	11	4	3	3.1	1.1		70	40	5	4	11.5	2.9		
			20	9	4	2	2.8	.9		80	40	10	4	11.4	2.9		
15			12	4	2	2.7	1.4	80		35	5	5	12.1	2.2			
15			9	3	1	3.3	.9	90		40	10	4	11.0	3.2			
15			9	3	2	3.0	.9	90		35	5	7	10.9	2.3			
15			9	3	2	2.8	1.0	80		40	5	6	11.1	2.7			
15	8	2	2	2.6	1.3	70	40	5	5	10.8	2.9						
20	10	4	2	3.0	1.4	90	35	9	4	10.3	2.6						
		Av. S.D.	20	9	3	2	3.1			Av. S.D.	10	3	6	1	.8	.4	
2	4	60	30	25	5	10.5	3.3	3	220	110	50	45	23.7	7.0			
		60	25	25	15	10.5	3.0		220	120	90	60	23.6	7.9			
		55	35	20	15	9.6	3.7		220	130	70	45	22.2	8.7			
		60	30	20	10	10.4	3.6		210	110	80	55	21.2	6.6			
		60	30	40	20	10.2	3.4		210	120	80	45	22.4	7.4			
		65	35	25	15	9.8	3.4		200	110	90	50	20.0	6.8			
		50	25	20	5	9.1	2.8		220	120	100	55	22.4	7.0			
		60	30	35	10	10.4	3.1		210	130	90	35	19.9	8.6			
		60	30	35	20	9.7	3.3		210	110	100	40	21.1	7.2			
		60	30	25	15	10.1	3.2		210	120	60	45	20.4	8.0			
	50	25	10	10	8.3	3.3	210	120	80	50	20.7	7.6					
	60	30	25	10	10.8	3.8	210	130	90	40	20.0	8.6					
			Av. S.D.	60	30	25	10	10.0			Av. S.D.	210	120	80	45	21.5	7.6
	5	55	55	30	40	10	9.8	3.2	5	200	130	40	45	25.8	8.5		
			55	30	30	10	9.7	3.1		200	120	50	50	24.4	8.0		
			50	30	30	15	8.6	3.5		210	110	75	50	21.8	7.1		
			55	30	25	10	9.6	3.6		210	110	40	40	21.4	7.2		
			60	30	30	15	10.3	3.2		210	110	40	45	22.6	7.8		
			55	30	25	15	9.7	3.1		200	110	75	45	20.8	6.7		
			50	30	25	10	8.5	3.3		200	110	80	50	20.6	6.6		
60			25	20	5	12.2	2.8	200		120	30	50	21.0	7.8			
55			30	25	10	9.0	3.3	200		110	55	45	21.3	6.9			
55			30	35	10	8.9	3.3	200		120	50	50	20.0	7.7			
45	25	20	10	7.9	3.3	200	110	45	40	20.5	7.7						
		Av. S.D.	50	25	30	15	8.3			Av. S.D.	200	120	90	50	19.4	7.9	
11	35	35	15	10	5	7.3	1.7	10	130	65	40	20	14.2	4.4			
		30	15	5	5	6.7	1.7		120	55	50	25	13.6	3.9			
		30	15	5	5	6.2	1.6		130	70	30	20	16.9	4.6			
		30	15	10	5	6.3	1.7		130	55	40	20	13.3	3.8			
		35	20	10	5	7.0	2.0		140	65	45	25	14.5	4.5			
		35	15	5	5	7.5	1.8		120	55	50	20	13.0	3.5			
		35	15	10	5	6.1	2.0		130	55	35	15	13.8	3.6			
		40	15	10	5	7.4	1.3		130	60	50	15	12.7	4.4			
		30	15	10	5	5.3	1.6		130	55	35	20	15.4	3.7			
		35	15	10	5	6.8	1.7		140	65	55	20	13.2	4.4			
30	15	5	5	6.2	1.8	140	65	40	20	15.2	4.4						
30	15	10	5	5.4	2.3	140	60	50	15	13.9	4.5						
		Av. S.D.	35	15	10	5	6.5			Av. S.D.	130	60	45	20	14.1	4.1	

Footnotes are listed on page 19

Table 3.--Shear properties of resin-treated paper honeycomb core<sup>1,2</sup>-Con.

Core thickness	Core density 1.7 p.c.f. <sup>3,4</sup>							Core density 3.7 p.c.f. <sup>3,4</sup>								
	Moisture content	Maximum stress		Proportional limit stress		Modulus of rigidity		Moisture content	Maximum stress		Proportional limit stress		Modulus of rigidity			
		TL	TW	TL	TW	TL	TW		TL	TW	TL	TW	TL	TW		
In.	Pct.	P.s.i.	P.s.i.	P.s.i.	P.s.i.	$\frac{1,000}{\text{p.s.i.}}$	$\frac{1,000}{\text{p.s.i.}}$	Pct.	P.s.i.	P.s.i.	P.s.i.	P.s.i.	$\frac{1,000}{\text{p.s.i.}}$	$\frac{1,000}{\text{p.s.i.}}$		
2	76	15	8	3	2	3.1	1.1	57	70	40	10	10	10.2	2.9		
		15	6	2	1	3.7	.9		60	40	10	5	9.8	2.9		
		15	9	3	2	3.7	1.3		80	40	15	10	10.1	2.7		
		15	7	3	1	3.2	1.0		70	35	15	5	9.4	2.4		
		15	6	3	1	3.8	.9		80	40	15	10	9.6	2.7		
		15	7	3	1	3.1	1.1		70	35	15	5	9.4	2.4		
		15	6	4	1	2.6	.9		80	35	15	10	9.7	2.3		
		15	5	4	1	2.8	.7		80	40	15	10	9.3	3.0		
		15	6	3	1	2.9	.9		70	35	10	10	9.6	2.5		
		15	6	3	1	3.2	.8		80	35	15	5	9.0	2.8		
		15	6	3	1	2.6	.9		70	35	15	10	9.4	2.6		
		15	7	3	1	3.6	1.1		80	40	20	10	9.5	3.4		
		15	7	3	1	3.2	1.0		70	40	15	10	9.6	2.7		
		Av.	15	7	3	1	3.2		1.0	Av.	70	40	15	10	9.6	2.7
		S.D.	1	1	0.5	0.5	.4		.2	S.D.	5	3	3	1	.3	.3

- <sup>1</sup> "TL" plane is parallel to the core ribbon direction and parallel to the core flutes.
- <sup>2</sup> "TW" plane is perpendicular to the core ribbon direction and parallel to the core flutes.
- <sup>3</sup> At 73° F. and 50 percent relative humidity.
- <sup>4</sup> S.D. indicates standard deviation.

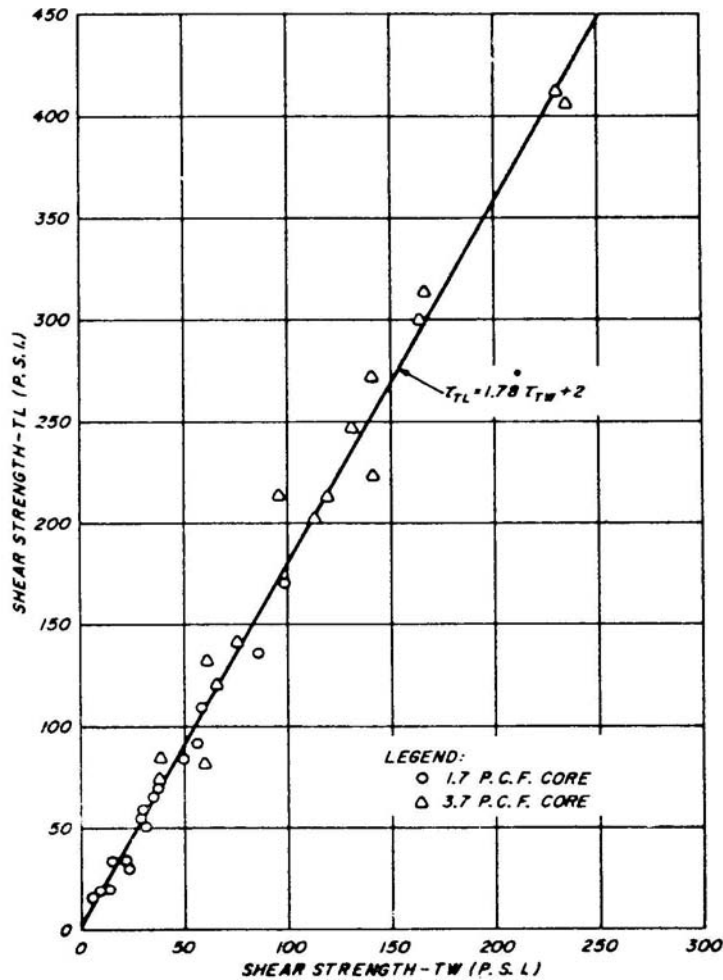


Figure 14. --Relationship between core shear strengths in TL and TW planes. M 129 090

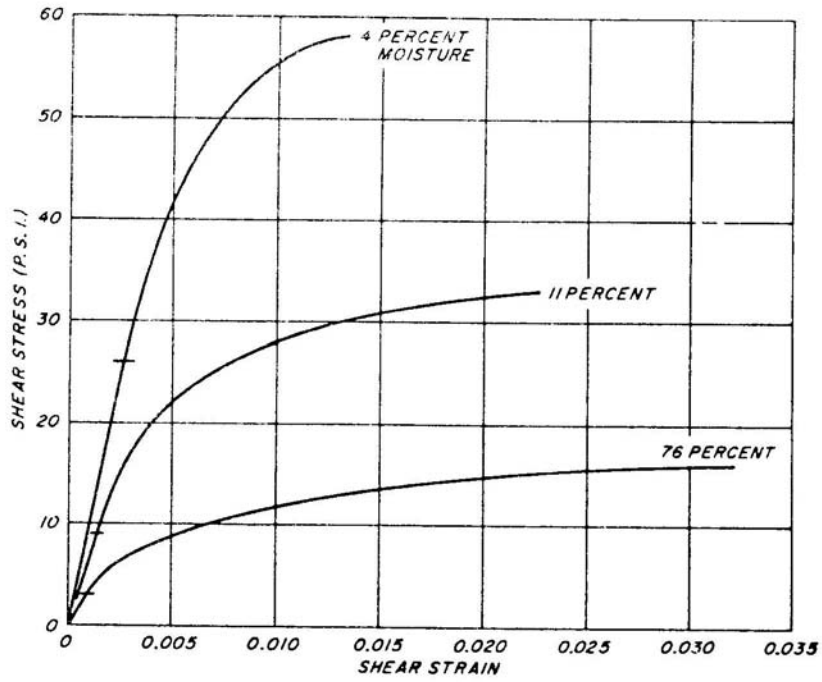


Figure 15.--Typical shear stress-strain curves (TL plane) for 1.7 p.c.f. core at several moisture contents.

M 129 091

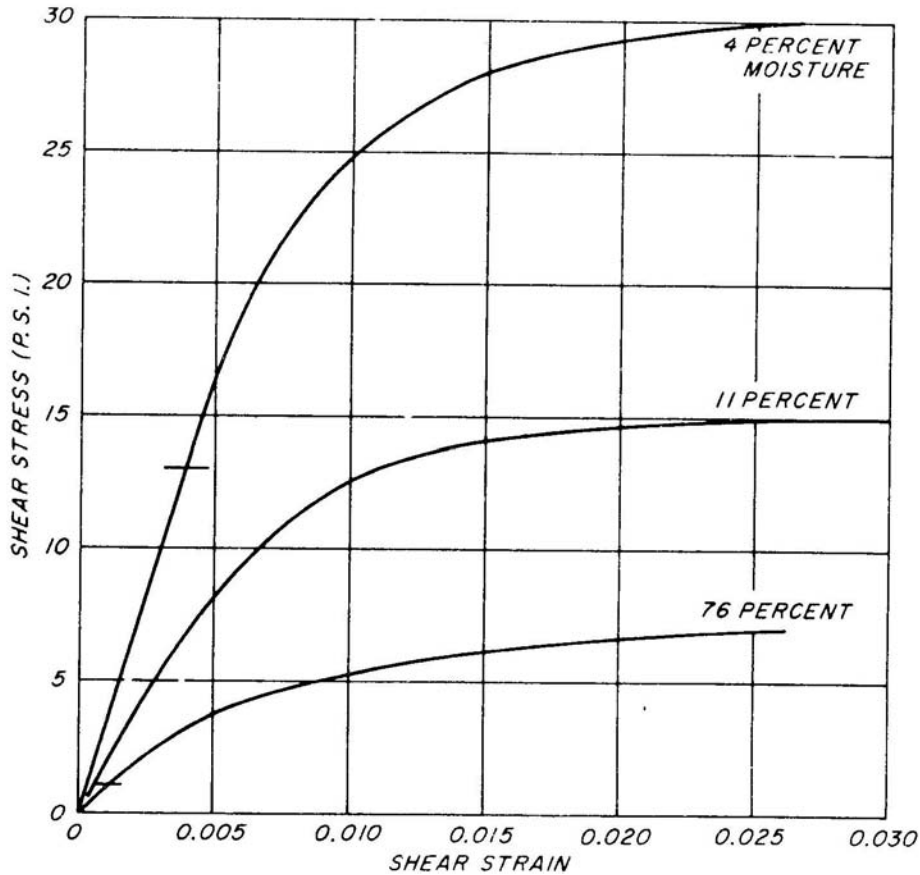


Figure 16.--Typical shear stress-strain curves (TW plane) for 1.7 p.c.f. core at several moisture contents.

M 129 192

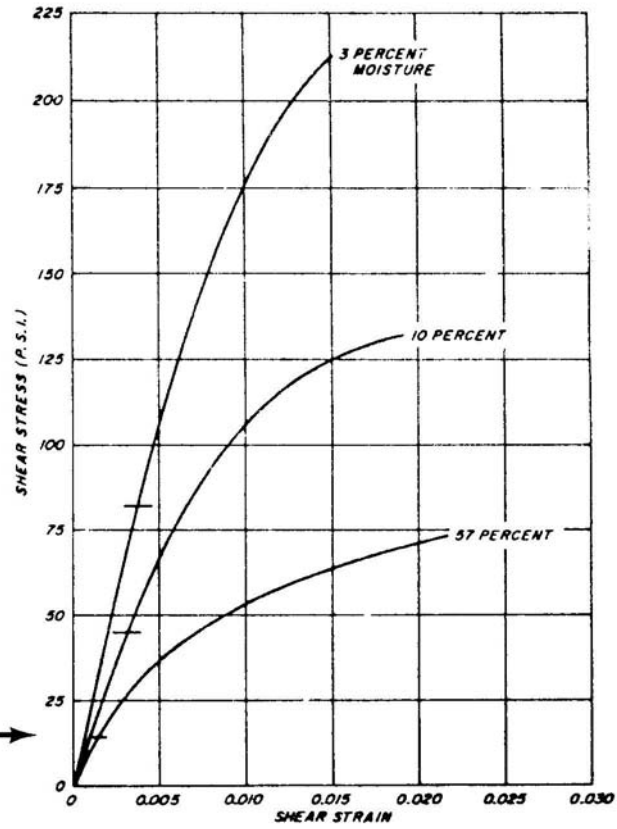


Figure 17.--Typical shear stress-strain curves (TL plane) for 3.7 p.c.f. core at several moisture content.

M 129 093

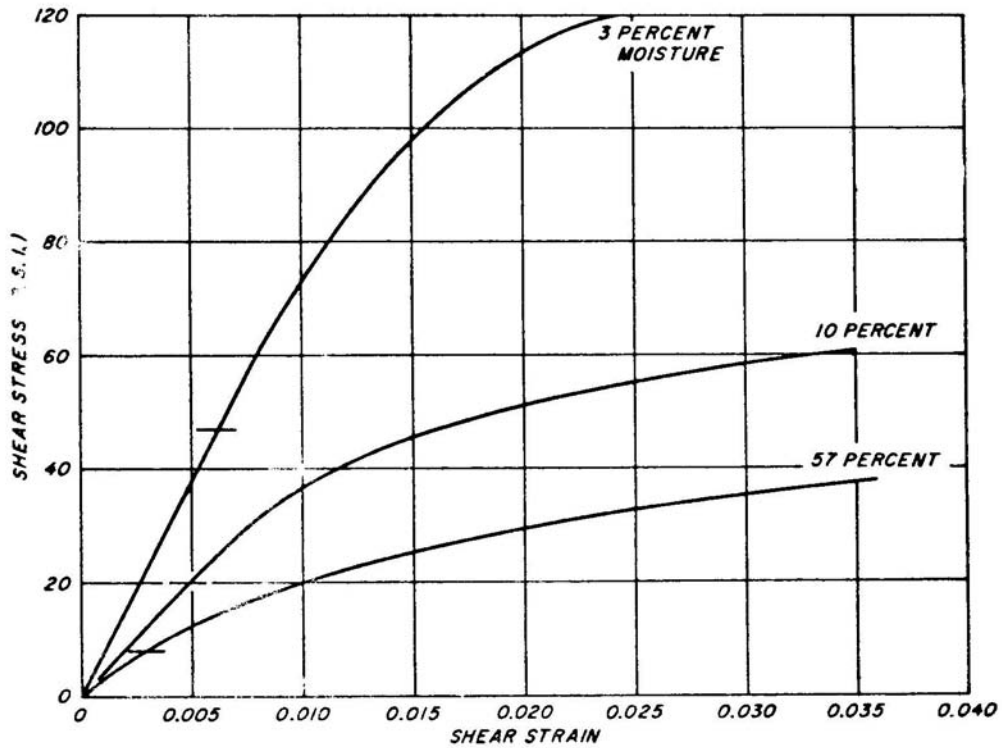


Figure 18.--Typical shear stress-strain curves (TW plane) for 3.7 p.c.f. core at several moisture contents.

M 129 094

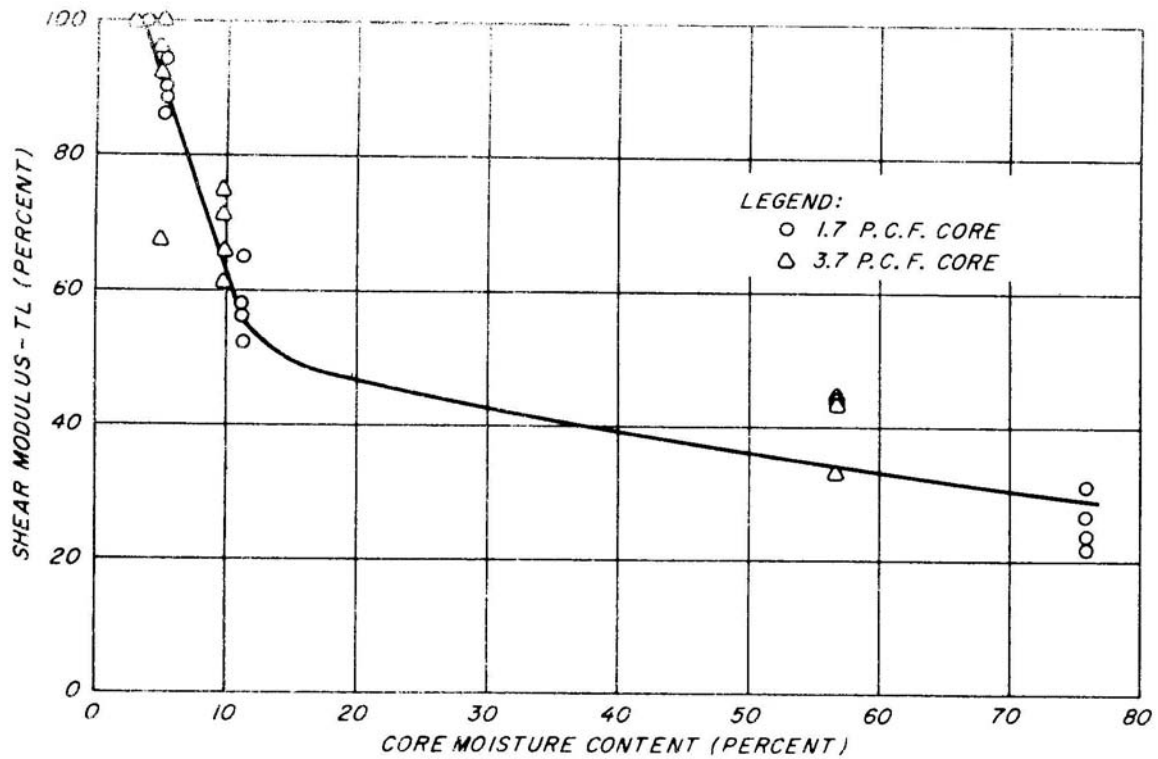


Figure 19.--Effect of moisture content on shear modulus in TL plane.

M 129 095

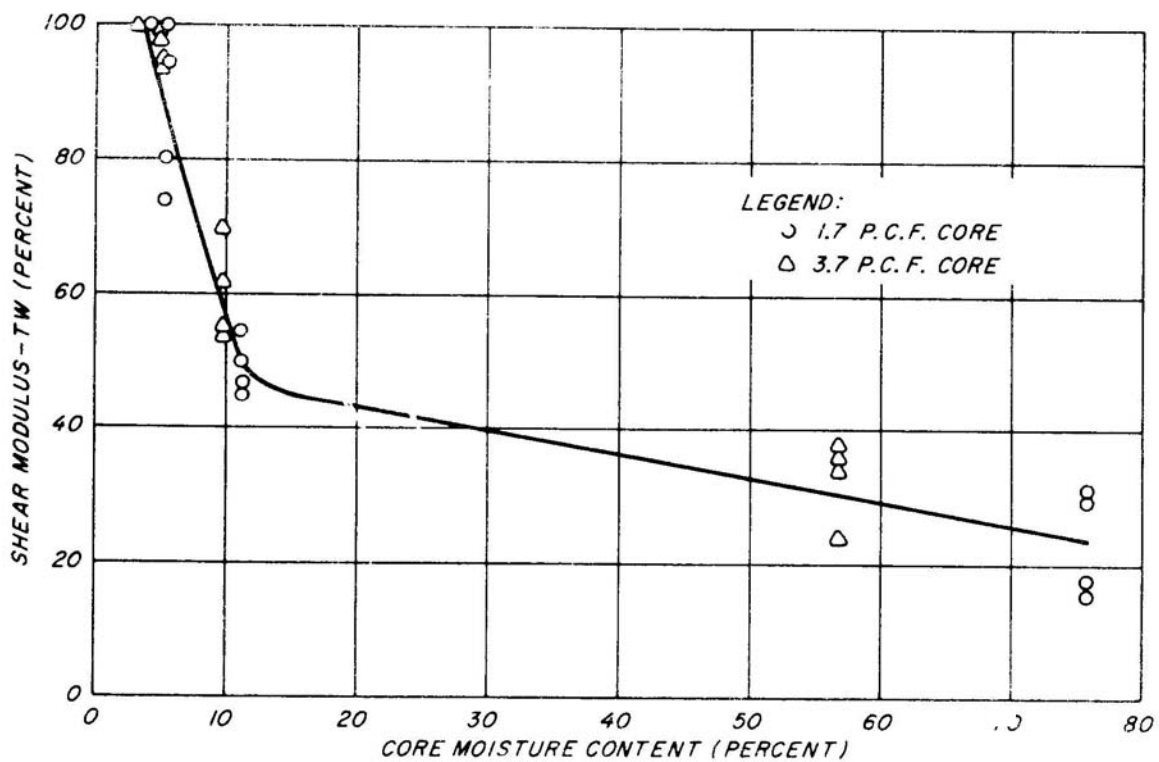


Figure 20.--Effect of moisture content on shear modulus in TW plane.

M 129 096

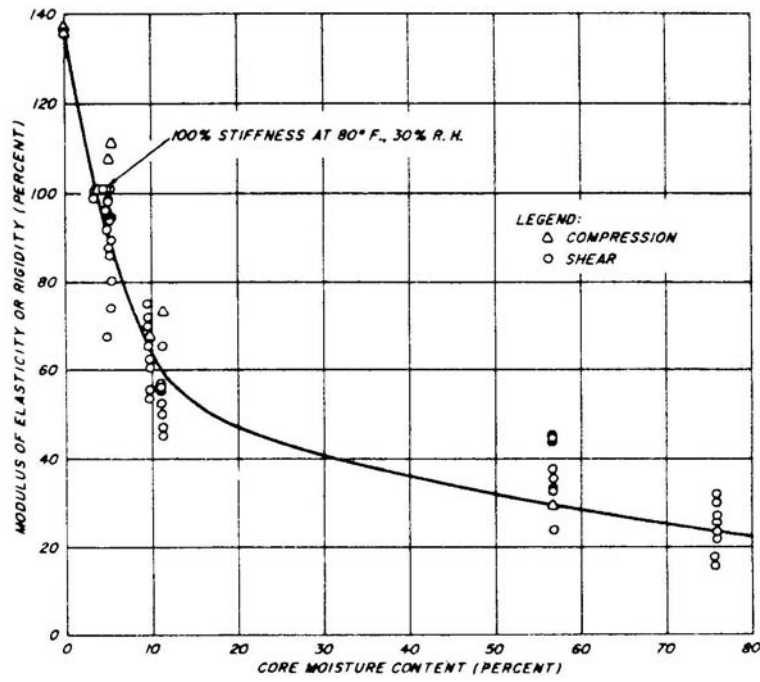


Figure 21.--Effect of core moisture content on shear and compressive stiffness of resin-treated paper honeycomb core. M 129 097

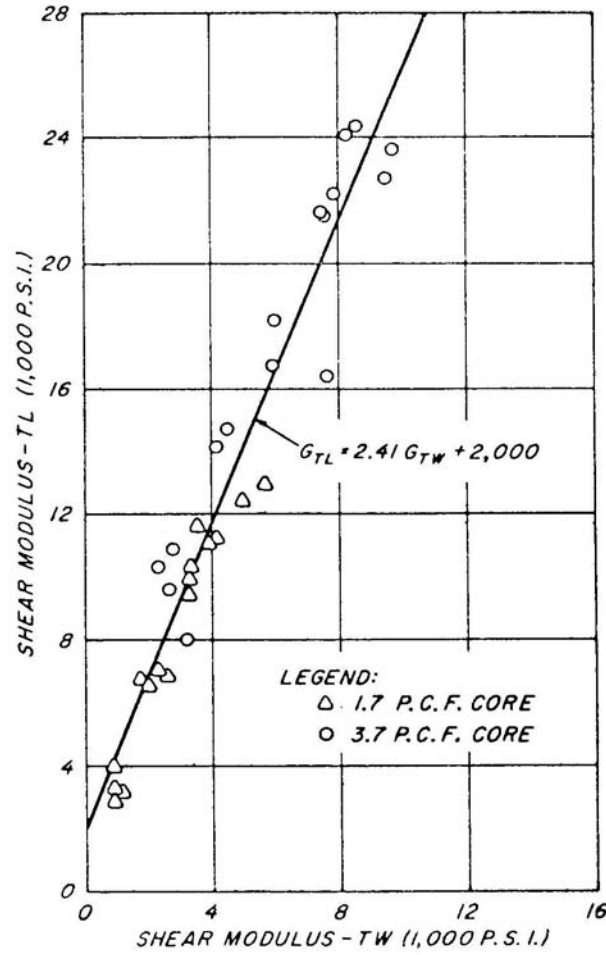


Figure 22.--Relationship between core shear moduli in TL and TW planes. M 129 098

about 60 percent of those at 4 percent moisture content, while cores at 60 percent moisture content were only about 30 percent as stiff. These data are also presented in the composite graph of figure 21, which shows the effect of core moisture content on shear or compressive stiffness.

Core thickness was not expected to have any pronounced effect on the modulus of rigidity. Because steel loading plates were bonded to the cores with an adhesive, the unsupported thickness of core which deforms under load is somewhat less than the nominal core thickness. Hence, calculated values of the modulus of rigidity are slightly higher than the true values. This

difference was negligible for 1- and 2-inch-thick cores for the thin gluelines used in this study, but a noticeable increase in calculated stiffness was expected for the 1/2-inch and 1/4-inch-thick cores. This expected trend is shown by the average shear modulus data shown in table 1. Values from this table to be compared must be for core of the same density, moisture content, and shearing direction,

The relationship between shear modulus (TL) and shear modulus (TW) is shown in figure 22. The formula  $G_{TL} = 2.41 G_{TW} + 2,000$  was determined by least squares.

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## CONCLUSIONS

Compressive strength of 1/4-inch-thick cores was 25 to 80 percent greater than that of 2-inch-thick cores, while strengths of 1-inch-thick cores were 10 percent greater, at most. Compressive strength of cores at 10 percent moisture content was about 50 to 70 percent of that at 4 percent moisture content, while cores at about 75 percent moisture content were about 20 percent as strong. Owendry cores were about 20 to 40 percent stronger than cores at 4 percent moisture content. The modulus of elasticity at 10 percent moisture content was about half that of owendry core, while cores soaked in water (60 to 80 percent moisture content) were only about 20 percent as stiff.

Core shear strength of 1/4-inch-thick cores was about two to four times as high as that for 2-inch-thick cores. Core shear strength and modulus of rigidity at 10 percent moisture content were about 50 to 70 percent of those at 4 percent moisture content, while cores soaked in water had 20 to 40 percent of the strength and stiffness of those at 4 percent moisture content. Shear strength in the TW plane was about 55 percent of that in the TL plane, while the shear modulus in the TW plane was about 35 percent of that in the TL plane.

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