MASTERS' THESIS

Eisenhauer
A preliminary study of the manufacture of compreg, impreg and normal laminated cottonwood...

1945

A PRELIMINARY STUDY OF THE MANUFACTURE OF COMPREG, IMPREG, AND NORMAL LAMINATED COTTONWOOD (POPULUS DELTOIDES) AND A COMPARISON OF THEIR MECHANICAL AND PHYSICAL PROPERTIES

By

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Approved: ____________________

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William D. Eisenhauer.

INTRODUCTION

The modification of wood through impregnation with chemically active substances and its compression under high pressures has in the past decade or two introduced a number of new products along with the opportunity to develop innumerable potential uses of wood.

Prior to the recent era of wood research, wood was considered an inferior resource even though its uses were many. However, with the advancement of other materials at such a rapid pace in the fields of colloid chemistry, concrete, and metals, most things could be made cheaper and approximately as good from materials other than wood.

"Improved wood" products have gone under a wide range of trade names and titles. Many of these titles are more or less proprietary and their definitions vary. For the purpose of this paper the following names and definitions will be used.

Compreg: Resin impregnated wood veneers which have been bonded under heat and high pressure in a laminated construction, the resin becoming fully and irreversibly polymerized in the wood at the time of bonding. The special case here is that a phenolformaldehyde resinoid acts as the bonding agent which may or may not be the case.

Impreg: Resin impregnated wood veneers as in compreg but the treated veneers are pre-polymerized in an oven prior to a tego film, laminated assembly. Bonding is under similar temperatures to compreg but normal plywood pressures are used. The type of adhesive and resin are the special variations.

Staypak: Thin veneers assembled with interlayers of tego film and bonded in a laminated construction under heat and pressure similar to compreg. Here again the adhesive and type of construction are often varied.

Normal Laminated: Thin veneers assembled in a laminated type of construction with interlayers of tego film. Bonding is under temperatures and pressures similar to impreg. Many different adhesives are used.

It might be well to note that the term "High Density Wood" has been more or less applied to a number of veneer combinations in which substantial wood impregnation and compression are the distinguishing characteristics. This would include compreg and staypak in the above.

Since the development of impregnated wood has been accelerated by the demand of war applications, emphasis so far has been given to military uses as for example, propellers for airplanes. However, still further applications are constantly appearing and the importance of this type of product is rapidly growing. These developments have ~~been~~ made available to the engineer, improved wood products having a wide range of physical and mechanical properties.

There are several primary objectives to be obtained by impregnation as contrasted to normal wood. Among the more important are improved wearing qualities, increased durability upon exposure, better dimensional stability, and higher mechanical strength characteristics. It would surely be a miracle if all could be completely satisfied.

In this report an effort will be made to investigate the manufacturing processes in the preparation of several of the modified wood forms. As many tests, both mechanical and physical, will be performed as time permits and testing machinery facilitates.

OBJECT: To investigate the proper procedure in the manufacture of compreg, impreg, and normal laminated cottonwood, and further, to compare their mechanical and physical properties.

MATERIALS:

500 sq. ft. of 1/16" rotory cut cottonwood veneer.

3 gallons of phenolformaldehyde Bakelite resinoid.

XR 5995 (60 percent solid resin content).

Galvanized iron bath 12" x 17" x 24".

Treating cylinder capable of withstanding 30 psi.

150 sq. ft. of "Tego" film glue.

Hydraulic hot press.

Wood working machinery for cutting and sanding specimens to size.

General laboratory measuring and weighing instruments.

PROCEDURE:

1. General. The treatment of wood in large-sized pieces with chemicals is extremely difficult even with the most readily treated species. This along with the cost of chemicals in treating on the bulkwood basis and the fact that degrade is great due to stresses set up in the treated and untreated portions of the solid pieces, the impregnation of wood with chemicals is most applicable to veneers. All data involving impregnation in this report have been obtained by using Bakelite resinoid XR 5995, a product of the Bakelite corporation, Bloomfield, New Jersey. These resinoids and their diluted solutions should be properly

stored to prevent premature resinification which tends to decrease its penetration and bonding to the cell wall structure.

The treatment of wood with appreciably prepolymerized resins constituents results in the mechanical deposit of the chemical in the coarse capillary structure. Materials of this nature inhibit the exit and entrance of water but fail to give it stability against shrinkage and swelling. For this reason unpolymerized systems which penetrate and bond to the active groups in the cell wall have been most widely and effectively used.

2. Manufacture of Panels.

A. Impregnation (cylinder and diffusion methods)

Cottonwood veneer sheets approximately 10 x 17 were cut from the rough stock. Pieces having knots, decay, and a slope of grain greater than 1 in 15 were discarded. Ten sheets were selected at random, and the specific gravity, based on volume and weight oven dry, determined and averaged.

A 30 percent water solution, by weight, of the resinoid was prepared and poured into a galvanized iron tank. Veneer can be treated by either the diffusion method in which the veneers are soaked in the impregnating solution or the pressure cylinder method in which the impregnant is forced under pressure into the wood. Both methods were employed in this work.

The cylinder method is the most applicable when the veneers are obtained in the dry form. The veneer is placed in the iron tank and weighted down so that it will remain immersed. With the cylinder closed, an air pressure of 30 pounds per sq. in. is applied for a period of 15 minutes at a temperature of 80°F. The time of immersion prior to the application of pressure, and the period after release of pressure and removal of veneers from the bath is recorded as the assembly time. The specific gravity of the resinoid solution was taken before and after each run. Moisture meter determinations were made and averaged for several veneers in each charge. The whole veneer charge for each run was weighed before and after treatment. No initial vacuum was used as it has been found unnecessary for most veneers up to 1/8" in thickness. Since there is no marked difference between the sapwood and heartwood of cottonwood, the sapwood schedule can be followed throughout. Table 1 shows the data for both pressure and immersion treatments.

The diffusion method is the simpler of the two processes in that it involves a minimum of costly equipment, however, time is sacrificed due to the lengthy soaking periods. As with the cylinder method, the veneer weights before and after impregnation were taken, moisture content calculated, and specific gravity of bath recorded. The two processes are essentially the same except that a 24 hour soaking period replaces the 15 minutes of 30 pounds per square inch of pressure in the cylinder method.

B. Conditioning.

When veneers are treated by the cylinder method, the solution is carried only into the coarse capillary structure of the wood. It is of utmost importance that this solution diffuse into the cell wall structure where it can play its most active part in fulfilling our primary purpose of impregnation-dimensional stability. Often the treatment is not uniform, especially in the pressure method, and days are required for the movement of the solution.

The treated cottonwood veneers of both the immersion and cylinder methods were wrapped and set aside under non-drying conditions for a period of 24 hours. This period permits diffusion into the cell wall structure. The veneers were then dried to a moisture content of 7 percent or below. As the water is removed, on drying, the resin constituents diffuse from the fiber cavities into the cell wall.

C. Compreg.

Seven compreg panels were prepared from pressure and immersion treated veneers of various solid resin content. The moisture content of all veneers at time of bonding were between 7 and 9 percent. This moisture content is somewhat higher than is generally desired but since the thickness of our panels are not extreme, it should have little or no effect. A bonding glue was not used in any of the panels regardless of the solid resin content. A laminated assembly was used, alternating the compression and tension sides of the veneers. Only veneers treated by the same method and of approximately the same solid resin content were combined into the same panel. Panels were pressed at 1000 pounds per square inch and at a temperature of 300°F. for a period of 36 minutes, 26 minutes of which were necessary for the required temperature to reach the center of the panel. Pyrometer readings were made on several panels to determine the temperature-time relations at the center of the panel. The results of the pyromter tests are shown in table 2 for several compreg, impreg, and normal panels. In bonding, the panels were kept in the press until the temperature fell below 200°F. The purpose of cooling in this manner is to prevent springback of panels pressed under incomplete curing conditions and blistering of the surfaces. Temperatures exceeding 300°F. were not used as there is a greater tendency to check due to imbrittlement of the resin. It should be noted that in the preparation of thick panels with certain resins, a considerable amount of exothermic heat resulting from the reaction within the wood structure may cause a charring at the center of the panel. This charring would be further activated at temperatures higher than 300°F. No attempt was made to preheat the panels prior to pressing to reduce stresses. Since the wood is somewhat plasticized with resin, and considerable time is required for application of pressures over 400 psi with the hand lever, major stresses and rupture of the fibers should not occur.

D. Staypak.

All figures on staypak were given to me by Mr. Wang Kai, a student of the University of Michigan.

Cottonwood veneers were tego bonded in a laminated construction under a pressure of 1500 pounds per square inch and a temperature of 300°F. for a period of 30 minutes. Tests were made under similar conditions to that of compreg in this report.

E. Impreg and Normal Laminated.

Six impreg panels were prepared from pressure and immersion treated veneers. Only veneers treated by the same method and of approximately the same solid resin content were manufactured into the same panel. Before bonding, the veneers are placed in an oven for 24 hours at a temperature of 200°F., the purpose of which is to set the resin. Some moisture is required for tego film assembly so a light application to one side of each veneer with a moist rag supplied the needed moisture. The veneers, removed from the oven, moistened, interleaved with tego film, were bonded under a pressure of 50 psi and a temperature of 300°F. for 25 minutes, 15 minutes of which was necessary for the required temperature to reach the center of the panel. All panels remained under pressure until platen temperature fell below 200°F.

Normal laminated cottonwood panels were prepared by interleaving the veneers with tego film glue, followed by bonding under a pressure of 50 psi and a temperature of 300°F. for 36 minutes, of which 26 minutes were necessary for the required temperature to reach the center of the panel.

3. Preparation of Test Samples.

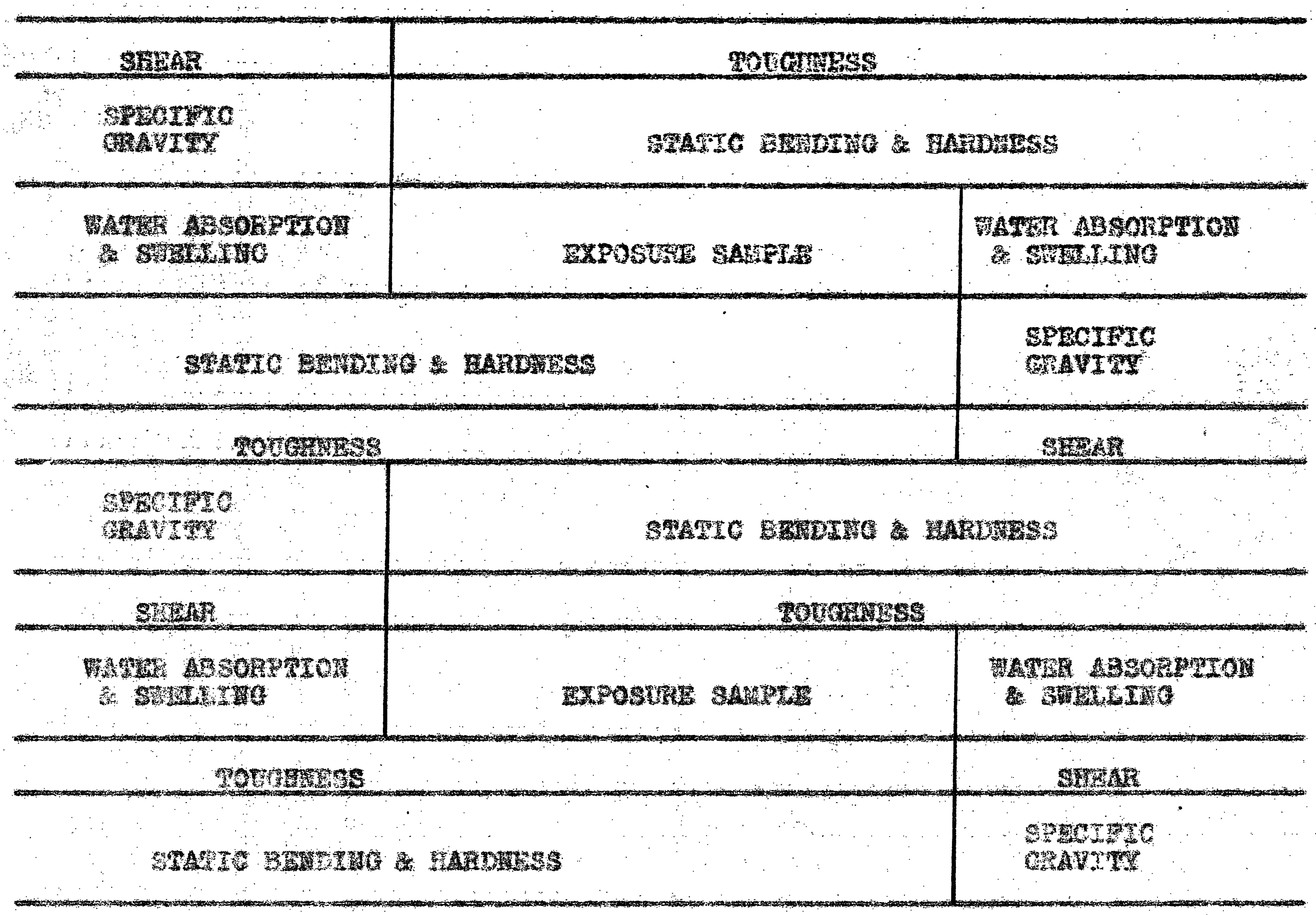
Test specimens were cut from compreg, impreg, and normal laminated panels according to the diagram shown in Figure 1. Due to a concentration of resin at the ends of the compreg panels, it was necessary to trim off a considerable portion. Specimens were cut in the rough with a circular saw, followed by power and hand sanding to the exact dimensions. The cylindrical shear specimens were machined in The Department of Metal Processing. All specimens were cut the full thickness of the material. Any overheated surfaces that occurred in sawing were removed on sanding. The exact dimensions of the test specimens and the conditioning that preceded each before testing, will be given with the explanation of the individual test.

4. Description of Mechanical and Physical Tests.

A. Specific Gravity.

Four sp. gr. specimens 1/2" x 1" x 2" were cut from the full thickness of all compreg, impreg, and normal laminated panels. The specimens were dried for 24 hours at a temperature of 210 plus or minus 5°F. After drying the specimens were weighed and the volume calculated from micrometer measurements. The specific gravity was determined by dividing the weight in grams by the volume in cubic centimeters.

Figure 1 : Cutting Diagram Showing Selection of Test Specimens from Each Panel.



B. Water Absorption and Swelling.

Eight specimens 1/2" x 1/2" x 1" were cut crosswise of the grain from the full thickness of all panels. The test specimens were dried at a temperature of 122 plus or minus 5°F. for 24 hours. After drying, the specimens were cooled in a desicator, weighed, length, width, and thickness measured with a micrometer, and completely immersed in water maintained at a temperature of 77 plus or minus 3°F. for 24 hours. At the end of the soaking period, the specimens were removed and the face moisture absorbed with a cloth. The specimens are then reweighed and micrometer measurements of length, width, and thickness quickly recorded. The percentage water absorption is then calculated on the basis of the dry weight. The percentage of swelling was calculated for length, thickness, and volume based on the dry weight.

C. Static Bending.

Four test specimens 1/2" x 1" x 11" were cut lengthwise of the grain from all panels. All specimens were the full thickness of the panel. In this test, each specimen was set up as a simple beam with concentrated midpoint loading. The distance between the bearing blocks was 9 inches. The load was applied at a head speed of .05 inches per minute. Simultaneous readings of load and deformation were taken past the proportional limit. The load increment for compreg was 50 pounds and that of normal laminated and impreg 25 pounds. The fiber stress, modulus of rupture, and modulus of elasticity were calculated. Specimens were conditioned for at least 96 hours at a temperature of 77 plus or minus 2°F. and a relative humidity of 50 percent.

D. Toughness.

Four test specimens 1/2" x 1/2" x 10" were cut lengthwise of the grain from all panels. Toughness determinations were made with a Forest Products Toughness Testing Machine at the Pennsylvania State College. An initial angle of 45° with weight position 5 was used for compreg and normal specimens. Impreg tests were run with a 30° initial angle and weight position 5. Specimens were conditioned for at least 96 hours at a temperature of 77 plus or minus 2°F. and a relative humidity between 42 and 67 percent. Toughness is recorded in inch lbs. The load was applied perpendicular to laminations except for compreg which was tested parallel to laminations by mistake.

E. Shearing Strength.

Four cylindrical shear specimens 1/2" in diameter and 1 1/2" in length were cut in the lengthwise direction from all panels. The shearing test specimens were tested in a three plate self-aligning testing jig. The load was applied at a rate of .025 inches per minute perpendicular to laminations. The maximum shear strength is calculated by dividing the maximum load by twice the cross sectional area.

F. Hardness.

Four test specimens 1/2" x 1" x 3", cut from previously tested static bending specimens, were used for the hardness test. A Rockwell "B" hardness (M scale), with a six second application of load, was run on the compreg. The temperature at time of testing was 78°F. Due to the softness of impreg and normal specimens, a standard solid wood hardness test, rather than the Rockwell, was necessary. In the standard hardness test the load required to imbed a .44 inch ball one half of its diameter into the wood is a measure of the hardness.

RESULTS:

A summary of the physical and mechanical properties of compreg, staypak, impreg, and normal laminated cottonwood is shown in Table 3.

DISCUSSION OF RESULTS AND INDICATIONS:

The discussion of the results will be made by referring to columns or groups of columns in the order that they appear in Table 3.

Referring to columns 3, 4, and 5, note that the specific gravities are quite uniform for all compreg panels when at the same time there exists considerable variation in solid resin content. This would indicate that the specific gravity of the final compreg product is negligibly affected by difference in resin content within the limits shown. The fact that the specific gravity of wood substance is about 1.46 and that of resin about 1.28 provides evidence that an increase in the specific gravity of the assembly below 1.3 would depend on the compression and the percentage of solid resin in the wood. Further, any increase above a specific gravity of 1.3 must be accomplished entirely by compression of the wood to the void volume approaches zero.

There appears to exist no consistent difference between the specific gravity of the impreg panels at the various resin contents. However, a consistently higher specific gravities resulted in impreg over normal panels, this indicates some increase in the lower specific gravities due to impregnation. The specific gravity of compreg and staypak would naturally be higher than impreg due to compression of the wood.

The increased compression (over 50 percent) of treated veneers is shown by comparing the compression and specific gravity figures of compreg and staypak. Note that staypak was bonded under a pressure of about 1.5 times that of compreg. Treated cottonwood veneers, under a 1000 pounds per square inch, compressed to about 1/3 their original volume. Since the specific gravity of the untreated veneer was about .41, a compression to 1/3 of its original volume would naturally triple its specific gravity. Also, the minor effect of the resin in increasing the density is verified.

The compression of impreg averaged somewhat higher than normal panels. The normal panels having a lower specific gravity and being unimpregnated, the reverse would be expected. This somewhat misleading result is probably due to the springback of the normal panel upon removal from the press. Actually the normal panels, while in the press, were compressed to a greater degree than indicated.

The figures in column 6 show that resin impregnation has reduced the water absorption of compreg over staypak. Likewise, staypak showed less water absorption than impreg or normal wood. Previous tests have shown that the water absorption of unimpregnated compressed wood is not materially reduced unless it is pressed under conditions that cause some of the lignin to flow. High density materials of this type, because of their density, inhibit the entrance and exit of moisture; but they in no way affect the equilibrium absorption. The water absorption of compreg at the end of 1 hour immersion was about 1/3 that of staypak, 1/15 that of impreg, and over 1/50 that of normal laminated material.

According to F. P. L. Bul. R1268, May, 1941, weight increases with compreg after 1, 4, and 7 days immersion were 0.5, 1.2, and 1.8 respectively. This would indicate that the equilibrium moisture absorption is not reached soon after immersion. Impreg reduced the water absorption about 75 percent that of normal laminated wood.

The swelling of compreg (columns 6, 7, 8) at the end of 24 hours immersion averaged less than 1 percent, about 75 percent of which occured in thickness and 25 percent in length, and a negligible amount in width. The high volumetric percents of compreg panels 0 and 6 were either due to poor treatment or more likely a relieving of compression rather than true swelling. Dimensional changes in pieces immersed in water are affected by the amount of water absorbed up to the point of equilibrium swelling. When treated or normal wood is immersed in water, the absorption will be higher than the absorption from the vapor phase due to capillary action. The swelling, however, would be the same under both conditions.

Impreg reduced the volumetric swelling about 75 percent that of normal laminated material. Note that impreg reduced the water absorption at about the same amount. There is a chance that equilibrium swelling has not been reached. Upon further soaking, equilibrium swelling present, impreg would show an increase in water absorption with no change in swelling. The swelling in thickness and length were about the same for impreg panels while normal panels swelled three times as much in thickness as in length. The reduction in swelling apparently predominates in thickness, that is, the direction that the greater swelling normally occurs. The unusually high swelling in thickness for normal laminated panel number 2 was caused by accidentally exceeding the pressure on bonding. The swelling in width can be found by subtracting the total swelling in thickness and length from the volumetric. Staypak had a swelling in thickness about 1/3 that of normal laminated wood. Staypak tends to retard and reduce the water absorption but will not affect the equilibrium moisture swelling.

Fiber stress, modulus of rupture, ~~and~~ modulus of elasticity and shear strength are shown for compreg in columns 10, 11, 12 and 13 respectively. The maximum and minimum values for the modulus of rupture were 37, 697 and 33,935 pounds per square inch. The corresponding modulus of elasticity values were 4.3 and 3.8 million pounds per square inch. The comparable maximum shearing values were 11,600 and 12,500 pounds per square inch. Results of tests made by the Forest Products Laboratory on compreg panels of 30 percent resin content show rupture values about 3000 pounds greater, elasticity values about .5 million less, and shear values about 1/3. The differences that exist between the modulus of rupture and elasticity can possibly be traced to the lower resin content of the panels made in this work. The modulus of elasticity and rupture of compreg panels were at least twice that of staypak. Staypak, in turn, had a slightly higher modulus of rupture and elasticity than impreg and normal panels. Mention was made in F. P. L. Report No. 1381, July, 1944) that shear values are highly dependent on the method; however, the discrepancy that exists should not be so great. It is believed that in the shear jig used, the edges of the plates shearing the specimen, were not sharp enough and a slight separation existed between the outside and inside plate. This would tend to introduce a bending of the specimen and a clogging of the fibers between the two plates.

The fiber stress for compreg and staypak were about the same and twice that of normal laminated wood. With the 25 lb. increments used in the testing of normal and impreg panels, a proportional limit could not be detected for impreg as it so closely approached the maximum load. The modulus of rupture, modulus of elasticity, and shear strength perpendicular to laminations between impreg and normal laminated specimens are about the same. Apparently, the three values are unaffected by the resin, in the percentages used, to any great extent.

The results of the Rockwell "B" hardness and standard solid wood hardness tests are shown in columns 14, 15, and 16. The surface hardness is apparently affected by resin impregnation as indicated by the higher Rockwell "B" values of compreg compared to those of staypak. Both compreg and staypak have higher hardness values than either impreg or normal laminated wood since neither one of the latter could be tested with a Rockwell. A consistently higher hardness value resulted on the face side of compreg compared to the side hardness. This is likely due to the resin concentration at the surfaces of the panel. Impreg specimens, tested under conditions similar to the normal laminated specimens, had a hardness of about 1 1/2 times that of the normal specimens. Here again, the resin impregnation has increased the hardness. Panels of high resin content and with the proper degree of compression approach the hardness and smoothness of plate glass.

The toughness values are shown in column 17. The individual variations in the wood are more pronounced in the straight laminated material than in the impreg or compreg. A greater number of specimens or an increase in the cross sectional area would eliminate the error. The results of impreg are less favorable than those of the normal laminated material. Impreg values were about 1/3 those of the normal specimens. Compreg values were superior to both impreg and normal and might have been somewhat higher had they been tested on the face. The increased strength brought about by compression of the wood has offset the brittleness imparted by the resin. No toughness values of staypak are available for comparison, however, one of the chief advantages of staypak over adequately stabilized compreg is its superior izod impact strength, generally about twice that of compreg. The percentage of resin in the panel, although not noticeable within the limits used in this work, seems to have a decided effect on impact properties.

The treatment of wood with phenolic and similar resins imparts to the product certain other characteristics worthy of mention, although not investigated in the scope of this report. Panels have demonstrated resistance to decay, acids, and electricity. It is only slightly more resistant to fire but it does minimize the spread by holding the structure intact. The meager data that is available on the painting of resin treated panels, indicates that ordinary painting does not stand up as well as might be desired. A suitable undercoat is the needed development.

The approximate cost of treating one board foot of cottonwood, in the veneer condition to a solid resin content of 30 percent, is about 12 cents according to the Forest Products Laboratory, Madison, Wisconsin. With heavier woods, like birch, the cost is about 18 cents. The cost of treating, drying, and curing has been estimated at $190, to $250 per thousand board feet.

Compreg is finding its most extensive use in airplane propellers, aerial masts, and connectors. Pulleys, gears, and lubricated bearings show promise. Panels with resin-treated compressed faces on an untreated or impreg core open possibilities for small boats, flooring, paneling, and skin coverings of airplanes. The increased plasticity of treated plies should respond nicely to various bag molding operations. The use of staypak in tool handles and mallet heads combines its cheaper cost and higher impact strength over that of compreg.

SUMMARY:

The chief objects of impregnation is to give wood stability against shrinking and swelling, improved wearing qualities, increased durability against exposure, and higher mechanical and physical properties. The extent to which these objectives may be accomplished will depend largely upon the nature of the resin, its completeness of distribution, its bonding power to the wood constituents, and the compression of the wood.

The results of this project can be summarized in the following:

1. Moderate variations in resin content (between 20 and 30 percent) have little effect on the mechanical and physical properties tested with the experimental accuracy maintained.

2. Impregnation increases the compressibility, facilitating higher density products with lower pressures.

3. Resin treated compressed wood is more homogeneous and water resistant than staypak, and staypak, in turn, more resistant than impreg or normal laminated wood.

4. Resin treatment of wood with or without compression increases its dimensional stability. The compression of wood without resin treatment tends to reduce the water absorption, but will not affect the equilibrium moisture swelling.

5. The modulus of rupture and elasticity of the compreg prepared in this project compares satisfactorily with values given for similar panels prepared and tested at The Forest Products Laboratory. The requirements of material, fabrication, and mechanical properties set up in the Army

Air Force Spec. No. 15065 June, 1942 were met in this work to the extent that the tests were made.

6. The modulus of elasticity and rupture of compreg is twice that of staypak, and staypak slightly higher than impreg and normal laminated wood. Shear values for all forms were too high. Staypak shear strengths were slightly higher than compreg, and compreg about 3 times those of impreg and normal laminated material.

7. Hardness is affected by the degree of compression and the resin content of the wood. Toughness decreases with an increase in the resin content. However, staypak has superior toughness over treated compressed wood, although not clearly indicated in the results of this report.

8. Compreg and impreg are expensive products, but with further investigation of its manufacture there are possibilities for a considerable reduction in cost. With its cost reduced, new uses should become evident.

Table 1

Impregnation Schedule Showing Record of Conditions for Each Run.

Run No.	No. of Veneers	Percent Resin Absorption*	Percent Solid Resin Content**	Conditions: Temp. 0°F.	Conditions: Time hrs.	Conditions: Pressure psi	Assembly Period min.	Initial Sp. Gr. of Bath	Final Sp. Gr. of Bath	M. C.*** Based on O.D.W.
1	27	52.3	20.0	80	1/4	30	15	1.07	1.07	12.3
2	30	50.8	22.4	81	1/4	30	11	1.07	1.075	12.1
3	30	51.6	22.4	81	1/4	30	12	1.075	1.08	13.5
4	20	51.1	25.0	74	1/4	30	12	1.08	1.085	13.1
5	18	51.3	21.7	76	1/4	30	10	1.07	1.07	12.1
6	20	52.2	30.4	76	24	--	--	1.08	1.085	13.1
7	30	48.6	20.9	83	24	--	--	1.07	1.07	12.9
8	23	50.5	29.3	81	24	--	--	1.07	1.07	13.6
9	15	50.0	25.7	80	24	--	--	1.07	1.07	10.3
10	23	55.5	36.9	82	48	--	--	1.07	1.07	12.2

Average Sp. Gr. of Veneer -- .414

* Absorption of resinoid solution based on dry weight of veneers
** Based on the dry weight of veneers
*** Moisture content of veneers at time of impregnation

Table 2

Pyrometer Results on Compreg, Impreg, and Normal Laminated Panel.

Compreg				Impreg				Normal			
1		2		1		2		1		2	
Time	Temp. 0°F.	Time	Temp. 0°F.	Time	Temp. 0°F.	Time	Temp. 0°F.	Time	Temp. 0°F.	Time	Temp. 0°F.
25	245	10	224	1	118	3	150	5	206	4	215
29	273	15	258	3	196	6	174	12	234	12	246
31	282	20	280	6	262	9	232	16	251	17	268
		<u>26</u>	<u>296</u>	9	290	11	266	24	270	25	280
						<u>15</u>	<u>291</u>	<u>26</u>	<u>273</u>	28	285
								30	285		

Underlined temperature and time indicates conditions followed in panels.

Table 3

Summary of the Mechanical and Physical Properties of Compreg, Impreg, and Normal Laminated Cottonwood.

Modification (1)	Panel Number and Treatment (2)	Solid Resin Content Based on Dry Wt. (3)	Specific Gravity O.D.W. (4)	Compression in Bonding* (5)	Water Absorption Percent Based on Dry Weight (6)
		percent		percent	percent
Compreg	P 0	20	1.32	77	1.80
"	P 1	29	1.32	77	1.15
"	P 2	21	1.33	80	1.12
"	I 3	36	1.33	77	1.08
"	I 4	25	1.30	80	1.08
"	I 5	22	1.31	80	1.48
"	I 6	22	1.31	81	2.23
Staypak	--	--	1.28	37.5	6.5
Impreg	P 1	30	.58	11.7	17.3
"	P 2	30	.52	4.6	22.6
"	P 3	21	.56	14.1	23.2
"	P 4	26	.52	3.8	22.2
"	I 5	22	.50	4.5	28.0
"	I 6	22	.50	4.6	29.5
Normal	1	--	.44	1.4	80.8
"	2	--	.47	5.2	90.2
"	3	--	.46	3.6	84.9

* Compression percent based on thickness of veneers at time of bonding.

Table 3 (Continued)

Modification	Swelling*			Static Bending		
	Thickness	Length	Volume	Fiber Stress	Modulus of Rupture	Modulus of Elasticity
	(7)	(8)	(9)	(10)	(11)	(12)
	percent	percent	percent	lbs. per sq. in.	lbs. per sq. in.	1000 lbs. per sq. in.
Compreg	.93	.25	1.18	10427	34270	3932
"	.55	.14	.67	11852	37697	3994
"	.45	.12	.59	11030	35922	3866
"	.36	.12	.48	9990	33935	3804
"	.38	.10	.48	11587	36437	3955
"	.72	.14	.85	11245	35232	4171
"	1.90	.17	2.1	11622	37537	4355
Staypak	7.9	---	----	11028	15387	1824
Impreg	2.0	1.4	3.8	-----	14060	1791
"	1.4	1.5	3.1	-----	12130	1521
"	2.6	1.5	4.5	-----	10580	1648
"	1.5	1.6	3.5	-----	9812	1562
"	1.8	1.8	4.0	-----	10560	1476
"	2.3	1.7	4.2	-----	12430	1545
Normal	7.5	3.0	12.6	5556	11920	1084
"	11.4	2.9	16.2	6226	13575	1611
"	8.6	2.8	12.8	6347	12865	1206

* Percent swelling in thickness, length, and volume based on initial dimensions.

Table 3 (Continued)

Modification	Shear Strength Perpendicular to Laminations	Hardness			Toughness
		Rockwell "B" M Scale		.44 in. Ball	
		Face	Side	Face	
	(13)	(14)	(15)	(16)	(17)
	lbs. per sq. in.	lbs. per sq. in.		lbs. per sq. in.	inch pounds
Compreg	11658	62	55	----	84.5
"	12547	56	47	----	124.8
"	12206	64	53	----	103.9
"	12229	59	52	----	107.7
"	12420	51	44	----	89.2
"	12736	52	49	----	89.5
"	11770	62	49	----	114.1
Staypak	14017	33	--	----	-----
Impreg	3686	569	--	948	24.4
"	3112	--	--	940	23.8
"	3558	--	--	1009	14.6
"	3071	--	--	913	18.9
"	3115	--	--	841	24.5
"	2997	--	--	868	27.4
Normal	3461	--	--	569	84.4
"	3466	--	--	614	69.3
"	3322	--	--	620	76.7

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