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RESIN-TREATED WOOD

(IMPREG)

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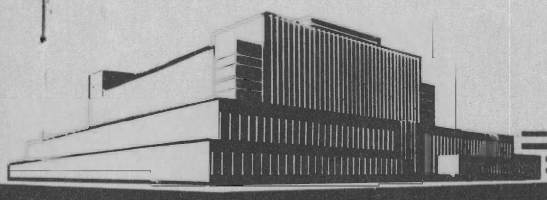

FOREST PRODUCTS LABORATORY
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UNITED STATES DEPARTMENT OF AGRICULTURE
FOREST SERVICE
In Cooperation with the University of Wisconsin

FOREST PRODUCTS LABORATORY RESIN-TREATED WOOD

(IMPREG)[1]

By

ALFRED J. STAMM, Chemist
and
R. M. SEBORG, Chemist

Forest Products Laboratory,[2] Forest Service
U.S. Department of Agriculture

Abstract

Dimensional stabilization of wood by treatment with phenolic resins is discussed, as well as the properties and applications of the treated wood.

Introduction

The chief objective of impregnating wood with synthetic resin-forming chemicals is to give it stability against swelling and shrinking. This is effectively accomplished only when the wood is treated with chemically active resin-forming constituents that penetrate the cell-wall structure and become bonded to the active groups in the wood upon formation of the resin.

The Forest Products Laboratory has shown that the treatment of wood with virtually unpolymerized phenol-formaldehyde mixes that are soluble in water in all proportions, followed by drying and then curing of the resin within the wood structure, minimizes swelling and shrinking most effectively and permanently of all the many resin-forming systems and treatments tested. Treatment with appreciably prepolymerized resin systems or nonpolor resin-forming constituents results in resins mechanically deposited within the coarse capillary structure of the wood. Such materials block and hence retard the entrance and exit of water, but they in no way affect the equilibrium moisture sorption or equilibrium swelling.

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[1] This report was originally written in 1942 for the U.S. Department of Defense, and has since been revised in 1943, 1950, 1955, and slightly revised in 1962.

Dr. Stamm is now research professor, School of Forestry, North Carolina State College, Raleigh, N. C.

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

Report No. 1380 (Revised)

Treatment Most Applicable to Veneer

The treatment of wood in large-sized pieces with chemicals is extremely difficult, even in the case of the most readily treated species. Only an outer shell of large specimens can be treated within periods of time that are commercially practical. Although treatments confined to the outer part of the wood are adequate to minimize decay, they are not adequate in appreciably reducing dimensional changes.

Because of these difficulties and the fact that the cost of the chemicals for treating is high on a bulkwood basis, the treatment has been found most practical when applied to sheets of veneer. With veneer the cost of treatment per unit surface is effectively minimized and the difficulties previously mentioned in treating massive material are not encountered.

Directions for Treatment

All data presented in this report were obtained by using a water-soluble phenolic resin produced by the Bakelite Corporation, Bloomfield, N.J. The resin-forming solids content of this resin was 61 percent. A number of other equally satisfactory resinoids have been tested. They are described in Forest Products Laboratory Report No. 1384, "Comparison of Commercial Water-Soluble Phenol-Formaldehyde Resinoids for Wood Impregnation."[3] Since the designation of resins changes, those listed in this report may now be listed under different designations.

These resinoids or their diluted solutions should be stored in a cool place and preferably be used within a month to avoid any premature resinification, which tends to decrease the penetrations of the cell-wall structure of the wood and bonding to this structure.

The antishrink efficiency (the reduction in the shrinkage caused by the treatment divided by the shrinkage of the control) increases with increasing resin content of the wood up to a maximum value of about 75 percent with a resin content of 30 to 40 percent, above which additional resin has but little effect. In the lower concentration range the synthetic resin is undoubtedly formed almost entirely within the cell walls. At concentrations greater than 30 to 40 percent, the cell walls are saturated with synthetic resin and the excess resin is deposited in the coarse capillary structure where it can show very little antishrink effect. Thus, there is no object in forming more than 30 to 40 percent of synthetic resin within the wood.

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[3] Burr, Horace K., and Stamm, Alfred J. Comparison of Commercial Water-Soluble Phenol-Formaldehyde Resinoids for Wood Impregnation. Forest Products Laboratory Report No. 1384. 1956.

Veneer can be treated either by a simple diffusion method in which the veneer is merely soaked in the aqueous resinoid solution, or by a cylinder treating method in which the solution is forced under pressure into the wood. For the treatment of freshly cut green veneer, the diffusion method is most applicable. However, dry veneer can also be effectively treated by this method. The time required for the veneer to be effectively treated depends primarily on the thickness of the veneer or on the density of the wood and, to some extent, on the species of wood. In general, the treating time varies directly as the square of the thickness. Green veneer 1/32 inch thick can be treated in 1 to 2 hours; whereas green veneer 1/8 inch thick will require about a day. Air-dried veneer will, of course, require considerably longer time when treated by soaking in the aqueous resin solution than is required for green veneer.

Dry veneer can be impregnated more rapidly by the cylinder treating method. This method is most applicable for the thicker veneers (1/16 to 1/8 inch). The veneer is placed in a galvanized iron tank inside the treating cylinder. The tank is filled with the treating solution and the veneer is weighted down so that it will remain immersed. The cylinder is closed and a pressure of 20 to 75 pounds per square inch of air pressure is applied for 1/4 to 5 hours, depending on the thickness and structure of the veneer. In the earlier experiments a vacuum was pulled before applying the pressure, but this was found to be unnecessary for most of the veneers treated in thicknesses up to 1/8 inch. It was found that a take-up of solution equal to the dry weight of the wood was desirable. Under these treating conditions the resinoid should be diluted to a solids content of from 30 to 35 percent, giving final resin content of 27 to 32 percent on the basis of the weight of the dry untreated wood.

Approximate treating times and pressures necessary to double the weight of air-dry veneer are given in table 1 for different species of 1/16-inch material at 85° to 90° F. These values will vary somewhat from batch to batch. Those persons interested in rather close control of the resin content of the wood should make trial treatments of each shipment of veneer to determine the exact treating conditions to use. If it is desired to reduce the treating time of the more hard-to-treat veneers, it can be done by increasing the pressure. A marked difference in the treatment of the sapwood and the heartwood of the woods listed in table 1 is found only in the case of spruce and maple. The heartwood of maple treats with such difficulty that sapwood should be specified in purchasing the veneer. With spruce, where the amount of sapwood is relatively small, either an effort should be made to eliminate the sapwood sheets or all the material should be treated according to the heartwood schedule. This will result in the sapwood having about double the resin content of the heartwood. It appears that this would be detrimental only where carefully balanced construction and minimum weight are important.

A complete survey of the species that can be readily treated has not been made. Most species can be treated; the denser species will, of course, require a longer time for adequate treatment. However, the natural water-insoluble resins in highly resinous softwoods interfere with the proper distribution of the synthetic resin-forming chemicals and result in less effective stabilization. No particular difficulty has been encountered in treating any of the nonresinous or moderately resinous softwoods. For

example, Douglas-fir, which is moderately resinous and one of the more difficult softwood species to treat with preservatives, can be treated by the pressure method in a reasonable length of time.

When the veneer is treated by the cylinder method the solution is carried only into the coarse capillary structure. It takes time for it to diffuse into the cell-wall structure where it is desired. When the resin is uniformly distributed throughout the coarse capillary structure, little time is required, but it may be a matter of days if the treatment is not uniform. In general it is desirable to stack the treated veneer under nondrying conditions for approximately 1 day with a canvas thrown over it to cut down air circulation. It is also advisable to stack veneer treated by the diffusion method in a similar manner in order to insure more complete diffusion.

The veneer can be dried in a continuous veneer dryer or stickered and dried in a kiln.

In commercial practice the treated veneer is first dried to a moisture content of approximately 10 percent in a veneer dryer at a temperature not exceeding 190° F. Temperatures above the boiling point of water will cause the solution in the wood to boil and thus force out part of the resin on the surface of the wood. After drying, the resin is cured by heating at a higher temperature. This can be done by rerunning the veneer through the veneer dryer at approx-amately 300° to 320° F. At 310° F. the curing time is about 30 minutes.

If the veneer is to be dried and cured in a kiln, it is necessary to sticker the veneer to allow ready circulation of air through the pile. The time of drying and curing will depend on the thickness of the veneer and the rate and temperature of the circulating air. Drying and curing the treated veneer in a kiln requires a much longer time than in a veneer dryer.

Assembly of Treated Veneer

The treated and cured veneer can be assembled with practically all kinds of glue; namely, animal, vegetable (starch), soybean, casein, and both hot- or cold-press synthetic resin glues of both the phenol-formaldehyde and urea-formaldehyde types. With glues containing considerable solvent, it is necessary to let the glues dry after application to the treated veneer surfaces to a greater extent before assembly than is necessary in gluing ordinary wood. This appears to be due to the fact that the treatment has reduced the tendency of the wood to absorb the glue solvent, consequently increasing the time necessary to get the desired absorption. When the assembly time is increased from the normal time of a few minutes to about 15 minutes, glue joints between resin-treated pieces of wood are as strong as those ob-tained with untreated wood with all the glues tested. Wet strengths of joints between resin-treated sheets of veneer are comparable to those for untreated veneer, the animal and starch glues losing practically all their bonding power, the soybean and casein glued joints retaining one-third to one-half of their original strength, and the synthetic resin glues giving joints that

retained a high percentage of their original strength. Because the chief object of the treatment described in this paper is to obtain a more weather-resistant, stable product, the treatment should, when possible, be followed by a synthetic resin-glue assembly.

Properties of Impreg

Moisture Adsorption and Swelling

The foregoing treatment will reduce the moisture adsorption from the vapor phase and the swelling and shrinking under equilibrium conditions to about 25 to 40 percent of the normal value. Under rapidly changing relative humidity conditions, such that equilibrium is not obtained, it will reduce the moisture absorption and the swelling and shrinking still further. When the treated wood is immersed in water the absorption of liquid water will exceed the adsorption of water from the vapor phase because of capillary rise into the microscopically visible capillaries that have not been filled with resin. The swelling, however, will be no greater than that occurring in water-saturated air because no further water is taken up within the cell-wall structure.

Because of the reduced swelling and shrinking of the treated veneer sheets, they should, when assembled with untreated veneer, be combined in such a way as to give a balanced construction. Thin plywood with a treated face on one side and an untreated face on the other will warp when it is exposed to relative humidity conditions different from those under which it was made because of the different tendencies of the two faces to swell.

Passage of Moisture Through the Wood

The passage of moisture through plywood under a relative humidity gradient is greatly decreased by the resin treatment. When all the plies are treated with 20 percent of resin, the moisture transfusion is reduced to about 0.1 of normal, and when treated with 40 percent of resin, it is reduced to about 0.05 of normal for resin-bonded wood. When only the face plies are treated, the effectiveness in reducing moisture transfusion is not materially less than when all the plies are treated.

Face Checking

Although plywood, with its cross-grained veneer sheets, is so constructed that it mechanically minimizes external dimension changes under varying moisture-content conditions, this construction does not reduce the actual percentage of moisture absorbed by the cell walls. Although dimension changes are curtailed in the plane of the sheet, the wood fibers must nevertheless swell as they absorb water. Hence, dimensional changes must occur either in the thickness direction of the plywood or into the fiber cavities; if the latter occurs, fibers are distorted or even ruptured. Synthetic resin glues do not

protect the veneer sheets, particularly the surface sheets, from dimensional changes. Differential stresses even in synthetic resin-glued plywood are hence set up across the outer plies, and eventually result in face checking. For these reasons a sheet of plywood is more subject to face checking than a solid board of the same dimensions.

The face checking of plywood under weathering conditions is markedly reduced when the face plies have been treated according to the foregoing procedure because of the reduction in swelling and swelling stresses. This was found to be true even for Douglas-fir, which is perhaps the most susceptible to checking of the species used for plywood.

Mechanical Properties

The treatment of wood with synthetic resins improves only the compressive strength properties. According to the limited tests so far available, the hardness and the compressive strength perpendicular to the grain are increased to a greater extent than the increase in weight. The compressive strength parallel to the grain is increased to a somewhat lesser extent, while the modulus of rupture and modulus of elasticity in bending are unaffected by the resin within the range of experimental error. Table 2 gives the meager strength data available on resin-treated solid wood. Subsequent tests on parallel laminated resin-treated veneer indicate that the toughness and the Izod impact strength are the only strength properties greatly affected by resin treatment and these are materially reduced.[4,5]

The improvement in compressive strength properties is not critically dependent upon the nature of the resin treatment as is the case for the other wood properties. The deposition of any hard solid material within the coarse capillary structure of wood would improve the compressive strength properties. Hence, if an improvement in compressive strength properties alone is sought, much cheaper treatments, such as with sulfur or waterglass, could be used.

Decay Resistance

The treatment of wood with synthetic resins according to the foregoing method increases the decay resistance of wood to a marked extent. This appears to be due to the fact that the cell walls of the treated wood cannot take up sufficient moisture to support decay. More recent data indicate that this form of resin-treated wood is also appreciably resistant to the action of termites and marine borers.

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[4]Erickson, E. C. O. Mechanical Properties of Laminated Modified Wood. Forest Products Laboratory Report No. 1639. 1959.

[5]Erickson, E. C. O. and Faulkes, W. F. Jr., Basic Properties of Yellow Birch Laminates Modified with Phenol and Urea Resins. Forest Products Laboratory Report No. 1741. 1959.

Acid Resistance

The resin-treated wood also has a high acid resistance, thus making it possible to use this material around storage battery cases, and the like.

Fire Resistance

The resin treatment alone adds but slight fire resistance to the wood. It does, however, tend to hold the charred structure intact and thus minimize the spread of fire. A few preliminary tests indicate that ammonium phosphate salts, equal to 10 to 15 percent of the weight of the resin, can be added to the treating solution and will appreciably increase the fire resistance of the wood. The salts are so fixed that they cannot be leached from the wood.

Heat Resistance

Although resin treatment has little effect upon the fire resistance of wood, it greatly increased the temperature to which the wood can be heated without appreciable change in properties. Because of this increased heat resistance, impreg patterns have been successfully used for shell molding. For this application the patterns are repeatedly heated to 400° F. for periods of 1 hour. Untreated wood will readily deteriorate when heated at this temperature.[6]

Thermal Conductivity

The thermal conductivity of resin-treated wood is not appreciably greater than that of ordinary wood. The forming of 60 percent of the weight of the wood of resin within the structure increases the thermal conductivity by approximately 15 percent. This is more resin than would normally be used so that, in general practice, a smaller increase would be expected.

Electrical Resistivity

From the fact that the electrical resistivity of wood is almost entirely dependent upon the moisture content, and that the recommended treatment reduces the hygroscopicity of wood to one-third to one-fourth of normal, it is not surprising that electrical resistivity is greatly improved. In Forest Products Laboratory Report No. 1385, "The Electrical Resistivity of Resin-Treated Wood,"[7] it is shown that the specific resistivity at 30 percent relative humidity is about 10 times that of normal wood and at 90 percent relative humidity is about 1,000 times that of normal wood.

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[6] Seborg, Ray M., and Vallier, A. E. Application of Impreg for Patterns and Die Models. Forest Products Research Society Jour. 4(5): 305-312. 1954.

[7] Weatherwax, Richard C., and Stamm, Alfred J. The Electrical Resistivity of Resin-Treated Wood (Impreg and Compreg), Hydrolyzed Wood Sheet (Hydroxylin), and Laminated Resin-Treated Paper (Papreg). Forest Products Laboratory Report No. 1385. 1956.

Dyeing and Painting

Water-soluble dyes have been sucessfully incorporated with the treating solution and fixed against leaching throughout the structure of treated plies. Unfortunately, sufficiently light-fast dyes that meet the other requisite conditions of solubility, heat stability, and low molecular weight have not been found that can be recommended for continued out-of-door exposure.

Only a few painting tests have thus far been made on resin-treated wood using three different types of house paint (white lead, zinc titanium, and lead titanium). The tests were made on Douglas-fir plywood with and without resin-treated faces and with and without an aluminum paint primer. The panels that had been painted with an aluminum primer were given two coats of paint and those without the aluminum primer were given three coats.

None of the finishes stood up so well as might be desired, because of the development of an alligatoring of the films on all the specimens after 1 to 2 years of weather exposure, thus making any definite conclusions impossible. The finishes on all the panels with treated faces and with no primer, however, were in all cases superior to those on untreated panels with no aluminum primer and were at least as good as the panels with untreated faces and an aluminum primer underneath after 4 years' exposure. The tests also indicated that an aluminum primer should not be used over treated faces as these panels were definitely inferior to the panels with treated faces and no aluminum primer. No loss of the paint film occurred on any of the panels with treated faces in 4 years, whereas some loss did occur in the case of the panels with untreated faces and no aluminum primer. The meager data indicate the desirability of working out a more suitable undercoat for resin-treated wood when painted with house paints.

Unfortunately, no data are yet available on painting of resin-treated uncompressed wood with airplane lacquers or enamels. A few tests on resin-treated, compressed wood, however, indicate that such a finish should be satisfactory.

Application

Impreg is now being used commercially for pattern and die models in the automotive industry.[6] Wherever patterns and die models are made and kept to close tolerances, impreg may be used to advantage. Impreg is used to make acid tanks, thus taking advantage of its high acid resistance. It shows promise for use as fillers in pulp-refining machines (Jordans). Impreg has also been used for military purposes, such as housings for electrical control equipment, in which its improved electrical properties were utilized.

Availability

Mahogany impreg for pattern and die models is produced commercially by Haskelite Corp., Grand Rapids, Mich.; by Nickey Bros., Inc., Memphis, Tenn.;

and by Koppers Co., Wood Preserving Division, Orrville, Ohio. Impreg boards for construction of acid tanks are also produced by Koppers Co.

Conclusions

The treatment of veneer with phenol-formaldehyde resin-forming materials greatly increases its stability against swelling and shrinking and, as a consequence, reduces the passage of moisture through the wood, warping and face checking. The treatment also materially reduces decay hazard and the electrical conductivity, and also improves the compressive strength properties with virtually no sacrifice in gluing ability, paintability, or thermal insulating properties. The increased cost should be offset by the increased stability and durability for specialty uses, but not for general plywood uses.

Table 1.--Cylinder treating conditions that will cause various species of 1/16-inch veneer to take up an amount of a 50 percent solution of Resinoid XR5995 at 85° to 90° F. approximately equal to the air-dry weight of the wood

Species	Pressure	Time
	Lb. per sq. in.	Hours
Western hemlock, heartwood	20	1/4
Redwood, heartwood	40	1/4
Sitka spruce, heartwood	70	1
Sitka spruce, sapwood	20	1/4
Basswood, heartwood	40	1/4
Cottonwood, heartwood	30	1/4
Yellow-poplar, heartwood	50	1/2
Sweetgum, heartwood	60	1
Sweetgum, sapwood	60	1/2
Birch, heartwood	75	2 to 5
Maple, sapwood	75	2 to 5

Table 2.--Effect of phenol-formaldehyde resin treatment on mechanical properties of wood[1]

Species	Resin content of wood	Hardness (side)	Compression perpendicular to grain fiber stress proportional limit	Compression parallel to grain maximum crushing strength	Static modulus of rupture	Bending modulus of elasticity	Toughness
	Weight percent	Percent	Percent	Percent	Percent	Percent	Percent
Sugar maple (sapwood)	23.1	41.7	68.4	18.5	2.0	7.7	-0.4
.....do.....	23.1	(35.3)	(45.3)	(17.0)	(.3)	(4.2)	(-7.0)
Sugar pine (heartwood)	47.7	84.7	52.0	23.5	2.8	7.4	7.7
.....do.....	47.7	(84.0)	(56.5)	(27.0)	(5.3)	(4.0)	(14.0)

[1] In terms of the percentage increase over the values for the controls. The data represent the average values for two treated specimens, two untreated controls, and two controls that were subjected to the same heat treatment as the treated specimens cut from each of five different planks. The first values are referred to the untreated controls and the values in parentheses to the heated controls. All values are corrected to the moisture content of the untreated controls (about 6 percent moisture content).

SUBJECT LISTS OF PUBLICATIONS ISSUED BY THE FOREST PRODUCTS LABORATORY

The following are obtainable free on request from the Director, Forest Products Laboratory, Madison 5, Wisconsin.

List of publications on Box and Crate Construction and Packaging Data

List of publications on Chemistry of Wood and Derived Products

List of publications on Fungus Defects in Forest Products and Decay in Trees

List of publications on Glue, Glued Products, and Veneer

List of publications on Growth, Structure, and Identification of Wood

List of publications on Mechanical Properties and Structural Uses of Wood and Wood Products

Partial list of publications for Architects, Builders, Engineers, and Retail Lumbermen

List of publications on Fire Protection

List of publications on Logging, Milling, and Utilization of Timber Products

List of publications on Pulp and Paper

List of publications on Seasoning of Wood

List of publications on Structural Sandwich, Plastic Laminates, and Wood-Base Aircraft Components

List of publications on Wood Finishing

List of publications on Wood Preservation

Partial list of publications for Furniture Manufacturers, Woodworkers and Teachers of Woodshop Practice

Note: Since Forest Products Laboratory publications are so varied in subject, no single list is issued. Instead a list is made up for each Laboratory division. Twice a year, December 31 and June 30, a list is made up showing new reports for the previous 6 months. This is the only item sent regularly to the Laboratory's mailing list. Anyone who has asked for and received the proper subject lists and who has had his name placed on the mailing list can keep up to date on Forest Products Laboratory publications. Each subject list carries descriptions of all other subject lists.

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Stamm, Alfred Joaquin
Forest Products Laboratory resin-treated wood (Impreg) by A. J. Stamm and R. M. Seborg. (5th ed., rev.) Madison, Wis., U. S. Forest Products Laboratory, 1962.
9 p., tbls. (F.P.L. rpt. no. 1380)

Dimensional stabilization of wood by treatment with phenolic resins, and the properties and applications of the treated wood are discussed.

Stamm, Alfred Joaquin
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